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ALUMINUM ANODIZING APPARATUS

Filed March 17, 1958

6 Sheets-Sheet 2



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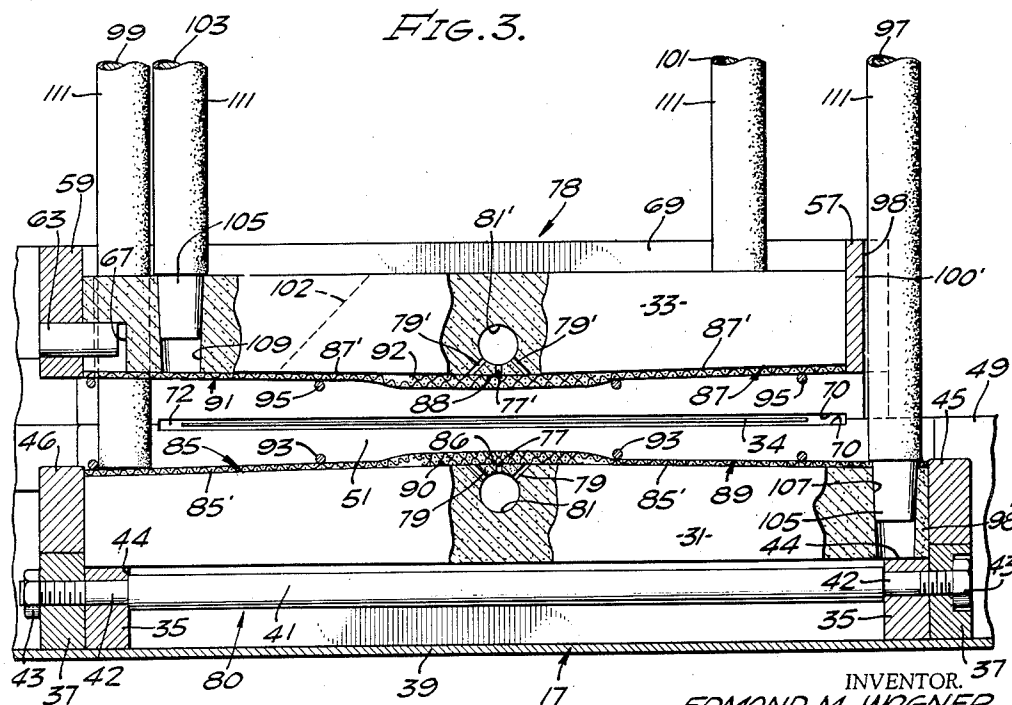
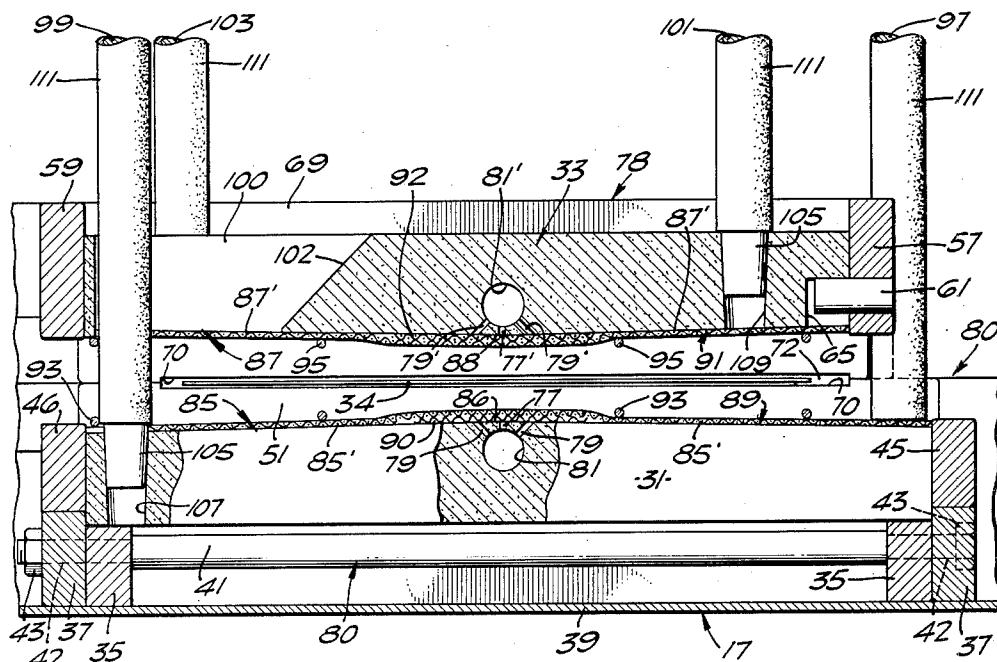
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ALUMINUM ANODIZING APPARATUS

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ALUMINUM ANODIZING APPARATUS

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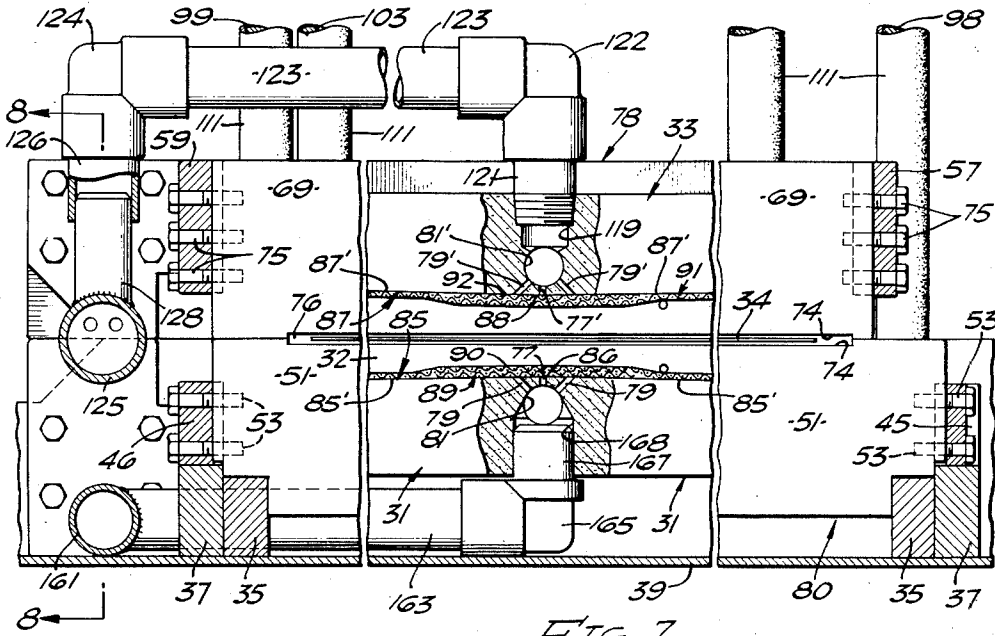


FIG. 7.

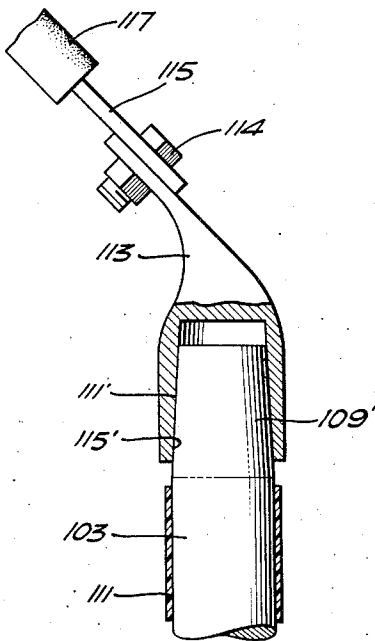


FIG. 11.

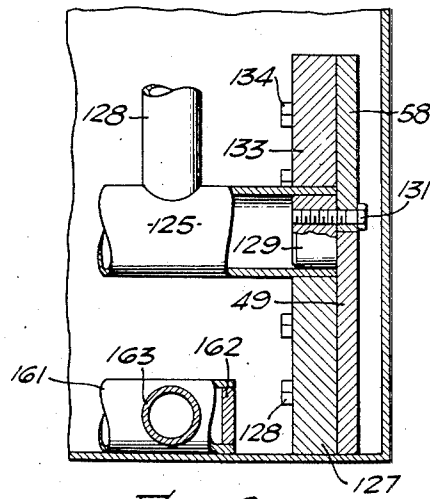


FIG. 8.

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ALUMINUM ANODIZING APPARATUS

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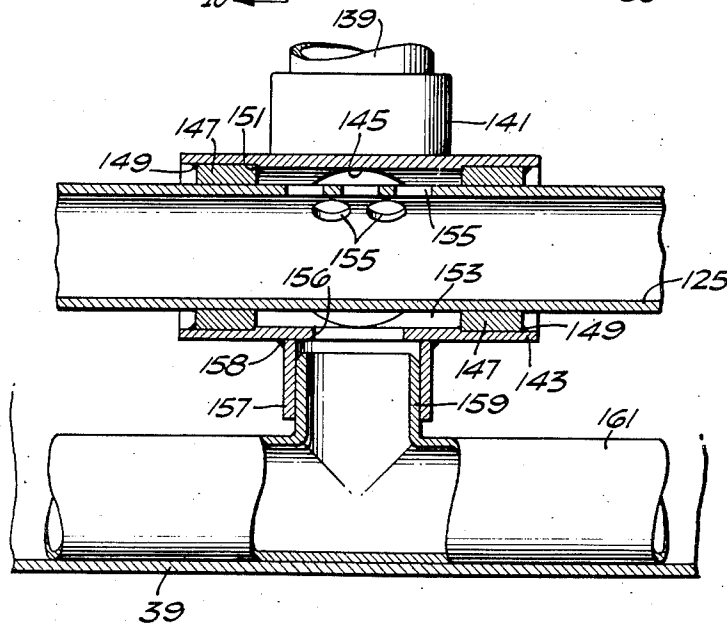
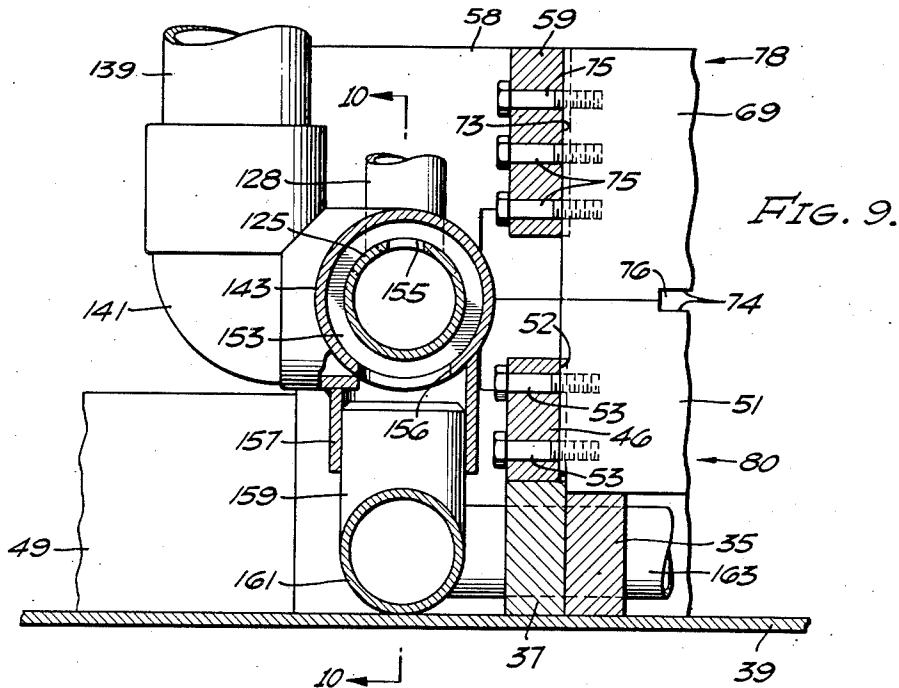


FIG. 10.

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ALUMINUM ANODIZING APPARATUS

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8 Claims. (Cl. 204—206)

This invention relates generally to application of an electrolytic oxide coating on aluminum preferably in the form of foil, strip, tubing, bars and the like, and is particularly concerned with novel apparatus for anodizing such forms of aluminum to produce thereon an adherent ductile oxide coating.

This application is a continuation-in-part of my co-pending application Serial No. 678,321, filed August 15, 1957.

Apparatus and procedure are disclosed in my above co-pending application for forming oxide coatings particularly in a continuous manner on aluminum foil, strip and the like, to obtain smudge-proof, bloom-free and adherent oxide coatings especially adapted for subsequent dyeing of the aluminum surface, or for subsequent drawing of the aluminum article.

Such apparatus comprises a plurality of plate-type electrodes which are resistant to corrosion by the electrolyte bath, and preferably composed of carbon, said electrodes being arranged in one or more electrolytic tanks, and disposed therein on opposite sides of the path of movement of the foil or strip of aluminum, to obtain uniform distribution of the aluminum oxide coating.

In the apparatus of my above application, means are provided in conjunction with the oppositely disposed electrodes for circulation of electrolyte through the respective electrodes and for discharging the thus circulated electrolyte into the space between the electrodes and the aluminum foil or strip at a plurality of locations lengthwise of the foil or strip, the electrolyte flowing outwardly toward opposite side edges of the foil from a point intermediate said edges.

In some instances, however, particularly where the rate of flow of electrolyte into the zone between opposite electrodes varies or is reduced, static bodies of electrolyte tend to develop in such zone adjacent the aluminum part, producing some non-uniform electrolytic oxidation of the aluminum surface and uneven and non-adherent oxide deposition on said surface. It is an object of this invention to provide means for diffusing and discharging the flow of electrolyte solution uniformly by means of a plurality of streams from the electrodes into the zone therebetween which defines the path of travel of the aluminum article.

Another object is to afford diffuser means of the aforementioned diffusing nature, which functions to distribute the electrolyte solution so as to provide a uniform flow thereof in the space between opposite electrodes and the aluminum foil or strip, outwardly toward the opposite longitudinal edges thereof, and substantially eliminating any quiescent bodies of solution in said space, and which also functions to provide uniform cooling of the electrolyte bath and strip and even temperature in both.

Also, employing the plate-type electrodes of my aforementioned application, a difficulty sometimes presents itself in the nature of an uneven distribution of current across the electrodes which causes the current density in the aluminum foil or strip to vary instead of remaining substantially constant, the preferred mode of operation. This results in a tendency toward non-uniform deposition of oxide coating on the foil or strip, and in certain circumstances produces non-adherent coatings. It is thus a still further object of the invention to provide means for controlling even distribution of the current across

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the faces of the electrodes. Yet another object is to design the plate electrodes in a manner to result in such uniform distribution of current across the electrodes and the maintenance of constant current density across the foil or strip, producing uniform quality and thickness of oxide coating thereon.

Yet another object is to provide means in combination for efficiently circulating electrolyte in the anodizing zone to maintain sufficiently low anodizing temperature and uniform electrolyte distribution and velocity, while at the same time maintaining constant current density in the aluminum article undergoing electrolytic oxidation.

The above and other objects and advantages will become apparent hereinafter.

The invention device comprises diffuser means, preferably in the form of an insulating screen, positioned adjacent the discharge openings or ports in the electrodes, which ports discharge electrolyte from the opposite electrodes into the anodizing zone between such electrodes.

The screen extends substantially across the inner faces of the opposing electrodes, from edge to edge of each such electrode. At an intermediate or middle portion across each of said screens, and over the liquid discharge ports in the electrode plates, said insulating screens are built up to present a finer mesh and greater multiplicity of distributing openings, than in the outer portions of the screens remote from said discharge ports. This multiplicity of openings in the diffuser screen adjacent the discharge ports provides increased area to carry the large volume of electrolyte from said ports, and tends to distribute the flow of solution in a manner such that a large plurality of fine streams of liquid are discharged from the screen into the central portion of the spaces between the opposite electrodes and the aluminum article, avoiding formation of static local bodies of solution particularly in the central portion of the zone between the electrodes, and distributing flow of electrolyte evenly into the space between electrodes over a wider area than heretofore accomplished. This results in uniform removal of heat during anodizing and in maintenance of an even bath temperature.

By reason of the uniform electrolyte velocity afforded by the diffuser member, uniform resistance of the electrolyte is provided, creating uniform current distribution through the solution across the electrodes. The use of an insulating screen as diffuser member also aids directly in even distribution of the current by reason of its adding substantially to the resistance across the gap between the electrodes, thereby reducing the effect of variation of electrical resistance of the electrolyte. However, a conductive diffuser member or screen can also be employed to obtain uniform distribution of electrolyte flow between the electrodes, although the insulating type is preferred because of the above described additional effect of providing increased electrical resistance across the gap between the electrodes.

Also, the invention device embodies a novel electrode design which aids in producing equal current distribution across the electrodes, said novel design involving tapering the cross section of the electrode from the middle to the outer edges thereof. According to a preferred embodiment, the inner adjacent surfaces or faces of the opposed electrodes, which surfaces face the aluminum article passing through the zone between the electrodes, are divergent, being closer together at the middle of each electrode section, and further apart at the outer longitudinal edge of the respective electrodes, so that the electrode plate is thicker at the middle of each said electrode section than at said outer longitudinal edges, and the distance between the opposite outer edges of the opposed electrodes is greater than the distance between the middle portions thereof. I have found that such a design equalizes the

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current distribution on the face of the electrodes and provides constant current density in the aluminum foil or strip being anodized, resulting in uniform oxide coatings thereon.

The device also includes the provision of electrode terminals in the form of a plurality of rods connecting the source of potential connected to each of the electrode plates, said rods being insulated along substantially their entire length to prevent short-circuiting of the current from said rods to the electrolyte solution and to various parts of the electrodes, instead of conducting the current uniformly to the solution via the face of the electrodes.

The invention will be more readily understood from the following description of a preferred embodiment of my apparatus, taken in connection with the accompanying drawings wherein:

FIG. 1 is an end view of the device shown in FIG. 2, taken on line 1—1 of FIG. 2;

FIG. 2 is a plan view of the invention device;

FIG. 3 is a transverse section taken on line 3—3 of FIG. 2;

FIG. 4 is a transverse section taken on line 4—4 of FIG. 2;

FIG. 5 is a longitudinal vertical section taken on line 5—5 of FIG. 2;

FIG. 6 shows a detail plan view of the electrode employed in the invention device, taken on line 6—6 of FIG. 5;

FIG. 7 is a transverse vertical section taken on line 7—7 of FIG. 2;

FIG. 8 is a section taken on line 8—8 of FIG. 7;

FIG. 9 is a vertical section taken on line 9—9 of FIG. 2;

FIG. 10 is a section taken on line 10—10 of FIG. 9;

FIG. 11 is a detail of the electrode rod structure; and

FIG. 12 is an assembly view showing an electrolyte circulating system employed in conjunction with my device.

Referring first to FIG. 12 of the drawings the novel electrode structure of the invention, designated generally by the numeral 15, is mounted within an anodizing tank 17 which in turn is mounted in a sump tank 21 on cross bars 19 therein, said cross bars 19 being connected as by welding to the sides of tank 21. Electrolyte solution in sump tank 21 is circulated via a line 23 and a pump 25 through a heat exchanger 27 and thence via main feed line 29 back to the anodizing tank 17.

Referring now to FIGS. 1-7 of the drawings, there is mounted in the anodizing tank 17 a series of identical lower electrodes 31, shown as three in number in FIGS. 2 and 5, and a series of identical upper electrodes 33, also shown as three in number in FIGS. 2 and 5.

As is seen in FIGS. 1-5 and 7, the lower series of electrodes 31 and the upper series of electrodes 33 are in the form of plates, said two series of electrodes being disposed in horizontal parallel planes. The lower three electrodes are in longitudinal alignment and the upper three electrodes 33 also are in longitudinal alignment with each other, as best seen in FIG. 5. Electrode plates 31 and 33 are preferably formed of a conductive non-corrosive and non-metallic material inert to the acid electrolyte, preferably carbon. It is convenient to design lower electrode plates 31 somewhat larger transversely thereof than the upper electrode plates 33 so that the upper electrodes are offset along one edge thereof from the lower electrodes, as seen in FIGS. 1 and 2, although it will be understood that both the upper and lower electrodes may be of the same size. The lower electrodes 31 are spaced from the upper electrodes 33 to form a zone 32 between said lower and upper electrodes through which an aluminum foil or strip 34 is arranged to be continuously conducted for production of an oxide coating thereon in the manner described more fully below. The terms "longitudinal" and "transverse" employed herein, unless otherwise indicated, are with respect to the aluminum foil or strip 34 being treated.

The lower electrodes 31 are mounted on oppositely

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disposed longitudinally extending parallel blocks or rails 35 (see FIGS. 3 and 4), which are clamped in position against outer longitudinally extending supports 37, both the blocks 35 and supports 37 being positioned on the bottom 39 of the anodizing tank 17. The blocks 35 and supports 37 are maintained in clamped position by means of a series of transversely positioned spaced tie rods 41 (see also FIG. 5) having fixed to their opposite ends studs 42 of smaller diameter than tie rods 41. Nuts 43 are threadably engaged on the studs 42 for clamping the blocks 35 against the shoulders 44 at opposite ends of the tie rods 41 and against the outer supports 37. Mounted on the supports 37 is a front side bar 45 and a rear side bar 46. Side bars 45 and 46 are substantially coextensive in length with the supports 37 (see FIG. 2) and are connected at their opposite ends by means of bolts 47 to a pair of lower insulator spreader members 49 mounted transversely of the bars 45 and 46 along opposite sides of the anodizing tank 17. Viewing FIGS. 2, 5 and 7 there is disposed at approximately equal distances intermediate insulator spreaders 49, a pair of lower insulator spacers 51 which extend parallel to each other and to the insulator spreaders 49. The insulator spacers 51 are mounted at their opposite ends in grooves 50 and 52 formed in the front and rear side bars 45 and 46 respectively, and are maintained in position by means of bolts 53 connecting the insulator spacers 51 with the side bars 45 and 46.

The upper electrodes 33 are mounted on an upper front side bar 57 (see FIG. 4) and on an upper rear side bar 59. The side bar 57 is disposed above and offset slightly inwardly from the lower front side bar 45 and is disposed parallel thereto. The upper rear side bar 59 is positioned directly above the lower rear side bar 46 and extends parallel thereto. Side bars 57 and 59 are of the same length as side bars 45 and 46, and are connected to a pair of upper insulator spreader members 58 (see FIG. 2) by means of bolts 60. Mounted at spaced intervals on the upper front side bar 57 is a series of pins 61 which are press fitted into member 57 and extend inwardly thereof as seen in FIG. 3. Also mounted in the upper rear side bar 59 is a series of pins 63 which are press fitted into member 59, said pins also extending inwardly of the side bars 59. It will be noted that the pins 63 are offset in a longitudinal direction from the pins 61. Each of the upper electrodes 33 carries along one edge thereof a series of recesses 65 to receive pins 61 and each of said electrodes also carries along its opposite edge a series of recesses 67 to receive the pins 63. Hence it is seen that the upper electrodes 33 rest on the pins 61 and 63.

Positioned directly above the lower insulator spacers 51 (see FIGS. 2, 5 and 7) are a pair of upper insulator spacers 69 disposed at equal intervals between the upper insulator spreaders 58 at opposite sides of the tank. Insulator spacers 69 are received in grooves 71 of the upper front side bar 57 and in grooves 73 of the upper rear side bar 59, and are maintained in position on side bars 57 and 59 by means of bolts 75.

It will be noted that the lower insulator spacers 51 electrically insulate and separate the three lower electrodes 31, and the upper insulator spacers 69 electrically insulate and separate the three upper electrodes 33.

Viewing FIGS. 3, 4, 5 and 7, shallow recesses 70 are formed in each pair of lower and upper contacting insulator spreaders 49 and 58 along adjacent inner contacting edges thereof, adjacent recesses in each pair of members 49 and 58 at opposite sides of the tank, forming slots 72. Also, the adjacent pairs of lower and upper insulator spacers 51 and 69 have recesses 74 formed along the upper edge of each of members 69, forming slots 76. Hence, as seen most clearly in FIG. 5, there are two end slots 72 and a pair of intermediate slots 76, all of said slots being in the same horizontal plane and in alignment with each other to permit passage of the aluminum foil

or strip 34 through the zone 32 between the lower and upper electrodes 31 and 33 of the anodizing tank 17.

Thus, it is seen that all three of the upper electrodes are positioned as a unit 78 within the insulator spreaders 58, front and rear side bars 57 and 59, and separated by the insulator spacers 69. This entire unit rests on the lower insulator spreaders 49 and the lower insulator spacers 51 of the lower electrode structural unit 80.

Viewing FIGS. 3-6, particularly FIG. 6, it will be noted that each of the lower electrodes 31 has in the upper face 85 thereof a series of longitudinally extending middle discharge ports 77 and two parallel rows of discharge ports 79. The ports 77 and 79 communicate with a main central port 81 in each of the lower electrodes 31, said main central port 81 extending longitudinally almost the entire distance through the electrode, the electrode having a hole 82 at one side communicating with said port 81, said hole being normally closed by a plug 84. Hole 82 and plug 84 are provided for cleaning and inspection purposes, and to facilitate manufacture. It will be noted that the central ports 77 are vertically disposed (see FIGS. 3 and 4) while the adjacent ports 79 are disposed at an acute angle, for proper distribution of electrolyte from the central port 81 through ports 77 and 79 and into the center of the anodizing zone 32.

In a similar manner, each of the upper electrodes 33 has in the lower face thereof a series of central ports 77' and two rows of adjacent ports 79', all of said ports communicating with a main central longitudinally extending port 81' similar to the central port 81 in the lower electrodes, one end of the upper central port 81' having a hole 82' closed by a plug 84'. As noted particularly in FIGS. 3 and 4, the discharge ends of the ports 77, 77', the ports 79, 79' and the main central ports 81, 81' are in respective vertical alignment with each other, and the ports 79 and 79' are inclined outwardly, for efficient circulation of electrolyte fluid from the central portion of the upper and lower faces respectively of electrodes 31 and 33 into the center of the anodizing zone 32, and for even distribution of the electrolyte outwardly toward the sides of the electrodes in the anodizing zone between the electrodes and the aluminum foil 34.

It will be noted, as seen in FIGS. 3, 4 and 7, that the adjacent faces 85 and 87 of the lower and upper electrodes, respectively, diverge outwardly from the center of each of said electrodes. Thus, the upper face 85 of each of the lower plate-like preferably carbon electrodes 31 has a double taper 85' which extends from an apex 86 substantially at the center of the upper face, downwardly to the outer edges of each of the electrodes 31, and the lower faces 87 of each of the upper electrodes 33 has a double taper 87' which extends from an apex 88 substantially at the center of the lower face upwardly to the opposite edges of each of the electrodes. Hence, the height of the zone 32 between the electrodes is greater toward the opposite outer edges of the electrodes than at the center of the electrodes between the apices 86 and 88. The divergence or tapering of the lower and the upper electrodes in the manner above described produces equal current distribution across the face of each of the lower and of each of the upper electrodes 31 and 33. Such equal current distribution provides a substantially constant current density in the foil or strip 34 being anodized, and results in uniform oxide coating thickness across the entire surface of the foil from edge to edge thereof and on each side of the foil. The degree of taper in the adjacent faces of electrodes 31 and 33 required to produce such equal current distribution may vary for different systems and parameters of operation such as width of electrode, spacing of electrodes, overlap between upper and lower electrodes and width of aluminum strip relative to width of electrode.

By the term "center" or "central," with respect to the location of the discharge of electrolyte from the adjacent faces of the electrodes into the anodizing zone therebe-

tween, is meant as intermediate location or zone between the outer edges of adjacent upper and lower electrodes that will provide distribution of electrolyte temperature and electrolyte velocity, which in conjunction with the length of current path and shape of the gap provided by the adjacent electrode faces, will lead to uniform current distribution on the face of the aluminum article being anodized. Since the apparatus described herein is substantially symmetrical, the zone described above, will be located substantially centrally.

Positioned adjacent the tapered face 85 of the lower electrode is a diffuser screen 89, preferably formed of an insulating material such as glass fibres coated with a material such as a vinyl resin. The central portion of the diffuser screen 89 has a thickened or built-up portion 90 providing a substantially larger number of fine ports or interstices than in the outer portions of the screen 89. This can be accomplished conveniently by employing a screen 89 of a uniform thickness across the entire tapered face 85 of each of the lower electrodes and inserting beneath the central portion of the screen, that is, between the screen 89 and the discharge ports 77 and 79 of the electrode, further thicknesses of screening. Thus, for example, I may employ three thicknesses of 14 x 14 standard mesh screening of the aforementioned type on the outer portions of the upper tapered face 85 of each of the lower electrodes and seven additional layers or thicknesses of a similar screening over the central portion of the face of the electrodes covering the ports 77 and 79. Similarly a diffuser screen 91 of the same nature as screen 89 is disposed adjacent the tapered face 87 of each of the upper electrodes 33. Again, as in the case of the lower electrodes, a greater thickness or built-up portion of screening 92 is disposed adjacent the central lower face of the upper electrodes opposite and covering the ports 77' and 79'. Thus, for example, as previously mentioned I may employ a 14 x 14 mesh screen using three layers thereof adjacent the outer portions of the upper face of each of the electrodes and seven layers of the same screening at the central portion of each of said faces covering the ports 77' and 79'.

Instead of employing a screen as described above, other types of porous media can be used as the diffuser medium. Further, the diffuser medium can be formed integral with the electrode plate instead of being a separate member positioned adjacent the face of the electrode plate. Thus, for example, the electrode plate itself can be formed of a porous electrically conducting material inert to the electrolyte solution, permitting diffusion of the electrolyte through the pores of the electrode plate into the anodizing zone without the necessity of a separate diffuser member used in conjunction with the electrode plate, or of holes 77 and 79, and 77' and 79'.

A series of longitudinally extending spaced parallel lower plastic rods 93 (see FIGS. 3-5) extend longitudinally of the tank and are press fitted at their opposite ends in holes 94 located in opposite lower insulator spreaders 49, and a second series of upper longitudinally extending plastic rods 95 are press fitted at their ends in holes 96 positioned in opposite upper insulator spreaders 58. The lower plastic rods 93 function to hold the lower screens 89 in position and the upper plastic rods 95 function to hold the upper screens 91 in position. Plastic rods 93 and 95 also serve as guides for the aluminum foil or strip 34 if it becomes slack and sags down or whips up. If desired, the plastic rods 93 and 95 may be omitted and the insulating diffuser screens 89 and 91 can be maintained in position against the respective tapered faces 85 and 87 of the lower and upper electrodes, by any other suitable means.

Viewing FIGS. 2, 3 and 4 particularly, there are positioned in each of the lower electrodes a pair of front electrode rods 97, there being a total of six such rods in longitudinal alignment, as seen particularly in FIG. 2. It will be noted that the electrode rods 97 are mounted

in the front offset portion 98' of the lower electrodes 31, said rods being received in recesses 93 formed along the front edge 100' of the upper front side bar 57, to permit placement of the upper electrodes in operative position above the lower electrodes without interfering contact between the electrode rods 97 and said upper side bar. There are also mounted in longitudinal alignment along the rear portion of the lower electrodes 31 a series of electrode rods 99, shown as six in number in FIG. 2, two of said rods 99 being provided for each lower electrode plate 31. The rear lower electrode rods 99 pass through transverse slots 100 formed in the upper electrode plates 33.

Mounted in longitudinal alignment in the front portion of upper electrodes 33 is a third series of upper longitudinally extending electrode rods 101, there being six in number, two for each electrode as seen in FIG. 2. Also mounted in the upper electrode plates 33 is a fourth series of six longitudinally positioned spaced rear electrode rods 103, two for each upper electrode plate. Rods 97, 99, 101 and 103 are preferably composed of a conductive material inert to the electrolyte solution, such as carbon. Such rods are preferably coated or impregnated with an acid resisting material such as a resin, e.g., a vinyl resin, so that the rods will not act as wicks to draw solution up to the electrical terminals 113.

Each of the rods 97, 99, 101 and 103 is of substantially the same construction, each having a tapered lower end 105 (see FIGS. 3 and 4). The tapered ends 105 of the lower electrode rods 97 and 99 are press fitted into tapered holes 107 in the lower electrodes 31, and tapered ends 105 of the upper electrode rods 101 and 103 are press fitted into tapered holes 109 in the upper electrodes 33. The upper ends 109' of each of the electrode rods are also tapered at 111' (see FIG. 11) to receive a terminal lug 113 having a matching tapered inner bore 115' which is press fitted over the upper taper 111' of the rods.

Disposed about substantially the entire length of each of the electrode rods 97, 99, 101 and 103 above the lower tapered portion 105 thereof is an insulating, e.g., a plastic sheath 111 (see FIGS. 1-4). This plastic insulating sheath functions to prevent undesirable current bypassing taking place between these carbon electrode rods and the electrolyte solution, and to permit the current to pass from the electrode rods to the respective electrodes and then into the electrolyte solution in the zone 32 between the lower and upper electrodes without bypassing or shorting. Each of the terminals 113 (see FIG. 11) at the upper end of each of the electrode rods is adapted to be connected by suitable fasteners at 114 to the terminals 115 of electrical leads 117 connected to the source of current (not shown).

Referring now to FIGS. 1, 2, 5 and 7, there is disposed centrally in each of the upper electrode plates 33 a tapered hole 119 which communicates with the main central longitudinally extending port 81' in said electrodes. In each of these tapped holes 119 is threadably engaged an inlet nipple 121 to which is connected an elbow 122 mounted on an upper distribution or inlet pipe 123 the opposite end of which is connected to an elbow 124, there being three such pipes 123 parallel to each other (see FIG. 2). The lower end of elbow 124 carries a nipple 126 which slides over a downwardly extending pipe 128 which is fixed to a longitudinally extending manifold pipe 125. As seen in FIGS. 2 and 7, each of the three pipes 128 is connected to pipe 125 which is mounted for limited pivotal or angular motion in the manner described more fully below.

Referring now particularly to FIGS. 2 and 8, it will be seen that the manifold pipe 125 is mounted on oppositely disposed blocks 127 which are connected to the rear portion of adjacent insulator spreaders 49 by means of bolts 123. The opposite ends of manifold pipe 125 are closed by plugs 129 which are mounted on members 58 by means of the bolts 131. Holding the upper por-

tion of manifold pipe 125 at opposite ends thereof in position are blocks 133 which are connected to the rear portion of upper insulator spreaders 58 by means of bolts 134, so that the entire upper electrode unit 78 is directly connected to manifold pipe 125 through the blocks 133. Thus, it will be seen that the pipe 125 functions both as a means for positioning the upper electrode structure and as a conduit for circulation of electrolyte to the electrodes 31 and 33, as described below.

Now referring particularly to FIGS. 1, 2, 10 and 11 there is provided a main electrolyte feed pipe 139 which is connected via an elbow 141 to a distributing bushing or ring 143. Bushing 143 is provided with a circular aperture 145 for communication with elbow 141, and said bushing is mounted on a pair of oppositely disposed sealing rings 147 which are connected as by welding at 149 to the bushing 143. The bushing 143 has a larger internal diameter than the external diameter of manifold pipe 125, and forms an annulus 153 between members 143 and 125 as best seen in FIG. 9. The manifold pipe 125 adjacent the annulus 153 is provided with a series of ports 155 for fluid communication between said annulus and the interior of the manifold 125. Hence it will be seen that electrolyte solution can be circulated through the feed pipe 139 into the annulus 153 via aperture 145, from said annulus into the manifold pipe 125 via the ports 155.

The bushing 143 has an aperture 156 in the lower portion thereof, which communicates with a depending flange 157 which slides over a pipe 159 in turn fixed on and communicating with a lower manifold pipe 161 which extends longitudinally from side to side of the anodizing tank along the bottom thereof directly beneath the pivoted manifold pipe 125. Branching off from the lower manifold 161 and in vertical alignment with pipes 123 is a series of three lower parallel distribution or inlet pipes 163 having elbows 165 attached to their inner ends (see FIGS. 5 and 7), said elbows being connected to nipples 167 each slipping into a hole 168 in the center of each of the lower electrodes 33, said holes 168 each communicating with the main central longitudinal port 81 in each of the lower electrodes 33.

Thus it will be seen that electrolyte solution circulated to the anodizing tank via pipe 29 and the feed pipe 139 is conducted via the annulus 153, aperture 156, the lower manifold pipe 161 and the lower distributing pipes 163 into the lower electrodes 31, and via the ports 81, 77 and 79 of the lower electrodes into the anodizing zone 32. Also electrolyte solution passes via annulus 153 and ports 155 into the manifold pipe 125, the upper distributing pipes 123 and the upper electrodes 33, and via the ports 81', 77' and 79' therein into the anodizing zone 32 between the upper and lower electrodes.

The opposite end walls 171 of the anodizing tank 17, as best seen in FIGS. 1 and 2 have attached to the upper ends thereof a flange 173 to the outwardly extending ends of which are attached depending plastic shields 175 which extend almost to the bottom of anodizing tank 17 and below the top of the sump tank 21. A plurality of aligned holes 177 is provided along each of the end walls 171 of the anodizing tank, said holes being at the desired maximum level of electrolyte solution to be maintained in the anodizing tank (as seen in FIG. 1). Thus, electrolyte solution in the anodizing tank overflows through the overflow holes 177 into the vertical conduit 178 formed by the plastic shields 175 into the sump tank 21 directly below, from which the electrolyte passes to the heat exchanger 27 (see FIG. 12) wherein the electrolyte solution is cooled by means of water passed in heat exchange relation with the electrolyte, and the existing electrolyte is then recirculated via line 29 to the feed pipe 139 for reuse in the anodizing tank 17. It will be noted that the level of the holes 177 is above the lower surface 87 of the upper electrodes 33 so that the anodizing zone 32 between the lower and upper electrodes is always full of

solution, and the level of such holes 177 is also preferably below the upper surface of said electrodes 33, as seen in FIG. 1 to prevent bypassing of solution across the top of the upper electrodes.

The electrolyte solution is distributed in fine streams through the screens 89 and 91 and passes outwardly from the center of the zone 32 toward the outer sides of the zone into uniform contact with both the lower and upper faces of the aluminum foil. The provision of a larger number of fine ports through the center of the diffuser screens adjacent the discharge ports, as indicated at 90 and 92 in FIG. 4, gives more even distribution of flow of electrolyte over the entire area of the upper and lower faces of the foil 34 passing through the anodizing zone, while substantially eliminating quiescent zones of solution therein. Without such distribution uniform temperature and current flow are difficult to maintain, and streaks tend to form in the strip opposite the lines of discharge ports 77 and 79 (see FIG. 6). The electrolyte solution overflowing through the ports 177 in the end walls 171 of the tank is discharged via the plastic shields 175.

As seen in FIG. 5, the aluminum foil 34 to be anodized is fed through a slot 180 between upper and lower blocks 179 and 181 mounted on one of the side walls 172 of the anodizing tank, and through a slot 183 in said side wall. The foil is then conducted through the anodizing zone 32 between the three upper and three lower electrodes via slots 72 and 76, while electrolyte solution is circulated through said anodizing zone, as above described. The foil 34 then proceeds through an aperture 185 in the opposite side wall 172' of the anodizing tank and is conveyed externally of the tank via aperture 180' between another set of lower and upper blocks 179' and 181' mounted on the tank side wall 172'.

Instead of employing a series of three lower electrodes and a series of three upper electrodes, as described above and shown in the drawings, I may employ a single lower electrode plate and a single upper electrode plate or any number of such lower and upper electrode plates.

Further, while I have shown the electrode plates 31 and 33 as mounted horizontally in spaced vertical relation to provide an anodizing zone which extends horizontally for horizontal movement of a foil or strip of aluminum through the anodizing zone, I may mount the electrode plates vertically to provide a vertically extending anodizing zone between the two sets of electrode plates 31 and 33.

The degree of outward divergence between the adjacent faces 85 and 87 of the electrode plates 31 and 33 from the centers of such faces, can be varied as determined by experimentation to obtain substantially equal current distribution from one edge of these plates to the opposite edge thereof as above described, for the particular anodizing conditions employed. The degree of such divergence or tapering will depend on the concentration and temperature of the electrolyte, the type of material of which the electrode plates are composed, the thickness of such plates, the potential and current density being applied, the particular type of metal foil or strip being anodized and the thickness of oxide coat being applied. Further, instead of straight outward tapers 85' and 87' applied to the adjacent faces 85 and 87 of the electrode plates 31 and 33, the configuration of such taper may be other than flat according to conditions required to get uniformity of current distribution. Thus, for example, faces 85 and 87 may be convex or concave, or they may be of a non-uniform or irregular configuration, but in all instances said adjacent faces 85 and 87 will diverge outwardly from each other, commencing at a point intermediate the outer edges of the faces, and preferably at the center of said faces, so that the distance between the electrodes is greater at the outer edges of the electrodes than at the centers thereof. In certain instances, the outward divergence of the adjacent electrode

faces may commence at a point other than the centers of such faces.

It will be understood that instead of anodizing aluminum foil or strip, or instead of anodizing an aluminum article which is passed or moved continuously through the anodizing zone, I can employ my apparatus for anodizing articles other than foil or strip, such as aluminum plates, and the aluminum article being anodized need not be moved continuously through the anodizing zone, but rather can be held stationary therein during electrolytic oxidation. If held stationary, velocity of the circulating liquid may be varied from that when a moving strip is used.

From the foregoing, it is seen that I have devised a novel anodizing apparatus providing an electrode design which compensates for uneven distribution of current across the face of the electrodes and results in obtaining constant current density in the aluminum article being anodized and consequent uniform oxide coating on such article. Also the invention device provides diffuser means for obtaining uniform and continuous flow of electrolyte solution discharged from the centers of the adjacent faces of the opposing electrode plates, throughout the entire anodizing zone between the electrode plates from edge to edge thereof. It is particularly noteworthy that the designing of the electrode plates to provide the divergent adjacent faces noted above, and the diffuser feature for the electrolyte passing into the anodizing zone are closely related in functioning to provide even current distribution so as to produce a uniform and adherent oxide coat on both sides of the aluminum article from edge to edge thereof.

The term "aluminum" employed herein is intended to denote pure aluminum or commercial aluminum containing small amounts of impurities, or aluminum alloys in which aluminum is the predominating element.

The apparatus hereof may be employed for electroplating operations as well as for anodizing.

While I have described particular embodiments of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention as set forth in the appended claims.

I claim:

1. Apparatus for anodizing an aluminum article, which comprises a first electrode plate and a second electrode plate, means mounting said plates in opposed parallel relation to each other, thereby providing a zone between said plates for placement therein of an aluminum article, means on said plates for connecting them to a source of electrical potential, a plurality of ports in each of said electrode plates, said ports discharging centrally from the inner adjacent faces of said electrode plates into said zone, a diffuser member composed of a plurality of layers of screen mounted along each of said inner adjacent faces of said electrode plates and over said ports for discharging electrolyte solution from within said electrodes into said zone in fine streams, and substantially uniformly distributed.

2. Apparatus as defined in claim 1, wherein said diffuser member is in the form of a plurality of layers of screen, the number of layers of screen over said ports being greater than the number of layers over the other portions of the adjacent faces of said electrode plates.

3. Apparatus as defined in claim 2, wherein said screen is composed of fiber glass covered with a plastic material.

4. Apparatus for anodizing an aluminum article, which comprises a first electrode plate and a second electrode plate, means mounting said plates in opposed parallel relation to each other, thereby providing a zone for placement therein of an aluminum article, means on said electrode plates for connecting them to a source of electrical potential, an inlet port in each of said plates, a central manifold port in each of said plates for receiving

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electrolyte solution from said inlet ports, a plurality of discharge ports in each of said plates communicating with said central manifold port, said ports being positioned in the central portion of the adjacent faces of said first and second plates, and insulating diffuser means having fine pores located on each of said plates over said ports for discharging said solution into said zone in fine streams.

5. Apparatus as defined in claim 4, wherein said diffuser means is in the form of a plurality of layers of insulating screen, the number of layers of screen over said ports being greater than the number of layers over the other portions of the adjacent faces of said electrode plates.

6. Apparatus as defined in claim 1, including a plurality of insulating guide rods disposed in said zone longitudinally of said electrode plates and positioned adjacent each diffuser member on the opposite side thereof from the adjacent faces of each of said electrode plates.

7. Apparatus for anodizing an aluminum article, which comprises a first electrode plate and a second electrode plate, means mounting said plates in opposed substantially parallel relation to each other, thereby providing a zone between said plates for placement therein of an aluminum article, said plates being thicker at the middle than at the ends and providing a larger space between the edges of said electrode plates than between the centers thereof to produce uniform current distribution across the adjacent faces of said plates, ports in each of said electrode plates for circulating electrolyte solution through said electrodes into said zone, and diffuser means having fine pores located on each of said plates over said ports for discharging said solution into said zone in fine streams, and means on said electrode plates for connecting them to a source of electrical potential.

8. Apparatus for anodizing an aluminum article, which

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comprises a first electrode plate and a second electrode plate, means mounting said plates in opposed substantially parallel relation to each other, thereby providing a zone between said plates for placement therein of an aluminum article, said plates each having a cross section in the form of a double taper extending from substantially the midpoint of the adjacent faces of said first and second plates to the outer edges of each of said plates, providing a larger space between the edges of said electrode plates than between the centers thereof to produce uniform current distribution across the adjacent faces of said first and second plates, a plurality of ports in each of said electrode plates, said ports discharging centrally from the inner adjacent faces of said electrode plates into said zone, a diffuser member having fine pores mounted along each of said inner adjacent faces of said electrode plates and over said ports for discharging electrolyte solution from within said electrodes into said zone in fine streams, and means on said electrode plates for connecting them to a source of electrical potential.

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