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W. G. COOK

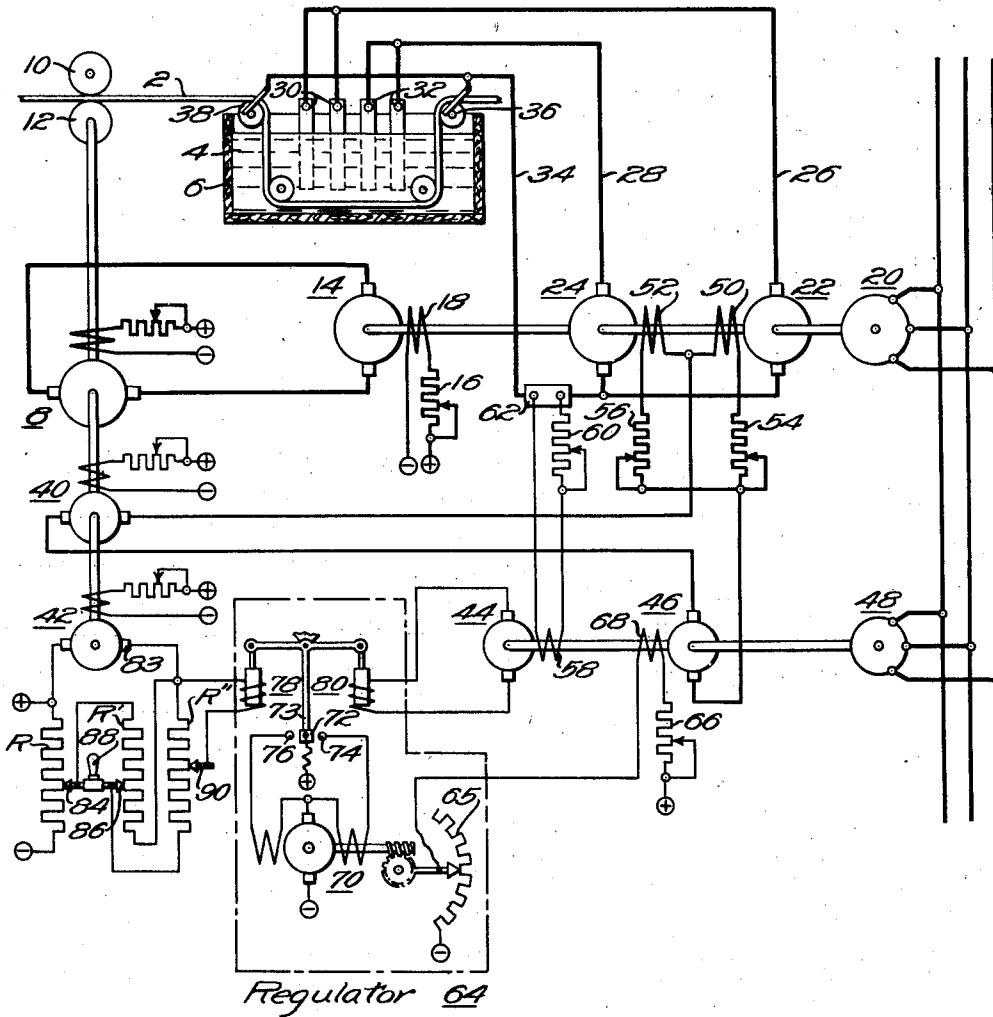
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CONTROL OF ELECTROLYTIC PROCESSES

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2 Sheets-Sheet 1

Fig. 1.



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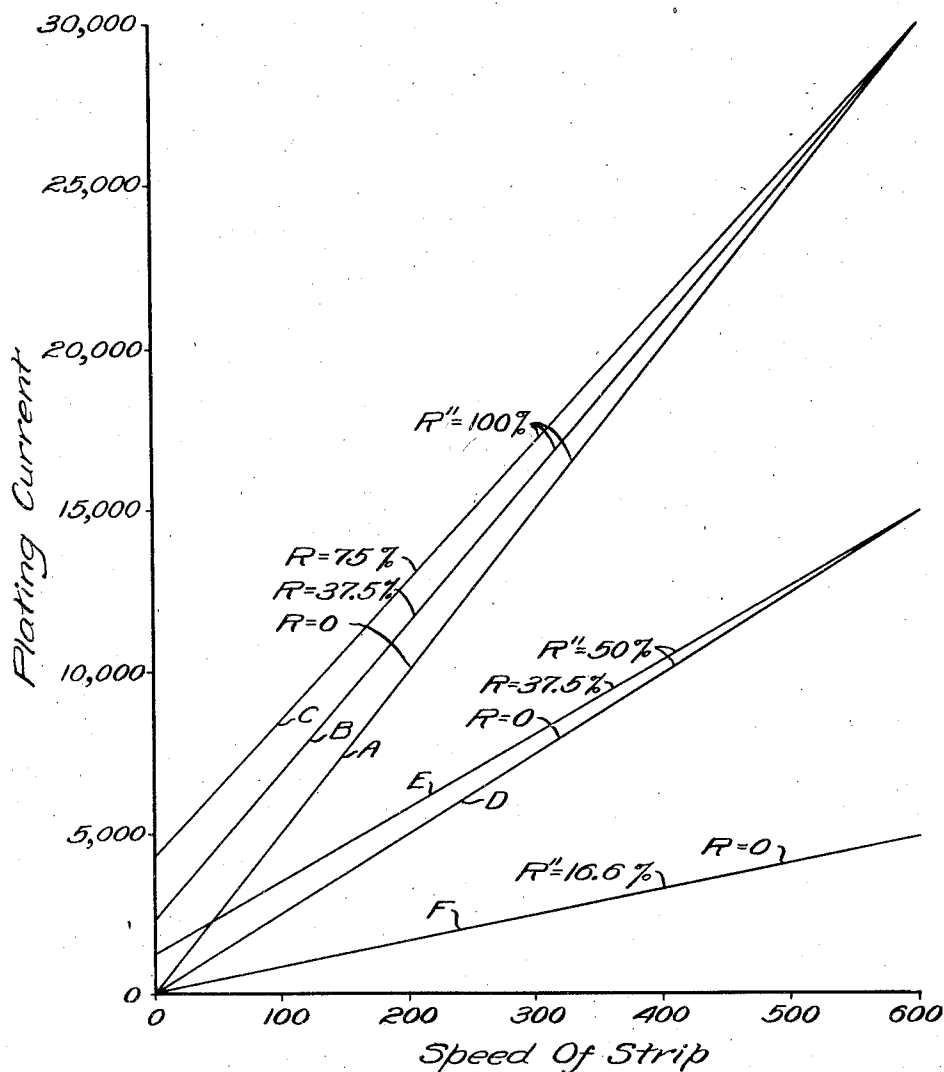
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Fig. 2.

Plating Current As Function
Of Speed At Various Settings Of
Resistors R, R' And R''



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CONTROL OF ELECTROLYTIC PROCESSES

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

In the manufacture of electrolytically coated or plated materials such as tin-plate, the material to be coated may be continuously passed through the electrolyte while the continuous length of material is formed by attaching the leading end of each successive length of material to the following end of each preceding length of material. This procedure requires that the normal speed of movement of the length of material through the electrolyte be reduced while each attaching operation is taking place.

The quantity of electrolytically deposited material is a function of the current density and the length of time the material is subjected to the electroplating process. It will be apparent, then, that when the speed of travel of the material through the electrolyte is reduced, the density of the plating current will have to be reduced to avoid wasting the plating material by making too great a deposit of the plating material on the length of material that is being plated.

It has been found that under certain circumstances the plating current should vary in direct proportion to the variations of the speed of the length of material in order to produce a uniform thickness of plate, while under other circumstances the plating current must vary as a function of, but not in direct proportion to, the speed of the length of material.

An object of the present invention is to provide a control system for an electrolytic process which shall function to so coordinate the speed of travel of a length of material, which is being continuously treated in the process, with the density of the current acting in the process, as to produce uniform treatment of the length of material regardless of changes of speed of travel of the length of material.

Another object of the invention is to provide a control system for a process for electroplating a continuous length of moving material which shall function to vary the plating current in response to variations of the speed of travel of the length of material through the electrolyte and which shall be selectively adjustable to provide any desired proportionality between the speed of the length of material and the density of the plating current and any desired variation of such proportionality as the speed of the length of material varies.

These and other objects of the invention will be apparent from the following detailed description taken in connection with the accompanying drawings in which:

Figure 1 is a diagrammatic representation of 60

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an electrolytic plating system embodying the principal features of a preferred embodiment of the invention; and

Fig. 2 is a graphical representation of the functioning of the system shown in Fig. 1.

Referring to the drawings, a strip of material 2 is drawn through an electrolyte 4 in a tank 6 by means of a motor 8 which drives roll members 10 and 12 which, in turn, engage the strip 2. The armature of the motor 8 is connected to be energized by the generator 14 whose output potential may be varied by a rheostat 16 which varies the energization of its field winding 18. The generator 14 may be driven by any suitable means such as a substantially constant speed alternating current motor 20.

A plurality of plating generators such as generators 22 and 24 may be driven by the motor 20 and these plating generators are connected by means of conductors 26 and 28 to separate sets of plating electrodes 30 and 32. The other terminals of the generators 22 and 24 are connected by means of a common conductor 34 to contact rolls 36 and 38 which engage the strip 2 as it passes through the electrolyte.

Pilot generators 40 and 42 are connected to be driven by the motor 8 and their speeds are, therefore, proportional to the speed of travel of the strip 2 through the electrolyte 4. Generators 44 and 46 may be continuously driven by any suitable means such as a substantially constant speed alternating current motor 48. The generators 40 and 46 are connected in series circuit relation as indicated in the drawings to energize the field windings 50 and 52 of the plating generators 22 and 24, respectively, through variable resistors 54 and 56, respectively.

The generator 44 has a field winding 58 which is energized through a variable resistor 60 by the potential drop across a shunt device 62 in the common lead of the plating generators 22 and 24. The excitation of the generator 44 thus varies in accordance with the plating current and its output potential is, therefore, a measure of the plating current density. A regulator 64 functions to control a variable resistor 65 which is in series circuit with a variable resistor 66 and the field winding 68 of the generator 46 so that the output potential of this generator is varied in accordance with the setting of the variable resistor 65 by the regulator 64.

The regulator 64 comprises a reversible motor 70 which is connected in driving relation with the variable resistor 65 and which may be made to rotate in a reverse or forward direction by means of a movable contact element 72 in cooperation with fixed contact elements 74 and 76. The movable contact element 72 is mounted upon a pivoted arm 73 which is disposed to be op-

erated in opposite directions by solenoids 78 and 80.

A variable resistor R is connected to be energized by substantially constant potential and is connected in series circuit relation with the pilot generator 42. A variable resistor R' is connected between a terminal 83 of the generator 42 and the movable contact element 84 of the variable resistor R and is thus acted upon by the sum of the potentials of the generator 42 and the portion of the variable resistor R engaged by the contact element 84. A variable resistor R'' is connected between the terminal 83 of the generator 42 and the movable contact element 86 of the variable resistor R'. The contact elements 84 and 86 of the variable resistors R and R' are disposed to be moved simultaneously by an operating element 88 and the relation of the resistors R and R' are such that movement of the operating member 88 will cause a decrease in the selected value of the resistor R' across which the resistor R'' is connected when the resistor R is so varied as to increase the potential acting upon the resistor R'. The solenoid 78 is connected between the terminal 83 of the generator 42 and movable contact element 90 of the variable resistor R'' and thus exerts a force upon the pivoted arm 73 proportional to the potential acting on the variable resistor R'' between its movable contact element 90 and the terminal 83 which in turn is proportional to the potential acting upon the variable resistor R' which in turn is controlled by the position of the movable contact element 84 of the variable resistor R and the output potential of the generator 42.

The solenoid 89 is connected to be energized by the output potential of the generator 44 and therefore exerts a force in opposition to that exerted by the solenoid 78 upon the pivoted arm 73 proportional to the plating current.

In the operation of the system the pilot generator 40 will so control the excitation of the plating generators 22 and 24 as to cause the plating current to vary in accordance with variations of the speed of the strip 2 through the electrolyte 4. With the variable resistor R so adjusted that none of the biasing potential which acts upon resistor R is effective in the series circuit hereinbefore described which includes the generator 42, the potential acting upon the solenoid 78 will be directly proportional to the speed of the strip 2 and the regulator 64 will function to maintain the desired direct proportionality between the speed of the strip 2 and the density of the plating current. Under these circumstances with the movable contact element 90 of the variable resistor R'' in a position where all of the potential drop across the resistor R'' is acting upon the solenoid 78 the maximum plating current will be provided by maximum speed of the strip 2. This condition is illustrated by the curve A in the graph of Fig. 2 which shows that the plating current varies from 0 to 30,000 amperes in direct proportion to the speed of the strip when the speed of the strip varies from 0 to 600 feet per minute.

If it is desired that there be not a constant proportionality between the speed of the strip and the plating current but that this proportionality decrease as the speed decreases, the operating member 88 may be moved downward to cause some of the bias potential which is applied to the resistor R to be effective in the circuit of the pilot generator 42 and added to the potential of the pilot generator 42.

In order to retain the same maximum plating current at the maximum strip speed, the downward movement of the operating element 88 will cause a decrease in the amount of resistor R' which is effective to supply potential to the resistor R''. To compensate for the added biasing potential in the energizing circuit for the resistor R' under these conditions the zero strip speed and the potential of the pilot generator 42 will be zero but there will be a biasing potential acting in the circuit to so energize the solenoid 78 as to cause the regulator 64 to require that there be plating current of a predetermined value.

This condition is illustrated in curve B of the graph of Fig. 2 in which when 100% of the resistor R'' is effective to energize the solenoid 78 and 37.5% of the resistor R is effective to supply a biasing potential, the plating current will vary from approximately 2300 amperes at zero strip speed to 30,000 amperes at the maximum strip speed of 600 feet per minute.

If it is desired that there be a more gradual change of plating current with change of strip speed the operating member 88 may be moved to cause a greater amount of biasing potential to be effective and such a condition is illustrated by the curve C in the graph of Fig. 2. Under the conditions illustrated the resistor R is so adjusted that 75% of the biasing potential is effective and 100% of the potential drop across the resistor R'' is effective to energize the solenoid 78. It will be noted that the plating current varies from approximately 4270 amperes at zero strip speed and 30,000 at a strip speed of 600 feet per minute.

If it is desired that the range of variation of the plating current over the range of strip speed of 600 feet per minute be from zero to a maximum current value less than 30,000 amperes, the movable contact element 90 of the variable resistor R'' may be moved upward so that a smaller portion of the potential drop across the resistor R'' will be acting upon the solenoid 78. The curve D in the graph of Fig. 2 illustrated a condition where the variable resistor R'' is so adjusted that 50% of the potential acting across it is effective in the circuit of the solenoid 78 and the operating element 88 is so adjusted that none of the biasing potential is effected in circuit with the generator 42. It will be noted that the range of variation of the plating current over the range of speed variation from 0 to 600 feet per minute is from 0 to 15,000 amperes. If it is desired that there be a more gradual change of plating current with changes of the speed of the strip, the operating member 88 will be moved downward to cause 37.5% of the biasing potential to be effective and produce the conditions illustrated by the curve E of the graph of Fig. 2.

The curve F of the graph of Fig. 2 illustrates the functioning of the system with none of the biasing potential effective in the circuit and only 16.6% of the potential drop across the resistor R'' effective to energize the solenoid 78.

It is to be understood that the particular points selected for illustration in the graph of Fig. 2 are merely illustrative and that any desired change in the proportionality between the speed of the strip and the plating current may be produced by the proper adjustment of the variable resistors R, R' and R''.

It is to be understood that the regulator 64 is merely illustrative of one type of regulator

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that may be employed to perform the regulator function described herein and that any regulator that will function in response to potentials proportional to the speed of the strip and the plating current may be employed. It is also to be understood that only two plating generators have been shown and utilized herein merely for the purpose of illustration and that as many plating generators as desired may be employed and controlled in accordance with the principles described herein.

It is also to be understood that the description of the electrolytic process as an electroplating process is merely illustrative of the principles of operation of the control system and that the control system may be employed if desired in any operation in which it is desired that a current density in an electrolytic process vary in any desired manner in response to variations in the speed of the length of material which is being electrolytically treated in the process.

Thus it will be seen that I have provided a control system for an electrolytic process which shall function to so coordinate the speed of travel of a length of material which is being continuously treated in the process with the density of the current acting in the process as to produce uniform treatment of the length of material regardless of changes of speed of travel of the length of material or to provide any desired proportionality between the speed of the length of the material and the density of the plating current in the process and any desired variation of such proportionality as the speed of the length of material varies.

In compliance with the requirement of the patent statutes, I have shown and described herein a preferred embodiment of my 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 embodiment herein shown being merely illustrative of the principles of my invention.

I claim as my invention:

1. In a control system for an electrolytic process, first and second means responsive to the speed of travel of a length of material through the process, means responsive to said first speed responsive means for varying the density of current flow in the electrolytic process in accordance with the speed of travel of the material, regulating means, means responsive to the second speed responsive means and the current density in the process for causing the regulating means to vary the current density in the process, and selectively operable means for varying the effect of the second speed responsive means on the regulating means so as to produce the desired range of variation of the current density with a predetermined range of variation of speed of the length of material from a predetermined maximum current value corresponding to a predetermined maximum speed value.

2. In a control system for an electrolytic process, first and second means responsive to the speed of travel of a length of material through the process, means responsive to said first speed responsive means for varying the density of current flow in the electrolytic process in accordance with the speed of travel of the material, regulating means, means responsive to the second speed responsive means and the current density in the process for causing the regulating means to vary the current density in the process,

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first selectively operable means for varying the effect of the second speed responsive means on the regulating means so as to produce the desired maximum current value corresponding to the maximum speed value, and second selectively operable means for the effect of the second speed responsive means on the regulating means so as to produce the desired range of variation of the current density from the maximum current value which has been determined by the said first selectively operable means.

3. In a control system for a process for electroplating a continuous length of material as it passes continuously through a plating electrolyte, main generator means for supplying the plating current, means including a first pilot generator driven in accordance with the speed of the material for varying the excitation of said main generator means in accordance with variations of the speed of travel of the length of material through the electrolyte, a second pilot generator, means for driving the second pilot generator at a speed proportional to the speed of the length of material, regulating means responsive to the potential of said second pilot generator and the plating current, means responsive to said regulating means for further varying the excitation of the main generator means in accordance with variations of the proportionate relations between the plating current and the speed of the length of material from predetermined relations, and selectively operable means for varying the effect of the potential of said second pilot generator on said regulating means so as to provide any desired proportionate relations between the plating current and the speed of the length of material.

4. In a control system for the current supplying means for a process for electroplating a continuous length of material as it passes continuously through a plating electrolyte, means for controlling the current output of the current supplying means, means including a first pilot generator for controlling said control means to vary the plating current in accordance with variations of the speed of the length of material through the electrolyte, a second pilot generator, means for driving the second pilot generator at a speed proportional to the speed of the length of material, a source of biasing potential in series circuit relation with the second pilot generator, regulating means jointly responsive to the second pilot generator potential and the biasing potential, and to the plating current for further controlling said control means to vary the plating current, and selectively operable means for varying as desired the value of the biasing potential and the effectiveness of the sum of the biasing potential and the pilot generator potential on the regulating means to thereby vary the range of variation of the plating current within the normal range of variation of the speed of the length of material from a maximum current value corresponding to the maximum speed of the length of material.

5. In a control system for a process for electroplating a continuous length of material as it passes through a plating electrolyte, means for varying the plating current in accordance with variations of the speed of the length of material through the electrolyte, a pilot generator, a first potentiometer rheostat, a source of biasing potential of substantially constant value connected to energize the first potentiometer rheostat, a second potentiometer rheostat, circuit means con-

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necting said pilot generator, said second potentiometer rheostat and the variable portion of said first potentiometer rheostat in series circuit relation, a third potentiometer rheostat, circuit means connecting said third potentiometer rheostat and the variable portion of said second potentiometer rheostat in series circuit relation, and regulating means jointly responsive to the potential on the variable portion of said third potentiometer rheostat and the plating current for varying the plating current.

6. In a control system for a process for electroplating a continuous length of material as it passes continuously through a plating electrolyte, means for supplying variable amounts of current to the process, control means including regulator means jointly responsive to the speed of travel of the length of material through the electrolyte and the current density for controlling the current supplying means for varying the current density in accordance with variations of the speed of travel of the length of material over a predetermined speed range, first selectively operable means for controlling said regulator means to determine the maximum current value corresponding to the maximum speed value, and second selectively operable means for further controlling said regulator means independently of the operation of the control means for determining the range of variation of the current density over said predetermined speed range from the maximum current value which has been determined by the said first selectively operable means.

7. In a control system for an electrolytic process wherein a length of material is passed through an electrolyte, means for supplying variable amounts of current to the process, first generator means operable to supply a potential proportional to the speed of travel of the material, second generator means operable to supply a po-

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tential proportional to the current supplied, regulator means operable to control the output of said current supplying means, said regulator means being connected to respond to said second generator potential, a separate source of potential, a first potentiometer connected across said separate source and having one of its terminals connected to one terminal of said first generator means, a second potentiometer having one terminal connected to the opposite terminal of said first generator means and the variable terminal of the first potentiometer, a third potentiometer having one terminal connected to said opposite terminal of the first generator means and its other terminal to the variable terminal of the second potentiometer, said regulator means being connected to said third potentiometer, thereby to provide for selectively adjusting the regulator means to determine the maximum current supplied to the process and the rate of variation of said current with respect to the speed of the material over a predetermined speed range.

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