Feb. 9, 1960 W. R. GRAY 2,924,563

CONTINUOUS ELECTROPLATING APPARATUS

Filed Aug. 19, 1954 3 Sheets-Sheet 1

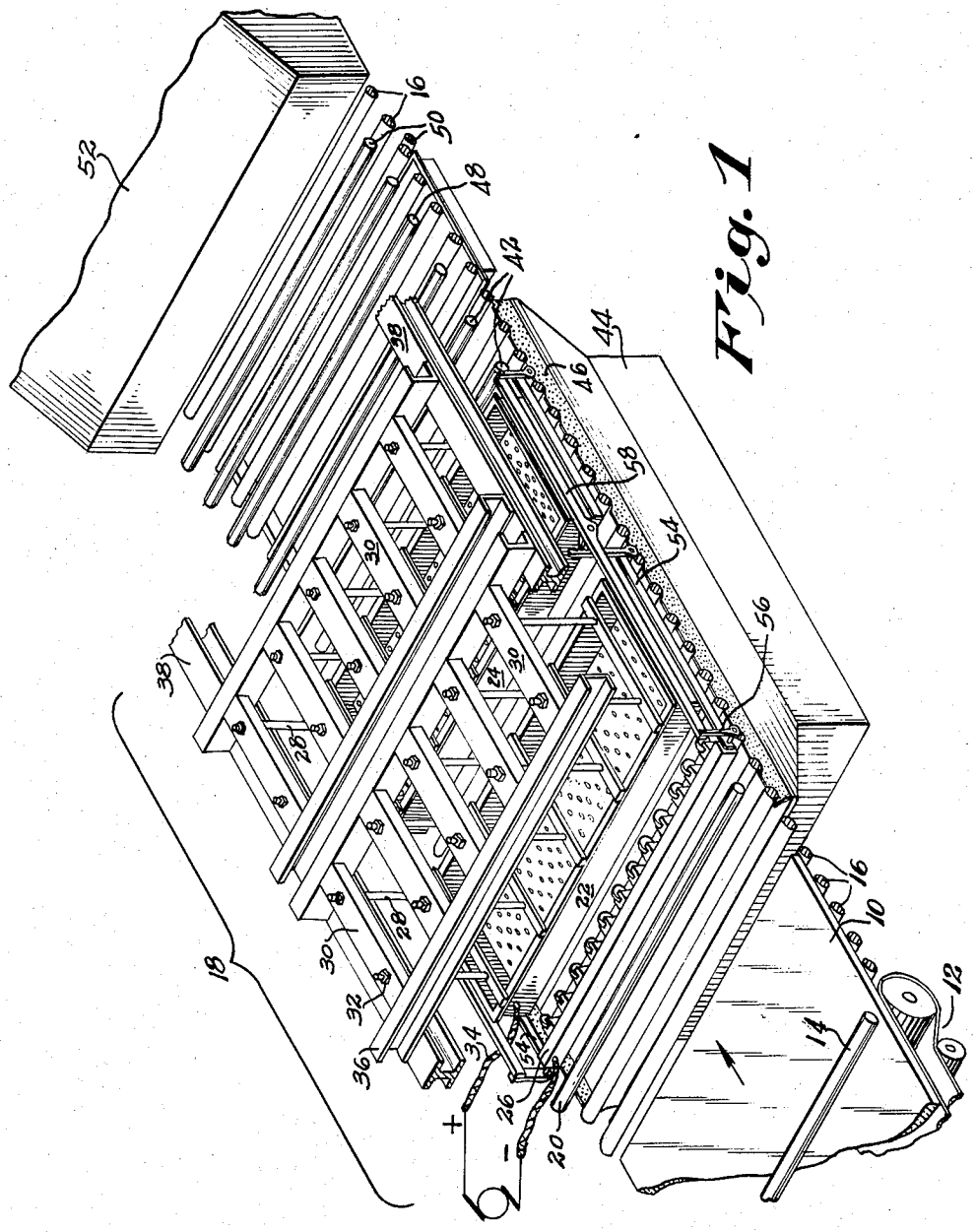


Fig. 1

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CONTINUOUS ELECTROPLATING APPARATUS

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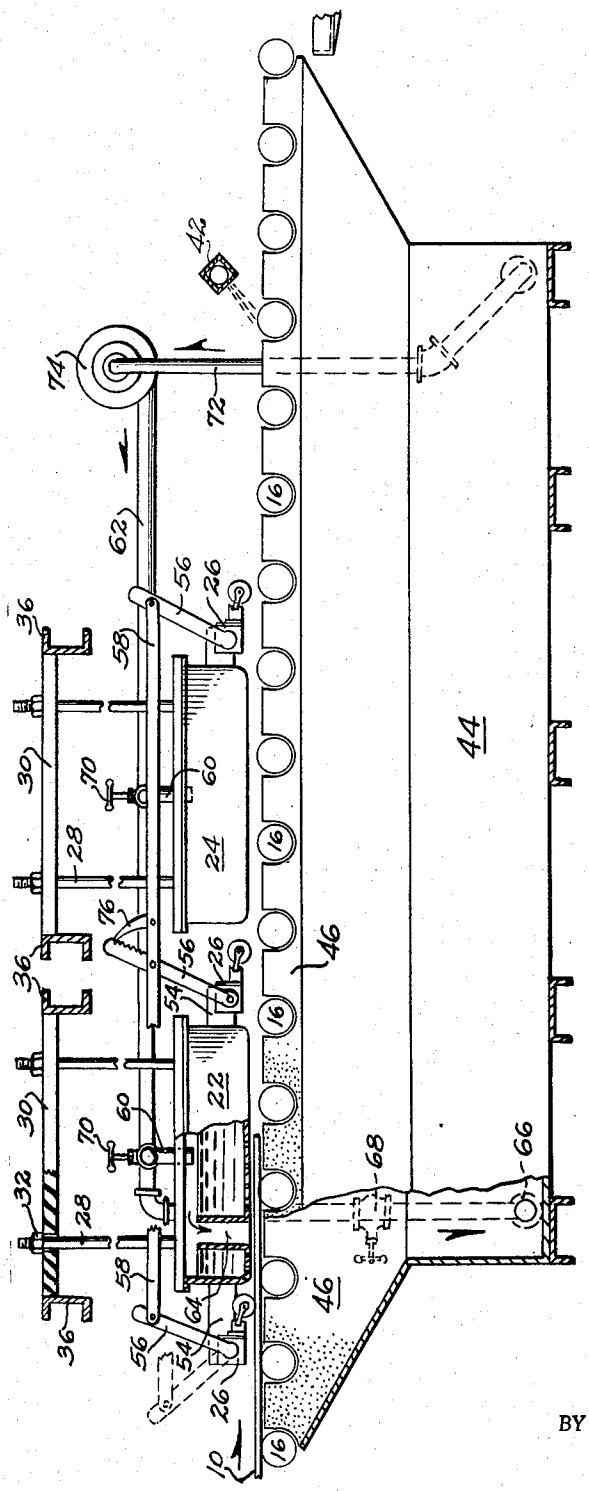


Fig. 2

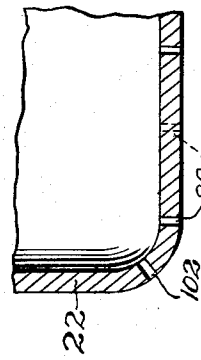
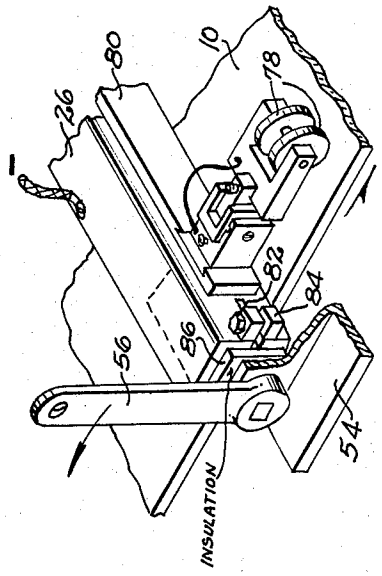


Fig. 5

Fig. 3



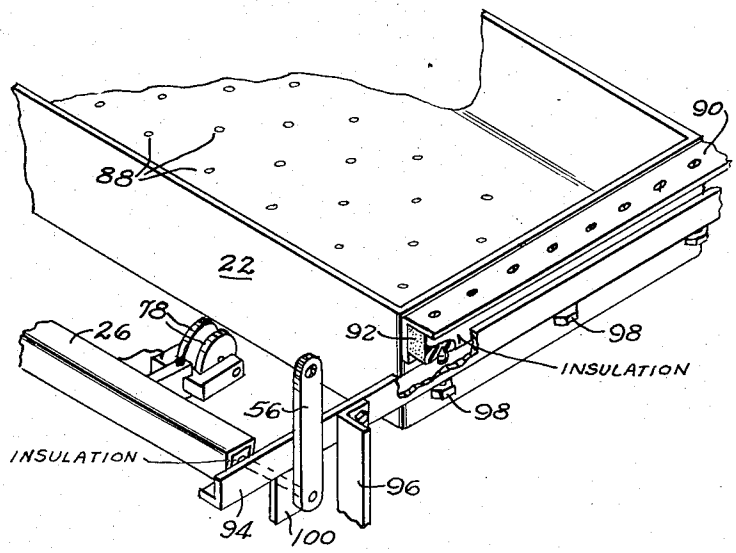
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CONTINUOUS ELECTROPLATING APPARATUS

Filed Aug. 19, 1954 3 Sheets-Sheet 3

Fig. 4



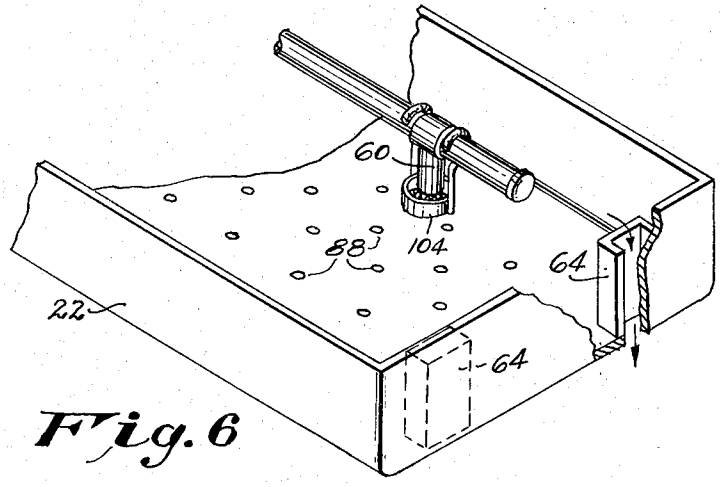


Fig. 6

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2,924,563

CONTINUOUS ELECTROPLATING APPARATUS

William R. Gray, Sarver, Pa., assignor to Pittsburgh Plate Glass Company, Allegheny County, Pa., a corporation of Pennsylvania

Application August 19, 1954, Serial No. 450,895

6 Claims. (Cl. 204—198)

This invention pertains to a method and apparatus for the continuous electroplating of a layer of one metal upon an article which already carries a mechanically fragile layer of another metal. More specifically, the invention provides improvements in the continuous electroplating of a protective copper layer upon a reflective layer of silver carried by a mirror. The invention constitutes improvements in, and this application is in part a continuation of, an application Serial No. 312,807, filed Oct. 2, 1952, by the same inventor, now U.S. Patent No. 2,753,298.

In the prior patent, a sheet or sheets of glass bearing a mechanically sensitive or fragile layer of silver was continuously plated with copper by passing the silver-coated glass sheet in a horizontal plane beneath anodes maintained in closely spaced relation to the silver layer, while a plating solution was flowed on to the glass sheet and silver layer in sufficient quantity to maintain a continuous film thereof between the anodes and the silver layer. Several spaced anodes were employed, and the solution was flowed onto the glass sheet in advance of the first anode, and between successive anodes, while the glass sheet moved continuously through the apparatus.

According to the present invention, the plating solution or electrolyte is introduced into the space between the anodes and the glass sheets by utilizing the anodes themselves as electrolyte containers. The anodes are provided with a multiplicity of perforations through which the plating solution flows into the interspace between the anode tank and the glass sheet. In other words, the present invention comprehends the use of the anode electrode not only as an electrical terminal of the plating apparatus but also as a distributing conduit for the plating solution. Several important advantages arise from this improvement, which will be pointed out more specifically below.

Prior attempts to provide the sensitive silver layer of a mirror undergoing manufacture with a protective coating such as one of copper have generally required the separate copper plating of the individual silvered pieces of glass. In a continuous production line, this necessitated turning the sheets from the horizontal plane which they occupy in the ordinary silvering stage, and lowering them into vertical copper plating tanks containing the plating solution and anodes. Each sheet remained in the tank for the time necessary to build up the desired coating of copper, when it was removed, rinsed and further treated in the usual way of mirror manufacture.

The intermittent aspect of this procedure interferes seriously with the otherwise smooth and continuous flow of glass sheets on a production line. Moreover, considerable care and skill had to be exercised in the handling of the glass sheet. Where the sheet to be plated is of the order of 7 or 8 feet wide and of the same length or longer, the mere weight of glass required relatively complex and powerful handling equipment, and a profusion of electrical controls and interlocks related to the lifting and lowering of this weight, all of which had to be accomplished with due consideration for the fragile nature of the glass itself and more especially the delicate silver layer thereon. To complete the electrical circuit through the plating solution, it was also necessary to make electrical connections to the silver layer, which acts as the cathode in the plating bath, and for uniform current density these connections had to be quite numerous, and they invariably produced some deterioration of the silver layer at the points of contact.

The invention set forth in the patent referred to above constitutes a commercial and practical procedure and apparatus for overcoming many of the objections to the prior art intermittent copper plating of mirrors. The present invention provides additional significant refinements in the continuous plating of such articles, in addition to a fundamental improvement in the manner in which uniform thickness of copper layer is obtained throughout the area of a large and unwieldy sheet of silver-coated glass.

Additionally, the present invention accomplishes a substantial increase in the speed with which the copper layer can be deposited, so that a high production rate can be obtained from a continuous production line. Further, the invention provides a conspicuous improvement in the perfection and continuity with which a uniform copper layer can be deposited, as well as increased efficiency in the use of the copper plating solution.

The above and other objects and advantages of the invention will best be understood by referring now to the following detailed specification of certain preferred embodiments of apparatus for practicing the invention, and of the method of procedure, taken in connection with the accompanying drawings, in which:

Figure 1 is an isometric view, with parts broken away for clarity, of a preferred form of apparatus in accordance with the invention.

Figure 2 is a longitudinal elevation of the principal parts of Fig. 1, with portions broken away or shown in section.

Figure 3 is a fragmentary perspective view of a detail relating to the mounting of the cathode connector bars of the machine.

Figure 4 is another fragmentary perspective view showing an alternate form of anode support and cathode connection arrangement.

Figure 5 is a fragmentary enlarged sectional view taken through the leading edge of one anode tank.

Figure 6 is a view similar to Fig. 4 showing the arrangement of an overflow duct for the anode tank.

Referring now to Fig. 1 of the drawings, a sheet of glass **10** is shown as emerging from a conveyor section **12** in which it has been silver plated by any convenient or well-known process, numeral **14** designating a water spray pipe by which the sheet **10** is being subjected to a final rinsing operation as it leaves the conveyor **12** and proceeds in a horizontal plane over a series of table rolls **16** to the copper plating section of the apparatus forming the major and central portion of this figure. The table rolls **16** continue to the righthand edge of the figure, and it is to be understood that these rolls are accurately aligned in the horizontal plane to provide adequate support for the glass sheet **10** throughout its travel through the plating apparatus. These rolls are supported in conventional side rails, omitted for clarity, and while not shown in the drawing, certain of the rolls **16** are power driven to propel the sheet **12** at the desired speed along its desired horizontal path of travel, by power drive means well-known to those skilled in the art of glass manufacture.

As the silvered sheet **10** approaches the central section

18 of the apparatus, with its silver coating on the upper surface of the sheet, it will pass beneath an initial air blow-off tube 20 which serves to remove from the silvered layer any residual rinse water or particles which it may have retained or picked up in the travel from the silvering conveyor 12. Such a blow-off may comprise a tube or pipe extending across the path of travel of the glass sheet and provided with a plurality of relatively small perforations on its underside; when supplied with either air under pressure or water, a tube of this kind may be employed either as an air squeegee or rinsing device for purposes to be described below.

The sheet 10 progresses into the copper plating section 18 of the apparatus and passes beneath a plurality of plating anodes of which two are indicated in the drawing by numerals 22 and 24. Each of these anodes actually comprises a tank having an open top and a perforated bottom, and formed of the metal which is to be plated. Through this perforated bottom, plating solution is allowed to flow onto the silver coated glass sheet to form and maintain a continuous film of the plating solution (herein, a copper plating solution) between the bottom surface of each tank and the silver layer on the glass sheet. In advance of the first anode tank 22 there is disposed a cathode connection roller assembly comprising essentially a bar support 26 extending transversely across and above the conveyor and carrying a multiplicity of smooth contact rollers adapted to ride gently upon the silvered surface and to make contact therewith to complete the plating circuit. One of these cathode connection assemblies is also disposed between each two anode tanks, and preferably one is arranged after the last anode tank as well.

It is essential that a continuous film of plating solution be maintained between the bottom of each anode tank and the surface being copper plated, in order to provide a uniform thickness of copper plate in the time during which the glass sheet is passing beneath the anode assemblies. For this reason, and also to facilitate the necessary electrical insulation between the anodes and the rest of the apparatus, the anode tanks 22 and 24 in this form of the invention are shown as suspended from above by rods 28 which pass upwardly through stringers 30. The rods 28 have their upper ends threads and provided with locknuts 32 by which the vertical position of each anode tank can be adjusted to a nicety.

The stringers 30 may be made of insulating material, and the electrical connection to the anodes accomplished by conductors such as 34 leading directly to each anode tank. However, as will appear below, such insulation may be accomplished in other ways.

The stringers 30 are shown in Fig. 1 as carried by channels 36 extending crosswise of the conveyor travel direction and resting upon and secured to lengthwise beams 38 which may form the major horizontal members of the machine frame. After passing beneath the last of the anode tanks, and the final set of cathode connection rollers, the copper plated surface is subjected to an air blast from blow-off tubes 42 whose orifices are directed at an angle downwardly and counter to the travel of the glass sheet, so that plating solution not already disposed of will be driven backward and caused to run off the sides of the glass sheet and thence into a collecting pan or tank 44 which also receives plating solution that has run off of the sheet during its passage through the plating section. Preferably, the upper longitudinal edge at each side of tank 44 may be provided with a guard strip 46 which is cut to fit around the ends of the table rolls 16, whereby this run-off solution is caught and returned to the bottom of the tank 44. Since most plating solutions will be of a nature deleterious to common metals, it is preferred that the tank 44 be coated inside with some resistant material. Conveniently, the entire interior of the tank may be lined with rubber, and where this is the case, the

strips 46 can readily be formed as upward extensions of the rubber sheet lining those vertical tank walls which parallel the conveyor direction. As will be described below, solution collected in 44 is returned to the anode tanks by a suitable pump to maintain a desired hydrostatic head of solution in each anode, and thereby to regulate precisely the rate of flow of solution to the space between the anodes and the glass sheet. The piping, connections and other exposed parts will preferably be made of materials resistant to the plating chemicals.

After passing the air blow-offs or squeegees 42, the now copper plated sheet passes one or more water sprays or rinse tubes 48, and one or more final air squeegees 50. If desired, the underside of the sheet may be dried by one or more of such air squeegees disposed beneath and between two of the adjacent table rolls 16. Finally, the plated and rinsed sheet may pass beneath a hood 52 in which are disposed infrared heating elements to accomplish the final drying of the copper plated mirror, or equivalent means for drying may be provided.

Fig. 1 also shows a preferred way in which the cathode connection bars 26 may be carried from the main frame of the apparatus, with provision for raising and lowering all of the cathode contact rolls simultaneously. Thus, each of the anode tanks 22, 24 and so on carry support bars 54 along their opposite ends. These support bars extend beyond the anode tanks so as to form a journal mounting for each of the bars 26, which are arranged so as to be rotated by a link 56 to tilt the contact rollers upward and away from the glass sheet. The links 56 for the respective contact bars 26 may be connected for concomitant rotary adjustment as by a common connecting bar 58, and the latter may be provided with a ratchet or dog engaging an upward toothed extension of one of the links 56 (in Fig. 1, the central one) so that the rotary position of all of the connector bars 26 can be maintained for purposes to be described below.

With the above general organization of the apparatus in mind, reference will now be made to succeeding figures of the drawing which show in greater detail the structural features by which the objects of the invention are accomplished. Thus, Fig. 2 shows to a larger scale, and partly in horizontal section, the parts of the apparatus in the region 18 of Fig. 1. In Fig. 2 like reference numerals denote the same parts as in Fig. 1. The plating solution may be of any desired or conventional formulation, such as that disclosed in the patent referred to above. The solution enters the anode tanks 22 and 24 through supply pipes 60, of which there may be several for each tank disposed widthwise of the conveyor and all being fed from a conduit 62. The solution in each tank is maintained at a constant level by reason of the fact that each tank is provided with one or more overflow conduits 64 through which any excess of liquid in the tank discharges into the collecting tank 44. These overflow conduits are preferably disposed along the end walls of the tanks which lie adjacent or beyond the lateral edges of the glass sheet 10 passing thereunder so that the overflow solution is little or not at all impeded in its return to the collecting tank 44. Beyond the point at which supply conduit 62 is connected to the headers of down pipe 60, it continues to a connection with tank 44 as as 66, and a valve 68 is provided in this line. Also, a valve 70 is provided for each of the headers feeding the supply pipes 60. By adjustment of these valves, the flow of plating solution into the anode tanks 22 and 24 can be proportioned to maintain a fairly constant head operating to discharge plating solution through the perforated bottoms of the anode tanks. From collecting tank 44 a line 72 returns plating solution to line 62 via pump 74. In its passage through this system, plating solution is thoroughly mixed, and the capacity of the system including tank 44 is so large compared with the instantaneous volume of fluid in the rather thin film between the bottom of each anode and the mirror 10 that the composition changes only very slowly as

the process continues. One filling of solution will suffice to operate the machine for a long period of time, and of course the solution can readily be replaced or subjected to make-up whenever conditions require. This utilization, at any one instant, of only a small volume of the plating solution in the electrolytic circuit is a major feature contributing to uniformity of the copper plating which is obtained.

Fig. 2 also shows more clearly the arrangement by which the cathode connection rollers are controlled. Here again, numeral **54** denotes a support extending to one or both sides of the anode tanks, and on which are journaled the cathode roller bars **26** with their links **56** connected by member **58** for simultaneous rotation to tilt the cathode contact rollers up and out of contact with the glass surface. The dog **76** cooperates with teeth on the central link **56** to hold the rollers in raised position when desired, as for cleaning or adjustment.

Fig. 3 is a detail illustrating the universal mounting of the cathode rollers **78** for free but limited swiveling in both vertical and horizontal planes in the manner completely described in the prior patent above. It is deemed unnecessary to repeat this description in connection with Fig. 3. Each set of rollers **78** is carried through the universal swivel device, by a fixture **80** secured to the bar **26**, which may be of hollow square cross section and made of conductive material such as metal to provide an electric circuit to the rollers **78**. The end of each bar **26** may be split as by a saw cut **82**, the edges of the cut each carrying a lug **84** to provide a clamp to retain a pivot block of insulation material **86**, the same extending somewhat beyond the end of bar **26**. A bearing shaft journaled within this block **86** is thus insulated from the bar itself, and it extends through the upstanding web of the support **54** and has its outer end rigidly connected to the control link **56**. It is clear that when the link **56** is turned in the direction of the arrow in Fig. 3, bar **26** will be rotated and the roller **78** elevated. The "up" position of link **56** is indicated in dotted lines at the left end of Fig. 2. The journal for bar **26** at the opposite side of the conveyor may be of the same construction but of course no link **56** will ordinarily be needed.

Reference has already been made to the guard strip **46** which extends upwardly from each lateral edge of tank **44**. Fig. 2 shows clearly how the tops of these strips **46** are cut away to encompass partially the table rolls **16**. Since the tank **44** will normally be made of steel or other corrodible material, it is convenient to line the tank with rubber or the like, and if this is done, the strip **46** may be integral with the rubber sheet lining the side walls (parallel to conveyor travel) as shown in the cut away portion at the left of tank **44** in Fig. 2.

By insulating both the anode tanks **22**, **24** and the cathode connection rollers from the machine frame, leakage currents and electrical hazards are minimized. However, the overhead support and position adjustments shown in Fig. 2 are sometimes undesirable, especially where the invention is applied to an existing silvering conveyor. Fig. 4 of the drawings shows in fragmentary perspective view a modified anode tank mounting which will now be described, and which makes the overhead support unnecessary.

In Fig. 4, numeral **22** again denotes an anode tank of which only one end is shown, and the same has its bottom apertured as at **88** as before. In this case, however, there are no cross strips or support rods **28** as in Figs. 1 and 2, but each end of the tank has secured thereto an angle iron **90** which carries an insulating bar **92** which may be of impregnated cypress wood, for example. A second angle iron **94**, supported from the machine frame by vertical members such as **96**, is oriented opposite to angle iron **90** but parallel to and beneath the same. A plurality of bolts **98** are threaded upwardly in the horizontal web of angle iron **94**, and their upper ends bear in sockets formed in the insulation **92**. This arrangement enables the leveling and vertical adjustment of tank **22** to be nicely controlled without requiring any overhead suspension. At the same time, a projecting portion or portions of the horizontal angle iron **94** may carry journal plates **100** in which are journaled the shafts of the cathode contact bars **26** and control links **56**. Further advantage of the Fig. 4 arrangement is that the height of anode tank **22** above the glass being processed can be adjusted without disturbing the cathode rollers **78**, whose own vertical position is individually adjustable (in pairs) by the adjustments of the roller brackets upon bar **26**.

The anode tanks themselves are of course formed of copper, as are the conventional anodes in a copper plating tank. Replacement of plating copper in the solution from the bottoms of these anodes is extremely slow, but eventually some adjustment of the height of each anode tank is necessary to maintain the proper spacing and hence thickness of the electrolyte film. This spacing may range from ⅛ to ¼ of an inch, but cannot exceed the latter figure substantially if a continuous electrolyte film is to be maintained, and if a uniform deposition of copper over the silver surface is to be achieved.

In one successful installation of the invention, following the principles outlined above, the conveyor was of a size for treating glass sheets up to approximately 90 inches in width, and each anode tank had a length of 8 feet, a width (parallel to conveyor travel) of 2 feet and a height of about 6 inches. The overflows were arranged to maintain about 4 inches of solution in each anode. The perforations **88** through the bottom of each anode were each ⅛ inch in diameter, and except for the row of perforations nearest the tank edges, were spaced 2 inches apart in the direction of tank length, and 3 inches apart on centers in the direction of tank width. The holes in adjacent rows were staggered to provide maximum distribution of solution over the glass sheet. As indicated by the detail in Fig. 5, at the leading rounded longitudinal edge of each tank such as **22**, a row of apertures were provided having their axes half way around the arc as at **102**, this arrangement aiding in ensuring a continuous film of solution between the anode and the glass plate **10** even before a given portion of the glass actually passes beneath the anode.

As indicated in Fig. 4, the staggered apertures **88** are uniformly distributed over the bottom surface of the tank, except at the edges where additional apertures are provided to maintain the electrolyte film completely up to the edge of the glass sheet. However, one or more rows of the apertures may be omitted along the trailing edge of the tank. In the preferred construction, a total of about 422 such holes were provided, and the electrolyte head maintained at 4 inches in the anode tanks provided a flow of approximately 0.18 gallon per minute from each hole, or 76 gallons per minute from each anode. The total capacity of the anode tanks, tank **44** and the remainder of the system was over 350 gallons, so that only a small portion of the electrolyte is actually involved in the plating circuit at any one instant.

Fig. 6 of the drawings is a perspective detail similar to Fig. 4, but with the anode tank **22** broken away to show the construction of the overflow duct **64**. More than one of these may be provided, and if so, the total number is distributed equally along the opposite narrower edges of the anode tank. Fig. 6 also illustrates an arrangement of the supply header feeding the supply pipes **60** for the anode, only one of these pipes being shown. In addition to filtering means which may be provided in the supply pump circuit, a sieve **104** may be suspended beneath each of the supply pipes **60** by hooks encircling the header, as also shown in Fig. 6.

Among the less obvious advantages of the present invention over the disclosure of the prior patent is the fact that the feeding of the plating solution directly from a tank anode into the film minimizes the production of air

bubbles in the film such as were liable to be entrained in the prior system. The supply pipes feeding the anode tanks terminate approximately at the solution level therein, but even if this is departed from the tanks themselves provide a storage volume within which bubbles rise to the top, whereas the solution being drawn off reaches the electrolyte film only from the bottom of the tank. This arrangement also permits a somewhat increased current density without departing from uniform plating conditions, and it is for this reason that the present invention is preferably used with double cathode contact rollers to reduce the current density at these contacts, and obviate burning of the silvered surface.

In the event a copper plating solution of the type described in the British Patent 503,095 issued to Dr. Bruno Schweig is used, the tank 44 may be fabricated of stainless steel and the various pipes used for conducting the solution from the tank to the anode may be made of copper. No rubber lining is required for the tank in such a case because the solution disclosed in the above-identified British patent is not harmed by contact with stainless steel or copper.

In the apparatus described above, two anode tanks and three sets of cathode rollers have been shown by way of example. It is to be understood that more or fewer of each can be employed to suit the desired speed of production and other considerations.

While the invention has been disclosed in connection with certain specific embodiments and methods, it is to be understood that various changes can be made in these devices and procedures without departing from the spirit of the invention as defined in the appended claims.

I claim:

1. Apparatus for the continuous electroplating of a glass sheet having a mechanically sensitive metallic mirror surface, comprising means for supporting and conveying such a sheet for lengthwise movement in a horizontal plane with its sensitive surface uppermost, at least one trough-shaped metallic container having a flat bottom extending across the width of the sheet and of substantial extent in the direction of lengthwise sheet travel, means supporting said container in closely spaced relation above the sensitive surface of said sheet, the container bottom having a multiplicity of small, discrete apertures extending therethrough and substantially uniformly distributed throughout the bottom area, at least one freely rotatable metallic contact roller supported in contact with said sensitive surface outside the area covered by said container, means for flowing plating solution into said trough-shaped container in sufficient quantity to maintain a body of solution therein and from which the solution can flow through said apertures into the space between said surface and the bottom of said container, and thereafter out from said space, at such a rate as to maintain a continuous contact layer of solution between the bottom of said container and the sensitive surface, and means for imparting a direct current potential difference between said container and said contact roller, whereby the container becomes an anode and the roller a cathode.

2. Apparatus in accordance with claim 1, including means for collecting excess solution that runs off the sheet and for recirculating the same into said container.

3. Apparatus in accordance with claim 1, including means for adjusting the height of said container above the sheet.

4. Apparatus in accordance with claim 1, including means for selectively lifting and lowering said contact roller out of and into contact with the sheet.

5. Apparatus in accordance with claim 1, in which there are a plurality of contact rollers disposed in alignment parallel to the opposite transverse edges of the container electrode, and means for concomitantly lifting and lowering all of said rollers as a unit.

6. Apparatus in accordance with claim 1, in which opposite edge corners of the container bottom transverse to the direction of sheet travel are rounded, there being spaced perforations through one rounded corner edge disposed at an angle outwardly from the perforations in the flat bottom of the container.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,924,563 February 9, 1960

William R. Gray

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 44, for "ends threads" read -- ends threaded --; column 4, line 62, for "as", second occurrence, read -- at --.

Signed and sealed this 11th day of April 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

ARTHUR W. CROCKER
Acting Commissioner of Patents