May 31, 1949. G. E. STOLTZ ET AL 2,471,912

CONTROL OF ELECTROLYTIC PROCESSES

Filed Dec. 8, 1942 2 Sheets-Sheet 1

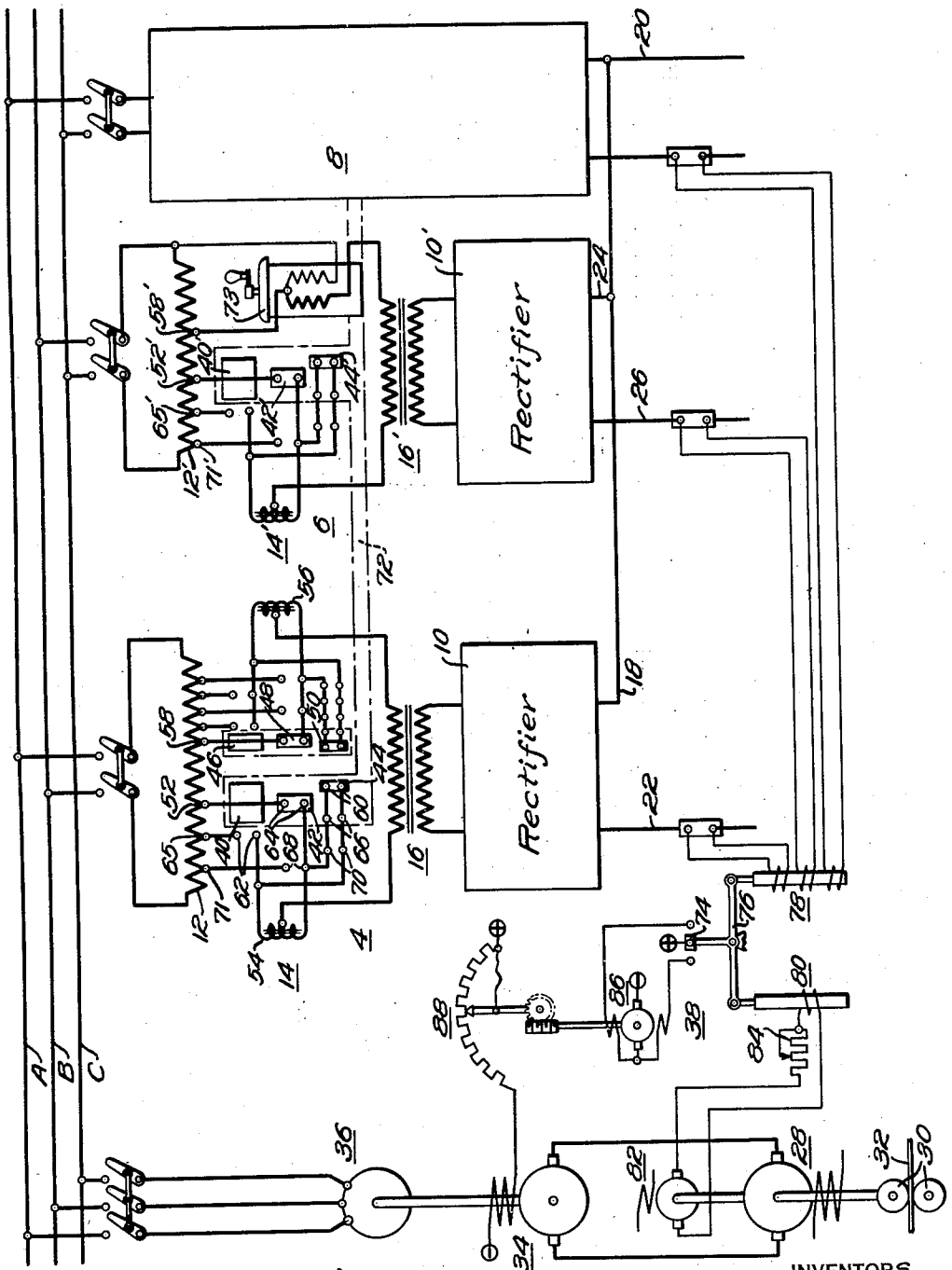


Fig. 1.

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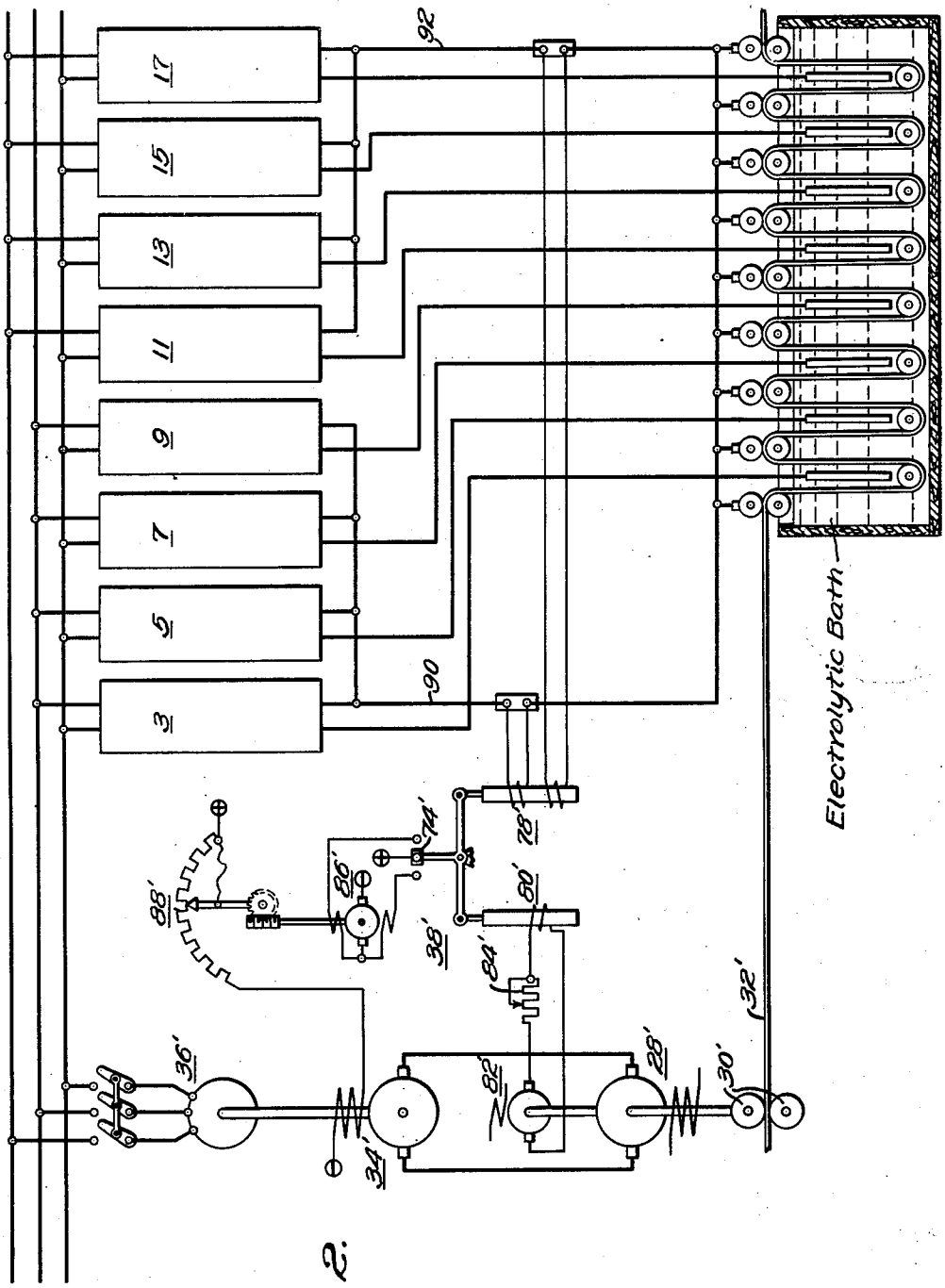


Fig. 2.

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Patented May 31, 1949

2,471,912

UNITED STATES PATENT OFFICE

2,471,912

CONTROL OF ELECTROLYTIC PROCESSES

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Application December 8, 1942, Serial No. 468,216

10 Claims. (Cl. 204—211)

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The present invention relates, generally, to electrolytic processes, 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 material is used than is necessary to properly coat the material for the purpose for which it is intended to be used.

It has been found that such metal 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 at a constant speed through an electrolytic bath and the current density is kept constant.

In order to expedite the production of plated material by this electrolytic process, it has been proposed that the process 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 continuous 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 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 provide a simultaneous decrease of plating current and speed of the length of material to prevent the deposition of an excess quantity of coating material.

An object of the present invention is to provide a control system for a continuous electrolytic

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process which shall function to coordinate the current density and speed in the process.

Another object of the invention is to provide a control system for an electrolytic process for continuously treating a continuously moving length of material which shall function to so coordinate the current supplied to the electrolytic process and the speed of travel of the length of material as to produce uniform treatment of the length of material regardless of changes in the current.

A further object of the invention is to provide a control system for an electrolytic plating process for plating a continuously moving length of material which shall function to so coordinate the speed of travel of the length of material and the plating current density as to produce a uniform plate thickness regardless of changes in the plating current density.

A further object of the invention is to provide a control system for an electrolytic process which shall function to vary the speed of travel of a strip through the process by varying the current flow in the process and automatically varying the speed of the strip in accordance with the current flow.

These and other objects and advantages of the invention will be apparent from the following detailed description taken in connection with the accompanying drawings in which like reference characters designate like structural elements and in which:

Figure 1 is a diagrammatic representation of an electrolytic plating system embodying the principal features of a preferred embodiment of the invention; and

Fig. 2 is a diagrammatic representation of an electrolytic plating system employing another embodiment of the invention.

In practicing the embodiment of the invention of Fig. 1, each unit of a plurality of plating current supply units 4, 6 and 8 is disposed to be connected to an alternating current source designated by conductors A—B—C. The current supply unit 4 comprises a rectifier 10 which is disposed to be energized from the alternating current power source through an auto-transformer 12, a voltage control device 14, and a step down transformer 16. A conductor 18 extends from the rectifier 10 to a bus 20 which may be connected to one electrode of an electrolytic bath (not shown) and a conductor 22 may extend to another electrode of the electrolytic bath. The supply unit 6 comprises a rectifier 10', an auto-transformer 12', a voltage control device 14' and

a step-down transformer 16' and has one of its direct current terminals connected by conductors 24 and 18 to the common conductor 20 and the other connected by a conductor 26 to an electrode of the electrolytic bath. The supply unit 8 may be similar in structure to and have connections similar to the supply units 4 or 6.

A direct current motor 28 is disposed to drive a set of pinch rolls 30 by which a strip of material 32, which is being electroplated, is pulled through the electrolytic bath. The motor 28 is disposed to be energized by a generator 34 which may be driven by any convenient means, such as an alternating current motor 36. A regulator 38 is disposed to be actuated in accordance with the speed of the strip 32 and the total plating current to vary the speed of the strip in accordance with variations of the plating current.

The embodiment of the invention of Fig. 2 is similar to that of Fig. 1 and illustrates a method by which groups of current supply units may be connected to the electrodes of the electrolytic bath and to the regulator 38'.

Considering the invention more in detail, the voltage control device 14 comprises contact elements 40, 42 and 44 which are simultaneously movable by any suitable control device and a similar set of contact elements 46, 48 and 50. With the contact elements 40, 42 and 44 in the position shown in the drawing the primary winding of the transformer 16 is connected to be energized in a circuit extending from a tap 52 of the auto-transformer 12, through the contact element 42, the contact element 44 to the opposite terminals of a reactor 54, from a mid tap of the reactor 54 through the primary of the transformer 16 to the mid tap of a reactor 56, through the end terminal of the reactor 56 and the contact element 50, through the contact element 48 to a tap 58 of the auto-transformer 12. With these connections it will be seen that the rectifier 10 will be energized by a minimum potential from the power source A—B—C through the auto-transformer 12.

When it is desired to increase the potential acting on the rectifier 10, the contact elements 40, 42 and 44 may be moved in the left hand direction. The contact elements 40, 42 and 44 are so disposed that when they are moved in the left hand direction the contact element 44 will be moved from engagement with the fixed contact elements 60 just before the contact element 40 engages the contact elements 62, and the contact element 42 will be moved from engagement with the fixed contact elements 64 just after the contact element 40 engages the contact element 62. With removal of the connection between the terminals of the reactor 54 by movement of the contact 44 from engagement with the fixed contact elements 60, the lower portion of the reactor 54 will be connected in series circuit with the primary of the transformer 16 and when the contact element 40 engages the fixed contact elements 62, the reactor 54 will be connected in series circuit with the portion of the auto-transformer 12 between the taps 52 and 65. The reactor 54 may be of such characteristics as to limit the flow of current through the reactor when it is thus connected to the winding of the transformer 12.

When, upon further movement, the contact element 42 disengages the fixed contact elements 64, the upper portion of the reactor 54 will be connected in series circuit with the primary of the transformer 16 and when the controller is moved to the position where the contact element 44 engages the fixed contact elements 66, the connection between the end terminals of the reactor 54 will again be established through the contact element 44. Thus, it will be seen that the reactor 54 functions to permit transition from one tap of the transformer 12 to another without opening the circuit to the transformer 16 and without placing too great a burden on the sections of the winding of the transformer 12 while changing from one tap to another. The contact elements 40, 42 and 44 will function in a similar manner when moved further in the left hand direction to engage the contact element 42 with the fixed contact elements 68, to then disengage the contact element 40 from the fixed contact elements 62, and to then engage the contact element 44 with the fixed contact elements 70 to thus increase the potential applied to the transformer 16 by connecting it to the tap 71 of the auto-transformer 12.

The contact elements 40', 42' and 44' function simultaneously with and in the same manner as the contact elements 40, 42 and 44 to thus simultaneously vary the plating current furnished by the several current supply units to the electrolytic bath. A connecting member 72 may serve to interconnect the simultaneously actuable contact element groups such as 40, 42 and 44, and 40', 42' and 44'.

In addition to the means for simultaneously varying the potentials supplied to the rectifiers each of the current supply units is provided with a vernier potential adjustment by which the potentials supplied to the individual rectifiers may be varied. The contact elements 46, 48 and 50 comprise the vernier potential varying device for the supply unit 4 and these contact elements may be moved to the right hand direction to function in a manner similar to the hereinbefore described functioning of the contact elements 40, 42 and 44 to vary the potential applied to the rectifier 10. A different type of vernier potential adjusting device is shown in connection with the current supplying unit 6 and comprises a manually adjustable voltage regulator 73 which may be any well known manually operable voltage regulator.

The regulator 38 comprises a contact element 74 mounted upon and movable by a pivot arm 76 which is actuatable by solenoids 78 and 80. A single winding of the solenoid 80 is connected to be energized by a pilot generator 82 through a calibrated resistor 84. The pilot generator 82 is driven by the motor 28 and thus has an output potential proportional to the speed of the strip 32. The solenoid 78 comprises a plurality of windings each of which is connected to a shunt in the conductors between each one of the rectifiers and the electrolytic bath. The solenoid is, therefore, energized in accordance with the total current supplied to the electrolytic bath by the supply units 4, 6 and 8. When there is a differential of energization of the solenoids 78 and 80 the contact elements 74 will be moved to circuit closing position to the right or left hand position to actuate a reversible motor 86, which in turn actuates a rheostat 88 in the circuit of the field winding of the generator 34.

In the operation of the system of Fig. 1 assuming that the contact elements of the voltage control device 14 are in the position shown in the drawing a very low current will be supplied to the strip 32 in the electrolytic bath and the strip will be moved through the bath very slowly. When it is desired to increase the speed of travel of the

strip, the contact elements 40, 42 and 44 may be moved in the left hand direction to increase the current flow in the electrolytic bath and this will result in the increased energization of the solenoid 78 to move the contact elements 74 to the right hand contact position. The motor 86 will then function to increase the energization of the field winding of the generator 34 by decreasing the effective resistance value of the resistor 88. The increase of the output potential of the generator 34 as a result of the increase of its excitation will cause a proportional increase in the speed of the motor 28 thus increasing the speed of the strip 32 and increasing the energization of the solenoid 80. When the speed of the strip has increased to the extent that the solenoid 80 is energized an amount equal to the energization of the solenoid 78, the contact elements 74 will be moved to the central position and the speed of the strip will be maintained constant until some further increase or decrease in the current flow to the electrolytic bath causes the regulator to effect the necessary change in speed of the strip 32.

It is to be understood that though only three current supply units are shown in the embodiment of the invention of Fig. 1, such current supply units may be necessary for certain electroplating operations. It will also be understood that there is a practical limit on the number of windings that may be placed on the solenoid 78 and the embodiment of the invention of Fig. 2 illustrates a method by which the solenoid 78' of the embodiment of the invention of Fig. 2 may be made to respond to the total current supplied by a large number of current supply units without having a number of windings for the solenoid 78 equal to the number of current supply units.

In the embodiment of the invention of Fig. 2, two common conductors 90 and 92 are connected to the terminals of one polarity of the electrolytic bath and groups of the current supply units are connected to these common conductors. Thus the current supply units 3, 5, 7 and 9 have individual conductors connected to electrodes of the electrolytic bath and their conductors of opposite polarity all connected to the common conductor 90. In a similar manner the current supply units 11, 13, 15 and 17 are connected to individual electrodes of the electrolytic bath and to the common conductor 92. The two windings of solenoid 78' are connected to be energized through the shunts of the conductors 90 and 92 and thus the sum of their energizations is a measure of the total current supplied to the electrolytic bath by the several current supply units.

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 so coordinate the current supplied to the electrolytic process and the speed of travel of the length of material as to produce uniform treatment of the length of material regardless of changes in the current.

In compliance with the requirements of the patent statutes, we have shown and described herein the preferred embodiments 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 the invention.

We claim as our invention:

1. In a control system for an electrolytic process, means for supplying variable amounts of current for the process, means for effecting the travel of a length of material through the electrolytic process at different speeds, and means jointly responsive to the current flow in the electrolytic process and the speed of travel of the length of material through the process for so controlling said second-mentioned means as to maintain a predetermined ratio of speed and current.

2. In a control system for an electrolytic process, a plurality of current supply units for supplying the current for the electrolytic process, means associated with at least one of the current supply units for varying the total current supplied to the electrolytic process by said supply units, and means jointly responsive to speed and current for automatically controlling the speed of travel of a length of material through the electrolytic process in accordance with the total current supplied to the electrolytic process by the plurality of supply units, thereby to maintain a predetermined ratio of speed and current.

3. In a control system for an electrolytic process, a plurality of current supplying units for supplying current to the electrolytic process, means for varying the current supplied by said units, an opposed-winding relay, means energizing one winding of the relay in accordance with the speed of travel of a length of material through the electrolytic process, means energizing the opposed winding of the relay in accordance with the total current supplied to the electrolytic process by the plurality of current supplying units, and means controlled by said relay for varying the speed of travel of the length of material to maintain a predetermined ratio between speed and current.

4. In a control system for an electrolytic process, a plurality of current supplying units for supplying variable amounts of current to the electrolytic process, variable speed means for causing a length of material to travel through the process an opposed-winding relay, said relay having a first winding and a plurality of opposing windings, means energizing said first winding of the relay in accordance with the speed of travel of a length of material through the electrolytic process, means individually energizing each of said opposing windings in accordance with the current supplied by a separate one of the current supply units, and means controlled by said relay for varying the speed of said variable speed means to control the speed of travel of the length of material through the electrolytic process in accordance with the total current in the process.

5. In a control system for an electrolytic process, means for supplying electric current to the process, a drive motor for effecting the movement of a length of material through the process, a continuously driven generator for energizing said motor, means for varying the current acting in the electrolytic process as desired, and means including regulator means for varying the excitation of said generator in accordance with variations of the proportionality between the speed of travel of the length of material and the current acting in the electrolytic process.

6. In a control system for an electrolytic process, a plurality of supply units for supplying current to the electrolytic process, means for varying the amount of current supplied to the electrolytic process by each of the supply units, variable-speed means for causing a length of material to travel through the process, a relay having a first winding and a plurality of windings opposed to the first winding, means including a pilot

generator for energizing said first winding in accordance with the speed of travel of the length of material through the electrolytic process, means energizing each of the opposed windings in accordance with the current supplied to the electrolytic process by a separate one of the current supply units, and means responsive to said relay for so varying the speed of the variable speed means and the travel of the length of material through the electrolytic process as to maintain a predetermined ratio between the total current supplied to the electrolytic process and the speed of the length of material.

7. In a system for controlling the deposition of plating material on a strip of material as it is passed through an electroplating bath, a plurality of rectifier units for supplying plating current to the plating bath, means for simultaneously varying the energization of the rectifiers to thereby simultaneously vary the amount of current supplied to the plating bath by the rectifiers, means for separately varying the energizations of the rectifiers to thereby vary the amount of plating current supplied by the separate rectifiers, means for varying the speed of the strip, and relay means jointly responsive to the total plating current supplied by the several rectifiers and the speed of the strip for actuating said speed varying means in accordance with variations of the total plating current, thereby to vary the speed of the strip in accordance with plating current.

8. In a control system for an electrolytic process, means for supplying electric current to the process, means operable to selectively control the current supplied to the process, actuating means operable at various speeds for effecting the travel of a length of material through the process, and control means including regulating means jointly responsive to the speed of the length of material through the process and the current in the process for controlling the speed of said actuating means in accordance with the current in the process to maintain a predetermined ratio between speed and current.

9. In a control system for an electrolytic process, means including current rectifier means for supplying direct current for the process, means operable to adjust the amount of current supplied to the process, motor-operated means operable to cause a length of material to be moved through the process, a variable voltage generator for supplying power to said motor means, a motor-operated rheostat for controlling the voltage of said generator to control the speed of the motor-operated means and the speed of travel of the material, and relay means jointly responsive to the current supplied to the process and the speed of travel of the material for controlling the operation of the motor-operated rheostat.

10. In a control system for an electrolytic process, means including current rectifier means for supplying direct current for the process, means operable to adjust the amount of current supplied to the process, motor-operated means operable to cause a length of material to be moved through the process, a variable voltage generator for supplying power to said motor means, a motor-operated rheostat for controlling the voltage of said generator to control the speed of the motor-operated means and the speed of travel of the material, a differential relay having opposed operating windings operable to control the motor-operated rheostat, a pilot generator driven in accordance with the speed of travel of the material for energizing one of said opposed windings with a voltage proportional to said speed, and means connecting the other of said opposed windings to be energized in accordance with the current in the process, thereby to provide for maintaining a predetermined ratio between speed and current.

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