Aug. 2, 1949. C. G. JONES 2,477,808

ELECTROLYTIC APPARATUS FOR TREATMENT OF MOVING STRIP

Filed May 8, 1946 3 Sheets-Sheet 1

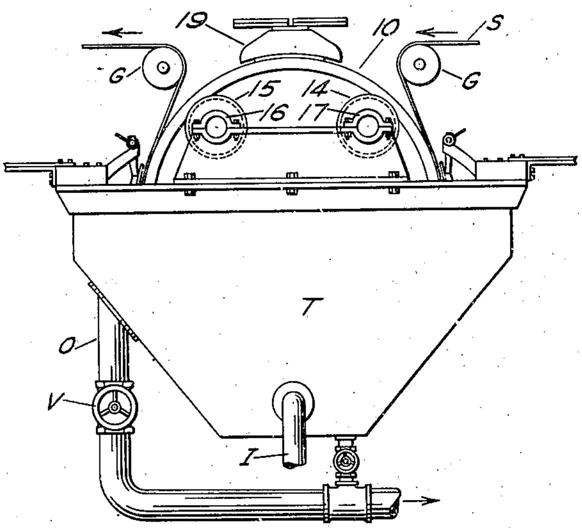

Fig.1.

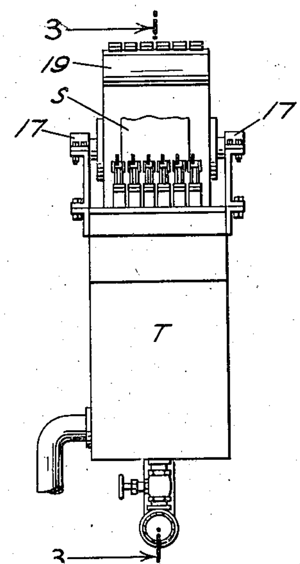

Fig.2.

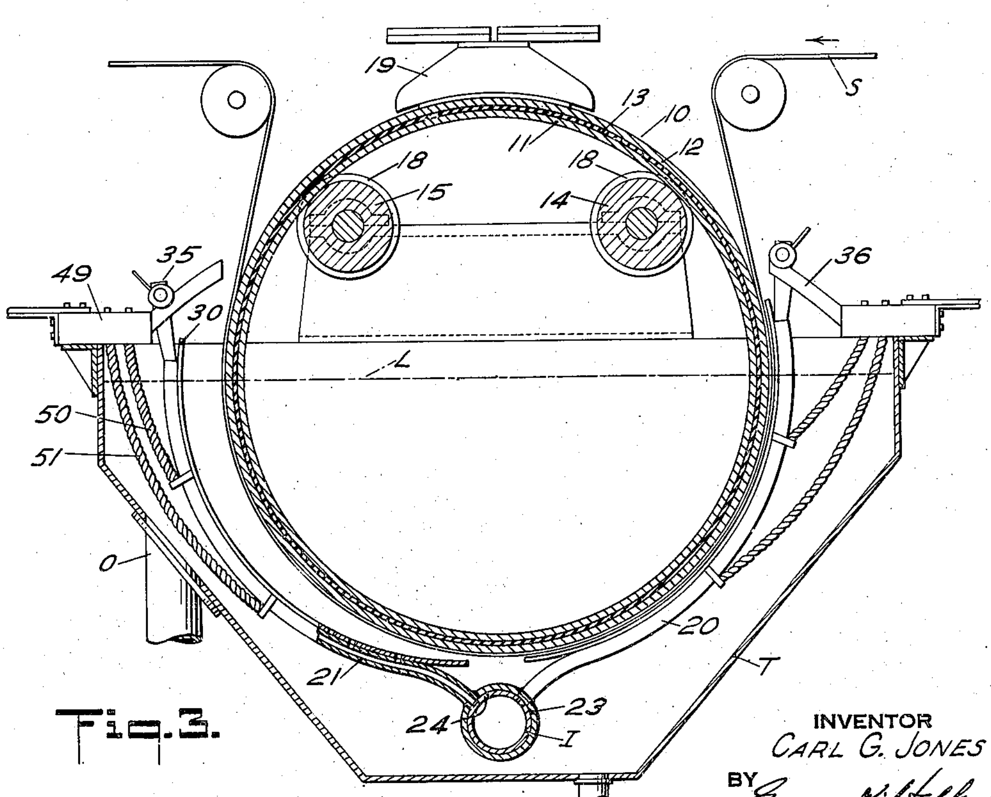

Fig.3.

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ELECTROLYTIC APPARATUS FOR TREATMENT OF MOVING STRIP

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Fig. 4.

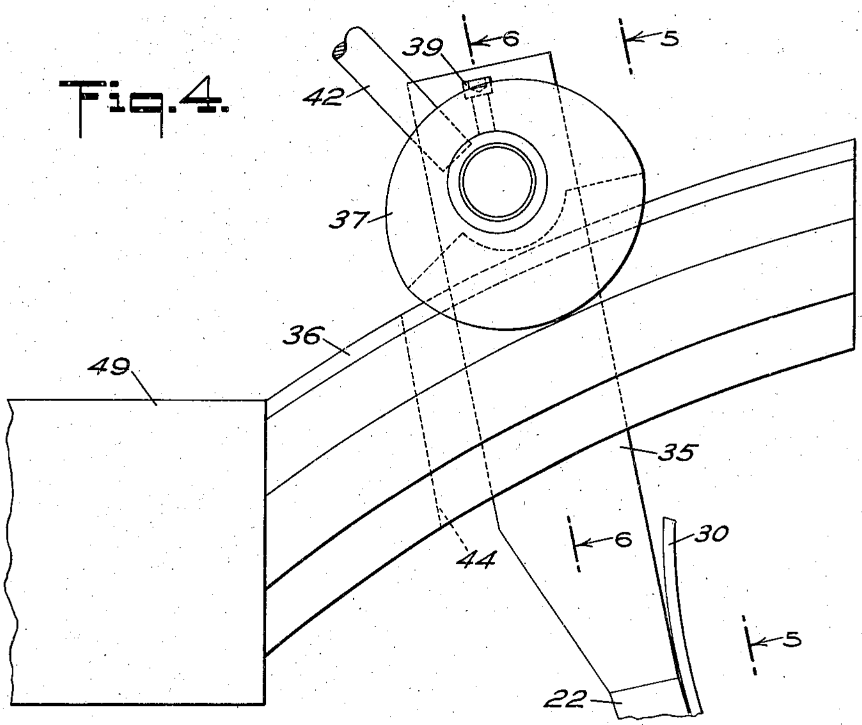


Fig. 5.

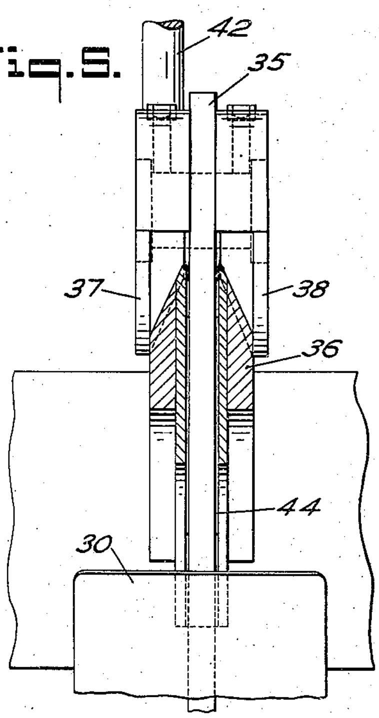
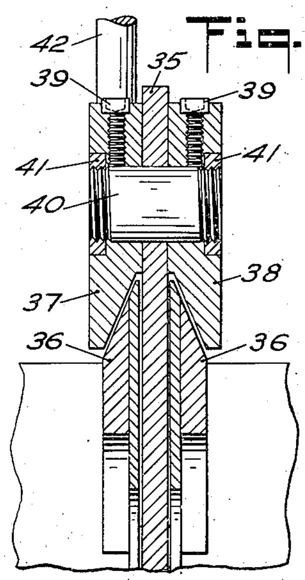


Fig. 6.



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ELECTROLYTIC APPARATUS FOR TREATMENT OF MOVING STRIP

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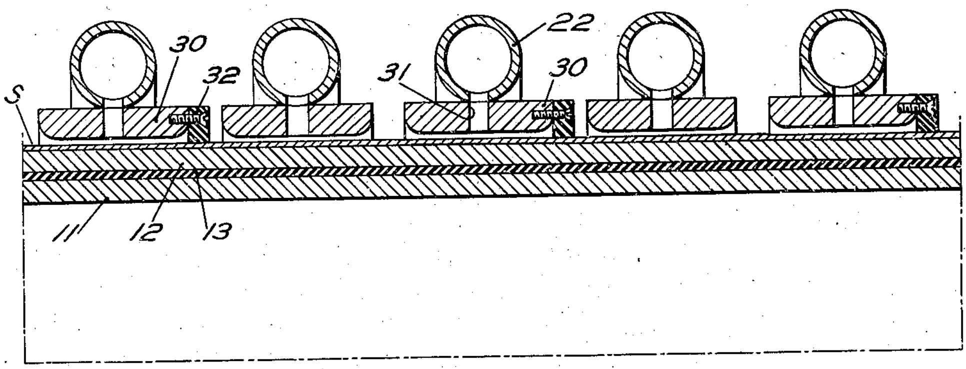

Fig. 7.

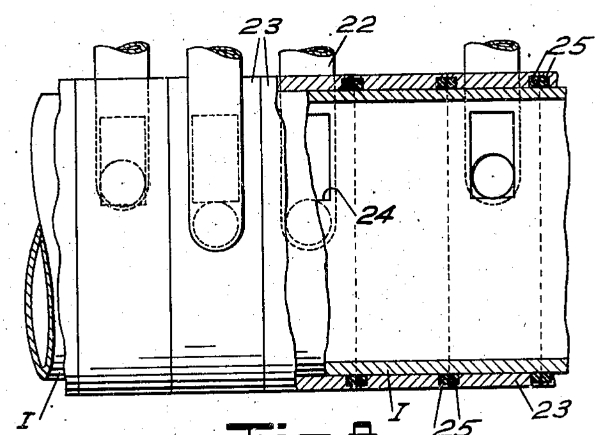

Fig. 8.

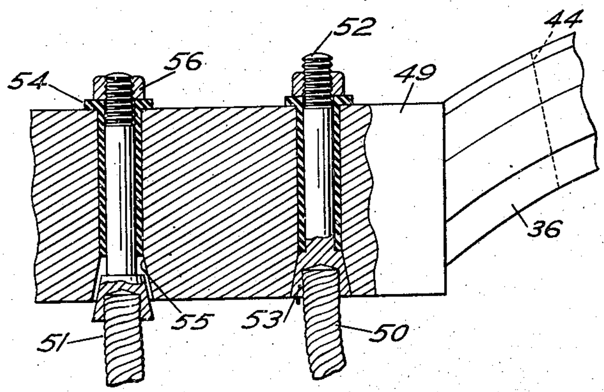

Fig. 9.

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UNITED STATES PATENT OFFICE

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ELECTROLYTIC APPARATUS FOR TREATMENT OF MOVING STRIP

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Application May 8, 1946, Serial No. 668,183

5 Claims. (Cl. 204—211)

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This invention relates to electrolytic processing of metal strip and is especially directed to improvements in electrolytic apparatus whereby substantially increased production of electrolytic tin plate may be attained, with maximum uniformity of coating thickness, as compared with electrolytic tin plate heretofore commercially manufactured.

There has been proposed an electrolytic coating or tin plating machine for steel strip comprising a drum suspended in a tank, anodes proximate the outer surface of the drum, either of tin and therefore soluble in the bath to replace the metal deposited on the strip or else relatively insoluble, and means for supplying electrolyte to the tank as the strip acting as the cathode is continuously moved over the drum between it and the anodes.

But in apparatus of this general character it has been found difficult, if not impossible, to produce a high yield of tin plated steel strip with satisfactorily uniform thickness of tin coating across its width, as the plating current tends to concentrate adjacent the edges of the strip and thus cause excessive deposition of tin in those areas as compared with the center portion of the strip, while non-uniform flow of electrolyte in contact with the strip tends to impair the quality of coating when relatively high-rate production is attempted due to spent solution not being flushed away from the strip surface with uniform or sufficient rapidity after the tin ions have been deposited therefrom on the strip.

Moreover, the difficulties incident to threading a strip through the apparatus at the initiation of its operation and of passing through it defective welds, which unavoidably occur in securing together the ends of successive strips to form a continuous one, have served as further deterrents to wide adoption and use of such apparatus.

It is therefore a primary object of the present invention to provide improved electrolytic apparatus in which a drum serving as a conductor of given polarity contacts one face of a strip while the other is exposed to contact with a bath of electrolyte constantly renewed with ion-rich solution flowing in a space between the strip and a plurality of electrodes of opposite polarity so disposed with respect to the face of the strip as to effect substantially uniform current distribution across it with consequent uniform electrolytic treatment thereof, while affording means which facilitate passage through the apparatus of defective welds or the like without damage to the strip or to the apparatus itself.

Another object is to provide apparatus of this

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character in which a plurality of relatively adjustable electrodes supply current for the electrolytic treatment and also serve as conduits for the passage of fresh electrolyte into the bath and into intimate contact with the strip face.

A further object is to provide apparatus in which such adjustable electrodes, arranged in substantially parallel planes spaced transversely of the path of the strip, may be selectively rendered ineffective in the electrolytic treatment, whereby strips of different widths may readily be successively accommodated for treatment and like uniformity in the latter attained substantially irrespective of differences in strip width.

A still further object is to provide novel means for carrying current to the adjustable electrodes in such apparatus whereby the current is distributed along the length of each while operatively positioned but when inoperative current may be withheld therefrom, whereby although the electrode remains in the electrolytic bath it has no effect upon the treatment being carried out, its movement to inoperative position having interrupted its functioning as a conduit for fresh electrolyte.

A still further object is to provide apparatus which, while perhaps primarily most useful for electrolytically depositing a tin coating on steel strip in the manufacture of commercial tin plate, may also be used for depositing other metals on steel or other metallic strips or may be used for electrolytic cleaning or pickling of steel or other metal strips without change in its structure.

Other objects, purposes and advantages of the invention will hereinafter more fully appear or be understood from the following description of a preferred embodiment of it as shown in the accompanying drawings and during which to facilitate the disclosure I may emphasize most strongly its use in tin plating steel strip as illustrative of the several electrolytic processes wherein it may be advantageously employed.

In the said drawings Fig. 1 is a somewhat diagrammatic side elevation of the apparatus;

Fig. 2 is an end view thereof;

Fig. 3 is an enlarged vertical section on the line 3—3 in Fig. 2;

Fig. 4 is a fragmentary further enlarged detail of one anode clamp and connector assembly;

Figs. 5 and 6 are sectional views on lines 5—5 and 6—6 respectively in Fig. 4;

Fig. 7 is a fragmentary enlarged detail showing several anodes and a part of the cathode drum in horizontal section;

Fig. 8 is a fragmentary enlarged detail of the electrolyte inlet pipe and associated parts; and

Fig. 9 is a fragmentary detail, partly in section, of other anode connectors.

In the several figures like characters are used to designate the same parts.

Referring now more particularly to the drawings, the apparatus generally illustrated in Figs. 1 and 2 comprises a tank T provided with an inlet pipe I through which electrolyte may be supplied by a pump (not shown) and an outlet pipe O for removal of spent electrolyte from the tank, this pipe having a valve V for maintaining a suitable constant level L of the electrolyte therein by controlling the flow of spent electrolyte therefrom. Disposed above the tank on suitable supports (not shown) are guide rollers G over which a strip S passes in its travel into and from the tank.

Within the tank is a hollow open-end drum **10** comprising an inner cylinder **11**, outer cylinder **12** and an intervening cylindrical layer of micarta or other suitable insulation **13**, the drum being supported on flanged rollers **14**, **15** carried in bearings **16**, **17** on the sides of the tank. The roller flanges **18** extend radially from the main body of the rollers a distance less than the combined radial thickness of inner cylinder **11** and insulation **13** and the drum as a whole is thus rotatable on its own axis while supported on the rollers in metal-to-metal contact, but with its outer surface, that of cylinder **12**, electrically insulated from the rollers. If desired the drum may be formed sectionally from a plurality of identical inner and outer rings insulated from each other and held together axially in any convenient way, but as the present invention is not concerned with the specific construction of the drum no further description of it is required.

Above the drum and supported independently thereof, I provide a current collector **19** comprising means engaging the drum surface for conveying the electrolyzing current between the drum and one pole of the current source (not shown) but the specific construction of the collector is also of no concern in the practice of this invention, it being adequate for the purposes thereof that a rotatable drum be provided with means for electrically connecting it with the current source, usually the negative pole of the latter.

However, the electrodes of opposite polarity, usually the anodes, are of special and novel construction and in accordance with the invention a plurality of them are arranged in pairs respectively spaced axially of the drum at suitable intervals; as the anodes comprised in each pair are similar though arranged in opposite relation with respect to the drum, specific description of but one such pair is required. Thus each pair comprises a leading anode **20**, extending generally arcuatey from near the bottom of tank T normal to the drum axis and toward the incoming strip and a trailing anode **21** extending correspondingly in the general direction of the outgoing strip. Each anode comprises a curved pipe or tube **22** shaped to conform generally to that part of the drum it overlies when in operation and is supported at one end from a ring or collar **23** embracing inlet pipe I, the collar having a hole extended through it in alignment with the passage in the anode, while the inlet pipe is provided with a port **24** for admission of electrolytic fluid from the pipe to each anode when in position to communicate therewith through registry of the hole in the collar. All these collars are movable on the pipe relatively to each other and are provided with gaskets **25** to prevent escape of electrolyte between them, and the flow of electrolyte from inlet pipe I into the tank thus requires at least some of the anodes be positioned to communicate with the pipe, the volume of flow of course being in proportion to the number thereof so communicating at any given time.

The anode tubes as noted are curved in general conformity with a sector of the drum, and each has welded to its inner face an anode bar **30** having rounded inner edges and a series of spaced ports **31** aligned with corresponding holes in the tube, whereby electrolyte introduced under pressure through the inlet pipe I passes through anode tube **22** and ports **31** and is projected forcibly against the adjacent surface of strip S when the anode tube is in communication through port **24** with the pipe. Alternate anode bars **30** are provided with arcuately formed hard rubber or other dielectric strip guides **32** conforming generally to but projecting radially inward a little beyond the inner faces of the anode bars, for a purpose which will hereinafter appear.

The upper end of each anode carries an anode extension in the form of a relatively flat upstanding blade **35** projecting between a pair of terminal bars **36** and supporting a contact clamp assembly comprising a pair of rotatable clamping discs **37**, **38** secured by set screws **39** to a stud **40** on which threaded collars **41** assist in holding the discs firmly on the stud but rotatable therewith relatively to the anode extension. The discs **37**, **38** are oppositely arcuately and eccentrically beveled on their inner faces to form with blade **35** grooves receiving the upper correspondingly beveled edges of terminal bars **36**, one of the discs being provided with a clamping rod **42** whereby the entire clamp assembly may be rotated to engage terminal bars **36** between the discs and the blade or to free the latter therefrom, the bars being curved on an arc (exaggerated in Figs. 4 and 9) whose center is the center of inlet pipe I about which the entire anode, including its extension and clamp assembly, is movable as before described. Adjacent the base of, and between each pair of bars is a thin layer of insulation **44** within which the blade enters when fully retracted, and as in this position the clamp assembly is usually in released position, electrical connection between the base and blade is thus interrupted, but is restored when the clamp is actuated, at any position of the anode, to engage the bars.

Additional connections between the terminal base **49**, which supports bars **36**, and each anode are provided by flexible cables **50**, **51** respectively secured at points spaced along the curve of the anode to anode tube **22** and having severable electrical connection with the terminal base through plugs **52** provided with tapered heads **53** and extending through insulating sleeves **54** in holes **55** in the terminal base. Nuts **56** on the plugs enable the latter to be drawn up so their heads engage the adjacent tapered ends of holes **55** to effect electrical contact with the base, or when backed off, to interrupt electrical connection therewith.

It will thus be apparent that when the clamp assembly is operated to engage the bars, and especially to hold the corresponding anode in operatively adjusted position proximate the drum, and the nuts **56** are set up on plugs **52**, electrical connections are established between the terminal base and the anode to distribute current along the anode at three spaced points, or at any other number desired, depending on the number of cables **50**, **51** and corresponding plugs **52** and associated parts provided; usually two are sufficient and this number therefor is preferred as suitable under most conditions of normal use of the apparatus, it being understood that one pole, usually the positive, of a source of electrolyzing current is connected with the terminal base **49** when the apparatus is in operation, the other pole, as noted, being connected with collector **19** contacting the drum.

To enhance understanding of the nature of the apparatus herein show and described, reference will now be made to its use in electrolytic tin plating one side of a steel strip S, from which it will be evident the other side may and usually will be plated subsequently in similar apparatus and in the same way, and that the tin plating of steel strip is but typical of the several electrolytic treatments, including pickling, cleaning and the like for the performance of which the apparatus is well adapted. Moreover, in the description availability of a source of electrolyte rich in tin ions will be assumed, and this may be a leaching plant in which tin ore concentrates are leached and their tin content converted to sodium or potassium stannate, as these alkaline electrolytes are excellent solutions from which the plate out tin coating on steel strip with the aid of my apparatus; as it is desirable from an economic standpoint that alkaline values be conserved, "spent" solution drawn from the plating tank is preferably returned to such leaching plant for regeneration and renewal of its tin ion concentration.

Moreover, the said apparatus requires, as has been noted, a source of current, preferably a low voltage direct current of about 9 volts and amperage adequate to provide up to about 750 to 1000 amperes, or even more, per square foot of strip surface being subjected to electrolytic deposition of tin at any one time. As the strip is usually in continuous motion through the apparatus it will be understood the area used in calculating the current strength is but a small portion of the total area of any strip of usual length, being a function practically solely of the strip width, plating drum diameter and plating drum submersion in the electrolyte.

Depending on the strip width, either some or all the anodes will actually contribute to the results attained, those not required, such as those at the opposite ends of the groups on either side of the drum when a narrow strip is being plated, being merely moved to inoperative position corresponding generally to that of anode **21** at the left in Fig. 3, with its cable connections interrupted, while the anodes nearer the center of each group are positioned operatively nearer the drum surface and the strip as in the position of anode **20** in said figure. When the strip is initially threaded through the apparatus, its end is passed first over one guide roll, then partially around the drum and over the second guide roll while all the anodes are retracted to inoperative position, as they are then spaced their maximum distance from the drum, which facilitates the threading operation. The leading end is of course then passed to winding mechanism (not shown) or other apparatus, such as a second similar tank where its other side may be plated, but in any case a substantial tension is maintained on the strip and its linear travel through the plating apparatus, subject to control by the operator, maintained at a speed suitable under the conditions of temperature, electrolyte strength, current density and other factors obtaining for producing on the strip a coating of the desired thickness.

The electrolyte may be kept fairly hot, such as at about 190° F. when alkaline solutions are used for tin plating, heat being supplied either by introducing hot solution through the inlet pipe I or by positioning steam heating means or the like in or near the tank. The electrolyte strength of course is determined by factors with which the invention is not directly concerned, but in order to minimize its rapid depletion it is desirable a fairly substantial head pressure be applied to the stream of solution entering through inlet pipe I, as the solution is then ejected forcibly from the anodes against the strip surface in jets through the anode electrolyte ports **31** and rapidly sweeps away the partially spent solution before it loses so much of its tin-ion content to the strip as materially to reduce the rate of tin deposition from it. Suitable adjustment of valve V with relation to the incoming stream of electrolyte maintains a substantially constant liquid level in the tank provided other conditions remain substantially static, and as they change the valve may require adjustment from time to time, since any material rising of the liquid level during plating reduces the current density and consequently may impair the uniformity of thickness of the finished coating, while a marked fall in the level, other things being equal, might result in increasing the current density above a safe or desirable value.

The current density at the strip surface is also subject to control and modification, independently of the current supplied from the source, by the adjustment of anodes relatively to the strip, and as the positions of the right and left hand anodes **20** and **21** in Fig. 3 represent respectively substantially the limit positions of such adjustments, it will be evident that when an anode is positioned like anode **20** in said figure its bar **30** closely conforms to the curvature of the strip on the adjacent drum surface and affords a minimum length of current travel through the electrolyte between the anode and the strip, resulting in maximum useful current flow. Normally, however, the anodes adjacent the edges of the strip are backed off a small distance from this position to counteract the tendency of the current to concentrate at the strip edges, and in this way substantially uniform current density across the strip is maintained, all current carrying anodes of course being clamped to the terminal bars by their respective clamps and also connected to the terminal bases through setting up of the nuts on their respective connector plugs.

The movement of the strip in the direction of the arrow in Fig. 3 in engagement with the drum rotates the latter on its roller supports, and collector **19**, which may be sectionalized, especially when a sectionalized drum is used, affords adequate electrical contact with the drum for passage of current between the strip and the current source, thus completing the electrolyzing current circuit, and rapid and highly uniform plating of tin on the strip consequently may be accomplished as long as the strip continues to be fed to and drawn through the apparatus, electrolyzing current is supplied and an adequate flow of electrolyte is maintained.

Furthermore while reference has thus far been made principally to a single strip, it will be understood this is not intended necessarily to mean only a strip rolled from a single ingot and therefore continuous only from one end to the other of the metal of one original piece, as a plurality of strips welded end to end are desirably fed successively and continuosly to the apparatus for plating. Such welds usually produce zones of increased thickness in the strip as a whole, especially when the parts are carelessly lapped in welding, but such splices and other slight irregularities that may occur in the strip do not normally affect the operation or effectiveness of the apparatus, insulating guides **32** on alternate anodes being ordinarily effective to prevent any direct contact between the strip and the anodes, such as might tend to short circuit the current source. There sometimes occur, however, conditions which result in strip splices or welds of abnormal thickness too great to pass between the anodes and the drum with safety when the former are in operative position, but as these are of rare occurrence and advance warning of their presentation to the machine is normally given, it requires but a moment for an attendant, when or just before such splice reaches the apparatus, to loosen the anode clamps and retract the anodes, allowing the defective splice to pass through and beyond the apparatus without damage to either it or the strip and thereafter to reposition the anodes to allow the plating to proceed as before.

As I usually prefer to provide a minimum clearance between the strip face and the anode bars of about one-quarter inch, it will of course be apparent conditions requiring retraction of the anodes as just described, with or without slowing or stopping of the strip as preferred, will ordinarily be of rare occurrence, but are mentioned herein to emphasize the adaptability of my apparatus to abnormal conditions and to demonstrate the facility with which they may be met, and it is believed its operation under normal as well as abnormal conditions for substantially any kind of electrolytic plating or other treatment of steel or other metal strips will be evident from the foregoing without further description.

It will be appreciated, however, that when the apparatus is used for cleaning or pickling the effects of combined electrolytic and mechanical action obtainable produce better results than either of these used singly or both successively in accordance with prior practices, as the mechanical impingement of the electrolyte projected in high velocity jets against the strip surface tends to break up any film of oil, grease, scale or the like on the strip while rapidly removing gases formed at its surface by the electrolytic action and also accelerates emulsification of oils and greases through mechanically mixing finely divided particles thereof with the electrolyte while current is flowing in the latter.

It is of course to be understood that while I have herein described one embodiment of the invention with considerable particularity and suggested certain expedients which may be resorted to and alterations in conditions through modification of various adjustments and/or controls such as those of temperature, current, speed of strip travel, electrolyte composition and flow and the like, I do not thereby desire or intend to limit or confine myself thereto or thereby in any way, or to the form, construction, arrangement or relationship of the several elements and/or parts comprised in the apparatus as these and numerous other changes and modifications such as will readily occur to those skilled in the art may be made if deemed advisable without departing from the spirit and scope of the invention as defined in the appended claims.

Having thus described my invention, I claim and desire to protect by Letters Patent of the United States:

1. In apparatus for progressively subjecting a strip to electrolytic action, a vessel for electrolyte solution, means for passing the strip therethrough along an arcuate path including a substantially cylindrical contact element supported for rotation about its axis adapted to engage the radial inner face of the strip while traversing said path, a plurality of curved electrodes spaced radially outward from said path conforming substantially thereto and movable independently toward and away from the element about a common axis parallel to the axis of but outwardly spaced from said path adjacent the element, each electrode having a passage extending arcuately therein and apertures directed radially inward therefrom toward the axis of said path, a collar surrounding said common axis supporting each electrode from one end thereof and providing a port communicating with said passage, a pipe extending through all the collars about which said collars are respectively rotatable, the pipe having ports respectively communicating with the collar ports when the corresponding collars are in positions to align their ports therewith, and means for supplying electrolyte under pressure to said pipe whereby said electrolyte is ejected from the apertures selectively in accordance with the positioning of the several curved electrodes and their supporting collars relatively to said pipe.

2. Apparatus for progressively subjecting a moving strip to electrolytic action comprising a drum supported for rotation about a fixed axis and constituting a contact element for the strip beneath the surface of a liquid electrolyte, a tank for holding the electrolyte, means for passing the strip partially about the periphery of the drum in contact therewith and with said electrolyte, a series of curved electrodes partially embracing the drum each having a plurality of spaced ports directed inwardly toward the axis of curvature of the electrode and a passage communicating with the ports, the electrodes respectively conforming substantially to arcs of more than 90° on radii greater than that of the drum and mounted for oscillatory movement in laterally spaced planes toward and away from the drum about a common axis parallel to the drum axis and lying adjacent and radially outwardly spaced from the path of the strip about the drum, and an inlet pipe coaxial with the paths of oscillatory movement of the electrodes having ports respectively positioned to communicate with the passage in an electrode when the latter is at the inner limit of its oscillatory movement to enable electrolyte to pass from the inlet pipe thereto, said communication being interrupted when the electrode is at the outer limit of said movement.

3. Apparatus for progressively subjecting a moving strip to electrolytic action comprising a drum supported for rotation about a fixed axis and constituting a contact element for the strip beneath the surface of a liquid electrolyte, a tank for holding the electrolyte, means for passing the strip partially about the periphery of the drum in contact therewith and with said electrolyte, a series of curved electrodes partially embracing the drum each having a plurality of spaced ports directed inwardly toward the axis of curvature of the electrode and a passage communicating with the ports, the electrodes respectively con-

forming substantially to arcs of more than 90° on radii greater than that of the drum and mounted for oscillatory movement in laterally spaced planes toward and away from the drum about a common axis parallel to the drum axis and lying adjacent and radially outwardly spaced from the path of the strip about the drum, supporting means for the electrodes having spaced ports respectively conforming to and positioned to register with the passages in the electrodes when each of the latter is disposed substantially at the inner limit of its oscillatory movement, communication between the supporting means and the electrodes through said ports being progressively restricted as the electrodes approach the outer limit of said movement.

4. In apparatus for progressively subjecting a strip to electrolytic action, a vessel for electrolyte solution, means for passing the strip therethrough along an arcuate path including a substantially cylindrical contact element supported for rotation about its axis adapted to engage the radial inner face of the strip while traversing said path, a series of axially spaced curved electrodes disposed radially outward from said path and conforming substantially thereto, and a ported tubular member having its axis parallel to that of said path but outwardly spaced from the path pivotally supporting an end of each electrode for oscillatory movement of the electrodes toward and away from the element about the axis of said tubular member, each port in the latter communicating through an electrode passage with a plurality of inwardly directed spaced apertures in the electrode for discharging electrolyte from the tubular member through the electrode passages and apertures radially inward toward said path.

5. Apparatus for progressively subjecting a moving strip to electrolytic action comprising a drum supported for rotation about a fixed axis and constituting a contact element for the strip beneath the surface of a liquid electrolyte, a tank for holding the electrolyte, means for passing the strip partially about the periphery of the drum in contact therewith and with said electrolyte, a series of curved electrodes partially embracing the drum each having a plurality of spaced ports directed inwardly toward the axis of curvature of the electrode and a passage communicating with the ports, the electrodes respectively conforming substantially to arcs of more than 90° on radii greater than that of the drum and tubular supporting means for the electrodes positioned adjacent the drum and supporting the electrodes for oscillatory movement in laterally spaced planes toward and away from the drum about a common axis parallel to the drum axis and lying adjacent and radially outwardly spaced from the path of the strip about the drum, said tubular means having spaced outlets each conforming to and positioned to register with one end of the passage in a corresponding electrode for introducing electrolyte into the electrode passage for projection through the electrode ports toward said path when the electrode is at the inner limit of its permissive movement, communication through said outlet being progressively restricted as the electrode is moved toward the outer limit of its said movement.

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