METHOD AND APPARATUS FOR THE ELECTROLYTIC COATING OF METAL STRIP

Filed April 1, 1943 6 Sheets-Sheet 1

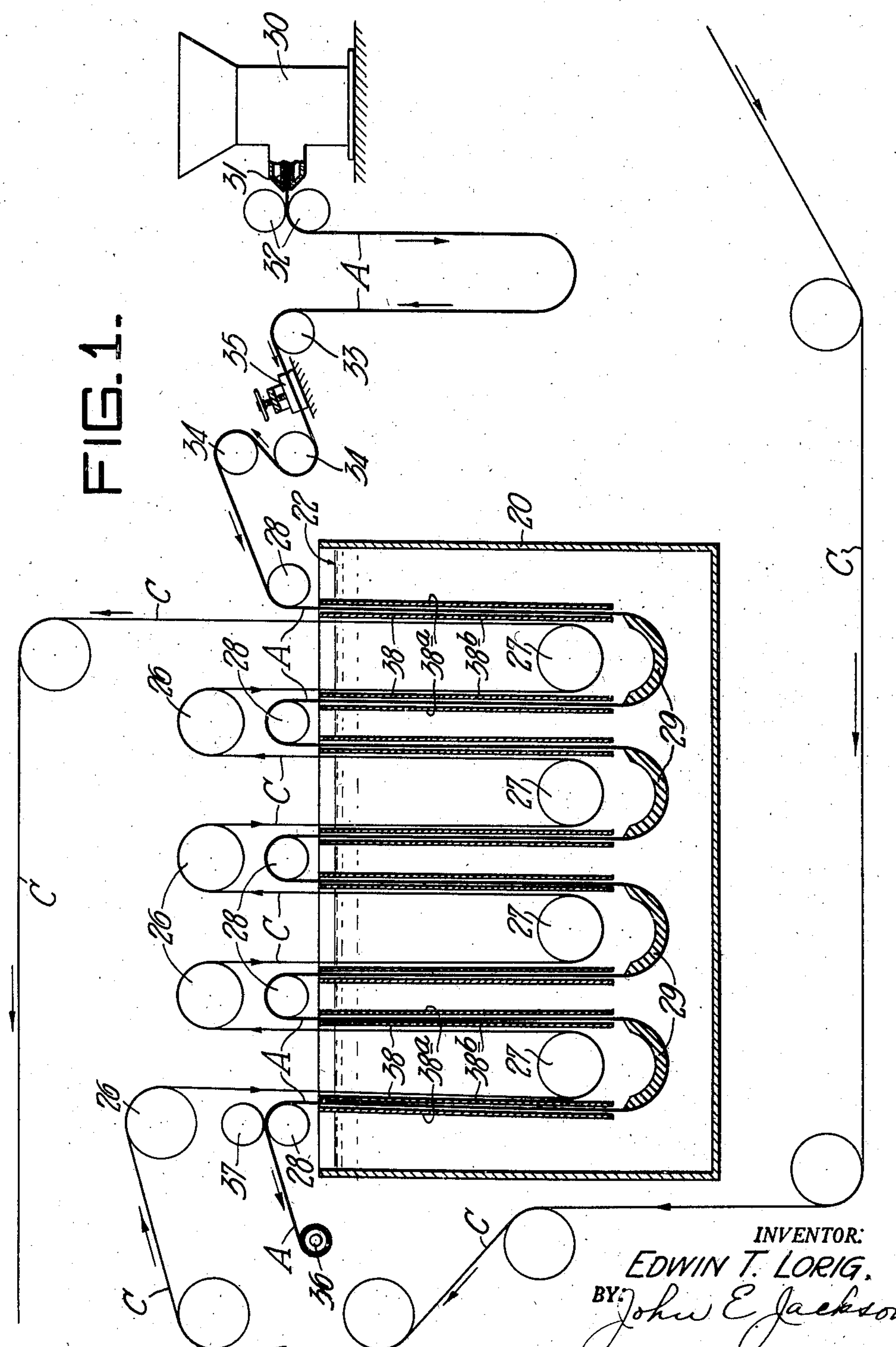

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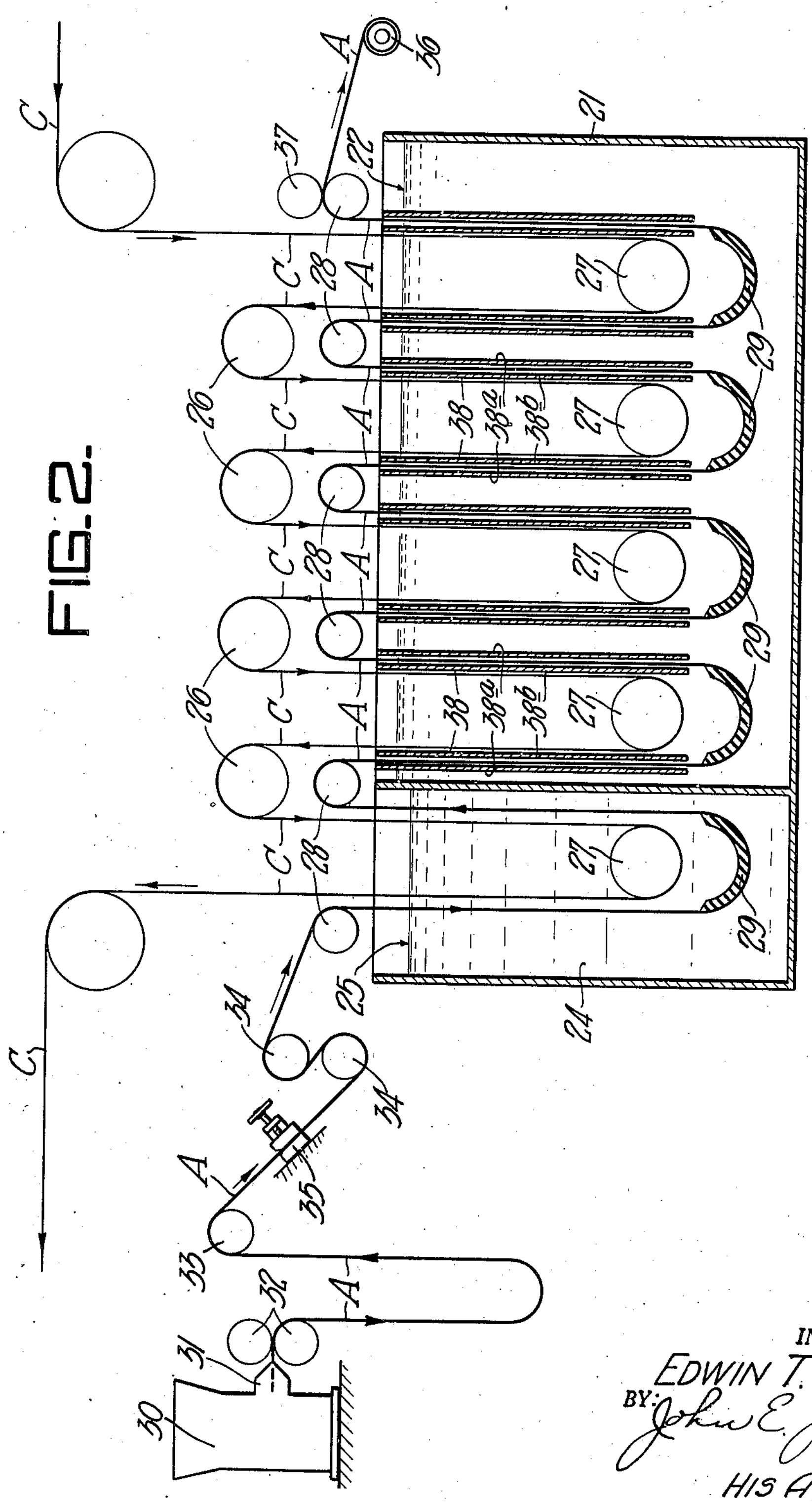
FIG. 2.



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Feb. 15, 1949. E. T. LORIG 2,461,556

METHOD AND APPARATUS FOR THE ELECTROLYTIC COATING OF METAL STRIP

Filed April 1, 1943 6 Sheets-Sheet 3

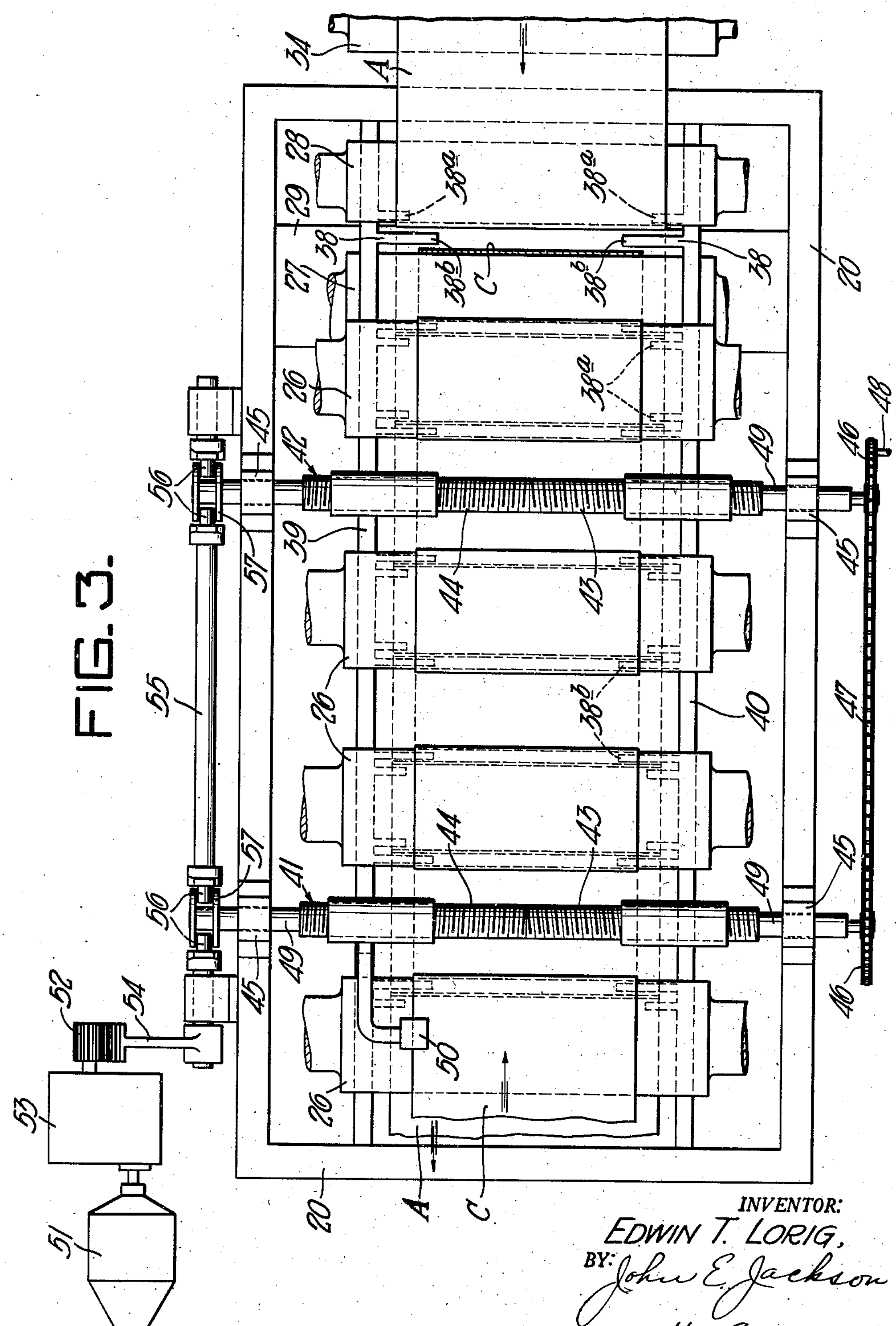

FIG. 3.

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METHOD AND APPARATUS FOR THE ELECTROLYTIC
COATING OF METAL STRIP
Filed April 1, 1943 6 Sheets-Sheet 4

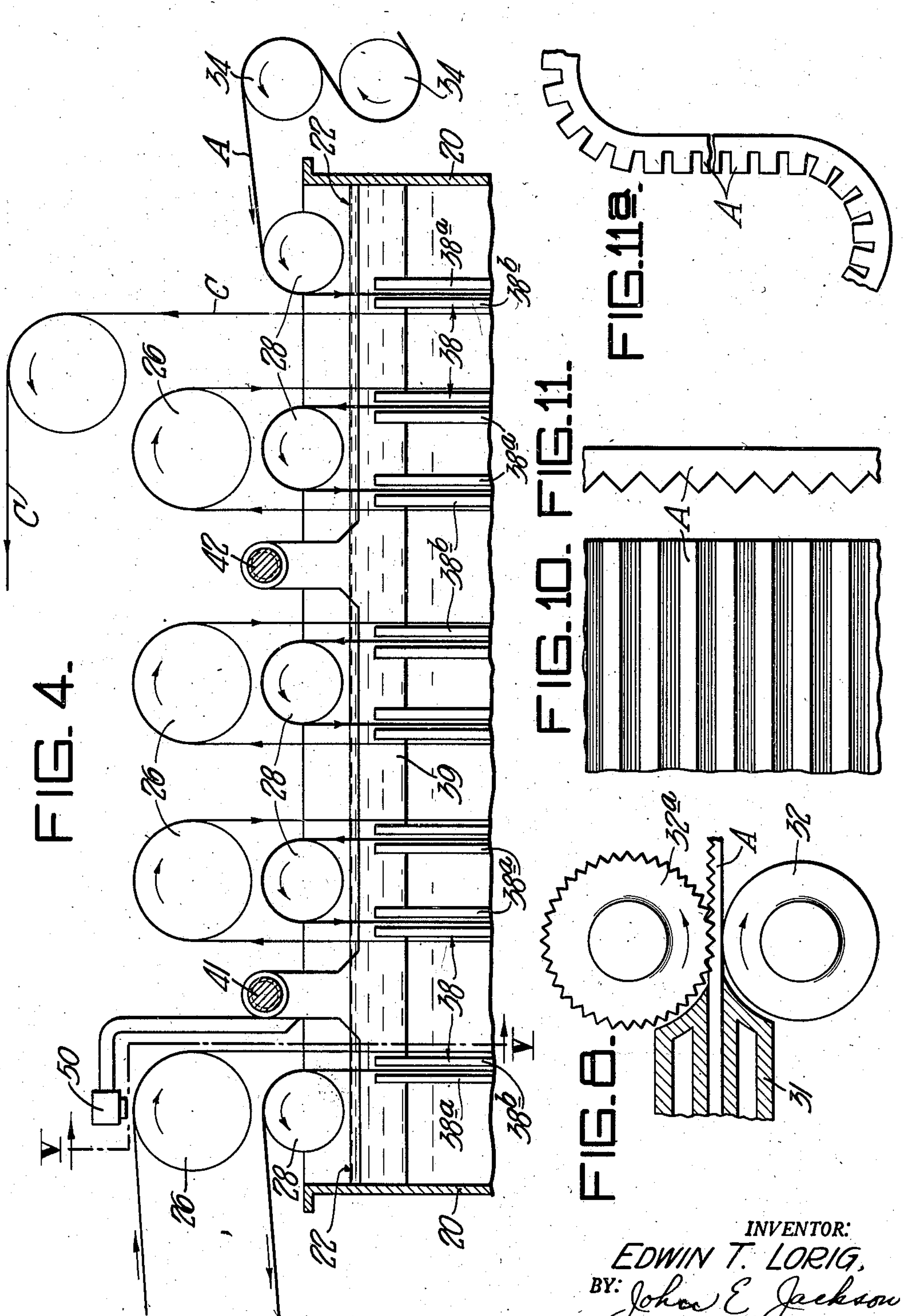

FIG. 4.

FIG. 10.

FIG. 11.

FIG. 11a.

FIG. 8.

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METHOD AND APPARATUS FOR THE ELECTROLYTIC COATING OF METAL STRIP

2,461,556

Filed April 1, 1943

6 Sheets-Sheet 5

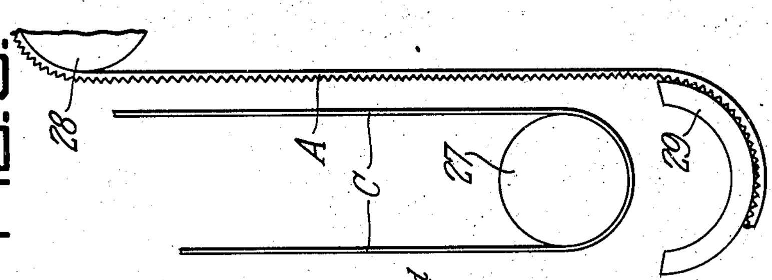

FIG. 9.

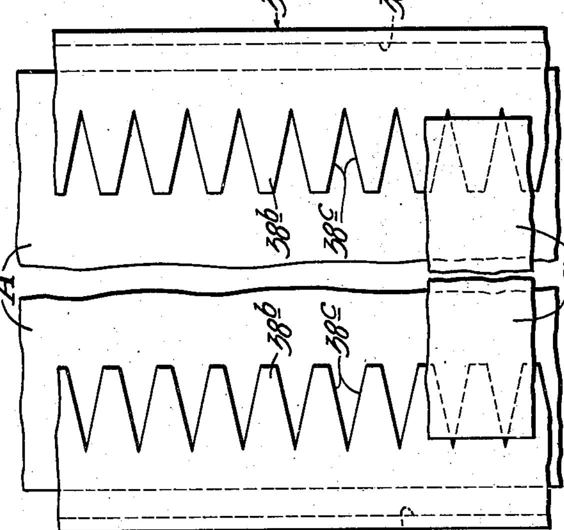

FIG. 6

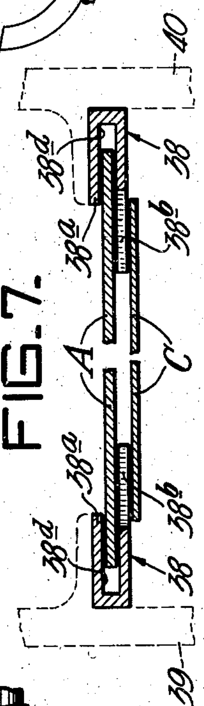

FIG. 7.

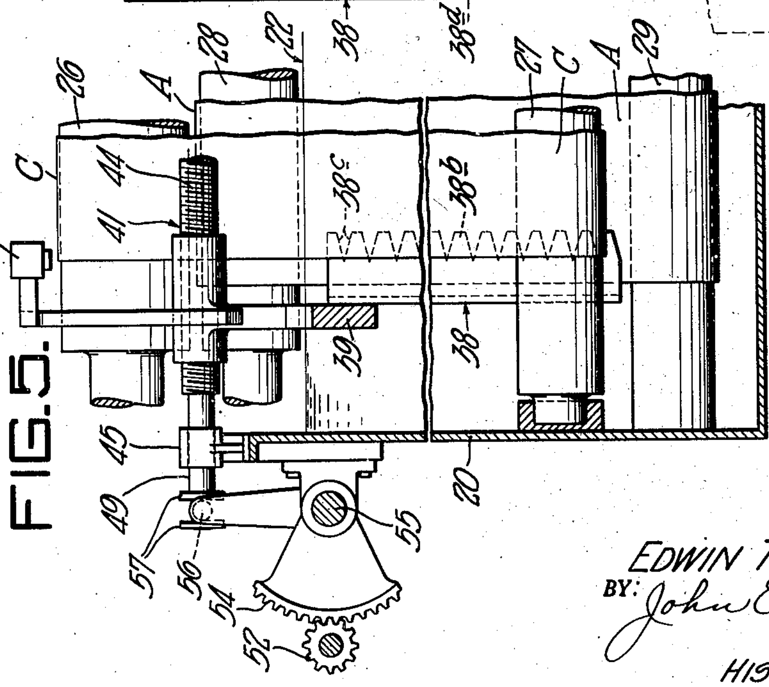

FIG. 5.

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FIG. 12.

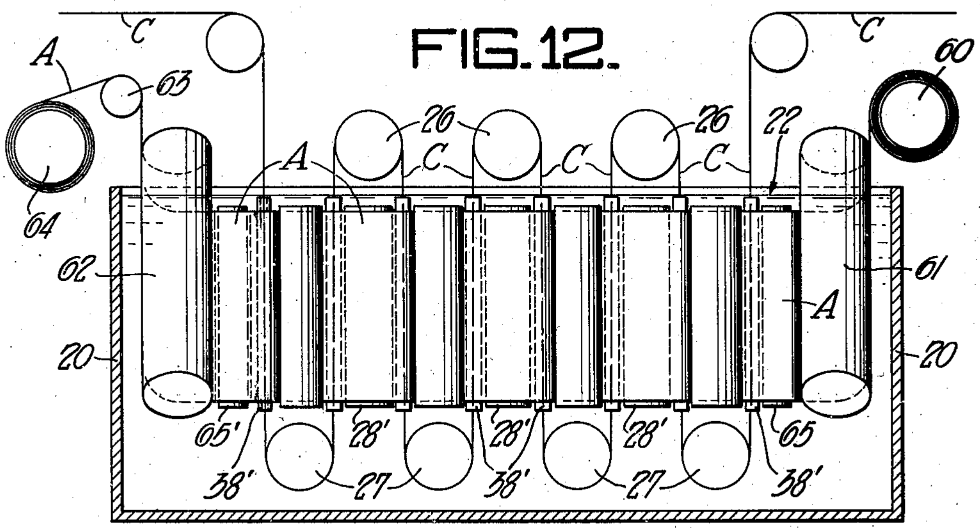


FIG. 14.

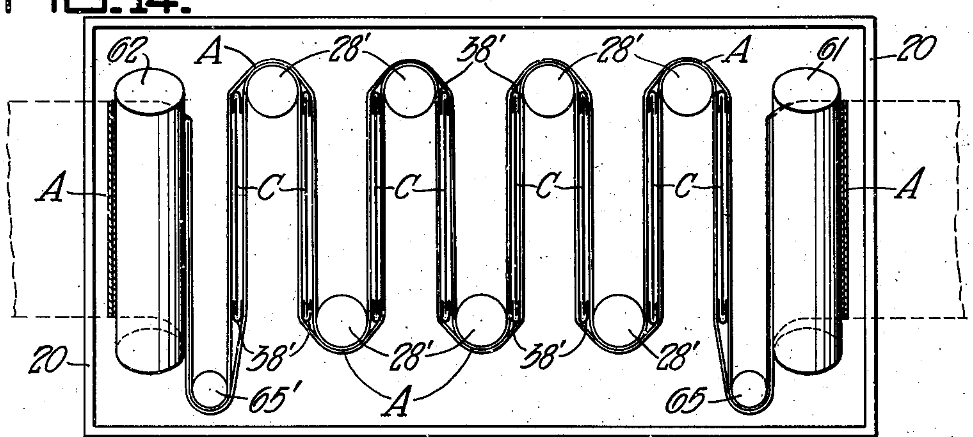


FIG. 13.

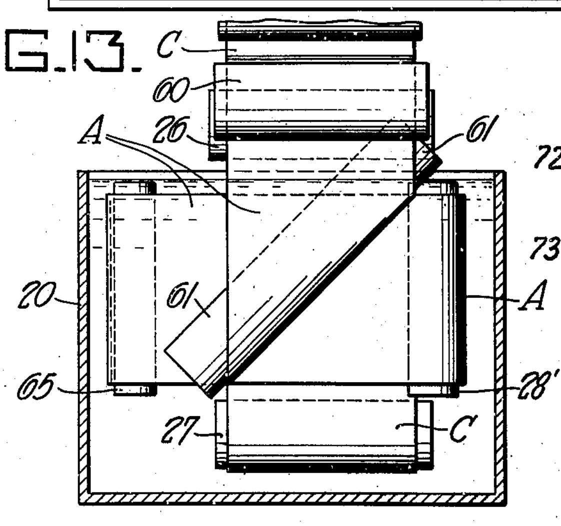
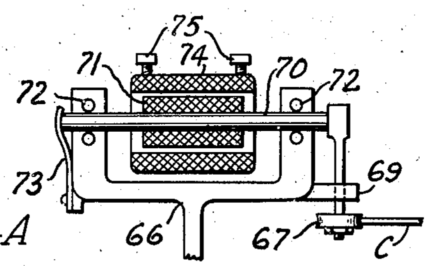


FIG. 15.



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Patented Feb. 15, 1949 2,461,556

UNITED STATES PATENT OFFICE

2,461,556

METHOD AND APPARATUS FOR THE ELECTROLYTIC COATING OF METAL STRIP

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Application April 1, 1943, Serial No. 481,467

5 Claims. (Cl. 204—28)

1

The present invention relates to the production of bi-metallic articles, and is especially concerned with the manufacture of electroplated metal strip, such as the production of tin-plated steel strips, in an improved manner involving high speeds and superior results.

In the past, continuous lengths of metal have been plated by immersion in electrolytic baths in which the plating metal is disposed as anode and the metal to be coated is arranged as cathode. Usually, the major path of the cathode and placement of anodes were horizontal. Requirements for increased production ultimately have provided that the cathode be disposed in and out of the bath in a sinuous fashion, thus to expose a greater amount of its linear extent and surface area to the electrolytic action in one plating tank. In this arrangement, instead of the anodes being placed above and below the cathode as in the case of substantially horizontal operations, the anodes are suspended from bridges arranged across the electroplating tank so that they depend therefrom between adjacent courses of the sinuously-disposed base metal. If both sides of the base metal are to be plated simultaneously in one operation, duplicate sets of anodes must be provided so as to present effective anodic action closely adjacent the areas of the cathode that are to receive the coating.

In some operations, the anodes for this latter type of equipment have been made in slab form, one for each bridge, which are of sufficient thickness to extend between the proximate faces of adjacent courses of base metal. In other cases, the anodes have been made in pairs, each of which serves an adjacent cathode surface. A further improvement has resulted from dividing the single slab type anodes, dependent from each bridge, into a plurality of bar-like anodes similarly suspended. From this is derived a more uniform plating condition, since uneven consumption of the anodes may be corrected by replacing the ones sustaining the greatest diminution in size. Even though this last arrangement has proved far superior to all previous constructions, and is capable of providing satisfactory coatings, still, due to the great number of operating variables entailed, many disadvantages remain which will now be discussed.

In electroplated coatings, the amount of coating deposited is dependent, among other things, upon the current density prevalent over any area of cathode surface under consideration. The current densities are determined by the amperage flowing in the system, and by the effective circuit

2

resistance with which the impressed voltage is countered. Since the metallic parts of the circuit, including both the anode and cathode, afford properties of relatively high electrical conductivity, in comparison to which the electrolyte is a relatively poor conductor, the spacing occurring between anode and cathode surfaces becomes a considerable factor in the all-over resistance of the circuit, and in the amount of coating deposited. This is the basis for one of the fundamental disadvantages flowing from the use of a bar-type or slab-type anode, since the current distribution is not uniform, thus effecting more rapid consumption of some of the anode surfaces than other portions thereof. Such non-uniform consumption is effective to vary the spacing between the anode and cathode surfaces, causing the resistance to vary accordingly, and, thus, altering the current densities sufficiently to cause non-uniform deposits to occur. Except in carefully controlled systems, this results in streaky coatings, the differences in the weight of which across the section may be readily observed by visual inspection.

To prevent this unsatisfactory result, it is necessary to shut down the electroplating line at recurrent intervals for the purpose of removing the anodes for inspection. Those that have been consumed to the extent of providing too great a space between the anode and cathode surfaces must be removed and replaced manually. This is usually accomplished by arranging the order of anode consumption so as to effect most removals at one end of a bridge, and so as to make anode additions at the opposite ends of such bridges by sliding the anodes therealong to fill in the blank file to make room for the new one. As between adjacent bridges, it is preferable that this be accomplished in opposite directions; that is, if one bridge is serviced by the removal of anodes from the left-hand end (thus necessitating the sliding of the intervening anodes leftwardly) and by the addition of a new anode to the right-hand end, then, on adjacent bridges, this is accomplished by effecting the removal of the anodes from the right-hand ends (thus necessitating the sliding of the intervening anodes rightwardly) and the addition of the new anodes at the left-hand end of such bridges. Since there are usually about sixteen bridges per line, the rightward and leftward distribution, respectively, of the new and consumed anodes tends to effect an average plating condition throughout the entire line that is conducive to the production of uniform coatings. The expenditure of much time, labor, and care must go into this result as the following facts and figures will demonstrate.

The trend is toward the use of cast anodes that are approximately 2" x 2" in cross-sectional area For the coating of the average 28½" sheet, fourteen anodes to the bridge are required, it being understood that the effective anode surface is usually less wide than the cathode surface to assist in the reduction of heavy-edge plating. With sixteen bridges per line, there is thus required 224 anodes weighing approximately seventy pounds each. Since at 50% consumption the anodes fail to provide a sufficient plating condition, they must be changed at this stage and be replaced with new anodes. For the production of 3000 base boxes for each eight-hour shift per line of one-half pound tinplate, the anode consumption is about forty-eight, averaging two width changes every eight hours, which, when multiplied by 16 (the number of bridges per line), involves sixty-four anodes per line every eight hours, or eight new anodes per hour. Since each anode that is replaced involves a used one and a new one, sixteen anodes must be handled each hour, or one every 3¾ minutes. The casting of new anodes for three production lines must be conducted, therefore, at the rate of 192 for every eight-hour operating period, or one anode every 2½ minutes. The anodes must be cast with great precision and with smoothness of surface, rendering high speed operations exceedingly difficult to maintain, and requiring the attendance of many proficient operators for the provision and maintenance of optimum operating conditions.

Apart from the high cost attendant upon the necessary labor for the maintenance of the proper operating condition, other disadvantages attend the use of bar-type anodes. The electrolytic action is such as to cause the anodes to be consumed more rapidly at the bottom than at the top of the tank, which is reflected in a gradually tapering section that sometimes attains such thinness near the bottom of the anodes as to cause them to break off, whereby a lump of the plating metal will fall down between the strip and the guide-rolls, fouling the machinery, and rendering the resumption of satisfactory operating conditions impossible so long as the piece of metal stays there. Costly interruption in operations and considerable trouble attend the removal of such broken pieces of anode.

Another direct effect of the wearing-away of the anodes, especially at the bottom, is the reduction of operating speeds, and an increase in the time in which a given weight of coating may be produced, thus materially slowing production. Further disadvantage is to be found in the lack of control over the distribution of coating, so that the natural tendency for the coating to concentrate at the edges of the cathode is realized. Even though the coating is subsequently fused, no redistribution of the coating is possible by this method, since the heavy deposits of coating adjacent the edges do not fuse readily, and when fused are disposed to draw into globules destructive of the continuity of the coating, and present a dull, gray, streaky appearance which is not acceptable to the trade.

The present invention relates to a method and equipment designed to circumvent these and other disadvantages by the use of a continuous anode disposed in relation to the cathodic base metal strip in a sinuous fashion comparable to the preferred disposition of the latter, as discussed above. One or more anodic strips, for the plating of one

or both surfaces of a base metal strip simultaneously, are contemplated, and the automatic features of control are such as to eliminate the operating variables and disadvantages discussed above, thereby to give rise to an operating optimum condition productive of a superior product and many related advantages.

It is, accordingly, an object of the present invention to provide an improved method and apparatus for electroplating elongated metal bodies continuously, so as to reduce operating variables and human error derived from manual control to negligible quantities.

It is another object to provide for electroplating under conditions in which a substantially constant distance between anodes and cathode is maintained throughout the greater portion of the time they are exposed to the electrolyte in plating relation. As a corollary object, it is provided that the anode and cathode surfaces shall be placed as closely as possible to each other without touching, thus to augment greatly the possible operating speeds for present commercial weights of coating, or greatly to increase the weight of coating for present commercial operating speeds.

It is still another object to effect the electroplating of metal upon metal under conditions which provide for substantially uniform current flow and density at all points between anode and cathode.

It is a further object to provide for the continuous and facile inspection of the anode and for the servicing thereof, without interrupting the electroplating operation to preserve the correct operating condition.

Another object is to increase anode consumption, and otherwise to provide for the more efficient utilization and handling of anodes.

It is another object to provide for the high-speed electroplating of strip with tin, or similar plating metal, at rates of linear flow in the order of 300 to 1400 feet per minute or more without sacrificing the uniformity and perfection of coating.

A further object is to eliminate the production of non-uniform coatings, especially heavy-edge coatings, by masking the anode and cathode strips to provide a selectively controllable coating gradient from central to edge portions of the strip, allowing the critical adjustment of the effective surface area of the anode in relation to the cathode, and by automatically maintaining this relationship, irrespective of extraneous movements.

It is a further and important object to provide for the automatic control of an electroplating operation in such a manner that unavoidable operating variables must be averaged throughout the transverse and linear extent of cathodes to result in uniform plating conditions in an automatic manner.

Other objects include a greatly improved, more efficient method and apparatus for electroplating, whereby the disadvantages of present methods and equipment are overcome; including the prevention of burning and overheating of coatings; the elimination of operating shutdowns usually attendant upon anode changes; and the great facilitation of anode formation, inspection, control, and maintenance.

The foregoing, as well as other objects and advantages not specifically mentioned, will become apparent hereinafter when the following specification is read in conjunction with the accompanying drawings in which:

Figure 1 represents a longitudinal, sectional-elevational view of one form of apparatus for plating one side of a strip metal object in accordance with the present invention.

Figure 2 represents a corresponding view of apparatus similar to that of Figure 1 for use in conjunction therewith to plate the opposite side of the same strip metal object in accordance with one arrangement.

Figure 3 represents an enlarged plan view of electroplating apparatus similar to that shown in Figures 1 and 2, but with parts broken away, and with certain elaborations added to show details of a preferred form of construction.

Figure 4 is a fragmentary, longitudinal, sectional-elevational view of the apparatus shown in Figure 3.

Figure 5 is a fragmentary, sectional-elevational view taken along lines V—V in Figure 4.

Figures 6 and 7 illustrate, in front elevational and sectional plan views, respectively, certain details of construction involved in the foregoing figures.

Figures 8, 9, 10, 11, and 11*a* disclose a modified form of anode, and its method of production, which may be used in accordance with the present invention.

Figures 12, 13, and 14 are, respectively, longitudinal sectional-elevational, sectional-end, and fragmentary plan views, with certain parts removed, illustrative of a modified form of the invention.

Figure 15 is a sectional detail view.

Referring in greater detail to the drawings in which like references refer to like parts throughout:

The invention, as illustrated in Figures 1 and 2, comprises a pair of electroplating tanks **20** and **21** which are adapted to sustain a level of liquid electrolyte **22**. The tank **21**, representing the last in the sequence of electroplating operations, is provided with a partition or septum **23** defining a compartment **24** which is adapted to retain a level **25** of water, or other suitable rinsing liquid, for washing the coated article as it leaves the electroplating baths.

A plurality of cathode rolls **26**, in conjunction with the plurality of cathodic guide rolls **27**, is arranged to conduct a strip of base metal C sinuously in and out of the tank in a continuous manner. Similarly arranged is a plurality of anode rolls **28** which, in conjunction with stationary guides **29**, serves to conduct a strip of plating metal A sinuously through the tank in a manner corresponding to the disposition of the cathode strip C, and in substantial parallelism with the latter, although out of contact therewith. The guides **29** may also assume the form of rolls, although the space is more efficiently utilized by adopting the half-moon construction illustrated. These guides are, preferably, composed of a composition that is inert towards the electrolytic solution, in relation to which the strip slips quite easily by virtue of the lubricating properties of the electrolyte and the smoothness of the bearings.

The anode strip A may be provided in preformed lengths appropriately coiled for delivery to the system, or it may be continuously formed by the provision of a melting pot **30** having a water cooled casting orifice **31** adapted to congeal the molten metal contained in the pot just before it emerges from the latter. A short length of strip of higher melting point than the plating metal, if inserted in the casting orifice before melting the plating metal, may be employed to withdraw the congealed metal therefrom after melting by means of driven pinch rolls **32**, the angular velocity of which is such as not to exceed the rate at which metal will congeal in the orifice. A continuous anodic strip A is, thus, continuously cast and guided by a guide-roll **33** and driven tension rolls **34** through a frictional drag clamp **35** by means of which the tension in the anode strip is regulated. A winding arbor **36** is provided at the exit end of the line for taking up the used anode strip, which is accumulated and returned to the melting pot **30**. In order to insure continuous operations, the last anode roll **28**, at the anode exit end of the tank, may be provided with a complementary driven roll **37**, which cooperates therewith to clamp the anode, and to effect its continuous advance, even though the winding operation at the arbor **36** may be temporarily suspended to permit the stripping of coils from the arbor **36**. The arrangements, as shown in the apparatus in Figure 2, are identical with those described above, although oppositely disposed, whereby, since identical references have been employed, the one description will suffice for both.

It will be observed that the direction of flow of the anode strip A is opposite to that of the base metal being plated. In the case of tin-plating operations, the anode strip may be cast of pure tin, or may be supplied from a prefabricated tin strip of appropriate width, in either case having an original thickness preferably of approximately 3/8″. Its rate of movement need be of a very low order, such as one or two inches per minute for most efficient consumption. Even though it is contemplated that at least two-thirds of the anode will be consumed by the time it emerges at the exit end of the tank, and, thus, will be one-eighth inch thick in the assumed example, it will still be possessed of sufficient strength to be pulled from the tank, and to assist in the advancement of the anodic line. Tin has sufficient tensile strength and ductility to withstand the repeated bends throughout the tank without failure. It may be assisted in its course by differentially driving the anode rolls **28** in such relation to the tension rolls **34** to afford tension close to the elastic limit of the material, so as to insure the taut suspension and rigid, planar disposition of its several courses throughout the system to perfect their parallel arrangement with corresponding courses of the strip C.

The cathode strip C representing the base metal to be coated, is likewise tensioned by means already described so as closely to parallel the anode strip and maintain a substantially uniform spacing from the latter the greater portions of the vertical courses thereof. In this respect, the most efficient plating condition is derived by having the anode and cathode as close as possible without touching, although it will be appreciated that variations in this distance are not critical in so far as uniform thickness of plating is concerned.

The arrangements shown and described in these figures necessitate the plating of the cathode strip, first, on one side, and, then, on the other, by the adoption of which arrangement complication of the construction is avoided, and high current densities, which tend to burn, melt, or otherwise disfigure the coating, are avoided. It is obvious, however, that, should it be desirable, another continuous anode could be added to one tank in a manner similar to those already described, so as to plate both surfaces of the strip simultaneously in one tank.

In the avoidance of heavy edges, the anode strips A are preferably narrower than the cathode strip. In the case of the prefabricated coil of anode metal, suitable slitters may be provided in lieu of the rolls **33** to trim the anode to the requisite width in accommodation of the width of cathode being run. In this case, the metal removed by the slitters may be remelted, recast and rolled again into an anode strip. In the case of the continuous casting arrangement, the casting orifice may be controlled to provide a strip of the necessary width, or slitters may be provided in the same manner as already described. To reduce to a certainty the manner of controlling heavy edges beyond that possible by these procedures last described, and to render the apparatus flexible in the treatment of various widths of strip, it is preferable to employ shields or masks **38** for disposition between the anode and the cathode to effect positive control thereof in a manner presently to be described. By this latter arrangement, it is possible to fabricate the anode strip at a width that will accommodate the widest cathode strip to be plated, and, then, to adapt the device to narrower width gauges by controlling the effective area of the anode by means of such shields or masks **38**. This latter effect may be obtained through the use of apparatus similar to that illustrated in Figures 3, 4, 5, 6 and 7, to which reference is now made.

The shields or masks **38** are preferably carried by a horizontal frame that is divided into two parallel parts **39** and **40**, respectively, which are carried independently of the mountings of the anode and cathode rolls on or adjacent the tank itself by propelling screws **41** and **42**, each of which has rightward and leftward threaded portions **43** and **44**, respectively. The propelling screws **41** and **42** are suitably journaled in stationary slide-bearings **45**, mounted in any suitable way proximite to the electroplating tank, as on the tank itself, as illustrated in Figures 3 and 5. At one of their ends, each of the shafts **41** and **42** may be provided with synchronized torque-imparting means, such as suitable gearing, or sprockets **46** and chain **47**, which, through automatic or manual means **48**, may be used to turn the propelling screws simultaneously, so as to vary the spacing between the frame parts **39** and **40**, upon which the shields **38** are carried. By this arrangement, any width of anode strip may be accommodated between the shields **38**, and the effective area thereof may be varied by moving the supporting frames **39** and **40** farther apart, or closer together, as the case may be, while preserving their parallel relationship.

It will be seen from the foregoing that the propelling screws act as centering devices for the frames **39** and **40**, and for the individual shields **38** depending therefrom, so that, if a cathode strip C of appropriate width were to be conducted through the system, no further adjustment would be required so long as the strip C traveled in a well-centered path. But such is not usually the case, since cathode strips, such as strip steel rolled on conventional hot and cold mills, frequently have almost imperceptible camber imparted thereto, whereby the longitudinal axis of the strip is not straight but curved, sometimes in one direction, sometimes in another, and, often in reverse curvatures. Since considerable linear extent of cathode strip is present in an electroplating tank at one time, by virtue of the serpentine course that it is made to follow, it is easy to see that such camber is influential in causing the strip to track back-and-forth off-center to a slight extent in a very slow, but, nevertheless, perceptible movement transversely of the tank. Were such movement not taken into account, definite and inacceptable variations in thickness in coating would be realized throughout the plated areas of such strips, rendering it necessary to correct for such condition, if perfectly uniform coatings are to be realized. The manner in which this is done will now be described.

It has been said that the propelling screws **41** and **42** are effective in supporting the frames **39** and **40**, and dependent shields **38**, in the tank. Even though, by revolving the propelling screws, the effective distance between the frames and shields may be varied, such adjustment is not available to cause the effective area of the anode to follow the strip in any of its departures from center. Since the width setting determinative of the correct relationship between anode and cathode areas is provided and maintained, it then becomes necessary to effect the movement of such setting to shift the effective anode area to agree with the placement of the cathode as it moves to and fro crosswise of the tank. This is accomplished by providing slide-bearing portions **49** adjacent each of the ends of the propelling screws **41** and **42**, which, in turn, cooperate with the stationary slide-bearings **45**, previously mentioned, to admit of the shafts **41** and **42** sliding in an axial direction. In this manner, as the strip C moves from one side to the other, the shafts may be moved a corresponding amount to preserve a well-centered relationship between the anode and the cathode, in so far as the effective area of the former is concerned, and this, even though the anode itself is not subject to transverse movement.

To insure that the propelling shafts, frames, and shields, are disposed according to the disposition of the cathode strip, and their movement coordinated with those of the latter, an electric-eye or photo-electric cell **50** is fixedly arranged to scan a marginal portion of entering cathode strip C for response to the proportionality of light-reflective surface, represented by the strip, to the relatively dark surface of the underlying roll **26**, which may be provided with a blackened area for this purpose. The photo-electric cell **50** is energized according to the relative degree of light derived from the strip within its scanning area, which light fluctuates as the strip tracks back and forth. The responses of the cell are applied to control a reversible electric motor **51**, through a circuit (not shown), which, in turn, drives a pinion **52** through a reduction gear **53** critically to move a segmental gear **54** either in clockwise or counter-clockwise direction, as the case may be, depending upon whether the strip has moved rightwardly or leftwardly beneath the electric-cell **50**. The segmental gear **54** controls a rocker-shaft **55** to which yokes **56** are rigidly secured for engagement with a pair of collars **57** that are carried upon the ends of the propelling screw shafts **41** and **42**, respectively. As viewed in Figure 5, if the strip moves leftwardly, more light will be reflected into the photo-electric cell **50**, which will cause the motor **51** to be actuated so as to turn the pinion **52** in a clockwise direction, as viewed in this figure. This drives the gear **54** and shaft **55** in a counter-clockwise direction, thus moving the yokes outwardly, and pulling the shafts 41 and 42, together with the associated frames and shields, leftwardly a corresponding amount, thus to maintain a centered relationship between the effective surface of the anode and the cathode strip being plated. If the cathode strip moves rightwardly, then, the reverse of the foregoing is true, whereby the propelling shafts 41 and 42 are caused to move, by the motor 51 and associated gearing and yokes, rightwardly a corresponding amount. Thus is the plating condition productive of the best coating continuously maintained.

It is obvious from the foregoing that any of the well known electronic devices and circuits may be used in conjunction with the photo-electric cell for giving effect to this result. Similarly, the photo-electric cell may be replaced by some other electrically-responsive device, such as, a solenoid with a tactile armature, as shown in Figure 15, for movement in response to the movement of the strip to vary the magnetic reluctance of its circuit, through which control and actuation of the motor 51 is ultimately derived.

Figure 15 illustrates means suitable for effecting said regulation by the aforementioned tactile armature in conjunction with a solenoid. In Figure 15, numeral 66 designates the frame supporting the device; 67 is a grooved wheel engaging the moving strip C and adapted to be shifted thereby in a horizontal plane. Wheel 67 is rotatably mounted on one extremity of a shaft 68 which passes through a guide 69 to prevent rotation thereof in a vertical plane. The upper extremity of shaft 68 is secured to the inward extremity of bar 70 carrying thereon armature 71, the bar being slidably supported at both ends thereof by roller bearings 72. The outward extremity of bar 70 coacts with an inwardly-acting spring 73, adapted to maintain the assemblage of bar 70, armature 71, shaft 68 and grooved wheel 67 in contact with the edge of moving strip C. Armature 71 is surrounded by a solenoid 74 placed concentrically thereto at a distance to suit the desired electrical characteristics of the circuit. Electric terminals 75 provide connection with the electric circuit employed and ultimately with the motor 51.

Control effected by the device depends upon the relative displacement of armature 71 in respect to solenoid 74. When strip C is in a neutral position, the electric circuit passing through solenoid 74 and electrical means auxiliary thereto is balanced, and motor 51 remains inactive. When strip C moves leftwardly, wheel 67 and assemblage corresponding thereto is also moved to the left, thereby changing the relative position of armature 71 and solenoid 74. Variation in magnetic reluctance corresponding thereto throws the circuit passing through solenoid 74 out of balance and causes motor 51 to rotate in the direction to impart inward motion of yokes 56 and thus pulling shafts 41 and 42 rightwardly. When cathodic strip C moves rightwardly, the reverse of the foregoing takes place.

With reference to Figures 6 and 7, the relationship of the shield 38 to cathode C and anode A may be readily understood. The shields 38 are channel-shaped members of suitable dielectric material constructed to have a short leg 38*a* and a long leg 38*b*. The long leg 38*b* extends between the anode and the cathode, and defines the effective surface of the former. As shown in Figure 6, the long legs of the shields 38 are provided with tapering notches 38*c* of suitable depth, which act to provide a plating-current gradient adjacent the edges of the cathode to effect a feathering of the coating applied to these portions so as to balance the tendency towards heavy edges. The notches 38*c* preferably terminate in points, the apices of which fall in a line at or slightly beyond the edges of the cathode C, and in substantial parallelism to the paths of travel thereof. As viewed in Figure 7, appropriate spacing 38*d* between anode-edges and shield-sides is provided to allow for the reduction of the effective anode area in accommodating cathode strips of narrower widths than those illustrated. It will be appreciated that a portion of the cathode strip C has been broken away from the view of Figure 6 to show the notches 38*c*, although the disposition of the marginal portions of the cathode strip is indicated in the fragment of the strip shown at the lower part of the view. In Figure 7, cathode C has been included in section to reveal the relationship of parts. In practice, the spacing between anode and cathode need be no greater than the thickness dimension of the notched shield-member 38*b*, although, to eliminate frictional drag and to preclude possible damage to the coating, it is preferable that slight spacing be maintained between the movable and stationary parts. It will be appreciated that the carefully regulated tension in both anode and cathode strips makes the precise disposition and control of the several parts, in preservation of this relationship, a relatively simple matter.

With a view toward increasing the efficiency of the anode, more rapid deposition of coating may be obtained by increasing the effective area of the latter, subject to the conditions of control described hereinbefore, by the modification shown in Figures 8 and 11, inclusive. An anode strip A may be prefabricated with its active surface serrated in a manner to increase the effective surface area thereof. In the case of the prefabricated anodic strip, this may be achieved in any suitable manner, as by passing the strip between knurling rolls. In the case of the continuous casting device shown in Figures 1 and 2, this may be done by making one of the pinch rolls 32, which withdraw the metal in solidified form from the casting orifice 31, with a corrugated or knurled surface, as shown at 32*a* in Figure 8, which serves to impress the pattern upon the surface of the anode. This is illustrated in plan in Figure 10, while the corresponding side elevational view is illustrated in Figure 11. In Figure 9 the operating relation of such an anode strip A, in relation to the cathode strip C, is illustrated. Although the effect of these serrations is to vary the distance between the cathode and anode surfaces, they lie transversely thereof, whereby their total effect is averaged over the entire length of strip being plated, resulting in a uniform condition. The averaging effect is improved by the fact that the anode moves in an opposite direction to that of the cathode. However, this is not of particular importance, since, even if the two were to move in the same direction, the surface speeds of each are so different as to effect the averaging of the plating condition practically to the same extent. The relative proportions of the serrations to the anode strip are subject to variation to suit the particular needs of a given set of operating conditions, those shown in the drawings being merely illustrative.

The serrated surface of the anode A has the additional function of increasing its flexibility, permitting its superficial masses to withstand repeated bending without alternately compressing and tensioning them beyond the elastic limit of the material to cause the anode to stretch unduly. Another manner for achieving this result without unduly weakening such an anode strip is shown in Figure 11A, wherein the anode A is illustrated as having substantially straight-sided grooves disposed transversely thereacross when the anode lies in a straight path, which become closed on an inward bend, and fanned-out on an outward bend to prevent plastic flow of the metal. Any shape and disposition of groove, notch, or discontinuity of surface, as applied to either or both anode surfaces, is contemplated for this purpose.

The invention may be carried out by an alternate anodic arrangement illustrated in Figures 12 to 14, which may be applied to coat one side of a cathode strip, if preferred, but is particularly well adapted to the coating of both sides of the strip simultaneously without entailing a complex structure and congestion of parts. In this case the cathode strip is introduced into the tank **20**, and conducted back and forth over cathode rolls **27**, in a manner similar to that already described. The anode, however, is composed of one or two strips (preferably two) which may be continuously cast as used, or prefabricated to form a roll of anode strip **60**, which is disposed on a horizontal axis of revolution to deliver two plies of anode strip downwardly into the tank **20** (see Figure 12). The anode strips are passed around a cylindrical roll **61**, whose axis of revolution is maintained at a 45 degree angle, which serves to turn the direction of travel of the anode strips 90 degrees, thus causing them to stand on end, with the planes of their major surfaces extending in the vertical.

As viewed in Figure 14, it will be seen that the anode strips A are conducted in a serpentine fashion back-and-forth across the tank by anode rolls **28'**, and are removed from the opposite end of the tank by means of another oblique roller **62**, guide roller **63**, and coiler **64**, in a manner similar to their entry. Small guide rolls **65** are employed at the approach and exit ends of the tanks to assist in introducing and withdrawing the anode strips to and from the tank. The anode rolls **28'** are disposed in staggered relation at opposite sides of the tank, and revolve about vertical axes. Intermediately of the tank, the anode strips are divided by means of shields **38'**, which allows for the passage of the cathode strip C continuously between them. In this case, the divider shields **38'** are of channel-shape, with both legs of the channel being of the same length, and provided with grading notches **38c**. These channel-shields **38'** may be stationary, or may be mounted in a manner similar to those previously described for movement toward and away from each other to accommodate different widths of cathode strip, and, coincidentally, to vary the effective area of anode made available thereto.

The anode rolls **28'** may be driven in a manner to advance the anode strips under tension, thus to provide uniform spacing between cathode and anode surfaces and to give effect to the same optimum operating conditions described hereinbefore.

In the modification shown in these figures, as in the preceding construction, the cathodic strip C is conducted through the tank at a relatively high rate of speed, while the anodic strip proceeds relatively slowly. Perforations (not shown) may be provided through the anode strips to permit circulation of electrolyte, or the anodes may be of a foraminous construction. Another obvious modification of the various arrangements shown would be the rearrangement of the anodic and cathodic strips with respect to each other so that, in any embodiment, the anode would be where the cathode is, and vice versa. The adaptations necessary to effect such transposition are obvious and need no further elaboration.

From the foregoing it will be observed that the continuous anodes herein provided are constantly being renewed, whereby no defective portion that might occur along their length stays long enough in one position to make its presence manifest in the coating of the cathodic strip. In the first embodiment of the invention, in which the placement of travel of both the cathodes and anodes substantially agree, the anode is subject to continuous inspection at the point where it emerges from the bath, at which point it may be scraped and kept clean.

The foregoing arrangements will appear to those familiar with the problems in this field as satisfactory solutions to the principal operating difficulties encountered in electroplating strip-like objects, the most important of which is the provision and maintenance of a uniform plating condition across the width of such objects all along the portions of their length that are exposed to electroplating action. At the same time, many alternative arrangements and modified constructions will suggest themselves which, though not specifically illustrated, will still be within the basic teaching of the present invention as recited in the claims. A few of these may be noted without attempting to exhaust the possibilities:

The prime requisite in realizing the benefits hereof resides in a continuous anode having an effective surface that presents an average uniform plating condition in relation to the cathode strip throughout the length thereof during plating. An anode, continuously presented and fed, may assume any one of a variety of forms to this end. Thus, a backing-strip or web of solid or foraminous material may be provided to carry the anodic metal, which may be cast thereon in fused condition, or prefabricated in bar or plate-like sections and affixed thereto, or deposited in powder or granular form thereon and secured by fritting, sintering, soldering, or by mechanical means, such as a suitable adhesive or retaining fabric. Such carrier strip may be of dielectric material, in which case the plating current is caused to emit from one surface thereof only to increase the directional plating efficiency. Also, if the dielectric carrier is sufficiently bendable and is preformed to a sufficient width in excess of the anode-width, per se, it may be folded over to over-lie edge portions of the effective surface area of the latter to accomplish a shielding function that would be operative for predetermined widths of cathode strip to the exclusion of the adjustable shields **38**.

The anode may assume the form of a reticular body in which filaments of plating metal are interwoven with each other for use in this form, or as a carrier fabric for the compartment of additional plating metal in powdered, fused, or massive form. Similarly, filaments of plating metal may be interwoven with filaments of dissimilar material that is either electrolytically inert or active, as desired, to enhance the flexibility or strength of the anode, or to provide for the deposition of polymetallic coatings in one operation, or both. Such a fabric, in which inert filaments were arranged with a view toward preventing heavy-edge plating, could be used to effect a coating-gradient to provide a uniformly-plated cathode. Therefore, whether the anode be a composite of articulated masses, a woven body, or a continuous strand, either with or without a carrier web, the primary purpose of the invention will be served.

The cathode may also consist of a metallic fabric; a plurality of elongated strips, each of relatively narrow width; or a multiplicity of sheets or plates articulated in any suitable manner for continuous presentation and advancement throughout an electroplating operation as here set forth. Although all of these alternates for both anode and cathode increase the complexity and cost of such operations, rendering the initially disclosed embodiments the preferred forms, still, they are deemed to be such reasonable modifications of the basic idea as clearly to fall within the purview of this invention.

It is not intended, therefore, that the invention be limited to the precise constructions illustrated, but that it be accorded a broader interpretation in conformance with the spirit of the accomplishments represented thereby, as is set down in the claims to follow.

I claim:

1. Electroplating apparatus comprising means for guiding a cathode strip through an electrolyte, means for guiding a strip anode in parallel, proximate relation to a cathode strip traversing said first-named means, shields extending between the edges of the cathode and anode strips, mountings for said shields adjustable transversely of the path of the cathode strip, a motor actuating said mountings and a control mechanism for said motor responsive to lateral shifting of the cathode strip.

2. The apparatus defined by claim 1 characterized by said control mechanism including a light-responsive element activated by the position of an edge of said cathode strip.

3. In a method of plating a coating onto a base-metal strip, the steps including passing the strip continuously through an electrolyte as a cathode, passing an anode in the form of a strip wider than the base metal strip continuously through the electrolyte, guiding the anode strip parallel to the base-metal strip and closely adjacent thereto, maintaining between the edges of the base-metal strip and the anode strip a shield having openings spaced therealong gradually diminishing in extent toward the edges of the base-metal strip, and automatically moving said shield transversely of the path of the strips on transverse shifting of the base-metal strip.

4. A method of electroplating strip-like objects continuously which includes: advancing such an object continuously through a bath of electrolyte as cathode; passing a strip-like anode continuously through the bath so that substantial portions of one of its surfaces fall closely adjacent areas of the strip-like object to be plated; interposing shielding means between portions of the adjacent areas of the strip-like anode and cathode to prevent heavy-edge plating on the latter; automatically shifting said shielding means transversely with respect to the direction of travel of said cathodic object to maintain a substantially centered relationship thereof continuously throughout the plating operation.

5. A method of electroplating which includes: advancing a strip-like cathode through an electrolytic cell; advancing a strip-like anode which is wider than the cathode coextensively with the cathode through at least a portion of the latter's path of travel through the cell; inserting masking means between the anode and cathode throughout the coextensive portions thereof so as to reduce the effective anode width to agree with the cathode width, and shifting said masking means transversely of the line of the cathode travel to maintain a centered relationship between the effective cathode and anode surfaces at the coextensive portions thereof.

EDWIN T. LORIG.

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Certificate of Correction

Patent No. 2,461,556. February 15, 1949.

EDWIN T. LORIG

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 4, line 16, for the word "anodes" read *anode*; column 6, line 58, after "latter" insert *throughout*; column 7, line 44, for "proximite" read *proximate*; column 9, line 67, for "shield" read *shields*; column 10, line 6, after "at" strike out the hyphen; column 12, line 57, after "anode" strike out the hyphen; line 66, same column, for "compartment" read *comportment*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 28th day of June, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.