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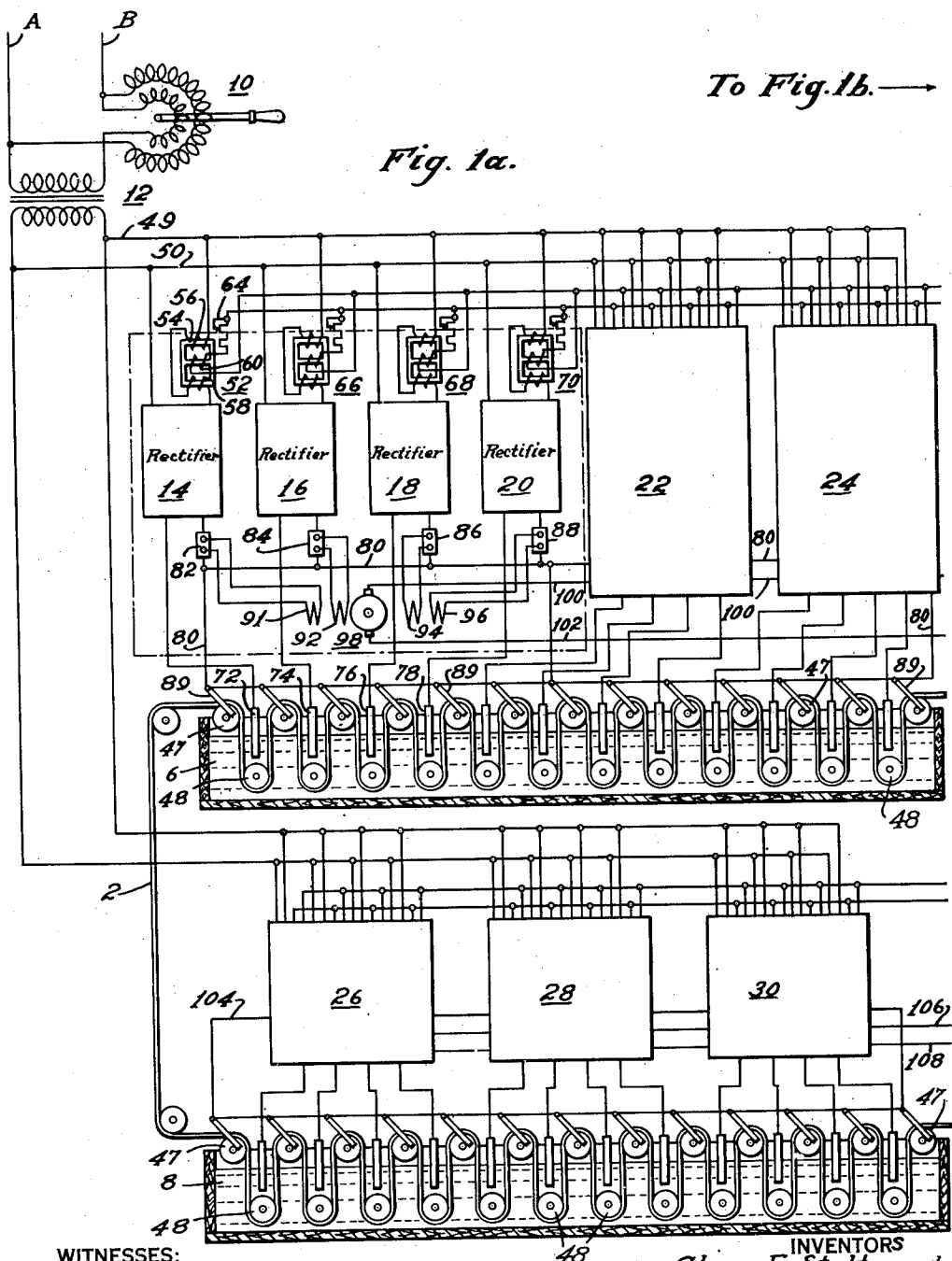
G. E. STOLTZ ET AL

2,473,918

CONTROL SYSTEM FOR ELECTROLYTIC PROCESSES

Filed Dec. 8, 1942

2 Sheets-Sheet 1



WITNESSES:

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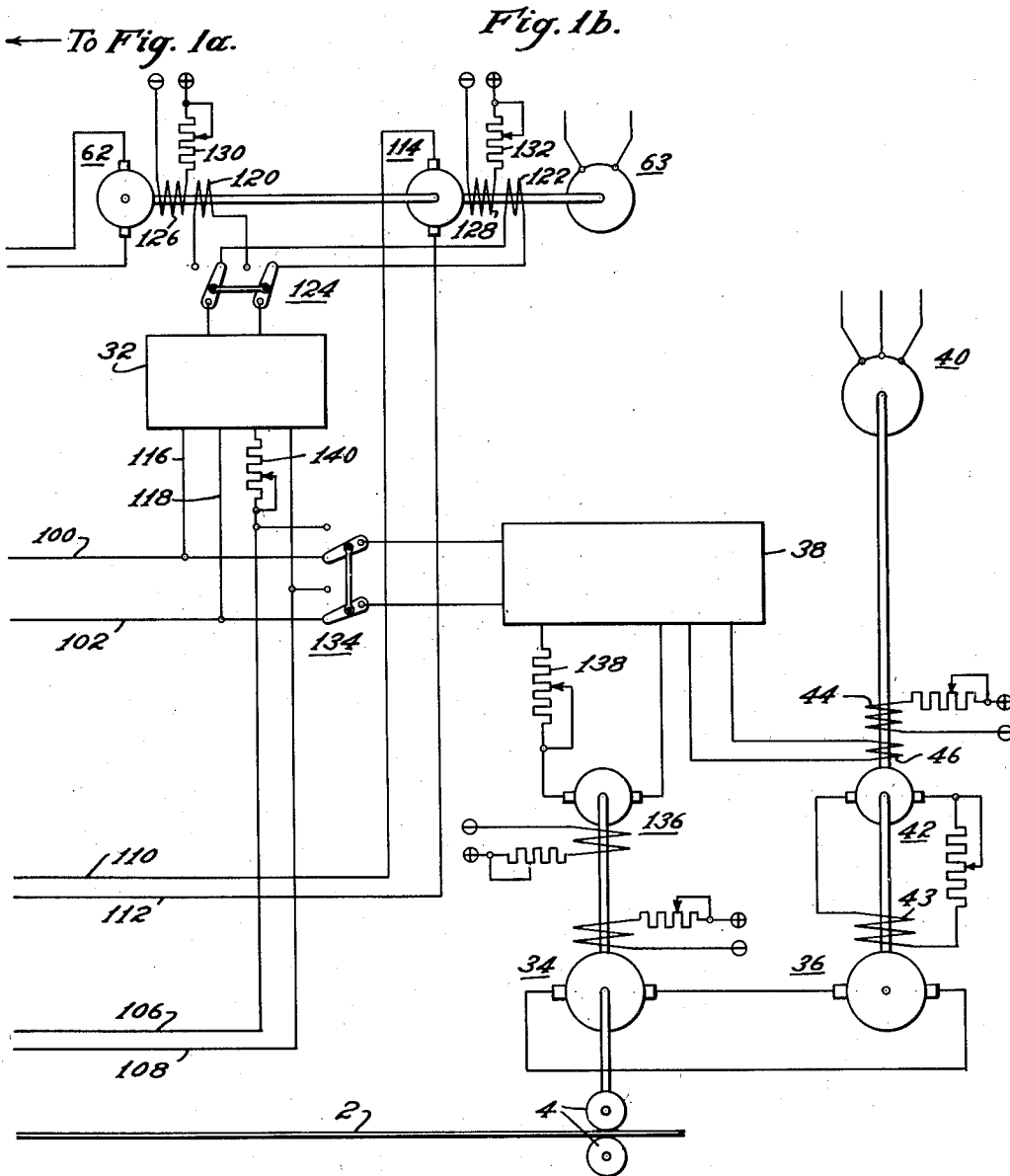
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UNITED STATES PATENT OFFICE

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CONTROL SYSTEM FOR ELECTROLYTIC PROCESSES

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The present invention relates, generally, to control systems, and, more particularly, to the control of the electrolytic treatment of continuously moving lengths of material.

In the manufacture of metal coated or plated materials such as tin-plate, it has been the practice to apply the coating material to the material to be coated by dipping it into the molten coating material. It has been found that this process is wasteful of the coating material for the reason that it is very difficult to control the thickness of the coating and, as a consequence, much more of the coating is used than is necessary to properly coat the material for the purpose for which it is to be used.

It has been found that such coatings may be applied very uniformly by electrolytic means, and long sheets of material have been thus coated by passing them through an electrolytic bath. The amount of material deposited electrolytically is a function of the length of time the material to be coated is exposed to the plating current and the density of the plating current. It will be apparent then that a uniform deposit of coating material will be made upon a strip of material as it moves through an electrolytic plating bath at a constant speed while the current density is kept constant.

In order to expedite the production of plated material by this electrolytic process, it has been found that the process can be made continuous by securing the ends of successive lengths of material together as they are fed to the plating apparatus to thereby avoid stopping the length of material and the plating apparatus for the purpose of threading each new length of material through the plating apparatus. In the operation of such a plating system, it is necessary that the speed of travel of the length of material through the plating apparatus be decreased materially when the next succeeding length of material is to be attached thereto to form the continuous length of material. It will be apparent that this decrease of the speed of the length of material through the plating bath will cause the length of material to be acted upon by the plating current for a greater period of time than when it is traveling at normal speed, and it will be necessary to decrease the density of the plating current to prevent the deposition of an excess quantity of coating material.

It has been proposed that coatings of different materials and/or of different thickness be electrolytically plated upon the two sides of strip material to

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meet the different functional requirements of the coatings on the two sides of the strip.

An object of the present invention is to provide a control system for an electrolytic process for continuously treating a continuously moving length of material which shall function to electrolytically treat different portions of the length of material differently, and which shall function to so control the speed of travel of the length of material as to produce uniform treatment of the length of material regardless of changes of speed of the length of material and/or the electrolytic current density.

A further object of the invention is to provide a control system for an electrolytic process for continuously treating a continuously moving strip of material which shall function to treat the two sides of the strip differently, and which shall so coordinate the current density acting on the two sides of the strip and the speed of travel of the strip as to produce uniform treatment of the two sides of the strip regardless of changes in the speed of travel of the strip through the process.

These and other objects and advantages of the invention will be apparent from the following detailed description taken in connection with the accompanying drawings which are a diagrammatic representation of an electrolytic strip tinning system embodying the principal features of the invention. The drawings comprise Figs. 1a and 1b, which when joined as indicated on the drawings constitute a single figure.

Referring to the drawings for a general description of the invention, a length or strip of material 2 is drawn by means of motor driven pinch rolls 4 through electrolytic baths 6 and 8 in succession. One side of the strip 2 is subjected to electrolytic treatment in the bath 6 and the other side is subjected to treatment in the bath 8. Current is supplied to the electrolytic bath 6 through a selectively variable voltage regulator 10, a transformer 12, rectifier units 14, 16, 18 and 20, and groups of rectifier units 22 and 24. Current is supplied to the electrolytic bath 8 through the rectifier groups 26, 28 and 30.

A regulator 32 functions in response to the currents supplied to the electrolytic baths 6 and 8 to so regulate the current in one of these baths as to maintain a predetermined proportion between the currents in the two baths. A motor 34 drives the pinch rolls 4 and its speed, and therefore the speed of the strip, is controlled by a variable voltage generator 36 which ener-

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gives the motor armature. A regulator 38 operates in response to the speed of the strip and the current flowing to either selected one of the electrolytic baths to so control the voltage of the generator 36 as to maintain a predetermined relation between the strip speed and the electrolytic current.

Considering the invention more in detail, the generator 36 may be continuously driven by any suitable means such as an induction motor 40. An exciter generator 42 may also be driven by the motor 40 and is connected to energize the field winding 43 of the generator 36. The exciter generator 42 has main and auxiliary field windings 44 and 46. By means of the motor 34 and the pinch rolls 4, the strip 2 may be drawn through the electrolytic baths 6 and 8 over the sets of idling rolls 47 and 48 and the speed of the travel of the strip may be varied by varying the energization of field windings 44 and 46 of the exciter generator 42 which in turn will vary the output potential of the generator 36 and therefore the speed of the motor 34.

The rectifiers 14, 16, 18 and 20 are connected to conductors 49 and 50 which in turn are connected to the secondary winding of the transformer 12. A saturable reactor 52 is connected in circuit between the rectifier 14 and the secondary of the transformer 12 to vary the energization of the rectifier 14 by varying the impedance in its alternating current circuit. The saturable reactor 52 comprises a core 54 on which there are wound alternating current windings 56 and 58 and a direct current winding 60. The windings 56 and 58 are connected in series circuit with the rectifier 14 and the effective impedances of these windings is made to vary by varying the energization of the direct current winding 60 to thus vary the degree of saturation of the core 54. The winding 60 is connected to be energized by a generator 62 which is continuously driven by any suitable motor 63. A variable resistor 64 is connected in series circuit relation with the direct current winding 60 to provide further adjustment of the energization of the winding 60. The energization of the rectifiers 16, 18 and 20 may also be varied by means of saturable reactors 66, 68 and 70, respectively, which are connected to be acted upon by the generator 62 simultaneously with the saturable reactor 52 and which have variable resistors connected in the circuits of their direct current windings similar to the variable resistor 64 which is associated with the saturable reactor 52.

One direct current terminal of the rectifiers 14, 16, 18 and 20 is connected to electrodes 72, 74, 76 and 78, respectively, in the electrolytic bath 6. The other direct current terminal of each of the rectifiers 14, 16, 18 and 20 is connected to a bus conductor 80 through shunt devices 82, 84, 86 and 88, respectively, and the bus 80 is in turn connected to the several contact members 89 which serve to conduct the current to the strip 2 through the several idling rolls 47. The shunt members 82, 84, 86 and 88 are connected to field windings 91, 92, 94 and 96, respectively, of a continuously driven direct current generator 98. The output potential of the generator 98 is applied to conductors 100 and 102.

The boxed groups of rectifier units 22 and 24 may each comprise a plurality of rectifier units and their control members associated with a current responsive generator, such as the generator 98, having their individual units controllable by the generator 62 and having their direct current

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terminals connected to energize the bus conductor 80 and individual electrodes in the electrolytic bath 6. The current responsive generators associated with the groups of rectifiers 22 and 24 may be connected in series circuit relation with the current responsive generator 98 so that the total potential on the conductors 100 and 102 will be proportional to the sum of the currents supplied to the electrolytic bath 6 by the group of rectifiers comprising the units 14, 16, 18 and 20, and the groups 22 and 24.

The groups of rectifiers 26, 28 and 30 may be connected to supply direct current to the electrolytic bath 8 similar to those associated with electrolytic bath 6 through a bus conductor 104 and through connections of the individual rectifier units to the respective electrodes in the bath. The groups of rectifier units 26, 28 and 30 may be connected to be controlled by the variable voltage regulator 10.

The groups of rectifier units 26, 28 and 30 may also each have associated therewith a current responsive generator similar to the generator 98 and these generators may be connected in circuit to energize conductor 106 and 108 which are connected to energize the regulator 32. The saturable reactors of the groups of rectifier units 26, 28 and 30 may be energized through conductors 110 and 112 by a generator 114 which is also continuously driven by the motor 63. The regulator 32 is also responsive to the potentials on the conductors 100 and 102 which are connected therewith by means of conductors 116 and 118.

The regulator 32 may be selectively connected to energize either a field winding 120 of the generator 62 or a field winding 122 of the generator 114 by means of a circuit selecting switch 124. The generators 62 and 114 also have main field windings 126 and 128 whose energization may be varied by associated variable resistors 130 and 132, respectively.

The regulator 38 may be selectively connected to be energized by the potential on the conductors 100 and 102 or the potentials on the conductors 106 and 108 by means of a circuit selecting switch 134. The regulator 38 is also connected to be energized by a pilot generator 136 which is driven by the motor 34 and therefore has an output potential proportional to the speed of the motor 34 and the strip 2.

In the operation of the system when it is desired to vary the speed of travel of the strip 2 through the electrolytic baths 6 and 8, the variable voltage regulator 10 may be actuated to vary the energization of all the rectifier units and thereby vary the amount of direct current supplied to the electrolytic baths 6 and 8. As a result of the variation of the current supplied to the electrolytic baths the regulator 38 will so change the energization of the field winding 46 of the exciter generator 42 as to so change the output potential of the generator 36. This will so change the speed of the strip driving motor 34 and vary the speed of the strip 2 as to maintain the desired proportionality between the total electrolytic current and the speed of the strip. With this proportionality between the electrolytic current and the strip speed maintained at the desired value the thickness of the plate deposited upon the strip will be substantially constant regardless of changes of the speed of the strip and/or the electrolytic current. This proportionality between the speed of the strip and the electrolytic current may be varied by means of a variable resistor 138 in series with

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the pilot generator 135 which varies the energization of the regulator 38 by the pilot generator 136 per unit of speed of the strip 2.

It will be noted that as the strip 2 passes through the electrolytic bath 6, a greater deposit of the plating material will be made on one side of the strip than the other because of the closer proximity of the plating electrodes to the one side of the strip as it passes through the bath. When the strip passes through the electrolytic bath 8 in the reverse direction, however, it will be noted that the other side of the strip is exposed to the greater plating action. Thus, the two sides of the strip may be subjected to different amounts of electrolytic action or have deposited thereon different amounts of the plating material by varying the electrolytic currents supplied to the strip by the separate baths 6 and 8.

The proportionate amounts of electrolytic currents supplied to the two baths 6 and 8 may be varied by varying excitations of the generators 62 and 114 each of which simultaneously varies the alternating current energization of the rectifier units associated therewith by means of the variation of the saturation of their associated saturable reactors. When it is desired to maintain a predetermined proportionality between the electrolytic currents acting in the baths 6 and 8 to thus produce a predetermined proportionality between the plating deposited on the two sides of the strip 2, a variable resistor 140 may be so adjusted as to cause the regulator 32 to respond to variations from the predetermined proportionality and to vary the excitation of either the field winding 120 or 122 depending upon the position of the selecting switch 124 to thus so vary the electrolytic current in the selected one of the baths as to maintain the desired proportionality.

It is to be understood that the regulators 32 and 38 may be any regulators in common use which will respond to variations in the proportionality of potentials applied thereto and function to control an electroresponsive element in response to variations in these potentials. Such a regulator and its functioning is shown and described in a copending application of W. G. Cook, Serial No. 458,362, filed September 15, 1942, now Patent Number 2,427,661.

It is further to be understood that the individual rectifiers may be any rectifier elements now in common use whose direct current potential varies with the alternating current potential applied thereto, and that any desired means for varying the reactances in series with the individual rectifiers may be employed in the place of the specific saturable reactors described herein.

While the invention has been described as applying to two separate electrolytic baths merely for the purpose of illustrating one manner in which different electrolytic actions may be effected on the two different sides of a strip of material, it is to be understood that the invention may be applied equally well to a system in which the sets of electrodes on the two sides of the strip are so disposed in a single bath and are so energized as to produce different electrolytic effects on the two different sides of the strip.

It is also to be understood that the invention has been described in connection with the process of continuously electroplating a strip of material merely to illustrate one electrolytic process to which the system is applicable and that the

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system is equally applicable to any of several electrolytic processes such as cleaning a continuously moving strip of material and the like.

Thus it will be seen that we have provided a control system for an electrolytic process for continuously treating a continuously moving length of material which shall function to electrolytically treat different portions of the electrolytic material differently, and which shall function to so control the speed of travel of the length of material as to produce uniform treatment of the length of material regardless of changes of speed of the length of material and/or the electrolytic current density.

In compliance with the requirements of the patent statutes, we have shown and described herein a preferred embodiment of our invention. It is to be understood, however, that the invention is not limited to the precise construction shown and described but is capable of modification by one skilled in the art, the embodiments herein shown being merely illustrative of the principles of our invention.

We claim as our invention:

1. In a control system for an electrolytic process employing a plurality of electrolytic baths, variable speed means for causing a length of material which is to be electrolytically treated to move through the baths, means for supplying current to the electrolytic baths, separate means for varying the current supplied to the separate baths, regulator means jointly responsive to the current flow in the separate baths, means for selectively connecting said regulator means in controlling relation with one of said current varying means to maintain a predetermined ratio between the currents supplied to the separate baths, and means responsive to the speed of travel of the strip and the current supplied to at least one of the baths for so controlling said variable speed means as to maintain a predetermined relation between the speed of travel of the length of material through the baths and the current flow in the baths.

2. In a control system for an electrolytic process employing a plurality of electrolytic baths, variable speed means for causing a length of material which is to be electrolytically treated to move through the baths, means for supplying current to the electrolytic baths, separate means for varying the current supplied to the separate baths, regulator means jointly responsive to the currents flowing in the separate baths, means for selectively connecting said regulator means in controlling relation with one of said current varying means to maintain a predetermined ratio between the currents supplied to the separate baths, a second regulator means, means for selectively connecting said second regulator means to respond to the current flowing in any of the electrolytic baths, means connecting the second regulator means to respond to the speed of the length of material, and means controlled by the second regulator means for so varying the speed of said variable speed means as to maintain a predetermined relation between the speed of travel of the length of material through the baths and the current flow in the bath to which the second regulator means is selectively connected.

3. In a control system for an electrolytic process employing a plurality of electrolytic baths, means for causing a length of material which is to be treated electrolytically to move through the baths, variable potential means associated with

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each of the baths, means for varying the current flow in each of the baths in accordance with the output potential of its associated variable potential means, and regulator means jointly responsive to the current flow in the separate baths for varying the potential of a portion of said variable potential means in accordance with the proportions of the currents in the separate baths to thereby maintain a predetermined proportionality between the currents in the separate baths.

4. In a control system for an electrolytic process employing a plurality of electrolytic baths, variable speed means for causing a length of material which is to be treated electrolytically to move through the baths, a generator associated with each of the baths, means for varying the current flow in each of the baths in accordance with the output potential of its associated generator, regulator means jointly responsive to the current flow in the separate baths for varying the potential of a portion of said generators in accordance with the proportions of the currents in the separate baths to thereby maintain a predetermined proportionality between the currents in the separate baths, and other regulator means responsive to the current in certain of said baths and the speed of travel of the length of material through the baths for so controlling the variable speed means as to maintain a desired proportionality between the speed of the length of material and the current in the baths.

5. In a control system for an electrolytic process employing a plurality of electrolytic baths, variable speed means for causing a length of material which is to be treated electrolytically to move through the baths, a generator associated with each of the baths, means for varying the current flow in each of the baths in accordance with the output potential of its associated generator, first regulator means jointly responsive to the current flow in the separate baths, selective circuit control means for connecting the regulator means to vary the potential of a desired portion of the generators to thereby maintain a desired ratio between the currents of the separate baths, second regulator means, means for selectively connecting said second regulator means to respond to the current flowing in any of the electrolytic baths, means connecting the second regulator means to respond to the speed of the length of material, and means controlled by said second regulator means for so varying the speed of said variable speed means as to maintain a predetermined relation between the speed of travel of the length of material through the baths and the current flow in the bath to which the second regulator means is selectively connected.

6. In a control system for an electrolytic process employing a plurality of electrolytic baths for treating a length of material as it passes through the baths, a group of electrolytic current supplying units associated with each of the baths, each unit of the groups connected to supply current to individual electrodes of its associated bath, means for varying the current supplied by each of the current supply units separately, means for varying the current supplied to each of the individual baths separately, means for varying the current supplied to the baths simultaneously, and means jointly responsive to the current flow in the separate baths for so actuating the separate bath current varying means for certain of the baths as to maintain a pre-

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determined relation between the currents of the separate baths.

7. In a control system for an electrolytic process employing a plurality of electrolytic baths for treating a length of material as it passes through the baths, a plurality of groups of rectifier units each connected to supply current to a separate bath, first means for so adjusting the individual rectifier units of each group as to provide a desired proportionality between the currents supplied by the rectifier units associated with each of the baths, second means associated with each of the groups of rectifiers which supply the separate baths for simultaneously varying the current supplied by the rectifiers of the group, third means for simultaneously varying the current supplied by all of the rectifiers, and means jointly responsive to the current flow in the separate baths for so actuating said second means associated with a portion of the baths as to maintain a predetermined proportion between the currents supplied to the separate baths.

8. In a control system for an electrolytic process employing a plurality of electrolytic baths, variable speed means for causing a length of material which is to be electrolytically treated in the baths to travel through the baths, a plurality of groups of rectifier units each connected to supply current to a separate bath, first means for so adjusting the individual rectifier units of each group as to provide a desired proportionality between the currents supplied by the rectifier units associated with each of the baths, second means associated with each of the groups of rectifiers which supply the separate baths for simultaneously varying the current supplied by the rectifiers of the group, third means for simultaneously varying the current supplied by all of the rectifiers, means jointly responsive to the current flow in the separate baths for so actuating the second means associated with a portion of the baths as to maintain a predetermined proportion between the currents supplied to the separate baths, and regulator means responsive to the speed of travel of the length of material and the current flowing in a portion of the baths for so controlling the variable speed means as to maintain a predetermined relation between the electrolytic current and the speed of the length of material.

9. In a control system for an electrolytic process employing a plurality of electrolytic baths for treating a length of material as it passes through the baths, a plurality of groups of rectifier units each connected to supply current to a separate bath, means for varying the potential applied to the rectifier units from an alternating current source of power, a saturable reactor individual to each rectifier unit for controlling the output thereof comprising an alternating-current winding in circuit between the source of alternating-current power and each of the rectifier units and a direct-current saturating winding, individual means for varying the direct-current energization of each of the reactors, means individual to each group of reactors for varying the direct-current potential applied to the separate groups of reactors, and regulator means jointly responsive to the current flow in the separate baths for so controlling a portion of the said potential varying means as to maintain a predetermined relation between the currents in the separate baths.

10. In a control system for an electrolytic process employing a plurality of electrolytic

baths, variable speed means for causing a length of material which is to be electrolytically treated to move through the baths, a plurality of groups of rectifier units each connected to supply current to a separate bath, means for varying the potential applied to the rectifier units from an alternating current power source, a saturable reactor associated with each of the rectifier units comprising an alternating-current winding in circuit between the source of alternating current power and each of the rectifier units and a direct-current saturating winding, individual means for varying the direct-current energization of each of the reactors, means individual to each group of reactors for varying the direct-current potential applied to the separate groups of reactors, regulator means jointly responsive to the current flow in the separate baths for so controlling said potential varying means as to maintain a predetermined relation between the currents in the separate baths, and regulator means jointly responsive to the current flow in a portion of the baths and the speed of travel of the length of material through the baths for so actuating said variable speed means as to maintain a predetermined relation between the current in the baths and the speed of the length of material.

11. In a control system for an electrolytic process employing a plurality of separate groups of electrodes, means associated with each group of electrodes for supplying electric current of variable amounts thereto from a power source, control means for controlling each of said current supplying means to provide for individually controlling the current supplied to each group of electrodes, and means including regulator means jointly responsive to the currents delivered by the current supplying means to the separate groups of electrodes for controlling at least one of said control means to maintain a predetermined ratio between the currents in the separate groups of electrodes.

12. In a control system for an electrolytic process employing a plurality of separate groups of electrodes, means associated with each group of electrodes for supplying electric current of variable amounts thereto from a power source, said means including a group of rectifier units and control means associated with each rectifier unit for individually controlling its output current, means associated with each group of rectifier units for collectively controlling the control means thereof, each of said means being operable to cause its associated group of rectifiers to deliver a predetermined amount of current to its associated group of electrodes, means associated with each group of rectifier units operable to produce a control potential proportional to the current output thereof, regulator means jointly responsive to said control potentials, switch means selectively operable to render any

one of the said means associated with each group of rectifier units responsive to said regulator means to thereby maintain a predetermined relation between the currents delivered to the separate groups of electrodes, and means for modifying the effect of at least one of the said control potentials on the regulator means, thereby to vary the ratio of the currents so maintained.

13. In a control system for an electrolytic process employing a plurality of electrolytic baths, motor-operated means for actuating a length of material to be treated through the baths, a variable-voltage main generator for supplying power to said motor operated means, an exciter generator for said main generator, a pilot generator actuated in accordance with the speed of the length of material through the baths, a plurality of rectifier units connected to each bath for supplying direct current thereto from a power source, variable reactor means associated with each rectifier unit for varying the potential applied thereto from the power source, a control generator associated with each group of rectifier units for collectively controlling the variable reactor means thereof, means for driving said control generators in unison, means for selectively varying the output potentials of said control generators to individually control the current delivered to the separate baths by the separate groups of rectifier units, generator means associated with each group of rectifier units operable to produce a control potential proportional to the total output current of each group, first regulator means responsive to said control potentials operable to also vary the output potential of said control generators to thereby maintain a predetermined ratio between the currents in the separate baths, second regulator means jointly responsive to at least one of said control potentials and the output potential of said pilot generator operable to control the excitation of the said exciter generator for the main generator to maintain a predetermined ratio between the speed of the material and the current in the baths.

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