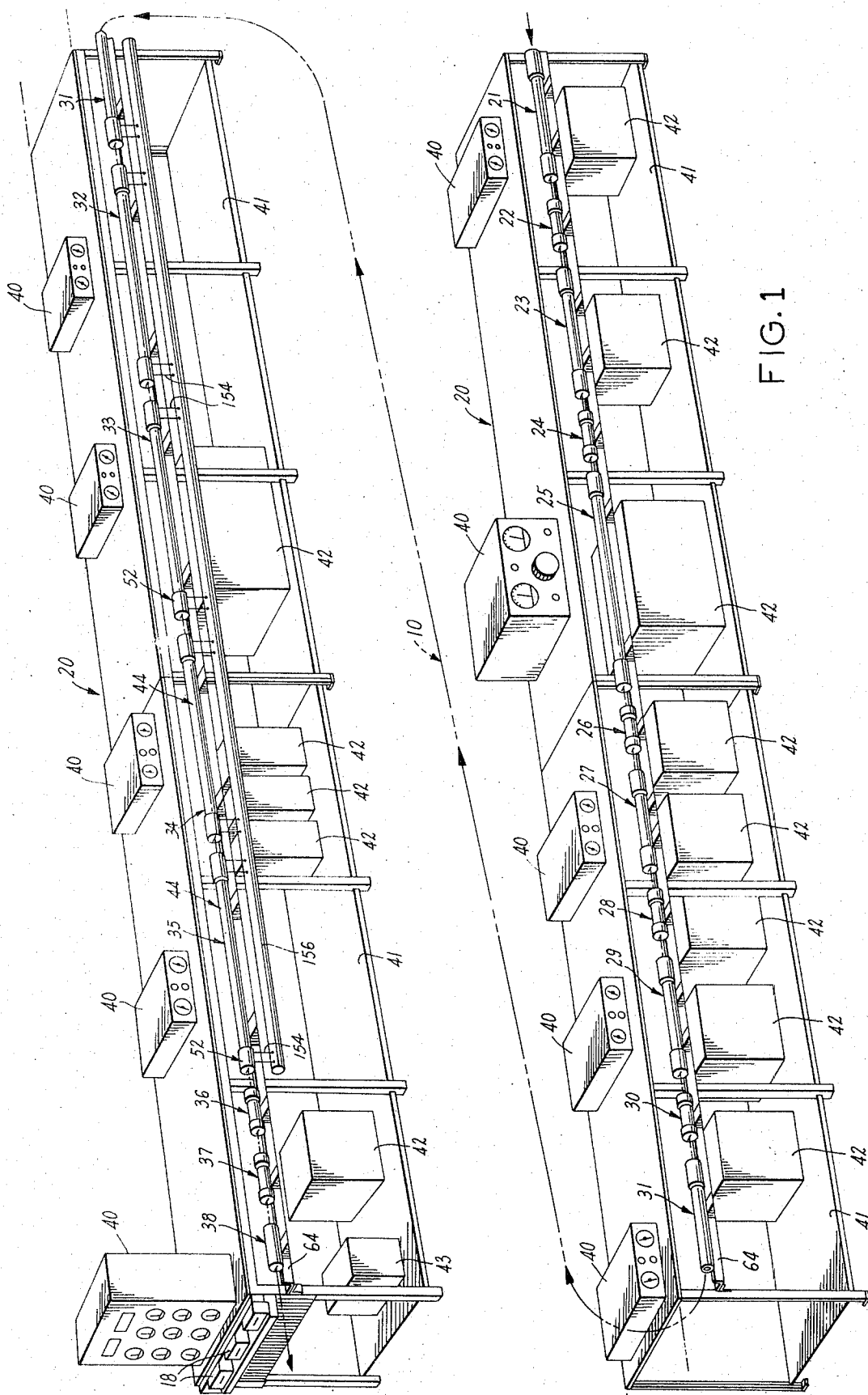
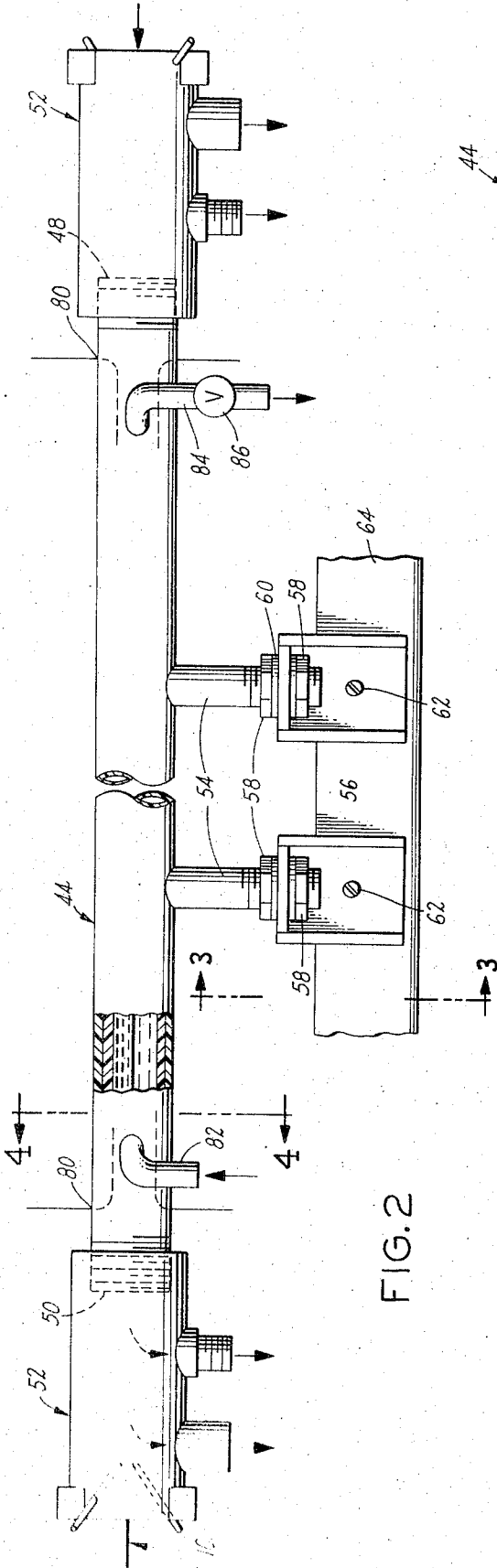
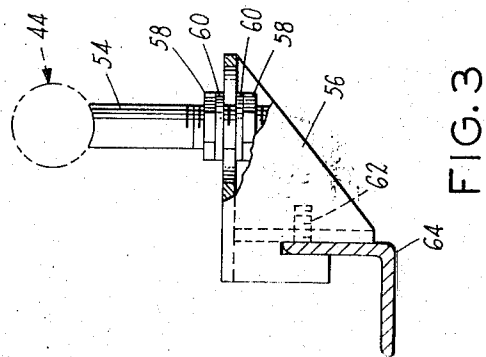
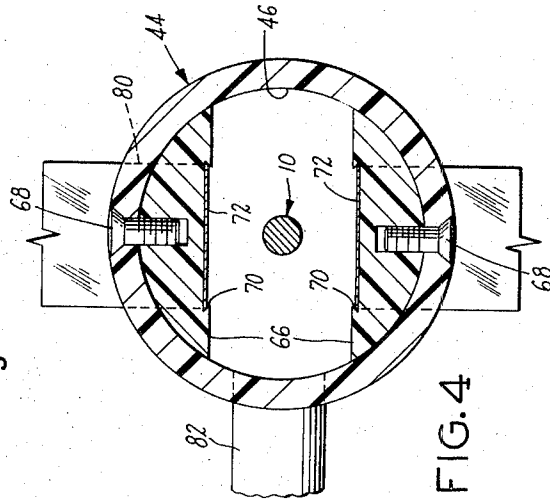
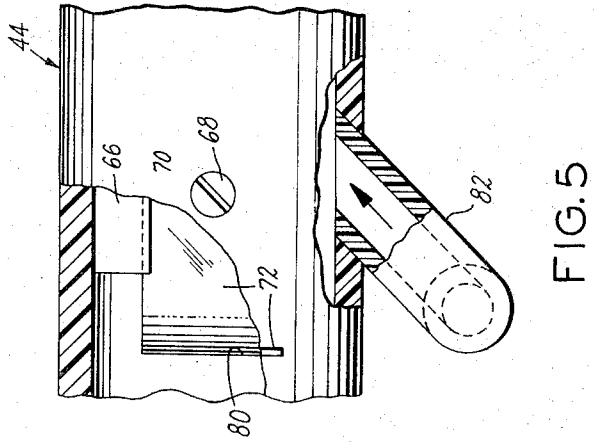






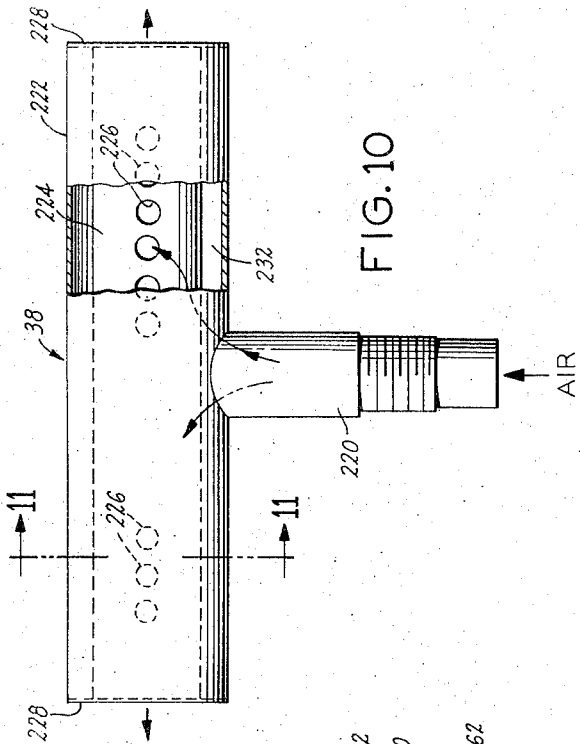


FIG. 10

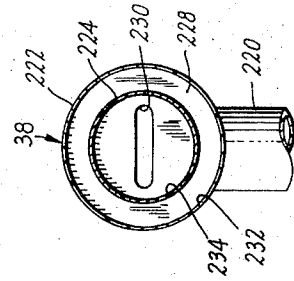


FIG. 11

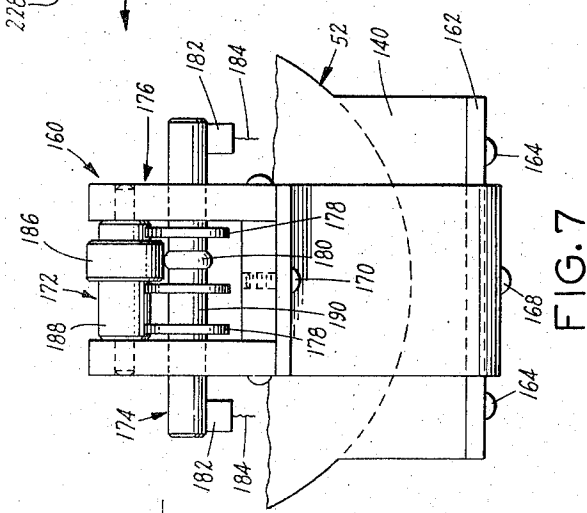


FIG. 7

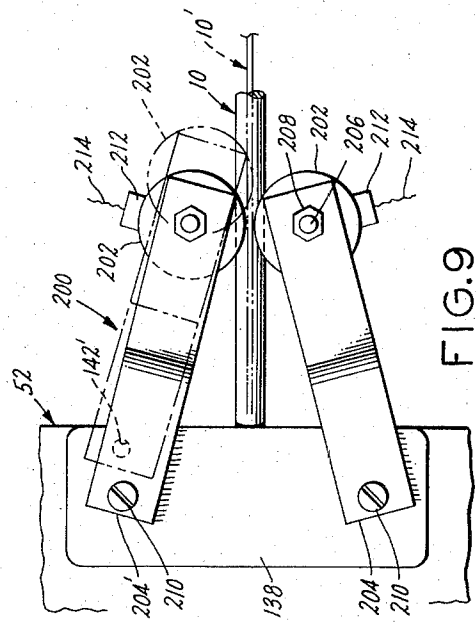


FIG. 9

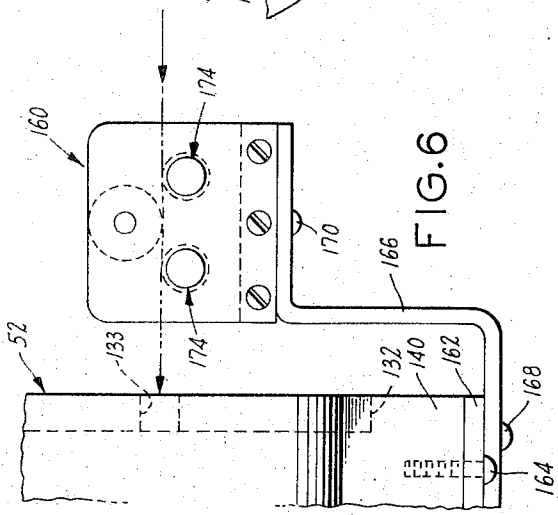


FIG. 6

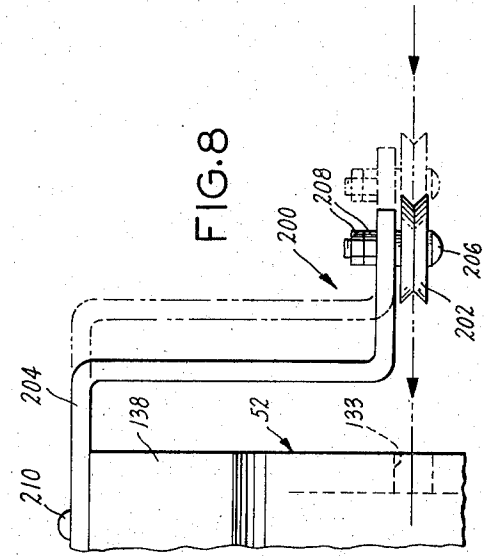


FIG. 8

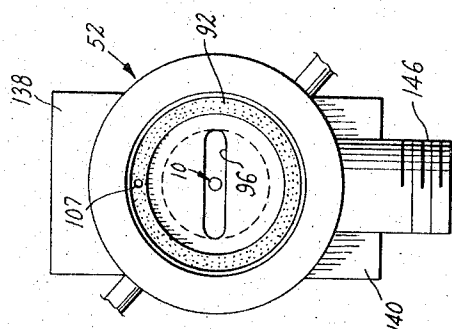


FIG. 15

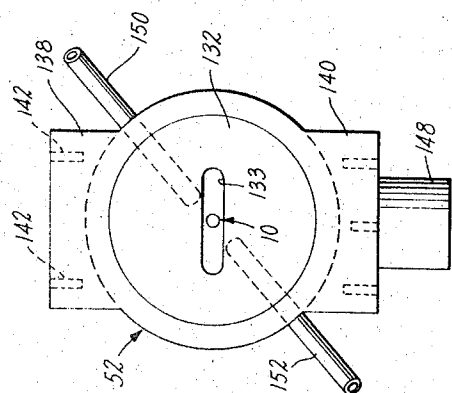


FIG. 14

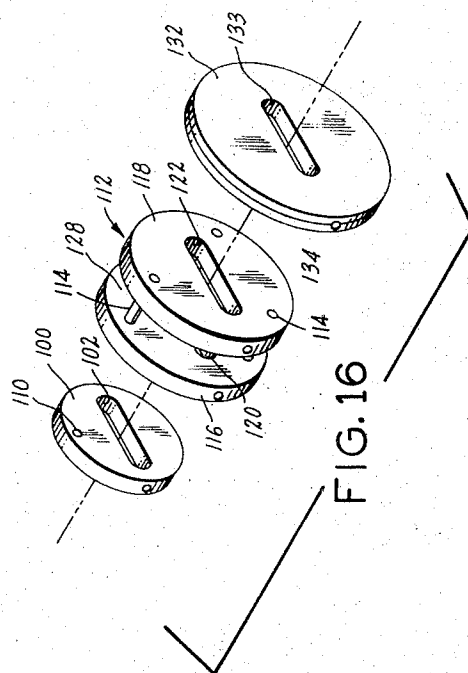


FIG. 16

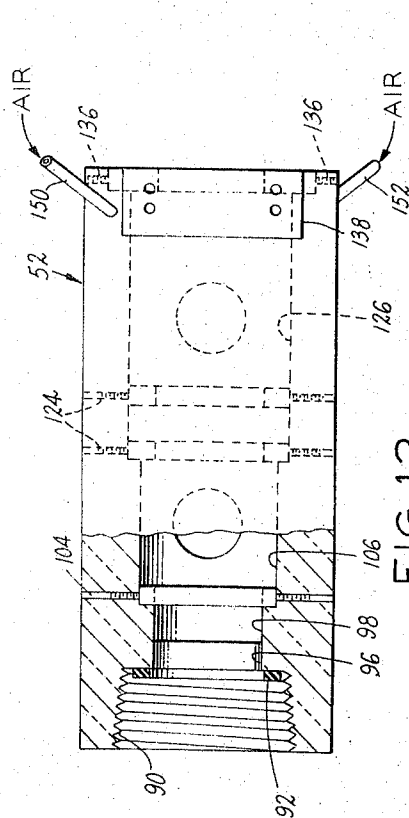


FIG. 12

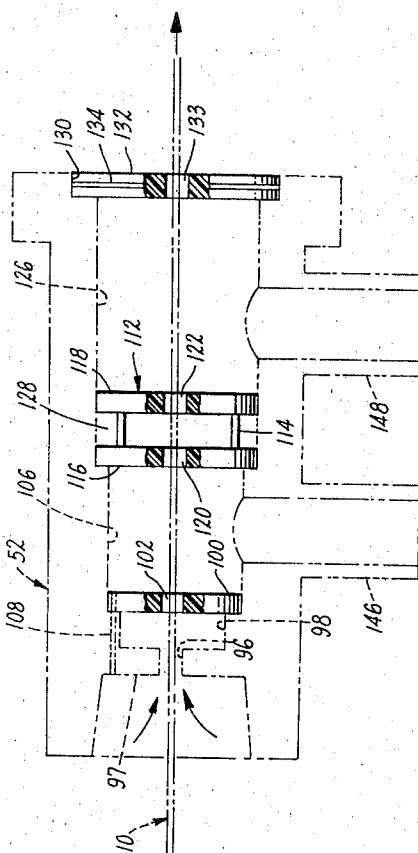


FIG. 13

METHOD FOR CONTINUOUS HIGH SPEED ELECTROPLATING OF STRIP, WIRE AND THE LIKE

BACKGROUND OF THE INVENTION

Attempts to achieve high speed continuous electroplating by the use of high current densities have inevitably run into the various problems including burning of the deposit which occurs in an electroplating chamber when a high potential is being applied across an anode and a workpiece and the difficulty of providing good electrical contact with the workpiece, particularly if some degree of interchangeability of workpiece size and configuration is desired.

A further problem inherent in the continuous electroplating art using electroplating operations at high speed has been inadequate drying of the workpiece following rinsing since the last traces of moisture should be removed before coiling or further processing.

Accordingly, it is an object of the present invention to provide a novel method for the high-speed continuous electroplating of a workpiece with metal in an electroplating station using novel drying means and contact means.

It is also an object to provide such a method which will rapidly dry the workpiece about its entire periphery.

Another object is to provide such a method which will provide good electrical contact with strip of different sizes and configurations.

SUMMARY OF THE INVENTION

It has now been found that the foregoing and related objects may be readily attained by the method of providing along the travel path of a moving, substantially continuous workpiece with a metallic surface, an electroplating chamber with an entrance and exit for the workpiece and an anode disposed therebetween substantially parallel to the travel path, and an electrical contact assembly is disposed externally of the electroplating chamber to apply an electrical potential between the workpiece and the anode in the electroplating chamber. A drying station provides a plenum chamber about a drying chamber and flow apertures spaced about and along the workpiece path.

An electroplating solution containing electrolyte and ions of the metal to be electrodeposited is passed through the electroplating chamber while a substantially continuous workpiece with a metallic surface is advanced along the travel path in contact with the electrical contact assembly, through the electroplating chamber and through the drying chamber. A voltage or potential is applied across the workpiece in the electrical contact assembly and the anode in the electroplating chamber to cause the metal of the solution to plate upon the workpiece in the electroplating chamber. A gas is introduced into the plenum chamber of the drying station at a lineal velocity sufficient to provide high flow through the apertures into the drying chamber onto substantially the entire surface of the workpiece passing therethrough to remove moisture therefrom.

The workpiece may be advanced along said path at a linear speed of about 25 to 5,000 millimeters per second, and the application of potential provides a current density of about 0.4 to 32.5 kiloamperes per square meter.

In one embodiment, the workpiece is a strip of elongated cross section and the electrical contact assembly comprises conductive roller members having their peripheral surfaces configured to provide a plurality of guide paths therethrough dimensioned to accommodate strips of different dimensions. In this embodiment the contact assembly is adjusted on its support to pass the strip through the guide path closely accommodating the dimensions of the strip and to align the adjusted guide path with the travel path through the electroplating chamber.

In the preferred embodiment, the gas introduced into the plenum chamber of the drying station is heated to a temperature above ambient and it exits from the drying chamber at the ends thereof.

The drying station is of generally cylindrical construction with the plenum and drying chambers being concentric about the workpiece travel path. Gas is caused to flow through flow passages about the periphery of the drying chamber onto the workpiece, and the gas containing removed moisture exits from the drying chamber through the ends thereof.

The apparatus comprising means for advancing the substantially continuous workpiece along a travel path including at least one rectilinear portion and at least one elongated electroplating cell located along the rectilinear portion of the workpiece path. The cell includes intermediate its ends an electroplating chamber with entrance and exit openings for travel by the workpiece therethrough, anode-support means for maintaining an anode disposed within said electroplating chamber substantially parallel to the workpiece path therethrough, and ports enabling passage of electroplating solution through the electroplating chamber. Pumping means is adapted to circulate the electroplating solution through the electroplating chamber and there is provided conductor means for applying a potential across the workpiece and the anode which includes an electrical contact assembly externally of the cell having conductive roller means providing a guide path for the workpiece aligned with the exit and entrance openings of the cell.

An elongated drying cell is provided along the workpiece path subsequent to the electroplating cell and has entrance and exit openings for the workpiece. It is comprised of a pair of spaced sidewall elements connected at their ends to define a plenum chamber therebetween, and the inner sidewall element has a multiplicity of flow passages therethrough spaced about and along the periphery thereof with the inner sidewall defining a drying chamber therewithin. The drying cell has a coupling for introduction of gas into the plenum chamber; and there is coupled thereto blower means for supplying gas to the drying cell. Desirably there is included means for heating the gas supplied by said blower means.

The electrical contact roller guide assembly desirably comprises a housing, a first roller rotatably mounted in the housing, and a pair of rollers rotatably mounted in the housing at points spaced to opposite sides of the first roller and defining therewith a roll nip therebetween. The several rollers have their circumferential surfaces cooperatively configured to provide along the axial length thereof a plurality of guide paths dimensioned to accommodate strip of different dimensions. Means is provided for adjustably mounting the housing on a support structure to shift the housing axially of the

rollers to orient different guide paths at a predetermined spatial relationship to the support structure. The first roller is non-conductive, and the pair of rollers are conductive with conductor means being electrically connected thereto for supply of current during rotation thereof. The pair of rollers are desirably configured to provide a plurality of radial collars spaced axially along the length thereof and defining guide paths therebetween, and the first roller has an axially elongated radial collar disposed between a pair of the radial collars on the pair of rollers. The pair of rollers include crown portions aligned with the elongated collar of the first roller, so as to accommodate a thin strip therebetween.

The air drying cell is comprised of a first elongated tubular sidewall element having a multiplicity of flow openings spaced along its length and about its periphery and a second elongated tubular sidewall element disposed outwardly of the first sidewall element and spaced therefrom. End walls enclose the spacing between the ends of the sidewall elements to define a plenum chamber therebetween, and they have openings therein for passage of the workpiece therethrough. A coupling on the second sidewall element provides an opening for gas introduction. The sidewall elements are substantially cylindrical and concentric, and openings in the end walls are spaced radially inwardly from the first sidewall element and concentric therewith.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a high-speed continuous electroplating system embodying the present invention with some of the conduits and the other elements being omitted for clarity and simplicity of illustration and with the continuous table assembly broken into two parts to accommodate size limitations,

FIG. 2 is a fragmentary front elevational view to an enlarged scale of an electroplating station, with a portion of the cell housing being broken away to illustrate internal construction;

FIG. 3 is a fragmentary sectional view of the electroplating station along the line 3—3 of FIG. 2;

FIG. 4 is a fragmentary sectional view of the electroplating station along the line 4—4 of FIG. 2 and to a further enlarged scale;

FIG. 5 is a fragmentary plan view of the left end of the electroplating cell as seen in FIG. 2 with portions of the housing being broken away to illustrate internal construction;

FIG. 6 is a fragmentary front view of an electrical roller contact guide assembly attached to the housing, and a workpiece shown in phantom passing therethrough;

FIG. 7 is an end elevational view of the electrical roller contact guide assembly shown in FIG. 6 and partially illustrating the cell housing;

FIG. 8 is a fragmentary elevational front view to an enlarged scale of a cell end showing an electrical pulley contact guide assembly with a second adjusted position shown in phantom line;

FIG. 9 is a fragmentary plan view of the electrical pulley contact guide assembly shown in FIG. 8 with a workpiece passing therethrough and the second position for one of the members thereof being shown in phantom line with a second workpiece, also in phantom line;

FIG. 10 is a front elevational view of the air drying station to a greatly enlarged scale with a portion of the housing broken away to reveal internal construction;

FIG. 11 is a fragmentary sectional view of the air drying station taken along the line 11—11 of FIG. 10;

FIG. 12 is a plan view of a cell end closure to a greatly enlarged scale with a portion of the housing broken away to illustrate internal construction;

FIG. 13 is a front elevational view of the transverse partitions in the closure which are partially in section and with the housing in phantom line to show the workpiece diagrammatically passing therethrough;

FIG. 14 is an end elevational view of the outer end of the closure shown in FIGS. 12—13 with the workpiece passing therethrough;

FIG. 15 is a similar view of the inner end of the closure; and

FIG. 16 is a perspective view of the closure partitions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning first to FIG. 1 of the attached drawing, therein illustrated is a complete electroplating system embodying the present invention, and specifically an electroplating system for the deposition of gold on a suitable metallic substrate such as copper wire, rod, strip or other substantially continuous conductive workpiece generally designated by the numeral 10 and diagrammatically illustrated by the arrows in FIG. 1. The various processing stations are located along an elongated two-tier table generally designated by the numeral 20 (which is shown in FIG. 1 as broken lengthwise into two parts in order to accommodate the limited size of the drawing sheet) and with the arrows indicating the path of travel of the workpiece through the various stations. In the illustrated embodiment, there are in series an electrocleaning station generally designated by the numeral 21, a tap water rinse station generally designated by the numeral 22, an acidtreating station generally designated by the numeral 23, a deionized water rinse station generally designated by the numeral 24, a nickel plating station generally designated by the numeral 25, another deionized water rinse station generally designated by the numeral 26, a nickel activating station generally designated by the numeral 27, another deionized water rinse station generally designated by the numeral 28, a gold strike station generally designated by the numeral 29, another deionized water rinse station generally designated by the numeral 30, a series of five gold plating stations generally designated by the numerals 31, 32, 33, 34 and 35, a dragout recirculating deionized water rinse station generally designated by the numeral 36, a tap water rinse station generally designated by the numeral 37 and a hot air drying station generally designated by the numeral 38. Associated with the electrocleaning station 21, the nickel plating station 25, the nickel-activation station 27, the gold strike station 29, the various gold plating stations 31 through 35, and the hot air drying station 38 are various monitoring and control units for determining and controlling operating parameters, replenishment, etc., as indicated by the meter and control boxes 40 located on the top tier of table 20. Switches 18 control the power supply to the various components. On the bottom tier 41 of table 20 are located a number of tanks 42 containing solutions and replenishment chemicals to be fed into the various stations as required and pumps (not shown). A blower and heater unit 43 provides heated air to the hot air drying station 38.

Not visible in FIG. 1 is an exhaust duct extending from station 31 through station 38 and located underneath the top tier of table 20, to assist in the evacuation of gas fumes. Also not shown in FIG. 1 for clarity of illustration of the overall system are a series of electrical contact guides which guide the workpiece in its travel through the various stations and supply electrical current thereto, as will be described and shown hereinafter with respect to the detailed drawings. The untreated workpiece may enter the system from a supply reel (not shown) immediately prior to station 21 or directly from its point of manufacture, and, after leaving the system, the electroplated workpieces may either be stored on take-up reels or subjected immediately to further processing. Transport means, which may be the take-up reel and auxiliary frictional contact drive roll assemblies spaced along the installation, is provided for advancement of the workpiece through the various stations comprising the electroplating system. Preferably the electroplating stations are disposed along a rectilinear length of the workpiece travel path.

Electroplating Cell

Turning now to FIG. 2, a typical electroplating station embodying the present invention, such as any one of stations 31, 32, 33, 34 or 35, employs an elongated generally tubular cell generally designated by the numeral 44 and providing an elongated substantially closed electroplating chamber 46 with entrance and exit openings 48, 50 respectively. On each end of the cell 44 is a closure generally designated by the numeral 52. As best shown in FIG. 3, the cell 44 is provided at spaced points along its length with depending threaded bosses 54, which are threadably secured in the cell support brackets 56 by a conventional arrangement of nuts 58 and washers 60. The cell support brackets 56 are in turn attached by means of machine screws 62 to a right angle bracket 64 extending the length of the table 20, so that the tubular processing stations are firmly affixed to the work table 20.

Turning now to FIG. 4, extending along the top and bottom of the chamber 46 in the cell 44 are elongated inserts 66 which are secured in position by the screws 68. The inserts 66 are desirably tapered at the ends as seen in FIG. 5 and the opposed inner surfaces thereof are provided with dovetail notches 70. Elongated anode strips 72 may be slid into these notches 70 for substantially the full length of the insert 66 and held in position by the undercut configuration. The dimensioning of the inserts 66 will vary with the desired anode to workpiece spacing which is selected according to good plating practice.

The wall of the cell 44 is provided with a slot 80 adjacent each of the tapered ends of inserts 66, slots 80 in the top and bottom at the left end portion of the cell being shown partially in FIG. 5. Each slot 80 is adjacent the end of one of the insert notches 70 so as to permit easy insertion of an anode strip 72 through a slot 80 into one end of the notch 70 and thence along the length of insert 66 until it exits through the slot 80 at the other end. Obviously once the anode strips 72 have been located in the inserts 66, each of the four slots 80 must be sealed with an insert, electrolyte-proof material, such as epoxy cement or a heat-stable silicone resin, to preclude leakage of electroplating solution.

The use of casing inserts 66 is limited to those plating stations utilizing insoluble anodes. Planting stations

using soluble anodes, such as the nickel plating station 25, may instead utilize more conventional construction such as separate compartments within the cell 44 into which the anodes may be placed through removed sections of the housing. Rinsing, drying and cleaning stations will naturally not require any anodes and therefore any inserts.

Solution Flow

As shown in FIGS. 2 and 5, the cell 44 is provided with inlet and outlet fittings 82, 84 respectively through which the chamber 46 receives and discharges electroplating solution. The arrows associated with the input and output fittings 82, 84 indicate electroplating solution flow direction opposite that of the workpiece 10 as indicated by the arrows at the closures 52, as is preferably provided to maximize the relative flow rate of solution past the workpiece 10 within cell 44 between the ports of the fittings 82, 84. Conventional pumping means (not shown) contained within tank 42 under station 31 recirculates the solution under pressure to maintain a desired solution flow rate into the inlet fitting 82. The outlet fitting 84 is provided with a throttle valve 86 which may be used to regulate, for a given solution input rate, the rate at which solution can leave through the outlet fitting 84 and, accordingly, the rate at which overflow will occur. Alternatively, for any given effective setting of the throttle valve 86, the volume of entering solution leaving cell 44 as an overflow can be increased, though not in a strictly linear proportion, by increasing the rate of solution entering the inlet fitting 82, of cell 44.

Cell Closures

Retaining most of the electroplating solution with the electroplating chamber 46 of the cell 44 are the closures 52 at each end thereof which are illustrated in detail in FIGS. 12-15. As seen in FIG. 2, the ends of the cell 44 are externally threaded and fit within the internally threaded recesses 90 at the inner end portions of the generally tubular closures 52. A resiliently deformable gasket ring 92 is seated between abutting surfaces of the elements to ensure a fluid tight seal.

As best seen in FIGS. 12 and 13, a passage extends through the closure 52 and has a slot portion 96 adjacent the threaded recess 90 and a series of steps in diameter increasing towards the outer end thereof which each define a chamber. The slot portion 96 opens into the first or near chamber 98 which is of the smallest diameter, and a partition wall member 100 having a slot 102 therein is secured by fasteners 104 at the shoulder formed by the step in diameter to separate the intermediate chamber 106. A gas conduit 108 extends from the aperture 107 in the gasket 92 in the threaded recess 90 through the slotted portion 97 above the slot 96 and the upper portion of the chamber 98, and the partition wall member 100 has gas passage 110 aligned therewith so that gases evolved in the electroplating chamber 46 may escape through the ends of the cell into the intermediate chamber 106.

A central partition assembly generally designated by the numeral 112 has a pair of axially spaced partition walls, 116, 118 secured together in spaced relation by pins 114 and transverse slots 120, 122 therein. It is secured in position by fasteners 124 against the shoulder formed by the next step in diameter to separate the remote end chamber 126. The large axial dimension of

this insert member 112 provides facile alignment and stable seating, and the spaced walls 116, 118 define a small chamber 128 therebetween.

Seated in the annular recess 130 at the outer end of the closure 52 is an end plate 132 which is secured by the fasteners 136 and has a gasket ring 134 seated in a circumferential channel to provide a seal. It is also provided with a transverse slot 133, and the slots 120, 122 in the central partition member 112, the slot 133 in the end plate 132, the slot 102 in the partition wall 100 and the slot 96 in the slotted portion 97 are aligned so that the workpiece 10 may pass freely therethrough.

Although the configuration of the closure 52 is generally cylindrical, it is provided at the outer or remote end with radially and vertically extending flanges 138, 140 which have threaded apertures 142 adjacent the sides of the outer ends thereof to mount the contact guides as will be more fully described hereinafter. Outlet fittings 146, 148 are provided in the bottom of the closure 52 to drain the chambers 106, 126; and a pair of diametrically opposed gas conduits 150, 152 extend through the wall of the closure 52 into the chamber 126 at an angle to the axis of the closure 52 and towards opposite surfaces of the workpiece 20. The outlet fittings 146, 148 are connected by the conduits 154, 156 seen in FIG. 1 to the solution supply tank 42 for the station so as to return the solution thereto. The gas conduits 150, 152 are connected to conduits (not shown) for air or other gas under pressure so that the gas stream will sweep solution from the surface of the workpiece 20. Preferably, the gas conduits 150, 152 are oriented so that they sweep the opposite surfaces of the workpiece 20 at spaced points within the chamber 126. Not shown is a control valve on the outlet fitting 146 or conduit 154 therefrom to limit flow outwardly of the chamber 106 especially during startup, as will be described more fully hereinafter.

Thus, it can be seen that interior of closure 52 is divided essentially into three principal cylindrical chambers: (1) a small inner or near chamber 93 located adjacent the electroplating chamber 46, and with which it communicates through the slot 96; (2) an intermediate chamber 106 which is provided at its bottom with a liquid outlet fitting 146 and (3) an outer or a remote-end chamber 126 located remote from the electroplating chamber 46 and provided at its bottom with an outlet fitting 148 and with the gas conduits 150, 152.

Electrical Contact Guide Assembly

An electrical potential across the anode strips 72 and workpiece 10 is developed by means of leads (not shown) connected to the anode strips 72 and a roller contact guide assembly as seen in FIG. 6 and 7 for workpieces of rectangular cross section and a pulley contact guide as seen in FIGS. 6 and 7 for workpieces of curvilinear cross section.

Turning first to FIGS. 6 and 7, an electrical roller contact guide assembly for rectangular workpieces, generally designated by the numeral 160, is supported on the bottom flange 140 of closure 52. A metal plate 162 is affixed at its ends to the bottom of flange 140 by a pair of screws 164 engaged in the threaded holes 142, and an S-shaped bracket 166 is connected at one end to the plate 162 by means of screw 168 and at the other end to the guide assembly 160 by means of screw 170. The screw 168 may be loosened to permit bracket 166 and roller contact guide assembly 160 to be swung out

of the way if the roller contact guide assembly is not needed. The metal plate 162 is utilized between the bracket 166 and the flange 140 because the metal plate can better withstand the repeated threaded assembly and disassembly.

The roller contact guide assembly 160 consists essentially of an upper roller generally designated by the numeral 172, a pair of lower rollers generally designated by the numeral 174; and a U-shaped housing 176 which maintains the upper roller 172 and the lower rollers 174 in rotatable, fixed juxtaposition. As best seen in FIG. 7, each of the lower rollers 174 is a long metal rod having three radial collars 178. Between two of the collars 178 is a crown surface portion 180. The ends of the rod 174 extend beyond the housing 176 and are in contact with biased carbon brushes 182 connected to a source of potential by the leads 184.

The upper roller 172 is maintained within the housing 176 in a position between and above the lower rollers 174 and ensures that a rectangular workpiece passing through the roller contact guide assembly 160 makes good electrical contact with the electrically-conductive lower rollers 174 and is itself conveniently made of non-conductive plastic. The upper roller 172 is provided with an enlarged collar 186 which defines a mix with the crown portion 180 of the lower rollers 174. In this manner the roller guide assembly 160 may easily be used with rectangular workpieces of different thicknesses; thin workpieces will be passed in the narrow clearance between the upper roller collar 186 and the lower crown portion 180, while thicker workpieces will be passed between the cylindrical surface 188 of the upper roller 172 and the surface 190 of the lower roller 174 between the collars 178. The S-shaped bracket 166 is designed so that the electrical roller contact guide assembly 160 may be swung into position with either of these roller passages both horizontally and vertically aligned with slot 133 of the end plate 132 of the closure 52.

Turning now to FIGS. 8 and 9, the pulley-shaped contact guide for workpieces of round or any other curvilinear cross sections, generally designated by the numeral 200 is composed of a pair of pulley-shaped metal rollers 202 each of which is rotatably mounted in one end of a Z-shaped metal bracket 204 by means of a plastic screw 206 and nuts 208. The other end of each Z-shaped bracket 204 is attached by a screw 210, seated in the threaded holes 142 in the upper flange 138 of closure 52. The rollers 202 are connected to a source of electrical potential by the carbon brushes 212 and leads 214.

In order to accommodate workpieces of circular cross section and of varying thickness, at least one of the Z-shaped brackets 204 of pulley contact guide 200 may be pivoted horizontally about screw 210 (as shown in phantom line in FIG. 8) as may be necessary to ensure that the path of travel of the workpiece is appropriately directed through the slot 133 of the closure 52. As best seen in FIG. 9, for operation with small diameter workpieces 10' it may be desirable to relocate screw 210 and Z-shaped bracket 204' so as to use aperture 142' to bring its roller outwardly and thereby permit more effective contact between the workpiece and the 45° beveled surfaces of the pulley-shaped rollers 202.

If a rectangular workpiece is to be processed, screws 210 may be loosened and the Z-brackets 204 on the upper flange 138 swung away to make room for the rol-

ler contact guide assembly 160. If a curvilinear workpiece is to be processed screws 168 may be loosened and the S-brackets 166 on the bottom flange 140 swung away to make room for the pulley-shaped contact guide 200 to be moved into operative position.

Drying Station

Referring now to FIGS. 10 and 11, the hot air drying station generally referred to by the numeral 38 is the last station traversed by the moving workpiece 10. The dryer housing is generally designated by the numeral 38 and is supported upon the support bracket 56 by a partially threaded conduit 220. It is comprised of a pair of spaced, coaxial tubular cylinders 222, 224 with the inner cylinder 224 being provided with a series of small apertures 226 along each side thereof adjacent the path of travel of the workpiece 10. End plates 228 close the ends of the cylinders 222, 224 and are provided with slots 230 to permit passage of the workpiece 10 there-through.

In operation of the hot air drying station 38, air is heated and forcefully blown through the conduit 220 by a blower located in the heating unit 43 seen in FIG. 1. The hot air passes into the outer chamber 232 provided by the spacing between the cylinders 222, 224 and is contained therein by the end plates 228. The pressure developed in the chamber 232 forces the hot air through the apertures 226 in the wall of the 224 into the inner chamber 224 inner cylinder and thence over the workpiece 10 to effect drying thereof. The expended moisture-bearing drying air escapes from inner cylinder 224 through the end plate slots 230 about the workpiece 10 (not shown) and into the atmosphere. Ducts may be provided if so desired.

Operation of the Illustrated Embodiment

To provide an understanding of the operation of the illustrated electroplating system embodying the present invention, the passage of the workpiece 10 through the various stations shown in FIG. 1 will now be briefly described. Here the operation of the cell and closure assemblies of the present invention will be described in detail only in connection with a gold plating station since the modification and operation of such cell assemblies for other stations will be readily apparent to those having ordinary skill in the art. The substantially continuous workpiece 10 is drawn from a supply reel (not shown) by a take-up reel (not shown) through the various stations at linear rates of about 1.5 to 300 meters per minute, depending on the desired thickness of deposit, other factors being held constant.

Electrocleaning station 21 includes a cell and closure construction similar to that described hereinbefore except that the housing is made of stainless steel rather than plastic and no anode inserts are required because the housing itself may be connected to a source of potential. A low sudsing or sudsless electrolytic alkali cleaning solution is passed through the chamber from the supply tank 42 at a moderately elevated temperature while an applied direct or reverse voltage differential between the housing and the workpiece causes the generation of large quantities of gas close to the workpiece 10, thereby providing a high level of mechanical agitation and scrubbing action.

The workpiece 10 is then passed into the cell with no electrical connections providing the tap water rinse station 22 wherein it is rinsed with tap water, and then it

is passed into the cell of the acid-cleaning station 23, wherein any remaining alkali traces on the workpiece are neutralized and the surface is activated. Residues of the chemicals used in acid-cleaning operation are removed at station 24 where high velocity deionized water is passed over the workpiece in the cell to prepare the workpiece for nickel plating.

The rinsed workpiece 10 is provided with a thin coating of nickel at station 25 using a nickel anode and a conventional Watts-type or nickel sulfamate electroplating solution. After another deionized water rinse at station 26, the nickel plated workpiece 10 is passed through the dilute sulfuric acid bath of nickel-activating station 27 to remove any surface impurities (for example, wetting agents) and then it is subjected to a further rinse with deionized water at station 28. In general, however, it has been found that the nickel-activating operation performed at station 27 and the subsequent deionized rinse performed at station 28 may be omitted without adverse effects.

A gold strike is deposited upon the nickel-plated workpiece in gold-strike station 29, which preferably uses insoluble platinum-clad tantalum anode strips in the casing inserts. The workpiece 10 bearing the gold strike is again rinsed with deionized water at station 30 before entering a series of five gold-plating stations 31 through 35. The use of a plurality of relatively short gold plating stations as opposed to a single gold plating station of extremely long dimension is preferred because it permits maintenance of a high current density and facilitates threading of anode strip 72 through the notch 70 of the casing insert.

A common conduit 156 connects the outlet fittings 146, 148 of the closures 52 surrounding the gold plating stations 31 - 35 so that a single reservoir of the plating composition is maintained in the tank 42 located under station 31. The strip 10 enters the outer chamber 126 of the closure 52 through the slot 133 at the one end of each cell of a station and then passes through the partitions 112, 110 and the slot 96 to enter into the electroplating chamber 46. Electroplating solution is being introduced into the chamber 46 through the inlet fitting 82 from the tank 42 at a high velocity so that a turbulent condition is maintained therewithin about the workpiece 10 and generally the major portion of the solution exits through the outlet fitting 84 and is recirculated back to the tank 42 through conduits (not shown). However, a significant portion of the solution also exits from the entrance and exit ends 48, 50 of the chamber 46 through the slots 96 in the closures 52 at each end, thus ensuring high solution flow and turbulence about the workpiece 10 throughout the path through the cell where applied potential causes current flow and might produce burning. The volume of flow through the slots 96 into the closures can be controlled conveniently by the throttle valve 86 on the outlet. The liquid passing through the slot 96 substantially completely fills the inner chamber 98 which is of a diameter substantially equal to the width of the slot 96 so that only a small volume of liquid is maintained therein. The solution then flows through the slot 102 from the inner chamber 98 into the intermediate chamber 106 from which it is discharged through the outlet fitting 146.

Gas evolving during the electroplating operation and any gases that may be carried into the chamber 46 are vented from the chamber 46 through the gas conduit 108 and gas passage 110 into the intermediate chamber

106, and they may exit therefrom in combination with solution being discharged through the outlet fitting 146.

Simultaneously with the movement of the workpiece 10 through the station, gas under positive pressure is being introduced into the outer chamber 126 through the gas conduits 150, 152. In the instance of the closure 52 at the discharge end of the station, this gas impinges upon the surfaces of the workpiece 10 to remove any solution remaining thereon. In addition, the gas introduced into the outer chambers 126 of both closures 52 develops a positive pressure therein tending to restrict flow of solution from the intermediate chamber 106 through the central partition 112 into the outer chamber 126. Solution which does enter into the outer chamber 126 together with the gas under pressure exits from the end chamber 126 through the outlet fitting 148, and the solution is separated from the gas and returned to the solution tank 42 through the conduits 154, 156.

The gold-plated workpiece 10 is rinsed with deionized water at station 36 in a recirculating dragout rinse operation, and this rinse water is passed through a resin ion exchange unit (not shown) to capture the gold values which will later be recovered from the resin. The gold-plated workpiece 10 is given a final rinse with tap water at station 37 and then dried with hot air (desirably 150°–200° F.) at the drying station 38 before being passed onto a driven take-up reel (not shown).

Production efficiencies in construction of the apparatus are achieved by utilization of standard modularized components wherever possible in the system. For example, the same cell construction closures, roller contact guides, and pulley-shaped contact guides are used for all stations involving liquid flow and electrical potential, although dimensions and anode insertion techniques may vary. For example, the rinsing station casings usually do not need to be as long as the plating station casings. The casing of the electro-cleaning station or similar stations may be constructed of conductive metal such as stainless steel rather than the usual high temperature plastic so that the casing itself may be used as an electrode.

As will be appreciated, the cross-sectional configuration of the cell and its chambers can vary from the generally cylindrical cross-section in the illustrated embodiment. However, such cylindrical configurations have proved highly advantageous from the standpoint of ease of fabrication and from the standpoint of minimization of potential stagnant areas within the chamber as might be encountered with internal cross sections providing angular side walls.

Although the material of construction for the cells may vary widely, it is generally desirable to use a synthetic plastic exhibiting both chemical and temperature resistance. The specific synthetic resin employed will usually vary depending upon the nature of the electroplating solutions to be contained therein. Among those resins which have been found suitable are chlorinated polyvinyl chloride, polymethyl methacrylate, polycarbonate, polypropylene, polyacetal, polysulfone, etc. Where transparency is not necessary, resins including urea/formaldehyde, polytetrafluoroethylene, ABS, and the like may be employed. Chlorinated polyvinyl chloride has proven particularly advantageous by reason of its relatively low cost and high chemical resistance for most applications.

Thus, it can be seen from the foregoing specification and drawings that the electroplating process of the present invention utilizes a novel electroplating installation which permits high speed continuous electroplating operation. The installation uses novel contact means providing effective contact with strip of different sizes and it also includes a novel drying station to ensure removal of moisture from the strip following rinsing and before further processing or coiling.

Having thus described the invention, I claim:

1. In a method for the high deposition speed continuous electroplating of a workpiece with noble metal, the steps comprising

providing along a rectilinear travel path of a moving workpiece at least one electroplating chamber with an entrance and exit for said workpiece at opposite ends thereof and an anode disposed therebetween substantially parallel to said travel path; an electrical contact assembly externally of said electroplating chamber to apply an electrical potential between said workpiece and said anode in said electroplating chamber; a rinsing station providing a rinsing chamber; and a drying station providing a plenum chamber about a drying chamber with apertures spaced about and along said path;

passing through said electroplating chamber a noble metal electroplating solution containing electrolyte and ions of the metal to be electrodeposited at a high velocity to maintain a turbulent condition therewithin; advancing a substantially continuous workpiece with a metallic surface along said travel path in contact with said electrical contact assembly, through said electroplating chamber, through said rinsing chamber, and through said drying chamber;

applying a voltage potential across said workpiece in said electrical contact assembly and said anode in said electroplating chamber to cause said metal of said solution to plate upon said workpiece in said electroplating chamber, said workpiece being immersed in said electroplating solution in said electroplating chamber;

passing a rinsing medium through said rinsing chamber to effect immersion of said strip in said medium to remove residual electroplating solution from the surface of said workpiece;

controlling fluid escape from the ends of at least said electroplating chamber and minimizing air interface with the noble metal electroplating solution in said electroplating chamber; and

introducing into said plenum chamber of said drying station a gas at a lineal velocity sufficient to provide high flow through the apertures into said drying chamber and directly onto substantially the entire surface of the workpiece passing therethrough to remove moisture therefrom.

2. The method of claim 1 wherein said workpiece is advanced along said path at a linear speed of about 25 to 5,000 millimeters per second.

3. The method of claim 1 wherein said application of potential provides a current density of about 0.4 to 32.5 kiloamperes per square meter.

4. The method of claim 1 wherein said workpiece is a strip of elongated cross section and wherein said electrical contact assembly comprises conductive roller members having their peripheral surfaces configured to provide a plurality of guide paths therethrough dimen-

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sioned to accommodate strips of different dimensions and wherein there is included the step of adjusting said contact assembly to pass said strip through the guide path closely accommodating the dimensions of said strip and to align the adjusted guide path with the travel path through the electroplating chamber.

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5. The method of claim 1 wherein said gas introduced into said plenum chamber of said drying station is heated to a temperature above ambient and wherein it exits from said drying chamber at the ends thereof.

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