(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 504 939 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **92104923.5**

(51) Int. Cl.[5]: **C25D 17/00**

(22) Date of filing: **20.03.92**

(30) Priority: **21.03.91 US 672981**

(43) Date of publication of application:
23.09.92 Bulletin 92/39

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL PT SE

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(54) Electrolytic cell anode.

(57) An electrolytic cell is disclosed comprising a cathode having a cathode surface movable in the cell, an anode spaced from the cathode, and means for maintaining an electrolyte solution between the cathode and the anode. The anode comprises at least one dimensionally stable elongated anode strip at right angles to the cathode surface direction of movement. The anode strip is laterally flexible and has a formed, first configuration. A support means supports the anode strip and flexes the anode strip into a second supported configuration which is different from the formed first configuration. The anode strip in the second supported configuration is uniformly spaced from the cathode. The invention is particularly applicable to a radial cell in which a plurality of anode strips are positioned in an arc circumferentially around the cell cathode.

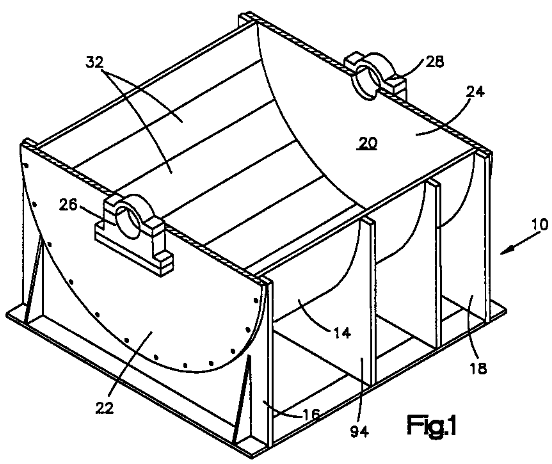

Fig.1

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Background of the Invention

Technical Field

This application is a continuation-in-part of prior Application Serial No. 425,084, filed October 23, 1989, assigned to the assignee of the present application.

The present invention relates to anodes for electrolytic cells, for such applications as electroplating, electrowinning, electrofinishing and electromachining, and particularly to anodes having a dimensionally stable active anode surface.

Description of the Prior Art

Dimensionally stable electrodes are well known. The term "dimensionally stable" means that the electrodes are not consumed during use. Typically, a dimensionally stable electrode comprises a substrate and a coating on surfaces of the substrate. The substrate and coating have to withstand the corrosive action of the electrolyte in which the electrode is immersed. One suitable material for the substrate is a valve metal, such as titanium, tantalum, zirconium, aluminum, niobium and tungsten. These metals are resistant to electrolytes and to conditions used within electrolytic cells. A preferred valve metal is titanium.

The valve metals can become oxidized on their surfaces increasing the resistance of the valve metals to the passage of current. Therefore, it is customary to apply electrically conductive, electrocatalytic coatings to the electrode substrate. The coatings have the capacity to continue to conduct current to the electrolyte over long periods of time without becoming passivated. Such coatings can contain catalytic metals or oxides from the platinum group metals such as platinum, palladium, iridium, ruthenium, rhodium and osmium.

The anode for an electrolytic cell such as an electrowinning cell is usually in the shape of a large surface which conforms generally to the shape of the cell cathode, but is spaced from the cathode. For instance, in the case of a radial cell, in which the cathode is in the shape of a relatively large, cylindrical drum, rotatable on the axis of the drum, the anode will have a cylindrically shaped concentric surface circumferentially superimposed over a relatively large part of the cathode.

It is difficult to manufacture such a large, anode, of dimensionally stable materials, to the tolerances necessary to achieve a uniform gap between the anode and the cathode. This is because the valve metals are resilient, and are difficult to roll to a predetermined curvature with close tolerance. Coating the valve metals further exaggerates the problem, since the coatings have to be heat treated, and the heat treatment can cause further deviation of the anodes from a desired curvature.

U.S. Patent No. 4,318,794 discloses a radial electrolytic cell for metal winning. A plurality of dimensionally stable, elongated, anode strips are positioned in the cell electrolyte spaced from a cylindrical cathode. The anode strips extend, longitudinally, parallel to the axis of the cathode. Each strip is relatively narrow in width, being co-extensive, circumferentially, with only a small surface or arc of the cathode. By employing a plurality of narrow strips, the tolerances to which each strip is rolled become less critical. Typically, the strips are about 2-4 inches in width.

U.S. Patent No. 4,642,173 discloses an electroplating cell. The cell comprises a dimensionally stable anode for depositing metal onto an elongated strip drawn longitudinally past the anode. The anode is immersed in an electrolytic solution and comprises an active surface which is directed toward the strip. The active surface comprises a plurality of lamellas supported so that all of the lamellas lie in a boundary which conforms to but is spaced from the path of the strip. Each lamella is welded to a support, along an edge, with the opposite edge of the lamella facing the strip. Being welded to a support, the lamellas are not readily replaceable. In addition, they are spaced apart from each other and thus do not present a continuous or substantially continuous anode surface.

Summary of the Invention

The present invention relates to an electrolytic cell which comprises a cathode having a cathode surface movable in said cell, an anode spaced from said cathode, and means for maintaining an electrolyte solution between the cathode and the anode. The anode comprises at least one dimensionally stable elongated anode strip at right angles to the cathode surface direction of movement. The anode strip is laterally flexible and has a formed, first configuration. A support means supports the anode strip and flexes the anode strip into a second supported configuration which is different from the formed first configuration. The anode strip in the second supported configuration is essentially uniformly spaced from the cathode. In a radial cell, the anode is flexed into a configuration, which, in cross-section, at right angles to the longitudinal dimension of the anode, is arcuate.

The present invention also resides, in one embodiment, in a novel anode configuration. The anode is dimensionally stable in an electrolyte. The anode is in the shape of an elongated channel having an active anode surface, and longitudinally extending flanges along opposite side edges of the active anode surface. The active anode surface has a thickness by which it is flexible. Supports engage the anode flanges so as to flex the active anode surface from a formed, first configuration, into a second supported configuration which is different from the formed, first configuration and which positions the active anode surface uniformly spaced from the cathode.

Preferably, the electrolytic cell comprises a plurality of elongated anodes positioned in side-by-side relationship, in an arc or plane, uniformly spaced from the cathode.

The present invention is useful for an electrolytic cell in which the anode defines an essentially continuous surface and the electrolyte flow is confined to a path defined by the anode and the cathode.

The present invention is also useful for an electrolytic cell in which the anode is immersed in the electrolyte contained within the cell.

Brief Description of the Drawings

Further features of the present invention will become apparent to those skilled in the art to which the present invention relates from reading the following specification, with reference to the accompanying drawings, in which:

Fig. 1 is a perspective schematic view of a portion of an electrolytic cell in accordance with one embodiment of the present invention;

Fig. 2 is an end elevation schematic view of the portion of the cell of Fig. 1;

Fig. 3 is an end elevation schematic view of an electrolytic cell which includes the portion of Fig. 1;

Fig. 4 is a plan schematic view of the portion of the cell of Fig. 1;

Fig. 5 is a side elevation schematic view of the portion of the cell of Fig. 1;

Fig. 6 is an enlarged plan view of a dimensionally stable anode used in the electrolytic cell of Fig. 1;

Fig. 7 is a further enlarged section view showing a portion of the anode of Fig. 6 and a part of the support therefor;

Fig. 7a is a further enlarged view of a portion of the support of Fig. 7 showing further details of the support;

Fig. 8 is an enlarged section view of a portion of two adjacent anodes of Fig. 6 showing further details of the anode support;

Fig. 8a is a reduced section view showing how the anode of Fig. 6 is flexed by the support structure of Figs. 7 and 8;

Fig. 9 is an enlarged detail view of a portion of the cell of Fig. 3 showing means for introducing electrolyte into the cell;

Fig. 10 is an end elevation view of an electrolytic cell and anode structure therefor in accordance with an embodiment of the present invention;

Fig. 10a is an enlarged section view of one anode of the anode structure of Fig. 10;

Fig. 11 is a sectional view of the electrolytic cell of Fig. 10 taken along line 11-11 of Fig. 10;

Fig. 11a is an enlarged detail view of a portion of the cell of Fig. 11;

Fig. 12 is an enlarged partial section view of a support for the anode of Fig. 10a;

Fig. 13 is a section view taken along line 13-13 of Fig. 12;

Fig. 14 is a partial section view of an anode assembly in accordance with another embodiment of the present invention; and

Fig. 15 is a partial section view of an anode assembly in accordance with a still further embodiment of the present invention.

Description of the Preferred Embodiments

The electrolytic cells of the present invention are particularly useful in an electroplating process in which a deposit of a metal, such as zinc, is made onto a moving cathode strip. An example of such a process is electrogalvanizing in which zinc is continuously galvanized onto a strip fed from a steel coil.

However, the electrolytic cells of the present invention can also be used in other electrodeposition processes, for instance plating other metals such as cadmium, nickel, tin and metal alloys such as nickel-zinc, onto a substrate, or the production of electrodeposited foil, for instance, copper foil used in the production of printed circuits for electronic and electrical equipment. The copper foil is electrodeposited from an electrolyte onto the surface of a rotating cathode. The foil emerges from the electrolyte and is stripped from the surface of the cathode, and is wound in the form of a coil onto a roll, all in a known manner.

Another electrodeposition process is surface treating foil, for instance copper foil, previously manufactured. Copper foil, when used for printed circuit boards, is bonded to a dielectric substrate. Electrodeposited copper foil has poor adhesion properties, because of its relatively smooth surfaces. It is conventional practice to surface treat the copper foil to obtain improved mechanical bonding properties between the substrate and the foil. One such treatment comprises forming a layer of dendritic copper or copper oxide particles on the surface of the foil. Another such treatment comprises forming a locking layer over the dendritic layer which adopts the configuration of the dendritic surface but helps maintain the dendritic layer intact.

The cell of the present invention can be also used in non-plating processes such as electromachining, electrofinishing, anodizing, electrophoresis, and electropickling. The anode of the electrolytic cell of the present invention can also be used in such applications as batteries and fuel cells, and in such processes as the electrolytic manufacture of chlorine and caustic soda.

Other specific uses for the apparatus of the present invention will be apparent to those skilled in the art.

In all of the above processes, it is necessary to carefully adjust the gap between the anode and the cathode. For instance, in electroplating, this in part controls the thickness of the layer which is electroplated. In the manufacture of electrodeposited foil, this in part controls the thickness of the foil. The present invention is concerned primarily with control of the anode/cathode gap.

Referring to the embodiment of the invention as depicted in Figs. 1-9, and particularly Figs. 1 and 2, there is shown a vessel 10 of an electrodeposition apparatus in accordance with the present invention. For the purpose of illustration, an electrodeposition apparatus for the production of electrodeposited foil will be described. The vessel 10 encompasses a cylindrical cathode 12, shown in phantom lines in Fig. 2. The vessel 10 has a concave shell 14 which is supported by end stanchions 16, 18. The shell 14 defines a chamber 20 which receives the cathode 12. The shell 14 is closed at its ends by circular end plates 22, 24 which are bolted to the stanchions 16, 18. The end plates 22, 24 support pillow blocks 26, 28 which in turn support the cylindrical cathode 12 when the electrodeposition apparatus is completely assembled. The cylindrical cathode 12 has an axial supporting shaft which is rotatably mounted in the pillow blocks 26, 28, in a known manner. The pillow blocks 26, 28 are positioned on the end plates 22, 24 so that the cathode is partially encompassed by the shell 14.

The vessel shell 14 and end plates 22, 24 therefor are preferably made of a current-conductive metal, having high tensile strength, such as steel and copper. The cylindrical cathode 12 can be of any conventional type. Typically, for the electrodeposition of copper foil, the cathode is a metal, e.g., steel or copper, drum having a surface layer suitable for use in an electrolytic bath. Examples of suitable metals for the surface layer are "Hastelloy" (trademark Union Carbide Corp., for a high strength, nickel-base corrosion resistance alloy) stainless steel, titanium, zirconium and tantalum.

It will be understood by those skilled in the art that although shell 14 is shown as substantially a semi-circle, other shell configurations can be used. For instance, the shell can be made so that it extends circumferentially a distance more than 180° around the cathode 12, for instance 260°. Generally, the shell 14 will be circular so that all surfaces of the shell 14 are equidistantly spaced from the cathode 12 which is contained by the shell. The end plates 22, 24 on the shell are removable. This permits the cathode to be inserted into the shell endwise rather than from the top. This mode of assembly is particularly useful if the shell 14 circumscribes the cathode by more than 180°.

In operation in metal electroplating, a thin film of metal is deposited from electrolyte in the shell 14 onto the surface of rotating cathode 12. Means, not shown, strip the film of metal from the cathode, on emergence of the film from the electrolyte, and coil the film in the form of a roll. It will be understood by those skilled in the art that the apparatus of Figs. 1 and 2 can be used for other electrolytic processes than manufacture of a metal film.

Referring back to Figs. 1 and 2, the shell 14 is lined on its inner surface with a plurality of elongated anode plates 32. Details of the anode plates 32 are shown in Fig. 6. Essentially, the anode plates 32 are elongated rectangular members having ends 34, 36, side edges 38, 40 and an active anode surface 42. The anode plates are bolted to the shell 14, in a manner to be described. As shown in Figs. 1, 2 and 4, the entire inner surface of shell 14 is lined with anode plates 32. The anode plates are positioned so that the edges 38, 40, Fig. 6, of one plate are contiguous with edges 38, 40 of adjacent plates. Thus, all of the anode plates together lie in an arc which is coaxial with the axis of the cathode and spaced from the surface of the cathode, the arc embracing, in the example of Figs. 1-9, about 180° of the circumference of the cathode.

The anode plates 32 are dimensionally stable electrodes. The dimensionally stable electrodes have a substrate which is capable of withstanding the corrosive action of the electrolyte in which the anode plates are immersed. Preferred materials for the substrate are a valve metal such as titanium, tantalum, zirconium, aluminum, niobium, and tungsten. These metals are resistant to electrolytes and conditions within an electrolytic cell. A preferred valve metal is titanium.

The valve metals can become oxidized on their surfaces increasing the resistance of the valve metal to the passage of current, thereby passivating the anodes. Therefore, it is customary to apply electrically conductive electrocatalytic coatings to the substrate which do not become passivated. Such coatings can contain catalytic metals or oxides from the platinum group metals such as platinum, palladium, iridium, ruthenium, rhodium and osmium. The coating also preferably contains a binding or protective agent such as oxides of titanium or tantalum, or other valve metal, in sufficient amount to bind the platinum group metal or oxide to the electrode substrate. An example of one such dimensionally stable anode is a titanium substrate which has been coated with an electrocatalytic coating containing ruthenium and titanium.

The substrate can also be a metal such as steel or copper which is explosively clad or plated with a valve metal, such as titanium, and then coated with an active oxide surface.

The anode plates 32 are thin gauge, resilient, rolled, or otherwise formed plates having sufficient flexibility so that they can be flexed a small amount using reasonable bolting force. The plates 32 should have sufficient thickness to carry current from a current connection throughout the anode active surface, and sufficient thickness so that the plates are self-supporting and capable of retaining, in the absence of applied force, the shape imparted to them by rolling or other forming. Broadly, by way of example, the anode plates 32 have a thickness of about 0.010 inch to about 0.5 inch. A thin coated titanium plate rolled, or otherwise formed, preferably has a thickness of about 0.20 to about 0.25 inch. The thinner the plate, the easier it is to install, and the lower the material cost.

The specific width dimension of the anode plates 32, between side edges 38, 40, is not critical. In the example illustrated in Fig. 6, the anode plates are relatively wide, about twenty-four inches.

As disclosed in parent Application Serial No. 425,084, each anode plate 32 can comprise several end-to-end segments 32a, 32b and 32c, Fig. 6, positioned longitudinally within the shell 14. The segments are separated by lines of separation 44 that are biased, e.g., biased with respect to the direction of travel of a metal film electrodeposited on cathode 12. This avoids unevenness of the electrodeposition of metal due to edge effects. The anode plates 32 from end 34 to end 36 can be relatively long, and dividing the anode plates into segments 32a, 32b and 32c facilitates forming and installation.

Fig. 7 shows the method of attachment of the anode plates 32 to the shell 14, and additional details of the vessel 10. Referring to Fig. 7, the vessel shell 14 has an inner lining 58. The lining 58 covers the entire inner surface of shell 14, and lies between the plurality of anode plates 32 and the shell 14. In the embodiment of Figs. 1-9, the lining 58 can be any suitable lining material for an electrolytic cell. Preferably, the lining has a high durometer hardness, for instance a Shore durometer of about 95 ±5, and is machinable. Preferably, the lining 58 is baked onto the inner surface of the shell 14. One suitable lining material is manufactured natural rubber. Other suitable materials are neoprene and EPDM (a terpolymer elastomer made from ethylene-propylene diene monomer). The purpose of lining 58 is to protect the shell 14 from corrosion by the electrolyte.

The anode plates 32 on their underside 60, opposite the active anode surface 42, have a plurality of spaced-apart bosses 62 welded thereto. The bosses 62 are shown in Fig. 6 in phantom lines. The bosses 62 are shown all aligned on the center-line of the anode plates. Each anode plate segment 32a, 32b, 32c, preferably has three bosses. This number of bosses can be increased if desired. Preferably, the bosses 62 are made of a valve metal, such as titanium. The bosses 62 are drilled and internally threaded. Bolts 64 extend through holes 66, in shell 14, aligned with bosses 62 and are threaded into the bosses 62 to secure the anode plates 32 to the shell 14. The bolts 64 can be made of steel or copper alloy, and preferably are coated with a dielectric, electrolyte resistant coating such as Teflon (trademark, E. I. DuPont de Nemours & Co.) for corrosion and galling resistance. The lining 58 has openings 68 aligned with holes 66 adapted to receive bosses 62. Similarly, the shell 14 is undercut on the inside at 70 to receive the bosses 62. The lining 58 is undercut at 72 to receive O-ring seals 74. One suitable seal material, for seals 74, is Viton (Trademark, E. I. DuPont de Nemours & Co.), a fluoroelastomer based on the copolymer of vinylidene fluoride and hexafluoropropylene. The O-ring seals 74 bear against the underside 60 of the anode plate 32 and prevent leakage of electrolyte from the interior of vessel 10 around the bolts 64.

As will be described, the current flow to the anode plates 32 is from shell 14 through the anode bosses 62. These anode bosses bear against a contact ring 76 seated at the bottom of undercut 70. The contact ring conveys current from the shell 14 to the anode bosses 62. The ring can be a knurled copper ring, or a compression ring such as shown in Fig. 7a. Referring to Fig. 7a, the contact ring 76 comprises a copper alloy strip 78. The copper alloy strip 78 is wound in the shape of a spring coil, and has a chevron cross-section, as shown. A fiber reinforced polymeric or rubber filling 80 is positioned between rolls of the copper strip 78. When an anode plate 32 is pulled down towards the shell 14, by turning bolt 64, this causes the boss 62 engaged by the bolt 64 to compress the contact ring 76 against the seat of undercut 70. The pressure exerted on the contact ring can be from 0 to about 12,000 pounds compression. This causes the copper alloy strip 78 of the contact ring to compress, as shown in Fig. 7a, and make good contact with the undercut surface 70 the shell 14 and boss 62, the compression breaking any formed oxide layer which could reduce contact voltage.

Referring to Fig. 8, the anode plates 32 are sealed at their edges 38, 40 by means of support strips 90. The support strips 90 are inserted into parallel grooves 92 machined into the exposed surface of the lining 58. The grooves 92 retain the support strips 90. The support strips 90 have a thickness whereby they protrude slightly above the exposed surface of lining 58. The opposed edges 38, 40 of adjacent anode plates 32 seat on the exposed surfaces of the support strips 90. The support strips 90 can be titanium strips or fiberglass. They are incompressible and thus are load bearing. The support strips 90 extend, longitudinally, coextensive with the anode plates 32, between the end plates 22, 24 of the electrodeposition apparatus, sealing the opposed edges 38, 40 of adjacent anode plates 32 the full distance between the end plates 22, 24. The end plates 22, 24 are also lined, on their inner surfaces, with a lining (not shown), similar to the shell lining 58. This seals the anodes 32, at their ends 34, 36 (Fig. 6), thereby sealing the vessel 10 against the leakage of electrolyte. Similar sealing can be employed at bias cuts 44, if the same are used.

The method of assembling the anode plates 32 into the electrodeposition apparatus in accordance with the present invention, will be apparent, by reference to Figs. 8a, 8, and 7. Initially, the anode plates 32 are rolled to a flat, or near flat configuration, as shown by the solid lines in Fig. 8a. It is understood that the anode plates can be rolled to a convex configuration or a concave configuration, depending upon the end configuration desired for the anode plates. The anode plates 32 are then placed in the shell 14, with the bosses 62 aligned with bolts 64 (Fig. 7). The bolts 64 are engaged with the bosses 62. At this point, the side edges 38, 40 of the anode plate 32 bear against the edge support strips 90, on the inner side of the lining 58 (Fig. 8). The bolts 64 are turned into bosses 62. This pulls the bosses 62 toward the shell 14 flexing the anode plate 32 into the configuration shown in dashed lines in Fig. 8a. When the anode plates 32 at bosses 62 are against or contiguous with contact rings 76 (Fig. 7), the anode plates 32 have the desired configuration, e.g., the same configuration as the shell 14.

The number of bolts 64, and anode bosses 62, which are employed for an anode plate 32, is important. The bolts 64, and anode bosses 62, should be sufficiently closely spaced together so as to pull the anode plates 32 uniformly towards shell 14, that is, so that there are no waves in the anode plates 32, in a longitudinal direction with respect to the plates. Also important is the distribution of current to the anode plates 32. The use of enough closely spaced bolts 64 and anode bosses 62 to force the anode plates 32 into non-wavy configuration, is sufficient to supply current uniformly to the anode plates.

As shown in the drawings, particularly Fig. 8, the anode plates 32 are spaced from lining 58 by a gap 98. It will be apparent that this gap, or the radial distance of the anode plates 32 from the axis of the cathode 12, can be varied by changing the radial dimensions of support strips 90 and contact rings 76 (Figs. 8 and 7, respectively). In addition, the configuration or arc prescribed by an anode plate 32, as shown in the dashed lines of Fig. 8a, can be varied by changing the radial dimension of either the contact ring 76 or the support strip 90.

Referring to Fig. 2, the shell 14 has at its bottom an orifice plate 48. The orifice plate 48 is fastened to the underside of the shell 14. Details of the orifice plate 48 are disclosed in Fig. 9. The orifice plate 48 has a plenum chamber 50 and an inlet connection 52 for introducing electrolyte into the plenum chamber 50. The plenum chamber 50 is open at its top in elongated orifice 54 through which electrolyte flows into the shell 14 and into the electrolyte chamber 84, between the cathode 20 and anode plates 32.

As shown in Fig. 9, the anode plates 32 have at their edges 38, 40, embracing the orifice plate 48, support strips 90, sealing the anode plates 32 against leakage of electrolyte between the plates and shell lining 58. The support strips 90 are the same as those shown in Fig. 8.

In the embodiment of Figs. 1-9, the flow of electrolyte into the electrodeposition apparatus is into the inlet 52 (Fig. 9), into plenum chamber 50 at the bottom of the cell, through orifice 54, and into the interior of the vessel 10. Since the anode plates are fully sealed, along edges 38, 40, and around bosses 62, the anode plates 32, with the cathode 12, define the annular electrolyte chamber 84 (Figs. 2 and 9) through which the electrolyte flows. Referring to Fig.3, the electrodeposition apparatus comprises an upper housing 82. The housing 82 has discharge plenums 86 along opposite sides. Each plenum 86 has a plurality of discharge ports 88. The electrolyte flows upwardly along both sides of the cathode 12, spilling out over edges of the discharge plenums 86 exiting in discharge ports 88.

The current flow in the electrodeposition apparatus is established by busses 96 affixed to end stanchions 16, 18 of the cell and ribs 94 (Fig. 1). Only two such busses are shown, in Figs. 2 and 3. The flow from the end stanchions and ribs is through the shell 14, contact rings 76 (Fig. 7), and bosses 62 into the anode plates 32. The flow of current is then through the electrolyte, through the cathode, and typically to conventional cathode brushes engaging the cathode support shaft in a known manner.

The apparatus of Figs. 1-9 can be characterized as a contained-flow apparatus, in which the flow of electrolyte is confined between the anode plates 32 and the cathode. Wiper seals (not shown) between the end plates 22, 24 and the cathode 12 prevent the cathode from being immersed in electrolyte except at the cathode active surface facing anode plates 32. It will be understood that the anode support structure disclosed can also be used in the type of cell in which the anodes are immersed in the electrolyte.

In the embodiment shown in Figs. 10-13, the electrodeposition apparatus comprises a tank 102. The tank 102 is rectangular in cross section, having bottom 104, and sides 106, 108. The tank is open at its top between sides 106, 108. During operation of the apparatus, the tank 102 is filled with a suitable electrolyte (not shown). A rotatable cylindrical cathode 110, shown in phantom lines, is positioned within the tank 102 so as to be partially immersed in the electrolyte. The cell of Figs. 10-13 can be characterized as a flooded design, in which the anode and part of the cathode are immersed in the electrolyte.

A plurality of supporting rubber coated steel beams 112, positioned near the bottom 104 of the tank, extend lengthwise in the tank. The beams 112 are supported by the tank end walls 114 (Fig. 11). The beams 112 in turn support a plurality of spaced apart supporting ribs 116, 118 (Figs. 10 and 11). Fig. 11 is a section view of Fig. 10, taken so that the side 106 of the tank is removed, revealing the inside of the tank. As shown in Fig. 11, the ribs 116 are end ribs positioned near end walls 114 of tank 102, and the ribs 118 are inner ribs, positioned at spaced intervals between the ribs 116. The end ribs 116 are supported by inner beams 112a (Fig. 10), and the inner ribs 118 are supported by all of the beams 112 (Fig. 10). As shown in Fig. 10, the ribs 116, 118 are arrayed in sets divided by gap 120, one set of ribs being arrayed along one side 106 of the tank 102, the other set of ribs being arrayed along the other side 108 of tank 102. Each rib 116, 118 along one side of tank 102 has a corresponding rib oppositely positioned along the other side of the tank. Each rib has a concave upper edge 122, a lower edge 124 which seats on a beam 112, and a vertical edge 126. The concave edge 122 of one rib faces the concave edge 122 of an oppositely positioned rib so that a pair of ribs together define, by the concave edges 122, a circular configuration as shown in Fig. 10. Preferably, the circular configuration is concentric with the circumference of cathode 110, although this is not essential. In the tank 102, the concave edges 122 of the ribs along one side 106 of the tank are all aligned lengthwise in the tank, and, similarly, the concave edges 122 of the ribs along the side 108 of the tank are all aligned lengthwise in the tank. This also is not critical, and other configurations for the ribs will be apparent to those skilled in the art.

To hold the ribs 116, 118 in overall alignment, the ribs are tied together by tie plates 128 welded to the vertical edges 126 of the ribs. Similar tie plates 128 are welded to the lower edges 124 of the ribs. The tie plates 128 extend lengthwise in the apparatus, parallel to beams 112, and are welded to all of the ribs 116, 118. This permits the ribs 116, 118 and other components of the electrodeposition apparatus to be preassembled outside of the tank 102, and then set in the tank onto beams 112, as a preassembly.

The electrodeposition apparatus of Figs. 10 and 11 comprises a plurality of anode plates 130, shown in Figs. 10a and 12. The anode plates 130 are positioned circumferentially around the cathode 110, generally concentric with the outer surface of the cathode, similar to anode plates 32 of the embodiment of Figs. 1-9.

Details of the anode plates 130 are shown in Figs. 10a and 12. The anode plates 130 are dimensionally stable, as with the anode plates of the embodiment of Figs. 1-9. The anode plates 130 are rolled as U-shaped channels 132 as shown in Fig. 10a. Each channel 132 comprises an elongated rectangular center portion 134 and longitudinally extending edge flanges 136, 138. The edge flanges 136, 138 are angled, for instance at generally right angles, with respect to the center portion 134. As with the embodiment of Figs. 1-9, the center portion 134, between edge flanges 136, 138 is relatively wide, for instance about 12-24 inches. The center portion has on one side 142, Fig. 10a, an active anode surface which, as will be described, faces cathode 110. Only the active anode surface and flanges 136, 138 are coated with a non-passivating coating.

During rolling, the anode plates 130 are rolled or otherwise formed so that the center portion 134 adopts an essentially flat configuration, as shown by the solid lines in Fig. 10a. However, it is understood that the channels 132 can be rolled or otherwise formed to a concave or convex configuration, depending upon the end configuration of the anode plates which is desired.

Referring to Fig. 12, the flanges 136, 138 of adjacent anodes are bolted together by bolts 140. The bolts 140 hold the outer face of one flange 136, of one anode plate 130, against the outer face of another flange 138, of another anode plate 130. In this way, the bolts 130 connect and hold together the entire array of side-by-side anode plates. The number of bolts 140, holding one anode plate to another, is sufficient to maintain an essentially uniform contact, lengthwise of each plate, between the connected flanges of adjacent plates.

The anode plates 130 are supported, at each bolt 140, by a bracket assembly 150 (Figs. 12 and 13). Each bracket assembly 150 comprises a current distribution bar 152, which extends the full length of the electrodeposition apparatus. Six such distribution bar 152 are shown in Fig. 11. The distribution bars 152 are affixed, e.g., welded, along one edge 152a (Figs. 12 and 13), to an adjustment clip 154. Each adjustment clip 154 is bolted to a cell rib 116, 118 by a bolt 156. The adjustment clips are positioned close to concave edges 122 of the ribs 116, 118. Each adjustment clip 154 has a slot 158 (Fig. 12). The adjustment clips 154 are movable circumferentially, on ribs 116, 118, by engagement of slots 158 with bolts 156. This permits circumferential adjustment of each anode plate 130 with respect to cathode 112. A jack screw 162 is welded to each rib and engages clip 154. The bolts 156 can be partially tightened on the clips 154. The jack screws 162 can then be turned forcing the clips 154 into a desired circumferential position. This permits fine positioning of the anode plates. The bolts 156 can then be fully tightened on the clips 154 securely holding the anode plates 112 to the ribs. The distributor bars 152 also have a slot 160 (Figs. 12 and 13). The slots 160 accommodate bolts 140. The slots 160 are oval-shaped, as shown in Fig. 13, which permits radial adjustment of each anode plate 130 with respect to cathode 110.

In the embodiment of Figs. 10-12, the anode plates are of titanium or other valve metal. The plates are coated, as mentioned above, on the active anode surface 142 and flanges 136, 138 with a non-passivating coating, for instance a platinum coating. Components of the bracket assembly 150 are similarly manufactured, clad and/or coated. For instance, the bolts 140 may be titanium bolts with a fluorocarbon coating to prevent galling, e.g., a Teflon coating. The current distribution bars 152 preferably comprise a copper core having a titanium cladding with a non-passivating coating. Other components immersed in the electrolyte, for instance the cell ribs 116, 118 and adjustment clips 154 are current carrying, and thus are made of titanium with a non-passivating coating such as of platinum at the electrical junctions.

In operation, current is introduced into the cell through busses 180 (Figs. 10 and 11), attached to inner ribs 118. The current flows from the busses 180 through the ribs 116, 118 to each current distribution bar 152, as shown in Fig. 11.

Assembly of the apparatus of Figs. 10-13 should now be apparent. The elongated channels 132 (Fig. 10a) are sufficiently flexible that they can be flexed laterally, in the center portion 134 between flanges 136, 138, to the configuration shown in dashed lines in Fig. 10a. As mentioned above, the anode plates 132 are initially rolled or otherwise formed so that the center portion 134, thereof, is relatively flat. Flexing the center portion 134 laterally into the concave configuration shown in dashed lines in Fig. 10a is achieved by spreading the flanges 136, 138 apart from each other and slightly truncating them as shown in Fig. 10a. Similarly, if a flat center portion 134 were desired, the anode could be rolled or otherwise formed to a convex or concave configuration, and then flexed into a flat configuration by appropriately manipulating the anode flanges 136, 138.

Referring to Figs. 12 and 13, the anode flanges 136, 138 are movable both circumferentially and radially in the cell. The anode flanges 136, 138 of the multiple anode plates 130 can be moved simultaneously radially towards the cathode, and at the same time spread apart, increasing the amount of flex or curvature in center portion 134 (Fig. 10a) of each anode plate. Conversely, the anode flanges 136, 138 of the multiple anode plates 130 can be moved simultaneously away from the cathode, and at the same time brought closer together, to reduce the amount of flex or curvature in the anode plates. Once the desired configuration of the multiple anode plates 130 is achieved, the plates can then be held in that configuration, by securely tightening the bracket assemblies 150 to ribs 116, 118.

In the apparatus of Figs. 10-13, even though the apparatus is a flooded design, with anode plates 130 and cathode 110 immersed in electrolyte, it is desirable to establish a flow of electrolyte in the gap 168 between the anode plates 130 and the cathode 110 (Fig. 10). This is accomplished by the use of induced flow in gap 120, Fig. 10, between ribs 116, 118 (by conventional means, not shown), into the gap 168 between the anode plates 130 and the cathode 110. The flow divides and extends upwardly in the gap 168, along both sides of the cathode 110, spilling over into the tank 102 at the upper edges of the uppermost anode plates. To confine the flow to the gap 168, the cathode 110 comprises at each end, a circumferential wiper seal 166 (Fig. 11a). The end ribs 116 each support a flanged seal ring 170. Each seal ring 170 extends all of the way around the inside of the cell, in an arc which has an axis coaxial with the cathode 110. Each seal ring 170 extends, as shown in Fig. 11, from the upper edge of one rib 116, on one side of the tank 102, to the upper edge of the rib 116 on the opposite side of the tank 102. The seal rings 170 each have a flange 172 (Fig. 11a). Each flange 172 has an annular slot 174. The slots 174 engage the wiper seals 166 and thereby confine the flow to gap 168.

It will be apparent to those skilled in the art, from the above, that the embodiment of Figs. 10-13 can be employed with a controlled flow apparatus such as disclosed with regard to Figs. 1-9. Alternatively, the anode design of Figs. 1-9 can be employed with a flooded cell design such as disclosed in Figs. 10-13. To adapt the anode plates 130 of the embodiment of Figs. 10-13 to controlled flow, a seal can be provided between contiguous flanges 136, 138 of adjacent anode plates 130. In this way, the anode plates would define, with the cathode, a completely confined channel through which the electrolyte would flow. If desired, the flanges 136, 138 could be undercut to accommodate a seal sealing the assembly against the leakage of electrolyte between the flanges.

Fig. 14 shows an alternative embodiment of the present invention in which the anode plates 210 can be flexed into a desired configuration. Each anode plate 210 is provided with a plurality of spaced apart main supports 230 aligned with the center line of the anode plate, a plurality of spaced apart edge aligned supports 240 aligned with one edge 242 of each anode plate, and a plurality of additional edge aligned supports 250, aligned with an opposite edge 252 of each anode plate. By suitably adjusting the supports 230, 240 and 250, the anode plate 210 can be flexed into a desired configuration. Electrolyte is contained in the apparatus within outer rubber-covered shell 260. All of the supports protrude through the shell and are adjustable radially with respect to the shell. The supports are sealed with respect to the shell 260 by seals 262.

A similar design is shown in Fig. 15. The cell comprises a plurality of anode plates 310. The anode plates 310 are provided, on their underside, with a plurality of bosses 312 similar to the cell of Figs. 1-9. The bosses protrude into holes 314 of a rubber lined shell 316. The shell 316 is similar to shell 14 of Fig. 1 extending circumferentially around a cathode (not shown). A rubber lining 317 covers the entire inner surface of the shell 316. The bosses are movable radially in the holes 314 and are sealed within the holes by seal rings 318. The bosses 312 are internally bored and threaded. Bolts 320 engage the bosses 312. The bolts 320 are located in holes 314, in a radial direction, by support washers 322 and spacer rings 324. Shims (not shown) similar to support strips 90 (Fig. 8), in shell 316, engage the longitudinally extending parallel opposite edges (not shown) of the anode plates 310. By suitably dimensioning the shims, spacer rings 324, and the amount bolts 320 are turned into bosses 312, the anode plates 310 can be flexed into whatever arcuate configuration is desired.

In the embodiment of Fig. 15, current is supplied to the anode plates by buss connections 326. Alternatively, the spacer rings 324 can function as contact rings, and current can be supplied to the anode plates 310, through the shell 316 and the spacer rings 324.

From the above description of preferred embodiments of the present invention, those skilled in the art will perceive improvements, changes and modifications. Such improvements, changes and modifications within the skill of the art are intended to be covered by the appended claims.

Claims

1. An electrolytic cell comprising:

a cathode having a cathode surface movable in said cell;

an anode spaced from said cathode;

means for maintaining an electrolyte solution between said cathode and said anode;

said anode comprising at least one dimensionally stable elongated anode strip at right angles to said cathode surface direction of movement, said anode strip being laterally flexible and having a formed, first configuration; and

support means for supporting said anode strip, said support means flexing said anode strip into a second supported configuration which is different from said formed first configuration.

2. The cell of claim 1 wherein said anode strip in the second supported configuration is uniformly spaced from said cathode.

3. The cell of claim 2 comprising a rotatable cylindrical cathode and a plurality of anode strips each having an active anode surface defining an arc coaxial with the axis of the cathode and spaced from the surface of the cathode, said active anode surface being bounded by parallel side edges parallel with the cathode axis, said plurality of anode strips being positioned in side-by-side relationship about the circumference of the cathode.

4. The cell of claim 3 wherein said anode strips are immersed in the electrolyte.

5. The cell of claim 3 wherein said anode strips define an essentially continuous surface and said cathode and anode strips define a confined passageway for the flow of electrolyte in the cell, said cell including means for sealing adjacent anode strips against the leakage of electrolyte between said anode strips.

6. The cell of claim 3 wherein said anode strips are channel-shaped comprising flange portions at said parallel edges which are angled with respect to said active anode surface, said flange portions being engageable by said support means to flex said active anode surface into a desired configuration.

7. The cell of claim 6 wherein adjacent anode strips are connected at said flange positions.

8. The cell of claim 3 wherein said support means comprises a surface conforming to said second supported configuration and said anode strips are flexed onto said surface.

9. An anode for an electrolytic cell which is dimensionally stable in an electrolyte, said anode being an elongated member in the shape of a channel, comprising:

a longitudinally extending active anode surface having opposed side edges;

longitudinally extending flanges along said opposed side edges;

said active anode surface having a thickness by which it is laterally flexible, from a formed first configuration, into a second supported configuration which is different from said formed, first configuration.

10. The anode of claim 9 wherein said elongated member is of a material selected from the group consisting of titanium, tantalum, zirconium, aluminum, niobium, and tungsten.

11. The anode of claim 9 wherein said second configuration is an arc.

12. The anode of claim 9 wherein said active anode surface comprises a non-passivating coating.

13. The anode of claim 12 wherein said coating contains a platinum group metal or contains at least one oxide selected from the group consisting of platinum group metal oxides, magnetite, ferrite and cobalt oxide spinel.

14. The anode of claim 12, wherein said coating contains a mixed oxide material of at least one oxide of a valve metal and at least one oxide of a platinum group metal.

15. An anode assembly for an electrolytic cell comprising:

an anode which is dimensionally stable in an electrolyte for said cell, said anode being of a substrate material selected from the group consisting of titanium, tantalum, zirconium, aluminum, niobium, and tungsten, and having a thickness by which said anode is flexible, said anode being in the shape of a channel, comprising:

an elongated active anode surface bounded by longitudinally extending generally parallel edges; and

longitudinally extending flange portions at said parallel edges which are angled with respect to said active anode surface;

support means engaging said flange portions and laterally flexing said active anode surface from a formed first configuration into a second supported configuration which is different from said formed, first configuration.

16. The assembly of claim 15 comprising a plurality of anodes in side-by-side relationship, the opposed flanges of one anode being contiguous with flanges of adjacent anodes on opposite sides of said one anode, said support means engaging each pair of contiguous flanges at a plurality of spaced-apart points.

17. The assembly of claim 16 for a radial cell wherein said anode flanges are movable circumferentially and radially in said cell.

18. The assembly of claim 17 wherein said support means comprises a plurality of longitudinally extending current distribution bars essentially co-extensive with said anodes, and fastening means connecting each contiguous pair of anode flanges with a current distribution bar.

19. The assembly of claim 18 including a plurality of spaced-apart support ribs extending in parallel planes laterally with respect to the plurality of anodes, a plurality of spaced-apart clips connecting each distribution bar to each rib, said clips being movable in planes parallel to the planes of said ribs.

20. The assembly of claim 18 wherein said distribution bars are movable radially.

21. The assembly of claim 18 wherein said current distribution bars comprise a core of a current carrying metal having a titanium cladding thereon and a non-passivating coating over said cladding.

22. The assembly of claim 21 wherein said fastening means comprises a metal core and a dielectric coating over said core.

23. An electrolytic cell comprising:

(a) a cathode having a surface movable in said cell;
(b) an outer shell contiguous with at least a portion of said cathode;
(c) at least one dimensionally stable elongated anode strip at right angles to said cathode surface direction of movement, said anode strip having an active anode surface and being laterally flexible defining a formed, first configuration;
(d) support means for supporting said anode strip so that said active anode surface faces said cathode, said support means comprising:
(i) a plurality of longitudinally extending spaced-apart bosses on the side of said anode strip opposite said active anode surface;
(ii) a plurality of fastening means connected with said shell adapted to engage said bosses and flex said anode into a second supported configuration which is different from said formed, first configuration.

24. The cell of claim 23 further comprising a dielectric shell lining resistant to electrolyte facing said cathode, said fastening means being conductive with the flow of current to said anode strip being through the shell and fastening means.

25. The cell of claim 24 including a contact ring seated on the cathode side of said shell between each boss and the shell, each contact ring being under compression loading.

26. The cell of claim 25 wherein each said fastening means comprises a conductive, metal core and a dielectric coating on said core.

27. The cell of claim 26 wherein said fastening means extend through said shell and comprise a portion engaging the outer surface of said shell, said fastening means being under tension loading.

28. The cell of claim 27 wherein said anode strip Comprises longitudinally extending parallel edges, said cell comprising elongated support strips between said edges and said shell biasing the anode strip with said contact ring into said second supported configuration.

29. The cell of claim 23 wherein said anode strip comprises longitudinally extending parallel edges, said cell comprising elongated support strips between said edges and said shell, said fastening means flexing said anode strip against said support strips into said second, supported configuration.

30. The cell of claim 29 comprising a plurality of anode strips in side-by-side relationship, the contiguous edges of adjacent anode strips being spaced-apart defining a plate edge gap and being sealed against the same support strip.

31. The cell of claim 30 wherein said support strips are of a dielectric material.

32. The cell of claim 30 wherein said shell comprises a dielectric shell lining resistant to electrolyte facing said cathode, said support strips being embedded in said lining but having a support surface above the exposed surface of said lining.

33. An electrolytic cell comprising:
(a) a cathode having a surface movable in said cell;
(b) at least one anode strip, said anode strip having an active anode surface and being laterally flexible;
(c) support means for supporting said anode strip so that said active anode surface faces said cathode, said support means comprising a plurality of longitudinally extending spaced-apart bosses on the side of said anode strip opposite said active anode surface; and
(d) a contact ring seated against each boss, each contact ring being under compression loading.

34. An electrolytic cell comprising:
(a) a cathode having a surface movable in said cell;
(b) a plurality of elongated anode strips in side-by-side relationship with each elongated anode strip being laterally flexible, while having longitudinally extending parallel edges with an active anode surface therebetween; and
(c) a plurality of elongated support strips extending between said parallel edges of said anode strips, the contiguous edges of adjacent anode strips being spaced-apart defining a plate edge gap and being sealed against the same support strip.

35. The cell of claim 34 wherein said anode strips being laterally flexible define a formed, first configuration and fastening means connected with said anode strips flex said anode strips against said support strips into a second, supported configuration.

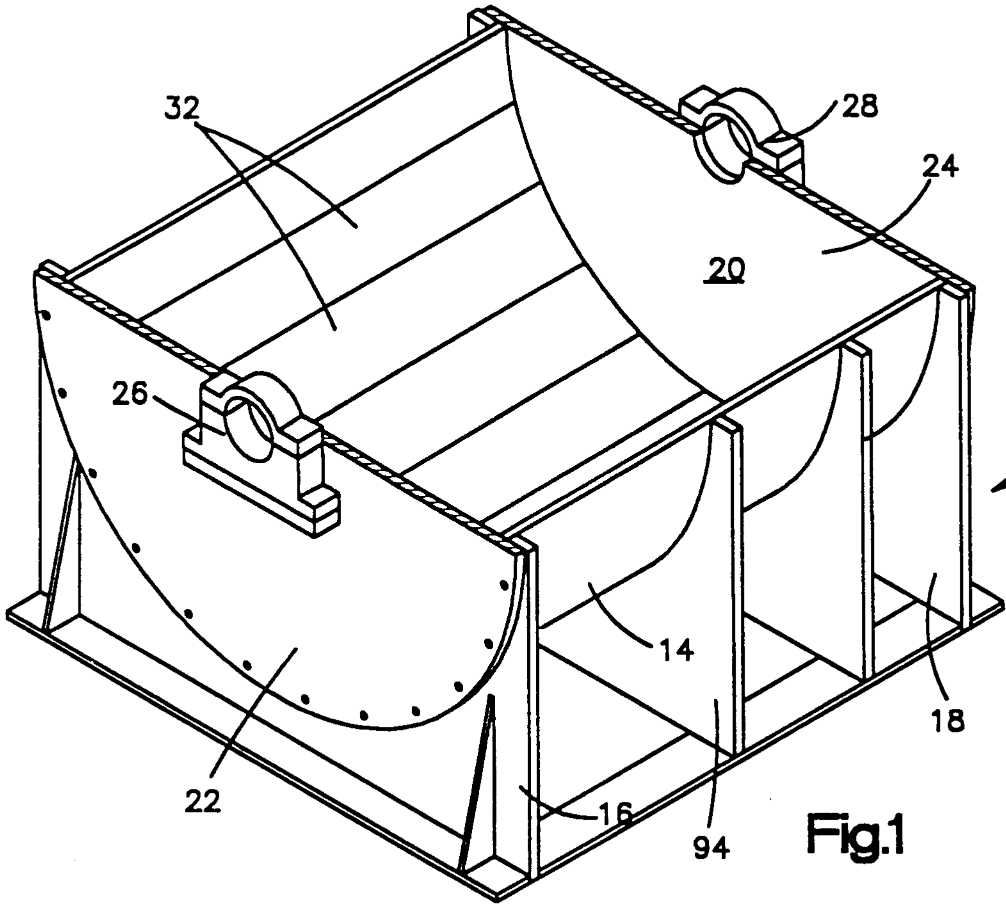
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Fig.1

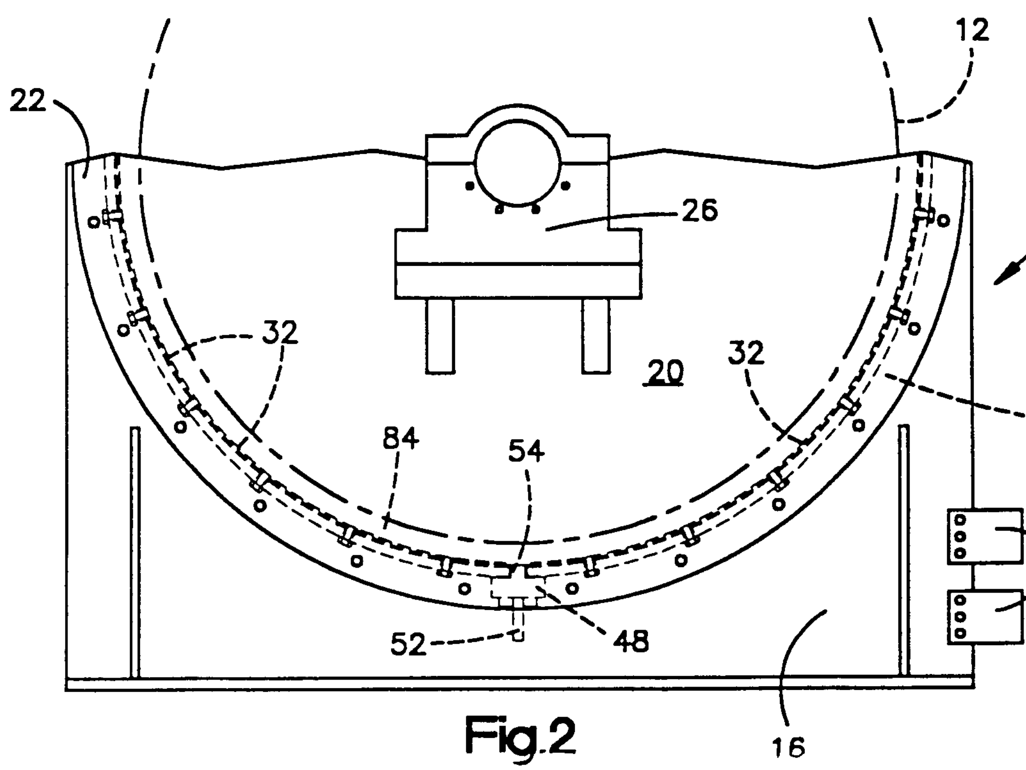
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Fig.2

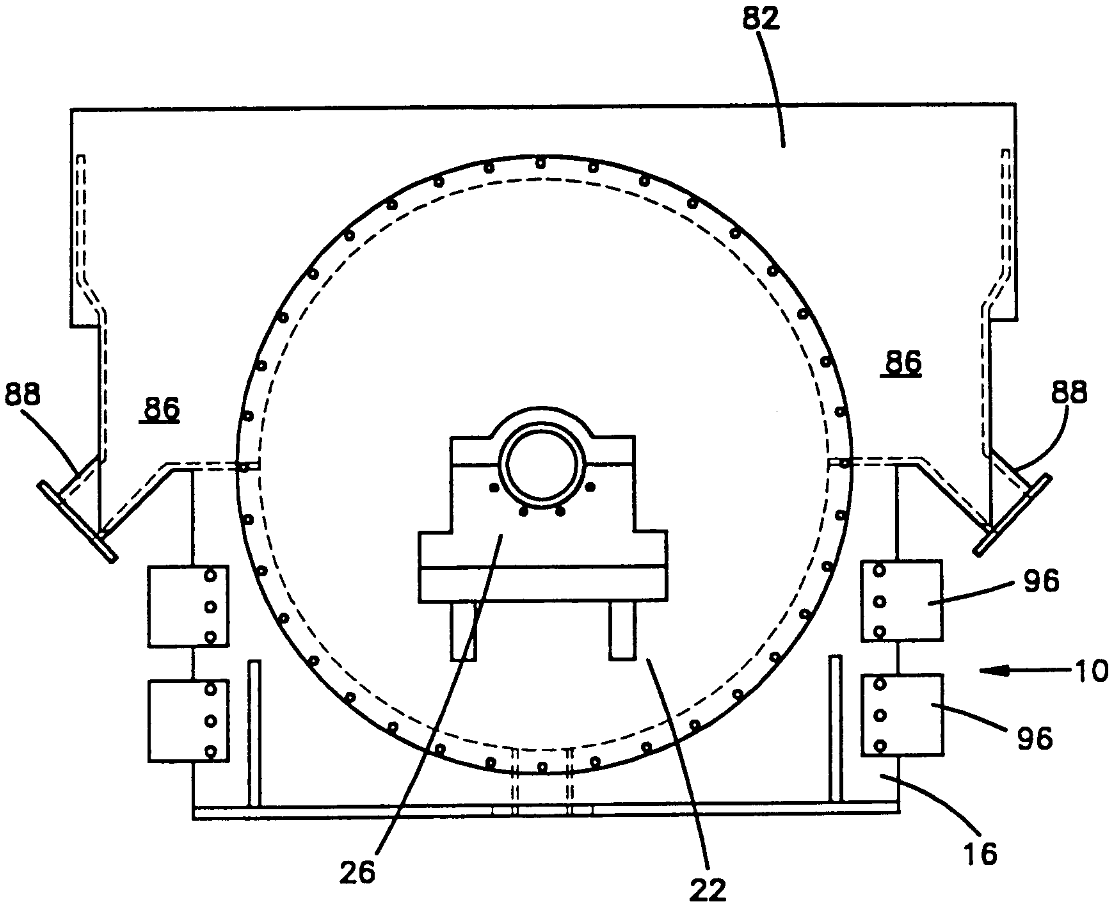

Fig.3

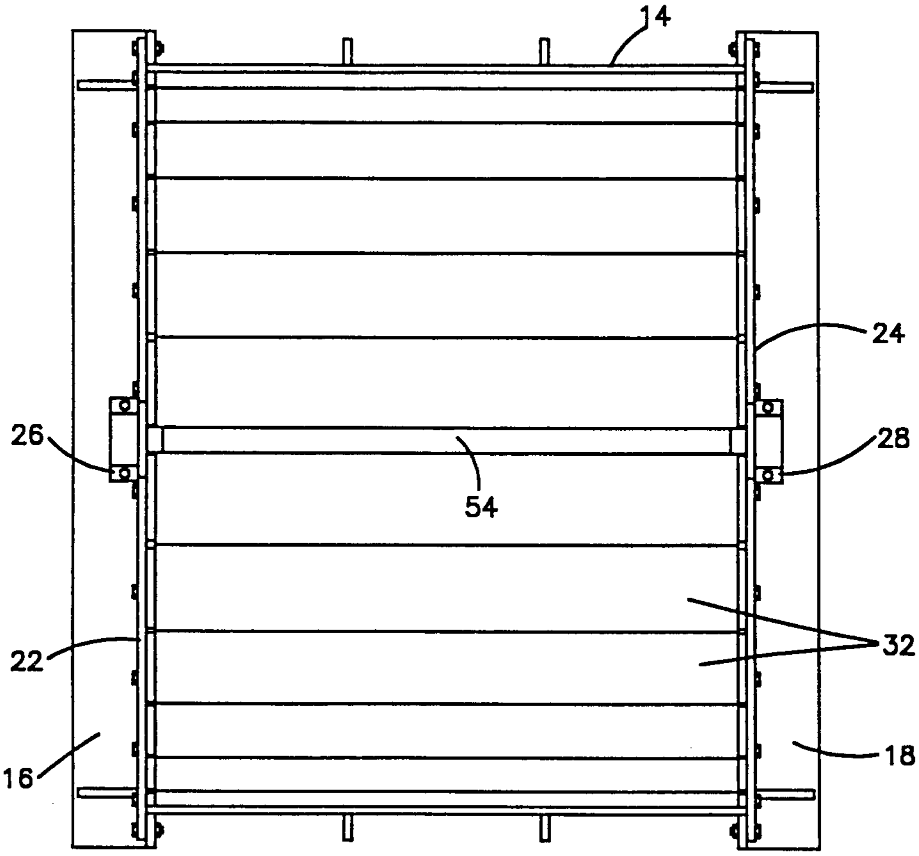

Fig.4

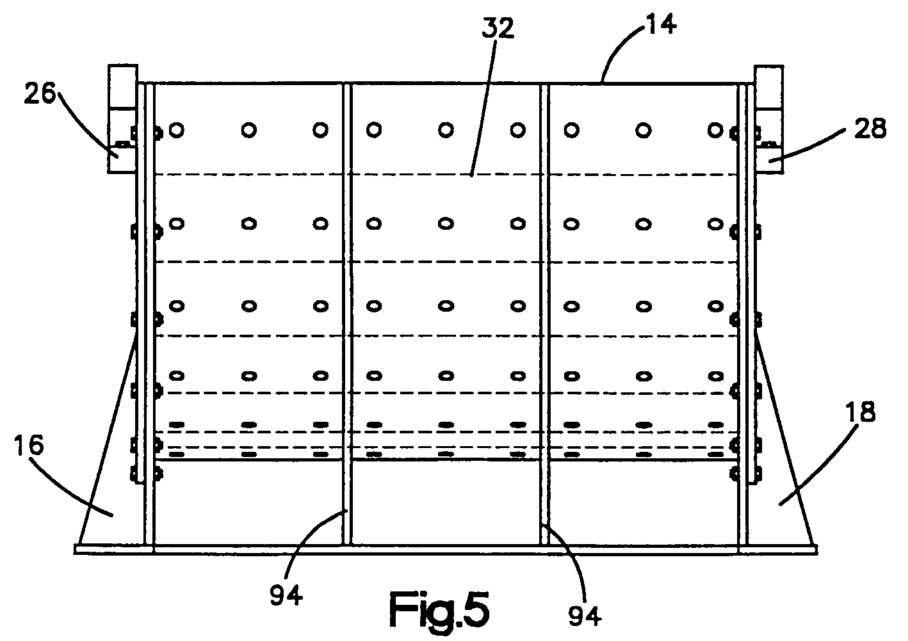

Fig.5

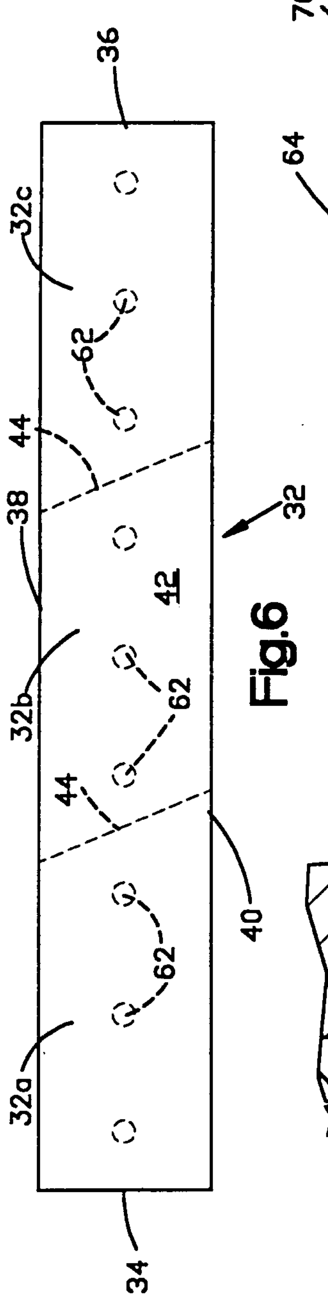

Fig.6

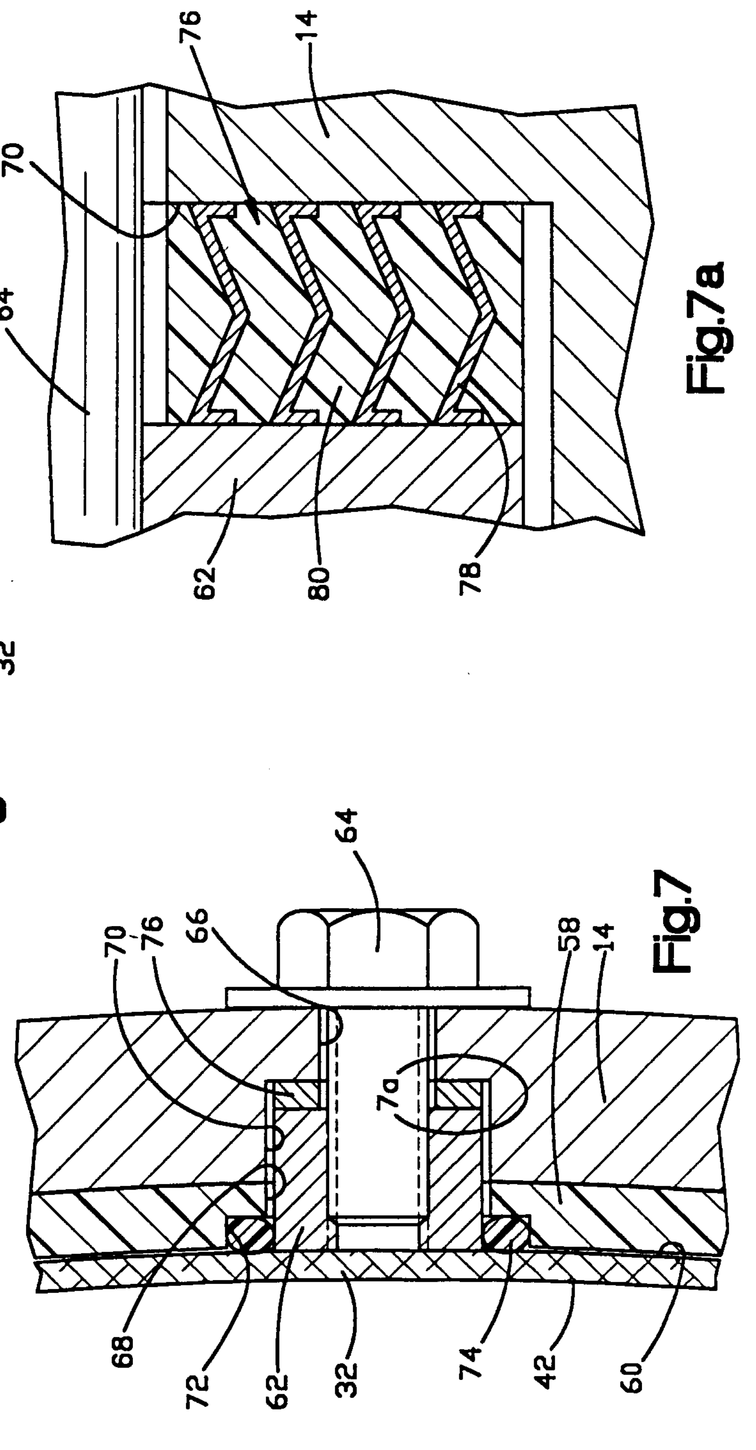

Fig.7a

Fig.7

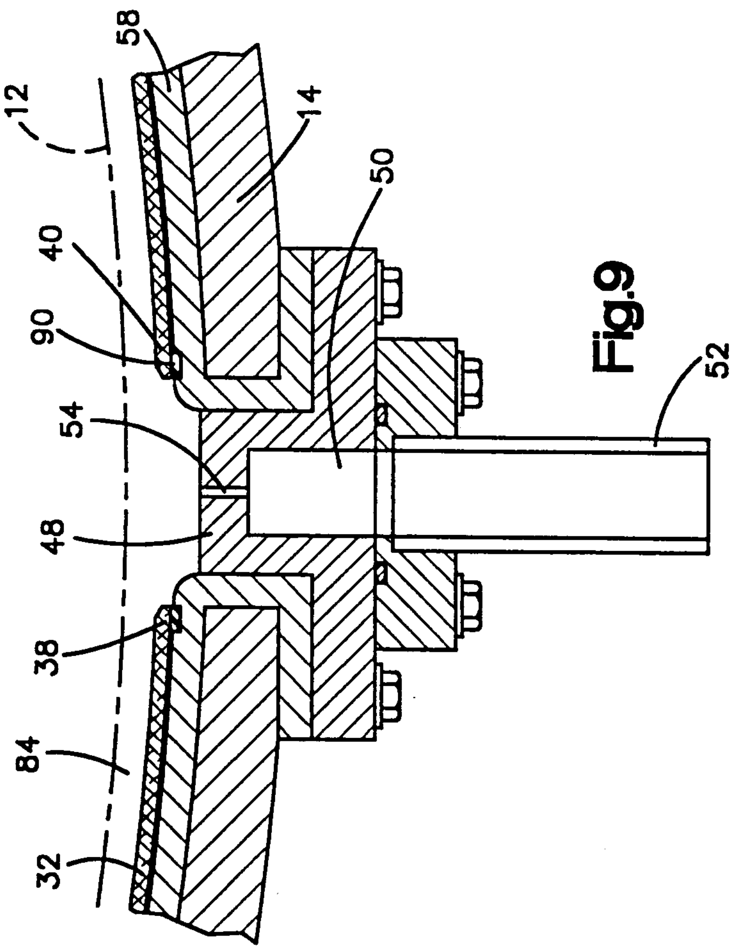

Fig.9

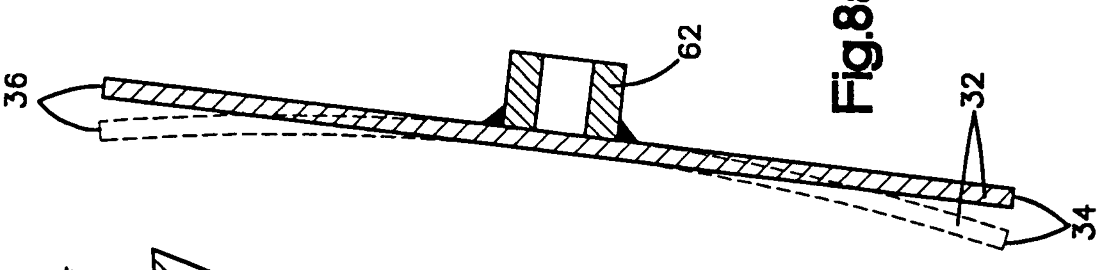

Fig.8a

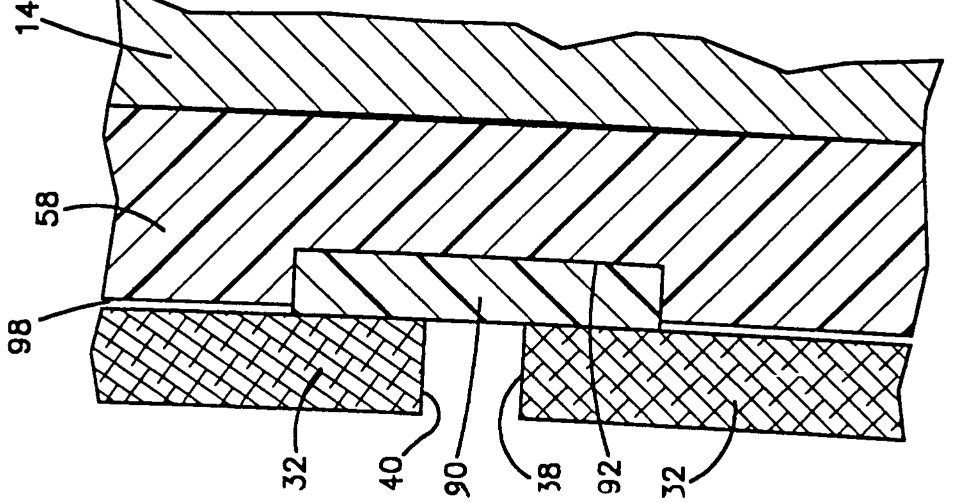

Fig.8

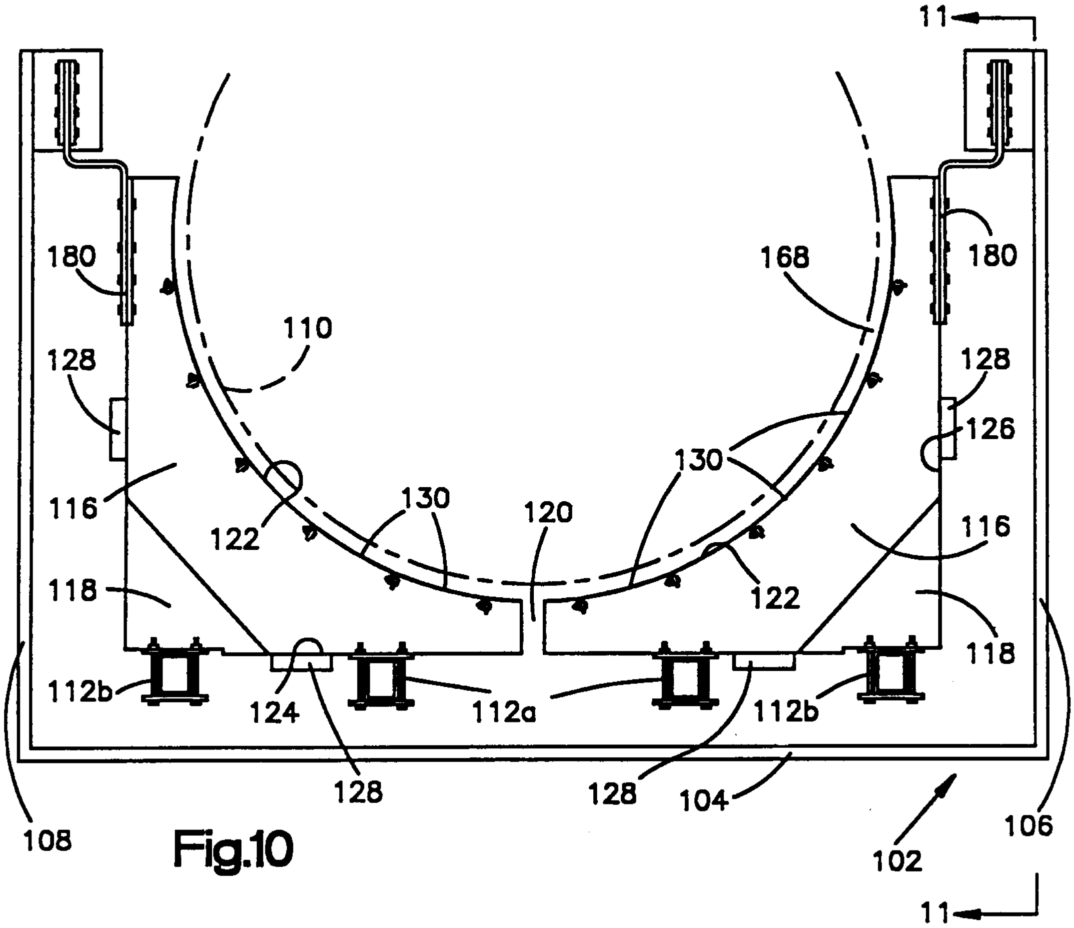

Fig.10

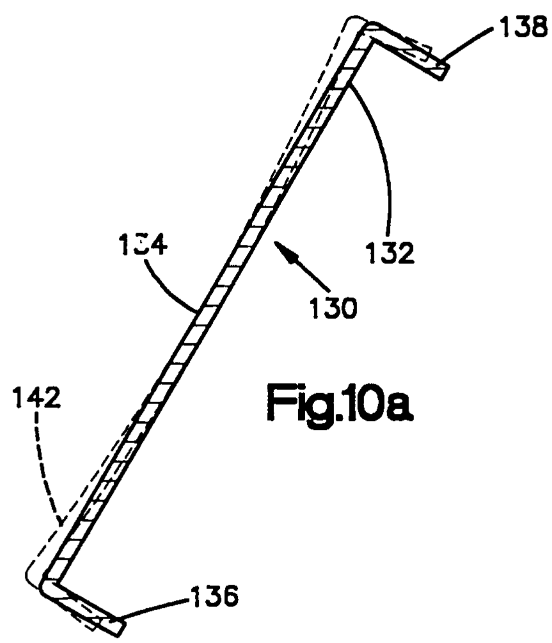

Fig.10a

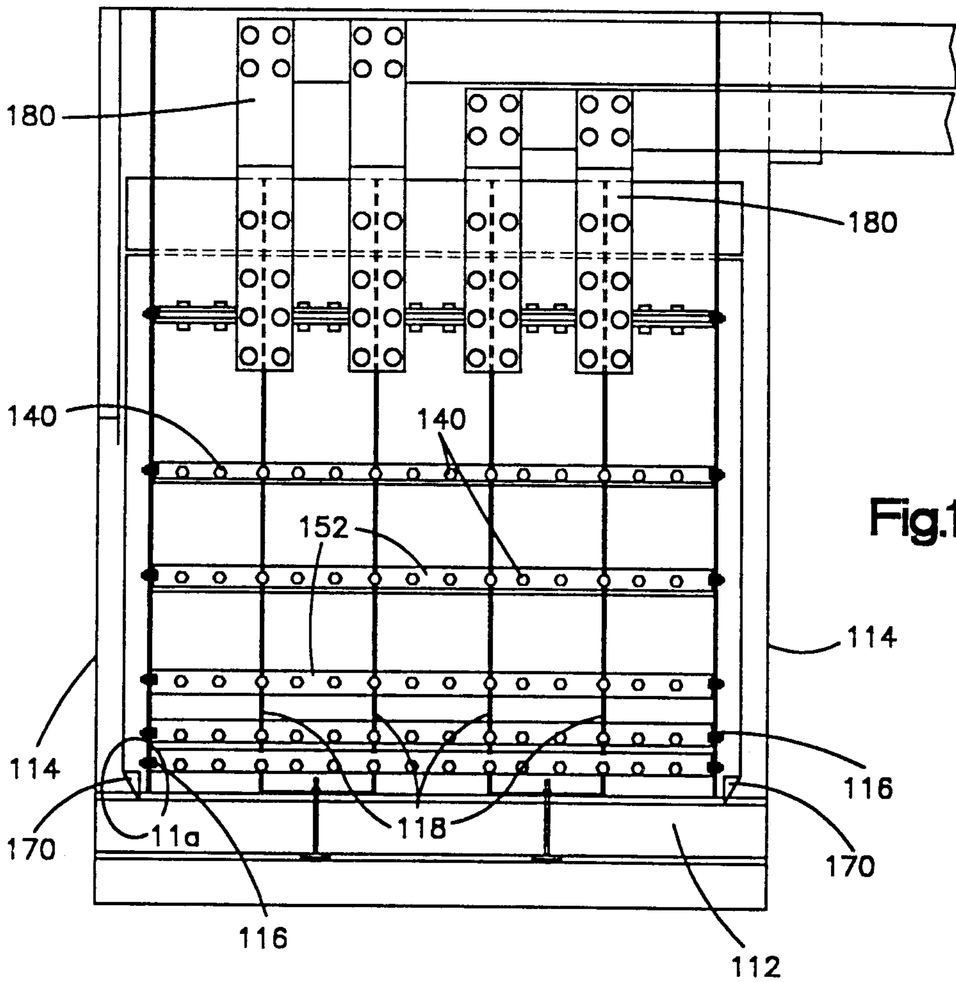

Fig.11

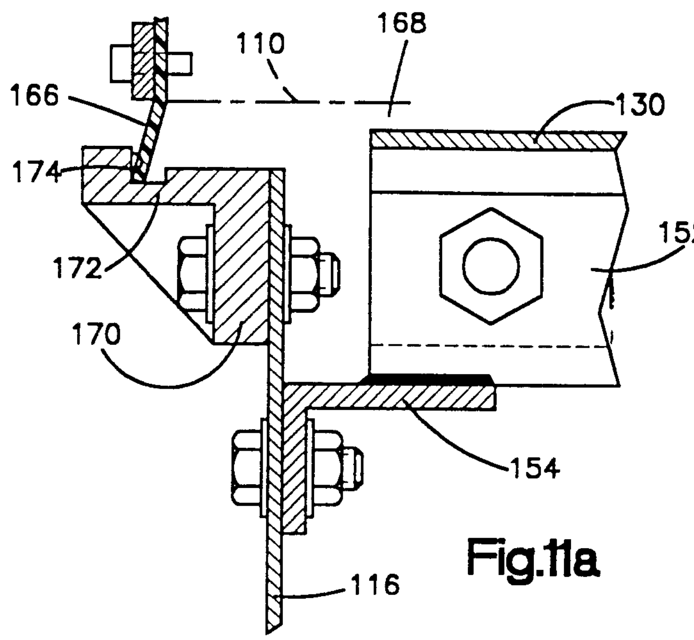

Fig.11a

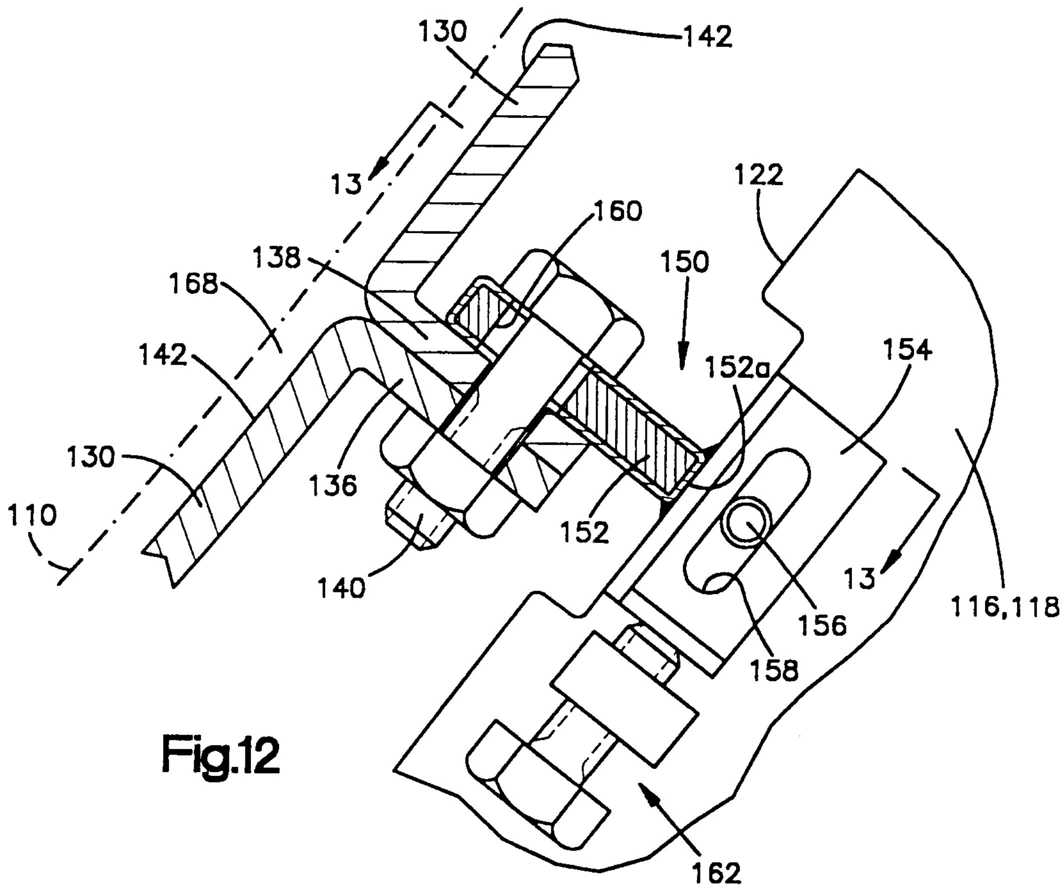
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Fig.12

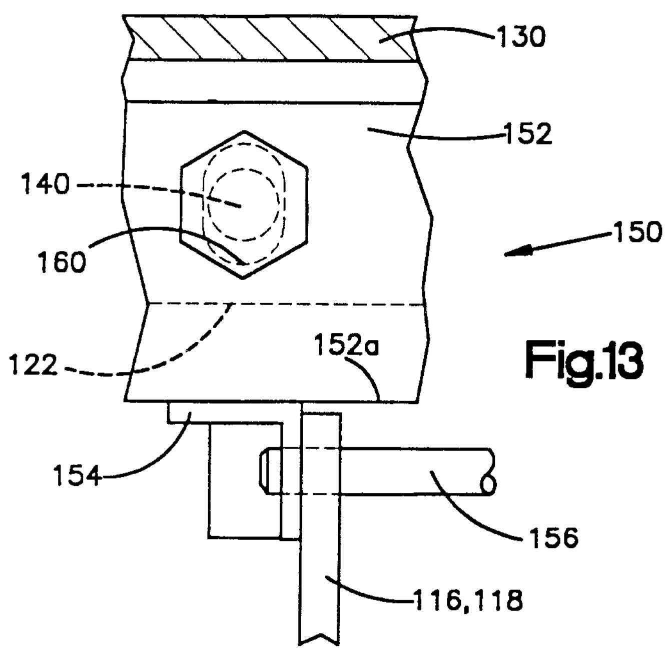
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Fig.13

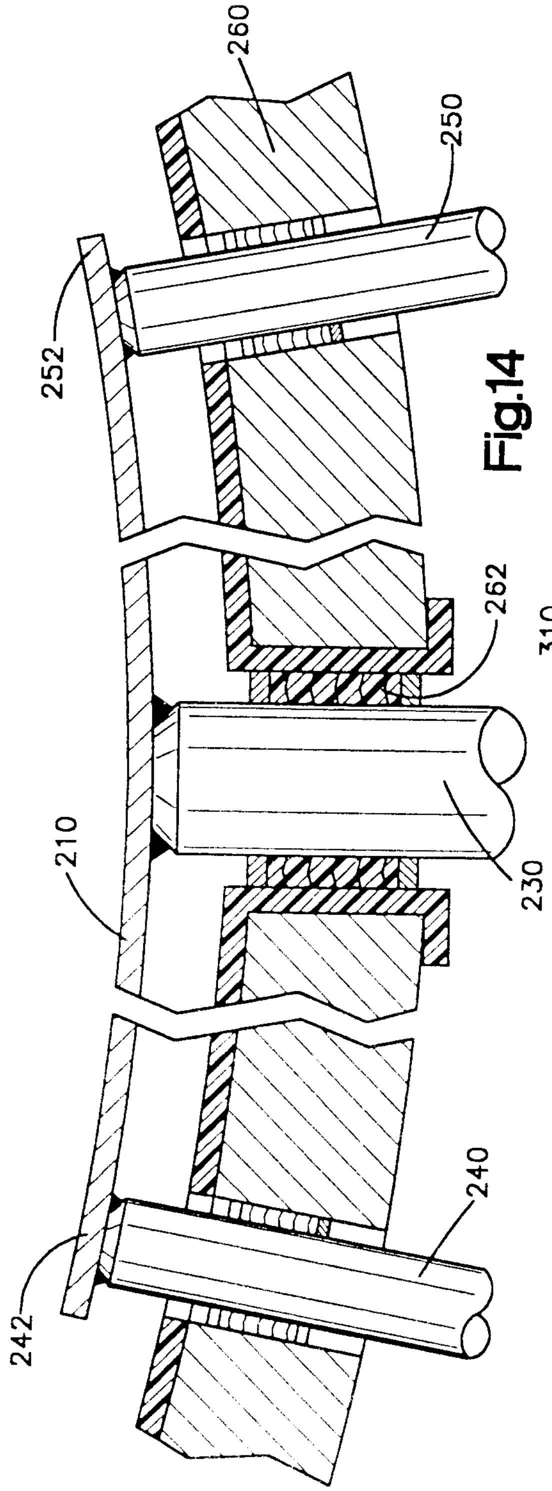
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Fig.14

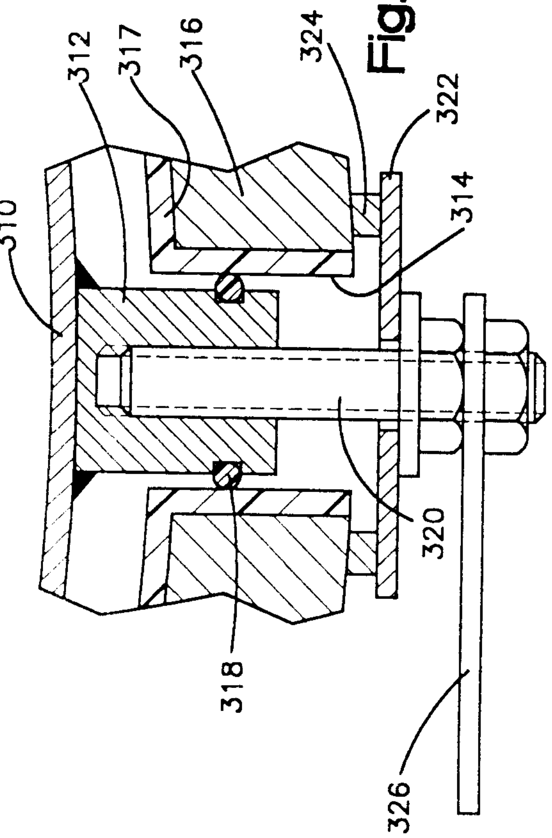
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Fig.15