United States Patent [19]

Austin et al.

[11] **3,900,383**

[45] **Aug. 19, 1975**

[54] **APPARATUS FOR ELECTROPLATING**

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[22] Filed: **July 24, 1974**

[21] Appl. No.: **491,377**

[52] **U.S. Cl.** .... **204/211;** 191/1 A; 204/28; 204/279

[51] **Int. Cl.** **C23b 5/68;** C23b 5/58; B601 9/00

[58] **Field of Search** .... 191/1 A; 204/27–28, 206–211, 279

[56] **References Cited**

UNITED STATES PATENTS

3,432,419	3/1969	Vitacco	204/213
3,634,223	1/1972	Carter	204/206

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[57] **ABSTRACT**

An electroplating roll is provided with a plurality of electrically conductive, contiguous segments insulated from one another and arranged on rotation to make electrical contact consecutively with a synchronously advancing metallic strip submerged in an electroplating bath to feed electric current to the strip. A commutator connects the segments consecutively to a source of electrical potential in a manner such that only segments of the roll which are entirely in contact with the strip are feeding current to the strip. With this electroplating roll, arcing caused by initial contact of the strip with the conductor ring and consequent burning of the strip becomes negligible. Control of electroplating current flow selectively to individual segments of the conductor ring also permits better control of the rate of plating of the strip in contact with the roll.

14 Claims, 6 Drawing Figures

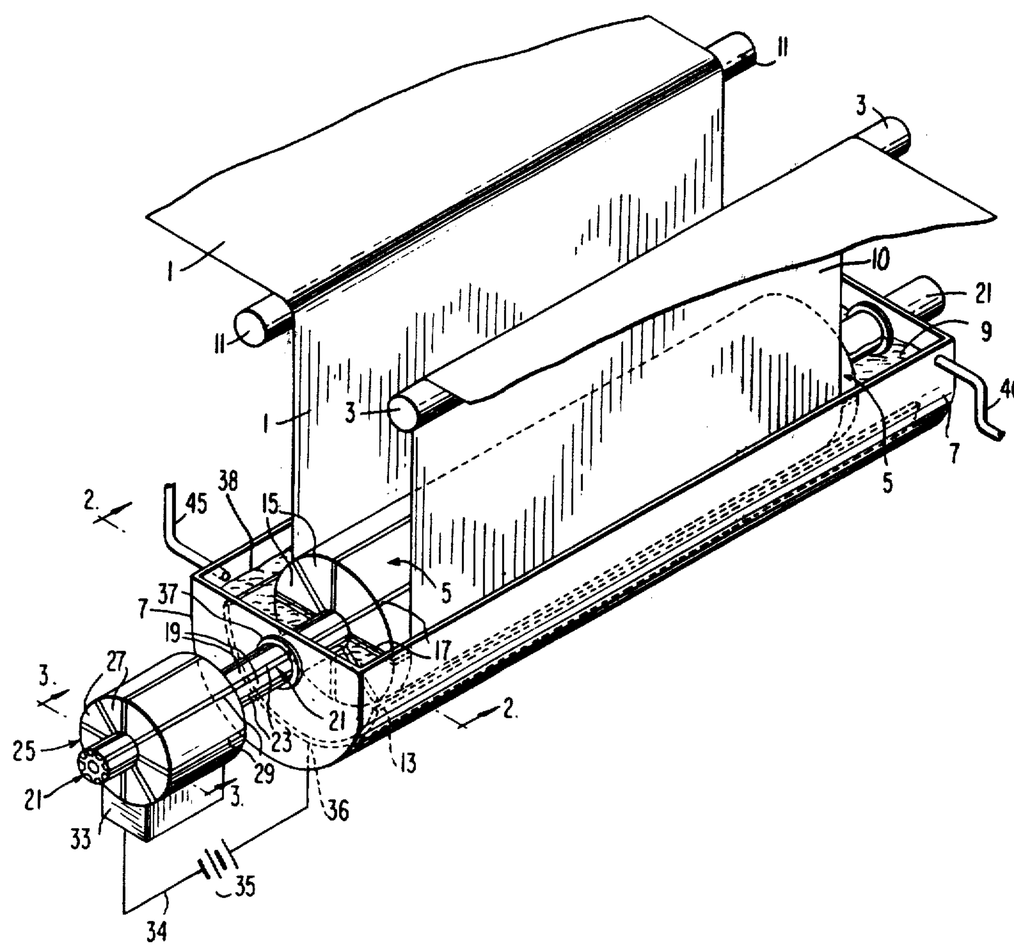
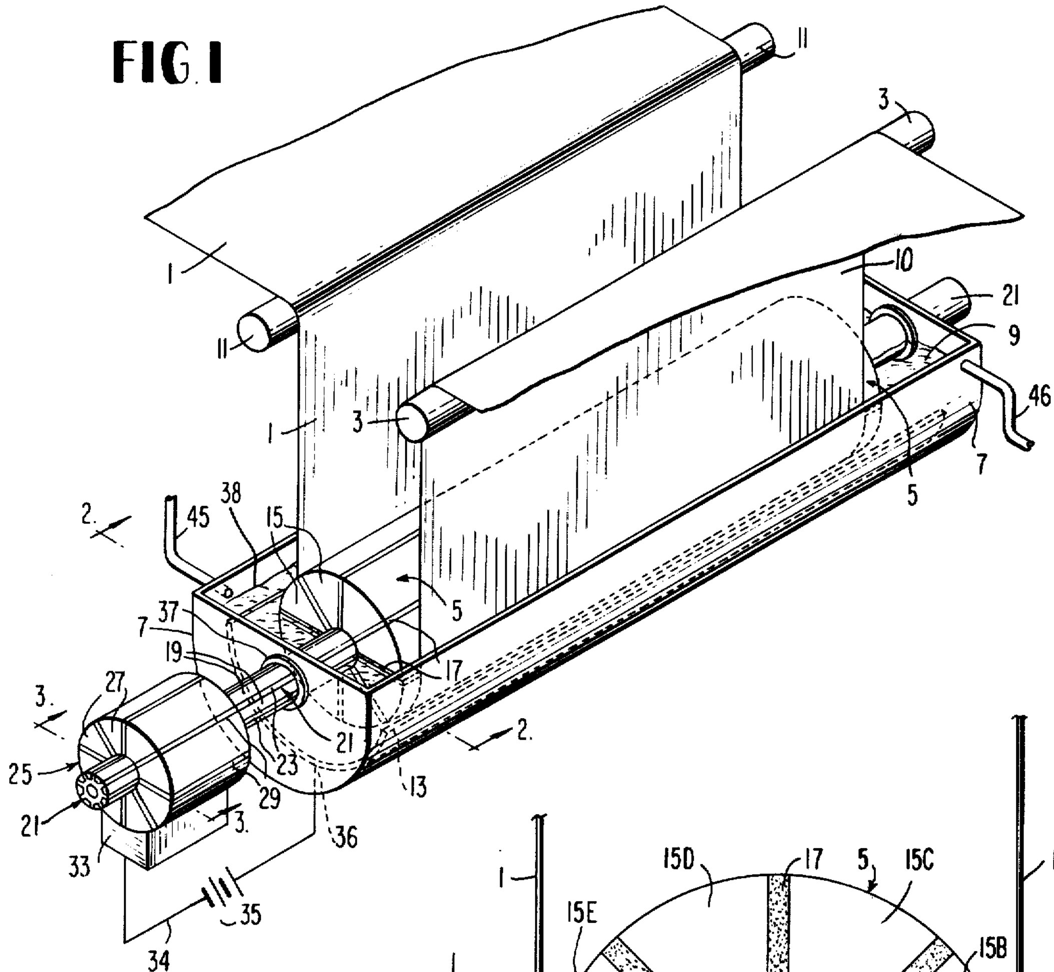


FIG. 1



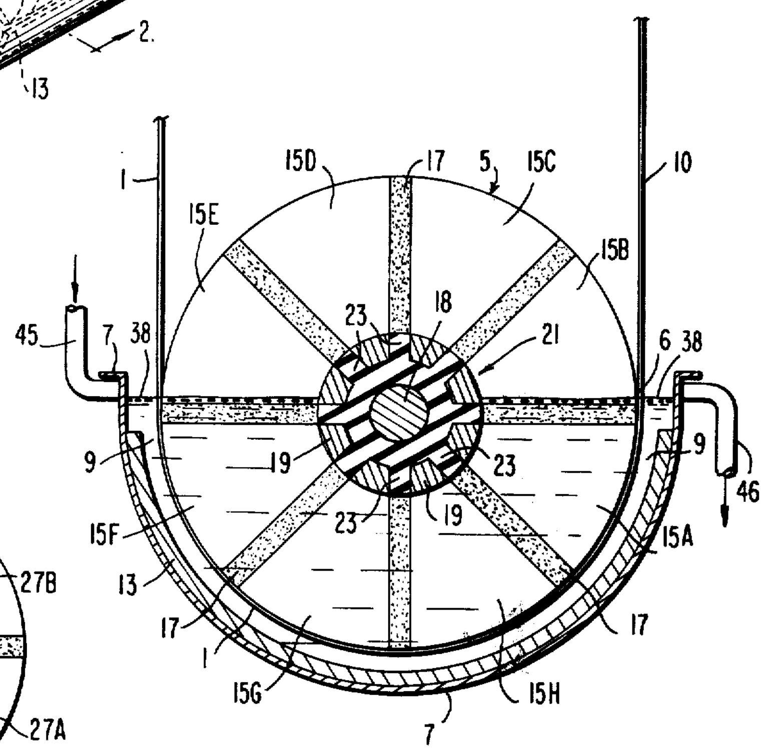


FIG. 2

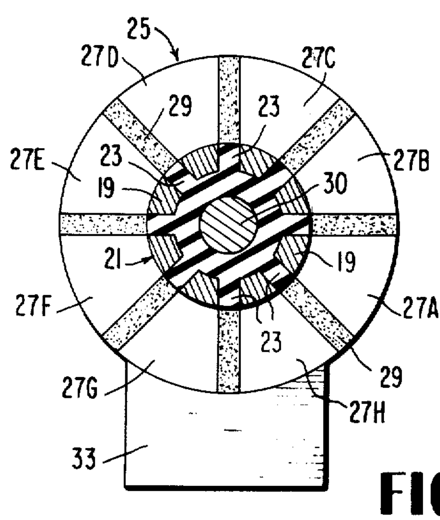


FIG. 3

FIG. 6

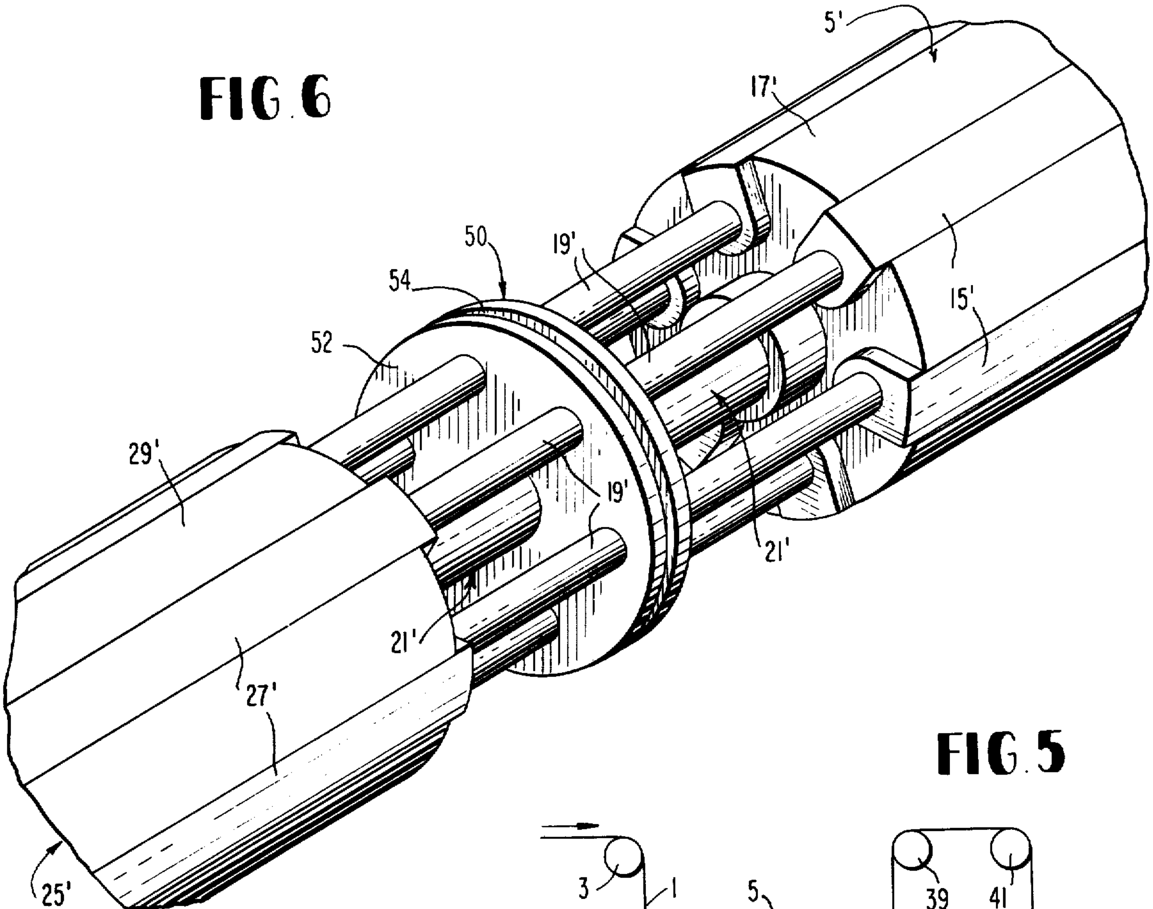
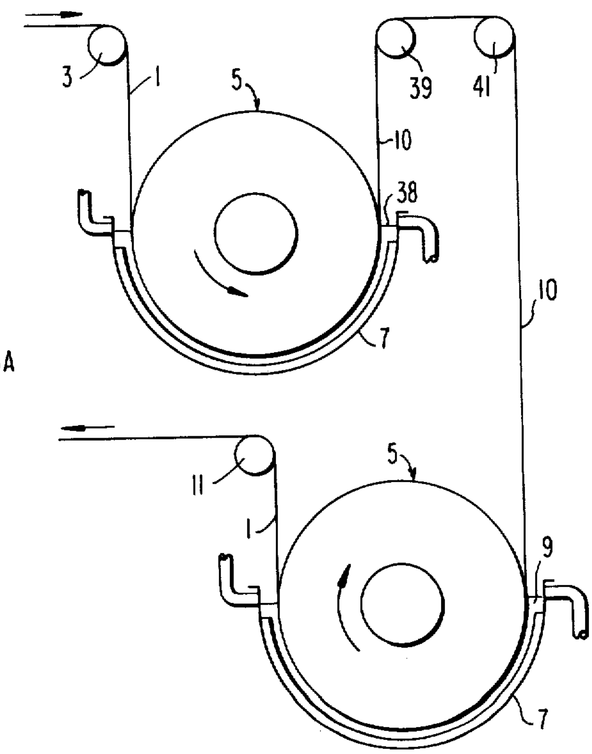


FIG. 5



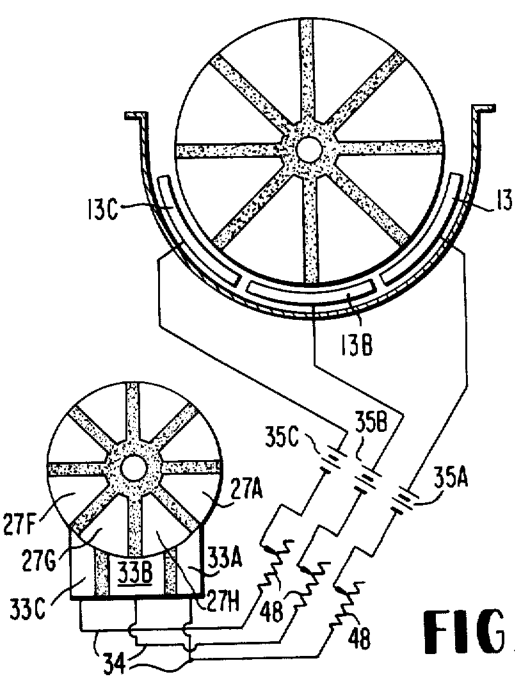


FIG. 4

APPARATUS FOR ELECTROPLATING

BACKGROUND OF THE INVENTION

The present invention relates to the field of electroplating or electrodepositing. In one of its aspects the invention relates to electroplating the surface of an electrically conductive strip or web of material. In another of its aspects the invention relates to the use of an electroplating drum or roll in an electroplating operation. In one of its concepts the invention relates to electroplating a surface of a strip of electrically conductive material passed around an electroplating roll with the strip of material in contact with the roll submerged in an electrolytic solution during the period of electroplating.

In the electroplating of a strip or web of material it is common practice to pass the strip of material around an electroplating roll so that there is contact between one surface of the strip and an electrically conductive circumferential ring on the surface of the cylindrical roll. The electroplating roll is submerged in a bath of electrolyte to a depth, usually to the center of the circular end plane of the cylinder, that assures maximum contact between the surface of the strip and electrolyte on one side of the strip while contact is maintained between the electroplating roll and the opposite side of the strip. During the plating cycle the cylindrical roll is rotated, moving the strip around the roll as electrical current is passed from an insoluble anode in the electrolytic bath through the electrolytic bath and the strip to the electrically conductive circumferential ring on the roll, thereby causing deposition from the electrolyte onto the surface of the strip exposed to the electrolyte.

One of the major problems associated with the operation of a continuous coating roll as described above is that arcing occurs between the strip and the conductor ring of the coating roll at the point of first contact. In continuous plating operations the circumferential conducting ring on the electroplating roll is maintained at a constant voltage which it is believed causes a preferential flow of current at the first area of contact between the strip and the conductor roll. This can establish a transfer of current called "line" contact in which all of the current is transferred within the small area which is the width of the initial line of contact times its length. At the high current flows required in electroplating operations, intense arcing takes place along this line of contact. The arcing is of sufficient intensity to burn this strip. The degree of arcing is intensified when intitial contact between the strip and the circumferential conductor occurs above the surface of the electrolytic bath.

It is therefore an object of this invention to provide a method for electroplating a strip or web of electrically conductive material by which arcing of the strip and consequent burning of the strip can be made negligible.

It is a further object of this invention to provide a method for electroplating a strip of material in which the initial application of an electroplating current to the strip can be controlled to take place along a line beneath the surface of the electrolytic bath as the strip is moved in contact with an electroplating roll through an electroplating bath.

It is another object of this invention to provide an electroplating apparatus in which the electroplating current passed from the anode through the electrolyte to the conductive electroplating roll can be varied as the submerged portion of the conductive roll surface is rotated in the electrolyte bath.

It is still another object of this invention to provide an electroplating conductive roll comprising a plurality of electrically conductive members, electrically insulated from one another extending in the direction of the axis of rotation of the roll and to form a segmented circumferential ring of electrical conductors around the cylindrical surface of the roll.

These and other objects and the advantages of the invention will become apparent from the following description of the embodiments of the invention.

FIG. 1 is a perspective view of an electroplating apparatus incorporating the present invention;

FIG. 2 is a schematic view in section taken on the line 2—2 of FIG. 1;

FIG. 3 is a schematic view in section taken on the line 3—3 of FIG. 1;

FIG. 4 is a schematic representation of an apparatus of FIGS. 3 and 4 showing a split commutator brush joined electrically to a split anode;

FIG. 5 is a schematic representation of electroplating apparatus in accordance with this invention arranged in series so that both sides of the strip can be plated in continuous operation, and

FIG. 6 is a perspective view of a preferred embodiment of the electroplating roll structure shown schematically in the preceeding figures.

Referring now to FIG. 1 for the general arrangement of an apparatus of the invention, it can be seen that an electrically conductive strip 1 is passed across a directing roll 3 and thence around a conductive electroplating roll indicated generally at 5 partially submerged in an electrolytic solution 9 in a bath tank 7 for containing the electrolyte solution, and thence around second directing roll 11. The directing rolls 3, 11 are aligned with the electroplating conductive roll 5 so that the strip 1 is maintained against the circumferential surface of the conductive electroplating roll 5 rotating in a clockwise direction.

The electrolyte solution 9 is in contact with the side 10 of the strip 1 that is away from the conductive electroplating roll (FIG. 5).

Contained within the electrolytic bath 9 in a position sufficiently removed from strip 1 to prevent direct contact with the strip 1 passing around the electroplating roll 5 is an insoluble anode 13. In general application, this anode means will have a configuration that conforms to the surface contours of the electroplating roll 5 so that the anode means can be described generally as a hollow cylindrical shape with diameter sufficiently larger than the electroplating roll 5 to accomodate the electroplating roll and the strip being plated within its cylindrical arc without direct contact between the surface of the anode and the near adjacent surface of the strip. The electrolyte solution 9 within the bath tank 7 is in contact with the surface of the anode 13 so that the passage of electrical current from the anode 13 through the electrolyte 7, through the strip 1 being treated, and to the discontinuous conductive ring formed by the electrically conductive segments 15 of the electroplating roll will cause deposition of metal from the electrolyte onto the surface of the strip with which the electrolyte is in contact.

The electrically conductive roll designed for use in this invention is schematically illustrated in FIG. 1 as an elongated cylinder composed of electrically conductive segmental elements 15 spaced in side-by-side circumferential arrangement to form the major portion of the cylindrical surface of the roll and insulated each from the other by electrically nonconductive members 17 which join together to form a core carried by a shaft 18 (FIG. 2). Electrically conductive elements 15 are individually connected to a means by which the flow of current through each member can be selectively controlled. In FIG. 1 the connecting means are shown as electrically conductive members 19 forming part of a drive shaft indicated generally at 21. These conductive members 19 are spaced each from the other and can be insulated from one another by electrically nonconductive members 23 forming part of the drive shaft 21. This shaft is connected in turn to a commutator roll indicated generally at 25 which is also divided into electrically conductive elements 27 insulated each from the other by electrically nonconductive members 29 which join together to form a core carried by a shaft 30 (FIG. 3). Thus the electroplating roll 5, the connecting shaft 21 and the commutator roll 25 each contains electrically conductive elements spaced around a cylindrical insulating core and electrically insulated each from the other to form in the cases of roll 5 and roll 25 a segmented electrically conductive ring.

If desired, insulation (not shown) may cover the electrically conductive elements of connecting shaft 21. This shaft passes through an electrolyte retainer 37 with either the shaft rotating relative to the retainer or the retainer rotating relative to bath tank 7. The discontinuous commutator ring formed by the electrically conductive elements 27 of the commutator roll 25 is connected through a brush member 33 into an electrical circuit 34 including a source of electrical potential 35 and anode 13 in the bath tank 7.

As can be seen, the electrical connection between brush member 33 and the electrically conductive ring of the commutator is so arranged that only a predetermined number of the electrically conductive members 27 are energized at any one time. As the electroplating roll 5 is rotated by movement of strip 1, shaft 21 causes commutator roll 25 to be rotated and electrically conductive elements 27 of the commutator roll 25 are energized and then de-energized as the elements pass in contact with the brush of the commutator. This causes current flow through the corresponding electrically conductive elements 19 and 15 of the shaft and electroplating roll, respectively.

Basic to the electroplating apparatus and method of this invention is the segmented electroplating roll 5 as schematically illustrated in FIG. 1 and as described above. The provision of the electrically conductive segmented ring at the roll surface permits control, hitherto unknown in the art, of the area of electrical contact between the strip being plated and the surface of the electroplating roll.

As will be shown in the discussion of the method of electroplating using the apparatus of the invention, the electroplating roll 5 can have its surface divided into any number of electrically conductive elements 15 with four conductive members being the minimum efficiently operating number. It can readily be seen that the greater the number of conductive members, up to the number where practicality is the limit, the greater the control that can be exercised over the portion of the surface of the roller through which electrical current is passed. For reasons of practicality, the number of conductive segments will generally be between four and twelve.

Referring now to FIGS. 2 and 3 of the drawing, an operation of electroplating one face of a strip by the process of this invention can be described. As illustrated in FIG. 2, the strip of material 1 is passed around a portion of the circumferential face of electroplating roll 5. The electroplating roll as shown in this view has its eight electrically conductive elements identified separately as 15A through 15H for better elaborating on the method of using the apparatus. Similarly the drive shaft 21 has its eight electrically conductive members elements separately identified as 19A through 19H. Each of the electrically conductive elements 19 of the drive shaft is aligned to connect with an electrically conductive element 15 of the electroplating roll. Similarly in FIG. 3 the commutator roll 25 has its eight electrically conductive elements separately identified as 27A through 27H, each aligned with a conductive element 19 of the drive shaft so that in FIGS. 2 and 3 electrically conductive elements 15A of the electroplating roll, 19A of the drive shaft, and 27A of the commutator roll form a continuous electrical conductor or conductive element. Similarly, each of the elements marked B through H are connected to form continuous electrical conductors comprising a conductive element of the electroplating roll, a conductive element of the drive shaft and a conductive element of the commutator roll.

As shown schematically in FIG. 2, in operation, a strip 1 is passed around the circumferential face of electroplating roll 5 so that the initial point of contact 6 between the roll 5 and the strip 1 can be in the neighborhood of but preferably at or above the surface 37 of the electrolyte solution 9 contained in the electrolytic bath 7. Electrolyte 9 is supplied through conduit 45 and withdrawn through conduit 46 to maintain the level within the bath and also to maintain the desired temperature within the bath.

The commutator roll 25, the same drive shaft 21 and the electroplating roll 5 rotate synchronously so that the electric current can be caused to flow successively through electrically conductive elements of the electroplating roll 5, the drive shaft 21 and the commutator roll 25. AS can be seen in FIG. 3 with the commutator brush 33 positioned so that electrical contact is established between electrically conductive elements 27G and 27H and the correspondingly numbered electrically conductive elements of shaft 21 and electroplating roll 15G and 15H, a clockwise rotation of the roll will establish electrical contact between the commutator brush and electrically conductive element 27A soon after the corresponding electroplating electrically conductive element 15A is submerged in the electrolyte 9. Electrical contact is maintained with element 27G until the leading edge of the corresponding element 15G is just below the surface 37 of the electrolyte 9 and before element 15G emerges from the surface 37 of the electrolyte 9. By this arrangement electrical current can be caused to flow through three elements at a time of the electroplating roll 5, e.g. 15G, 15H, 15A. Electrical flow is maintained only in that portion of the commutator roll 25 that is connected to the portion of the electroplating roll 5 that is submerged in the electrolyte 9. Similarly, element 27B and each of the other conductive commutator elements 27 is successively rotated into contact with the brush member 33 as elements 27G, 27H, and 27A are passed out of contact. No current flows to the electrically conductive elements 15 of the electroplating roll 5 that are not submerged in the electrolyte 9. Line contact above the surface of the electrolyte between the strip 1 being plated and an energized portion of the electroplating roll 5 is avoided. Suitable adjustment of the size of the area of contact between the commutator roll 25 and the commutator brush 33 can be made to expand or limit the area of electrical contact in which current will be passed between the electroplating roll 5 and the strip 1 being plated. Since the strip 1 is electrically conductive, some electric current will flow along the length of the strip from each side of an energized element 15. In view of the higher resistance of this path the current flow will be minimal; however with a larger number of elements 15 and 27 in the rolls 5 and 25, the brush area must be limited to prevent an energized element 15 from coming too close to the electrolyte surface 38.

It is also within the scope of the invention to provide a split commutator brush 33 or other control means by which the flow of current can be increased and decreased through certain conductive members of the electroplating process. This is illustrated in FIG. 4 using a split commutator brush 33. As commutator member 27A rotates clockwise into successive contact with members 33A, 33B and 33C of the brush having each of these brush members connected individually through controlled electrical sources 35A, 35B, 35C, to corresponding members of a split anode 13A, 13B and 13C, current of differing intensities are passed through the aligned members. The plating current can be made progressively greater through each successive member of the brush 33A–33C or the current of greatest intensity can be that applied as the strip is at the midpoint of travel through the plating bath (in electrical connection with 33B). The sizing and spacing of the conducting portions of the brush can also be advantageously varied causing the current flow to fluctuate in any conductive element of the roll 5 as contact between the commutator roll elements and any conductive element of the brush is made or broken. Referring to FIG. 4, as the conductive elements move clockwise, there will be an interval in which both 27H and 27A are in contact with 33A and 27H is also in contact with 33B. During this period the current flow in 33A and 33B can be held equal but the current flow in 33B can be sequenced by variable resistances 48 to increase as soon as 27H is no longer in contact with 33A. Similarly the current flow in 33B can be decreased coincident with contact of 27H with 33C.

Referring to FIG. 5, a two step system is illustrated with a strip 1 being passed around two electroplating rolls 5, 5 of this invention in series so that both sides 10, 10 of the strip 1 can be electroplated. The system illustrated involves the use of two electroplating rolls 5, 5 as described above, so arranged that a continuous strip 1 of material is passed around the electroplating roll 5 and then a second roll 5 in series, with the electroplating roll rolls 5, 5 operated to rotate in opposite directions. The illustrated counter rotation arrangement is most practically arranged with one electroplating bath 7 located above the other with the electrically conductive web 1 passed around suitable intervening rolls 39, 41 which permit the spacing necessary to cause the side 10 of strip 1 left unplated in passage around roll 5 to be in contact with the electrolyte 9 in passage around roll 5.

Means for completing the electrical circuit through the roll system can be made a part of a drive shaft as illustrated in FIG. 1. A preferred embodiment of the roll system of the present invention is illustrated in FIG. 6 in which like elements are numbered as in FIG. 1 but primed. In FIG. 6 the electrically nonconductive drive shaft 21′ is surrounded by rigid electrically conductive rods 19′ equal in number to the number of electrically conductive segmental elements 15′ of the electroplating roll 5′. Each conductive rod 19′ is attached at one end to one conductive element 15′ of the electroplating roller 5′ and attached at the other end to one electrically conductive element 27″ of the commutator roller 25′.

This configuration requires a special sealing member 50 for sealing the drive shaft 21′ and conductive rods 19′ as they pass through the end 36′ wall of the electrolytic bath tank 7. The seal can be formed from a round disc 52 of electrically nonconductive material, inert to the electrolyte, which is sufficiently greater in diameter than the distance of the conductive rods 19′ from the center of the drive shaft 21′ so that the conductive rods 19′ are insulated from contact with the electrolytic bath tank 7 and the material of the sealing member forms a liquid tight seal with the connecting rods 19′ and shaft 21′. As shown, the seal can be suitably grooved at 54 to maintain rotating, sealing contact with the wall of the electrolytic bath tank 7 to prevent flow of electrolyte 9 from bath tank 7. In such a configuration the seal can or need not be formed of a material of sufficient strength to bear part of the weight of the electroplating roll apparatus, bearings, not shown, being supplied for the shaft 21′ in any case. Such a sealing member is similar to that required for passing the drive shaft 21 alone, as shown in FIG. 1, through the wall of the electrolytic bath tank 7.

The roll system of the embodiment illustrated in FIG. 6 is formed by taking a steel shaft 21′ and mounting on it cylindrical insulating core members 17′ and 29′ which have channels machined in them to receive electrical conductive segmental elements 15′ and 27′. These electrically conductive elements are firmly affixed in place in the channels by any suitable means with their outer surfaces forming part of the overall cylindrical surfaces of roll 5′ and commutator member 25′. Preferably core member 17′ entirely encloses the inner sides of conductive elements 15′ over that portion of the roll 5—5 which contacts the strip, leaving exposed to the electrolyte bath only the cylindrical surface of each conductive element in that portion of the roll surface which contacts the strip, herein termed the effective portion of the roll surface. Prior to assembly of the conductive elements 15′ and 27′ and insulating core members 17′ and 29′ into the roll system, conductive rods 19′ and nonconductive sealing disc 50 are asembled on and around shaft 21′. The entire assemblage is then brought together with conductive elements 15′ and 27′ snugly receiving the ends of conductive rods 19′ in electrically conducting relationship. In this manner, each conductive element 27′, associated rod 19′ and associated conductive member 15′ together form a continuous electrically conductive structure for supplying current for carrying out the desired plating operation.

It will be apparent that the structure illustrated in FIGS. 1–3, like that of FIG. 6, can be considered as having two cores made up of nonconductive members **17** and **29** with their internal connecting structure carried by a shaft which extends between the cores and in the FIGS. 1–3 embodiment carries connecting electrically conductive members **19** and nonconductive members **23**.

We claim:

1. An electroplating apparatus comprising

a. bath container means including walls for holding an electrolyte,

b. an elongated shaft in the bath container means having one end portion extending through one wall of the bath container means,

c. an electroplating contact roll for passing conductive strip to be plated through the bath carried by the shaft and partially submerged in the electrolyte, the contact roll including a core member and a plurality of circumferentially spaced, electrically conductive segmental elements, elongated in the direction of the longitudinal axis of the shaft, affixed to the core member, the outermost surfaces of the plurality of segmental elements relative to the longitudinal axis of the shaft being of substantial area and falling in a cylinder having the longitudinal axis of the shaft as its center line,

d. an anode structure submerged in the electrolyte and having surface portions contiguous to but spaced from the electroplating roll,

e. an electrolyte retainer means surrounding the shaft where the shaft passes through the wall of the bath container means, and

f. means carried by said one end portion of the shaft outside of the bath container means for delivering electrical current selectively to each of the segmental elements.

2. The structure of claim **1** in which means (f) comprise

g. a second core member formed of electrically nonconductive material affixed to and surrounding the said one end portion of the shaft,

h. a plurality of circumferentially spaced, second electrically conductive segmental elements, affixed to the second core member, the outermost surfaces of the plurality of second segmental elements relative to the longitudinal axis of the shaft being of substantial area and falling in a second cylinder having the longitudinal axis of the shaft as its center line, and

i. an electrical conductor electrically connecting each electrically conductive segmental element of limitation (c) to a second electrically conductive segmental element of limitation (h).

3. The structure of claim **2** in which

j. the electrolyte retainer means is affixed to the shaft, the electrical conductors of limitation (i) pass through the electrolyte retainer means and the electrolyte retainer means space the electrical conductors from the shaft.

4. The structure of claim **3** in which

k. the nonconductive material of the first claimed core member in the effective portion of the roll extends between and separates opposed surfaces of adjacent first claimed electrically conductive segmental elements, the outermost surfaces of the nonconductive material of the first claimed core member relative to the longitudinal axis of the shaft falling substantially in said cylinder.

5. The structure of claim **4** in which

l. electrically conductive brush means for supplying electric current to the second segmental elements, having an electrical contact area complementary in shape to and coinciding with the second cylinder, make simultaneous electrical contact with a plurality of adjacent second segmental elements in number such that less than one half of the total number of second segmental elements are in electrical contact with the brush means at any one time during revolution of the structure about the longitudinal axis of the shaft.

6. The structure of claim **5** in which the brush means of limitation (l) comprise

m. a plurality of electrically conductive segments insulated from one another and disposed in circumferentially spaced relation in respect to the second cylinder and having areas of electrical contact complementary in shape to and coinciding with the second cylinder, and

n. separate electric circuit means connections for each segment of the brush means.

7. The structure of claim **1** in which

g. the nonconductive material of the core member in the effective portion of the roll extends between and separates opposed surfaces of adjacent electrically conductive segmental elements, the outermost surface of the nonconductive material of the core member relative to the longitudinal axis of the shaft falling substantially in said cylinder.

8. The structure of claim **2** in which

j. the nonconductive material of the first claimed core member in the effective portion of the roll extends between and separates opposed surfaces of adjacent first claimed electrically conductive segmental elements, the outermost surfaces of the nonconductive material of the first claimed core member relative to the longitudinal axis of the shaft falling substantially in said cylinder.

9. The structure of claim **8** in which

k. electrically conductive brush means for supplying electric current to the second segmental elements, having an electrical contact area complementary in shape to and coinciding with the second cylinder, make simultaneous electrical contact with a plurality of adjacent second segmental elements in number such that less than one half the total number of second segmental elements are in electrical contact with the brush means at any one time during revolution of the structure about the longitudinal axis of the shaft.

10. The structure of claim **9** in which the brush means of limitation (k) comprise

l. a plurality of electrically conductive segments insulated from one another and disposed in circumferentially spaced relation in respect to the second cylinder and having areas of electrical contact complementary in shape to and coinciding with the second cylinder, and

m. separate electric circuit means connections for each segment of the brush means.

11. The structure of claim **3** in which

k. electrically conductive brush means for supplying electric current to the second segmental elements, having an electrical contact area complementary in shape to and coinciding with the second cylinder, make simultaneous electrical contact with a plurality of adjacent second segmental elements in number such that less than one half the total number of second segmental elements are in electrical contact with the brush means at any one time during revolution of the structure about the longitudinal axis of the shaft.

12. The structure of claim 11 in which the brush means of limitation (k) comprise

l. a plurality of electrically conductive segments insulated from one another and disposed in circumferentially spaced relation in respect to the second cylinder and having areas of electrical contact complementary in shape to and coinciding with the second cylinder, and

m. separate electric circuit means connections for each segment of the brush means.

13. The structure of claim 2 in which

j. electrically conductive brush means for supplying electric current to the second segmental elements, having an electrical contact area complementary in shape to and coinciding with the second cylinder, make simultaneous electrical contact with a plurality of adjacent second segmental elements in number such that less than one half the total number of second segmental elements are in electrical contact with the brush means at any one time during revolution of the structure about the longitudinal axis of the shaft.

14. The structure of claim 13 in which the brush means of limitation (j) comprise

k. a plurality of electrically conductive segments insulated from one another and disposed in circumferentially spaced relation in respect to the second cylinder and having areas of electrical contact complementary in shape to and coinciding with the second cylinder, and

l. separate electric circuit means connections for each segment of the brush means.

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