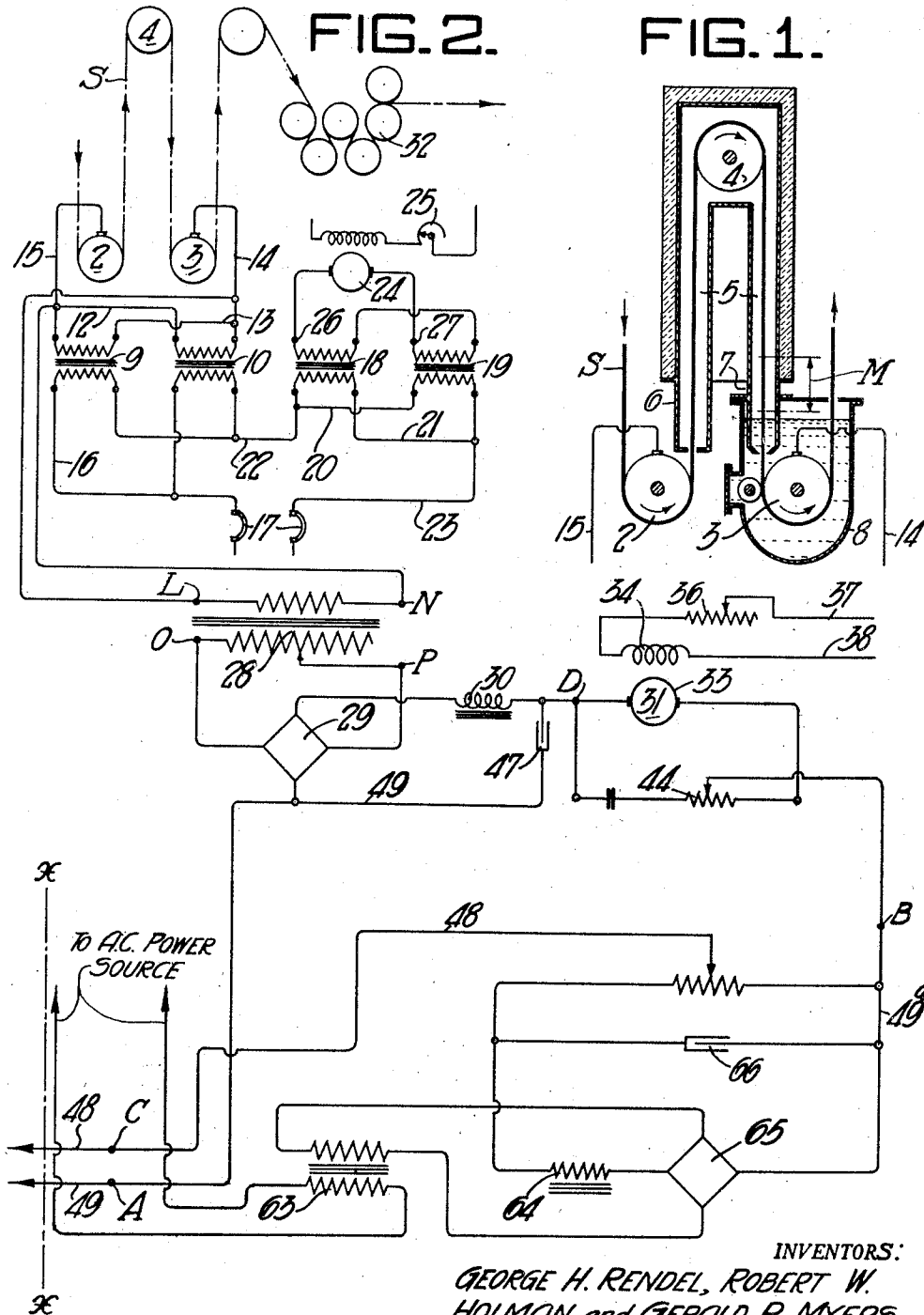


April 22, 1947.

R. W. HOLMAN ET AL
MEANS FOR AUTOMATICALLY CONTROLLING THE MELTING
OF COATING ON CONTINUOUS METALLIC STRIP
Filed Aug. 6, 1943

2,419,214

3 Sheets-Sheet 1



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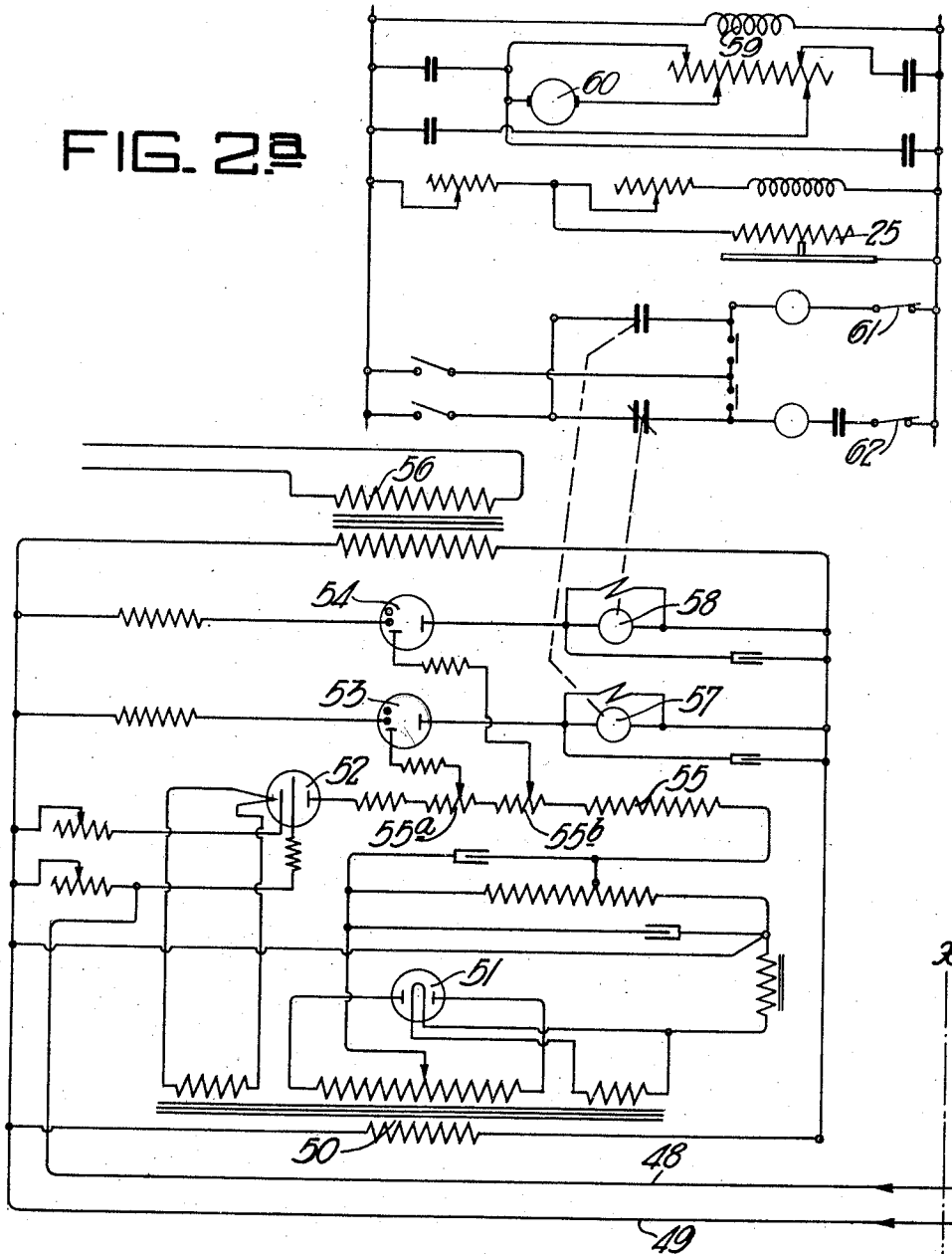
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3 Sheets-Sheet 2

FIG. 2a



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3 Sheets-Sheet 3

FIG. 3.

VOLTAGE CONDITIONS WHEN NO
CONSTANT SOURCE OF DIRECT
CURRENT OR BOOSTER VOLTAGE
IS SUPPLIED BETWEEN POINTS C AND B.

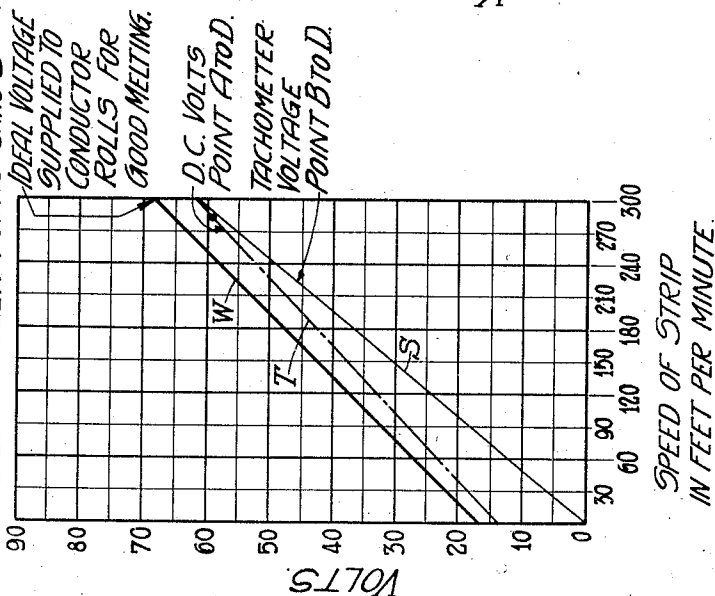
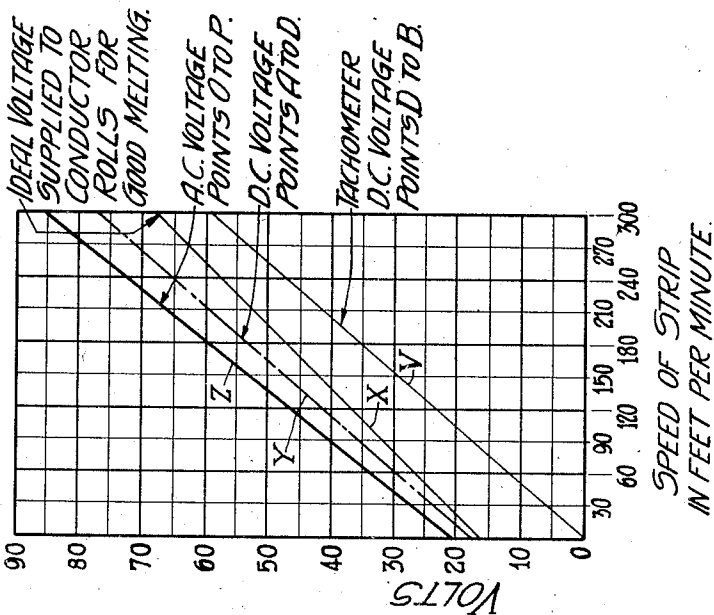


FIG. 4.

VOLTAGE CONDITIONS WHEN A CONSTANT
SOURCE OF DIRECT CURRENT OR BOOSTER
VOLTAGE IS SUPPLIED BETWEEN
POINTS C AND B.



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UNITED STATES PATENT OFFICE

2,419,214

MEANS FOR AUTOMATICALLY CONTROLLING THE MELTING OF COATING ON CONTINUOUS METALLIC STRIP

Robert W. Holman, Gerald R. Myers, and George H. Rendel, Gary, Ind., assignors to Carnegie-Illinois Steel Corporation, a corporation of New Jersey

Application August 6, 1943, Serial No. 497,690

11 Claims. (Cl. 219—11)

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This invention relates to improvements in electrical means for automatically controlling the heating of continuous metallic strip and the bright melting of electrolytically coated tin thereon by electric resistance heating.

It is now common practice to apply a coating, such as tin, to continuous length strip material, such as iron or steel, by electrolytic means. After the strip is electrolytically tin coated, it is usually passed through a melting unit wherein the coating thereon is melted so as to provide a finished strip having a bright lustre and smooth, even finish. Sometimes the melting is done by passing the strip through hot oil, heating the strip by electrical inductance, or by subjecting the strip to electrical resistance. In the resistance melting, the strip is usually disposed in a vertical plane during the melting of the coating thereon, passing over one conductor roll then upwardly over and around a deflective roll and then downwardly around another conductor roll into a tank containing a quenching medium with that portion of the strip disposed between the conductor at any particular time heated by electrical resistance so as to melt the coating thereon. Such a melting unit and quenching tank arrangement is disclosed in the copending application of Ewart S. Taylerson, Serial No. 447,966, filed June 22, 1942.

As the strip passes over and around the conductor rolls of the melting unit, it will be understood that the cross-sectional area of the strip changes due to various widths and thicknesses thereof and that the speed of the strip will change due to operating conditions. Accordingly, it will be seen that it is impossible to impress a constant voltage or current input to the conductor rolls and the strip for the reason that at times due to such changes in operating conditions, the strip would be heated far above the melting temperature of the tin coating thereby causing the same to flow therefrom resulting in spilling the coating on that portion of the strip and at other times, the strip would not be heated sufficiently to melt the tin coating thereon on other portions of the strip thereby defeating the purposes of the melting.

Thus, it will be seen that it is necessary to supply a variable source of alternating current so that the strip and coating thereon is properly heated to satisfy all operating conditions and it is to such a means for varying and controlling the supply of power to the strip that the present invention relates. Various means and equipment have been suggested and used for supplying a

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variable source of power but usually they have been expensive and necessitated special designing and construction for the particular application. In the present invention, such variable source of power is provided by standard equipment, by an improved electrical arrangement thereof.

Accordingly, it is the general object of the present invention to provide an improved electrical means for and method of controlling automatically the current supplied to a continuous length metallic strip for melting the coating thereon by electrical resistance as it passes over a pair of conductor rolls wherein the power input to the conductor rolls and the strip is varied as the cross-sectional area and speed of the strip varies so that the coating thereon is properly melted to satisfy all operating conditions.

It is another object of the invention to provide an improved electrical means for controlling automatically the voltage supplied to a continuous length metallic strip as it passes over a conductor roll whereby the voltage input to the conductor roll and the strip is varied as the speed of the strip varies so that the strip is impressed with the desired voltage for any given speed.

It is a further object of this invention to provide an improved electrical means for controlling the power input to a continuous length metallic strip as it passes over a conductor roll wherein the electrical means is controlled automatically by the speed of the strip.

It is a more specific object of the present invention to provide an improved electrical means for controlling automatically the current supplied to a continuous length metallic strip as it passes over a conductor roll including a tachometer generator which is driven by the strip-driving means wherein a balance is maintained normally between the voltage supplied to the strip by the conductor roll and the voltage output of the tachometer and arranged so that when the voltage becomes unbalanced therebetween due to an increase or decrease in the speed of the strip and the tachometer, the voltage input to the strip will be accordingly increased or decreased to again balance the voltage output of the tachometer so as to supply the proper amount of current to the conductor roll and the strip.

It is still another object of the invention to provide an electrical means for controlling automatically the current supplied to a continuous length metallic strip for melting the coating thereon as it passes over a pair of conductor rolls

whereby a minimum initial alternating current voltage is supplied to said conductor rolls and said strip so as to properly melt the coating thereon at the instant the strip starts moving over the conductor rolls.

Various other objects and advantages of this invention will be more apparent in the course of the following specification, and will be particularly pointed out in the appended claims.

In the accompanying drawings there is shown, for the purpose of illustration, an embodiment which our invention may assume in practice.

In these drawings:

Figure 1 is a vertical section through a melting unit together with the quenching tank of an electroplating line showing the conductor rolls with which our invention is incorporated;

Figures 2 and 2^a are wiring diagrams showing an electrical arrangement for controlling the supply of heating voltage to the strip and the conductor rolls of the melting unit as shown in Figure 1; and

Figures 3 and 4 are curves showing the voltage input to the conductor rolls and the strip in relation to the speed of travel thereof.

Referring more particularly to Figures 1 and 2 of the drawings, S indicates a continuous length of coated metallic strip as it is delivered from the electroplating bath of a continuous electroplating line with the strip traveling in the direction of the arrows, as shown in the drawings, and which is conveyed therethrough and therefrom by any suitable driving means. After the strip has been electrolytically coated, it is passed through a heating unit designed to melt the deposited tin or coating thereon with such heating being effected by any suitable means, but preferably by the electrical resistance of the strip.

In the present instance there is shown a resistance type melting unit which comprises, a pair of spaced apart energized conductor rolls 2 and 3 which are connected to a suitable source of power or transformer in a manner hereinafter to be described. There is provided an intervening upper deflector roll 4 with the coated strip S passing between the rolls 2 and 3 in an elongated vertical loop over the roll 4, during which travel, the strip is heated until the tin or coating material disposed thereon reaches its melting point. The vertical loop of the strip as it travels along, is enclosed preferably in an insulated substantially U-shaped muffle 5 having an entrance leg 6 and a discharge leg 7 which legs extend toward the inner periphery of the respective conductor rolls 2 and 3, and enclosing the strip to points adjacent to the latter. As the strip passes through the muffle 5, the heat generated therein due to the electrical resistance of the strip is designed to bring the tin or coated material on the strip to its melting point in a zone indicated at M adjacent the lower end of the discharge leg 7 of the muffle 5. Directly below the lower end of the discharge leg 7 and into which the same extends, there is arranged a tank 8 containing a quenching medium and in which the conductor roll 3 is disposed. The strip passes from the muffle 5 into and through the quenching medium in tank 8 from which the strip passes to subsequent processing steps.

The conductor rolls 2 and 3 are energized by a variable source of power by means of an electrical arrangement now to be described. The electrical arrangement or circuit of our invention comprises, preferably, a pair of transformers 9 and 10, although one may be used instead of two pro-

viding it has sufficient capacity. The secondary windings of these transformers are connected in parallel with each other and to the load or the conductor rolls 2 and 3, in the present case, by means of lines 14 and 15. The primary windings of the two transformers 9 and 10 are connected in parallel with each other and to one side of the line of a source of alternating current supply by means of a connection 16, preferably, through a circuit breaker 17. If one transformer is used, it will be understood that the secondary windings thereof are connected to the load or the conductor rolls with the primary windings thereof connected to one side of the line of the source of alternating current supply.

There is provided a saturable core reactor comprising two additional transformers 18 and 19, the primary windings of which are connected in parallel with each other by means of the lines 20 and 21 and in series with the primary windings of transformers 9 and 10 by means of the line 22. The primary windings of both of the transformers 18 and 19 are connected to the other side of the line of the source of alternating current supply by means of the line 23 through the circuit breaker 17. In other words, the primary windings of the transformers 18 and 19 are connected in multiple with each other and those of the transformers 9 and 10 also are connected in multiple with each other, and two multiple groups of primary windings of all of the transformers are connected in series with the primary source of alternating current supply. It will be understood that the latter two transformers 18 and 19 are designed to control the power output of the two transformers 9 and 10, and it will be seen by connecting the same as above described, that the input current from the source of alternating current supply will pass through both of the primary windings of the transformers 18 and 19, through the connection 22 and thence through the primary windings of both of the transformers 9 and 10.

The secondary windings of the two transformers 18 and 19 are connected in series with and in polarity opposition to each other, and with means, preferably an exciting generator 24, arranged in the series connection for supplying a direct current to the secondary windings of the transformers 18 and 19 for saturating the cores thereof. There is provided a rheostat 25 which controls a separate source of direct current used for exciting field winding of generator 24.

By connecting the secondary windings of the transformers 18 and 19 in series with and in polarity opposition with each other, it will be seen that no alternating current potential exists between the terminal 26 of the transformer 18 and terminal 27 of the transformer 19. Therefore, the direct current power connected to these terminals magnetizes the laminated cores of the transformers 18 and 19, thereby changing their reactance through an extremely wide range, i. e., from a very high reactance, when no direct current is applied, to a very low reactance, when a full rated direct current is applied to the secondary windings thereof. By providing such an arrangement, it will be seen that even when a full alternating current potential is applied to the transformer and the controlling transformer combination, a very small (approximately 3 percent of the rated capacity) output is obtained from the transformers 9 and 10. On the other hand, the output of transformers 9 and 10 can readily be increased any amount up to approxi-

mately 95 percent of rated output by changing the applied direct current voltage to the secondary windings of the transformers 13 and 19 by varying the power output of the generator 24 to the transformers. The subject matter described above is disclosed in the copending application of George H. Rendel, Serial No. 492,624, filed June 28, 1943.

According to the present invention, there is connected to the lines 14 and 15 or the alternating current voltage output of the transformers 9 and 19, a tap transformer 28 to which there is connected a dry plate rectifier 29, preferably, of the rectox type. The rectifier 29 is connected preferably, through an inductance coil 30, to a tachometer generator 31. The tachometer generator is driven, preferably by the driving means for driving the strip S, such as the bridge rolls 32 with the tachometer connected to the drive shaft of one of the rolls in any suitable manner so as to be driven thereby. The tachometer generator 31 is adapted to control the actuation of the rheostat 25 directly or through any suitable control or regulating means, such as an electronic control hereinafter to be described.

There is arranged in parallel with the armature circuit of the tachometer generator 31, preferably, a rheostat 44, the purpose of which will be hereinafter described. The tachometer generator is provided with field 34 which is connected preferably through a resistor 36 to a source of direct current supply by means of lines 37 and 38. There is connected in parallel with the rectifier 29, preferably, a condenser or capacitor 41. The rectifier 29 and the tachometer generator 31 are connected to a regulating means or an electronic control by means of lines 43 and 49. There is arranged in the line 43, in series with the tachometer generator 31, a transformer 53, an inductance coil 54, and a rectifier 55, the purpose of which will be later described. There is connected in parallel with the rectifier 55, preferably, a condenser or capacitor 56. The tachometer generator is the subject matter of the copending application of George H. Rendel, Serial No. 492,625, filed June 28, 1943.

The electronic control as disclosed and claimed in the copending application of Gerald R. Myers, Serial No. 497,691, filed August 6, 1943, consists generally of a transformer 50, a rectifier tube 51, a detector tube 52, and two power tubes 53 and 54. There is arranged in series with the detector tube 52, a resistor 55 and potentiometers 55^a and 55^b to which the power tubes 53 and 54 are respectively connected. It is the purpose of the rectifier tube 51 to supply a source of direct current power to the detector tube 52 by means of the connections shown. The detector tube 52, together with the power tubes 53 and 54 are connected across the line of a source of alternating current supply which is supplied, preferably, through a transformer 56. There is arranged in series with each of the power tubes 53 and 54, a relay 57 and 58, respectively. The relays 57 and 58 control the energization of the armature of the motor 60 which is driven from a separate source of direct current power and which controls the actuation of the rheostat 25 for varying the supply of current to the field winding of the generator 24 in a manner to be described. There is arranged in the circuit of the relay 57, preferably, a lower limit switch 61, and there is arranged in the circuit of the relay 58, preferably, an upper limit switch 62 for the purpose of limiting the lower and upper limits of the motor

operated rheostat 25 supplying current to the generator 24.

The electrical arrangement and apparatus as above described functions in the following manner to control the melting of the coating on the strip as it passes over and around the conductor rolls 2 and 3. It will be understood that the electrical apparatus of the present invention is essentially a modified form of voltage regulator, and it will be seen that it consists generally of four parts, namely, the tachometer generator 31, the speed of which is directly proportional to the operating speed of the strip; a direct current voltage source, which is supplied by means of the rectifier 29 from the voltage applied to the conductor roll by the transformers 9 and 19; an electronic control or regulator; and a motor-operated rheostat 25 which controls the output of the exciter generator 24 which, in turn, controls the voltage output from the transformers 9 and 19 or the impressed voltage on the conductor rolls and the strip.

By means of the present electrical arrangement, it will be understood that the voltage output from the tachometer generator 31 is continuously balanced against the voltage output from the rectifier 29 and when the voltage is balanced, it will be seen that there is substantially zero voltage between the lines 43 and 49 thereby permitting only a small amount of current to flow through the plate of the detector tube 52 of the electronic control. However, this current flowing through the detector tube causes sufficient voltage drop across the resistor 55 to permit power tube 54 to conduct current. It will be seen that when this power tube conducts current that the coil of relay 52 is energized but which through its normally closed auxiliary contact prevents the motor operated rheostat 25 from moving in a direction to increase the voltage supplied to the generator 24. When the speed of the strip increases, due to the fact that it is driven by the strip driving means, the output of the tachometer generator 31 increases thereby causing an unbalance of the voltage between the lines 43 and 49, line 43 becoming negative thereby making the grid of the detector tube 52 negative, thus causing the detector tube to cease conducting current there-through which results in reducing the voltage drop across the resistor 55 thereby causing power tube 54 to cease firing. When the power tube 54 ceases firing, it will deenergize the coil of relay 53, together with normally closed contacts, thereby causing the motor-operated rheostat 25 to rotate in a direction to increase the roll voltage. In other words, as the rheostat 25 moves in an increased direction, it increases the output from the exciter generator 24 thereby causing greater saturation of the secondary windings of the transformers 13 and 19 thereby reducing their reactance and increases the output from the transformers 9 and 19. When the voltage output from the transformers 9 and 19 has increased to the extent that the voltage output from these transformers as measured through the rectifier 29, balances the voltage output of the tachometer generator 31, conditions as outlined above recur, and the motor-operated rheostat 25 stops at its attained position, remaining fixed as long as the voltage output of the transformers 9 and 19 and the tachometer generator 31 are balanced.

When the speed of the strip decreases, the voltage output of the tachometer generator 31 correspondingly decreases thereby causing an unbalance of the voltage between lines 43 and 49, line

48 in such a case becoming positive thereby making the grid of the detector tube 52 positive so as to permit this tube to conduct more current which increases the voltage drop across the resistor 55 thereby causing power tube 53 to fire. When power tube 53 is permitted to fire, it will be seen that the coil of relay 57 is energized, and its normally open contacts close, thereby causing the motor-operated rheostat 25 to rotate in a direction to reduce the voltage. In other words, as the rheostat 25 is moved in a lower direction, it reduces the output of the exciter generator 24 thereby lowering the exciting current in the secondary windings of transformers 18 and 19 which increases their reactance and reduces the output from the transformers 9 and 10. When the voltage output from the transformers 9 and 10 has been reduced the required amount, the voltage output from these transformers as measured through the rectifier 29, balances the voltage output of the tachometer generator 31. Conditions as outlined above recur and the motor-operated rheostat 25, stops at its attained position again remains fixed as long as the voltage output between the transformers 9 and 10 and the tachometer generator 31 are balanced. From the foregoing description, it will be seen that it is the purpose of the electronic control to match the voltage output from the transformers 9 and 10 with that of the tachometer generator 31, and any deviation, or unbalance between these voltages will cause the regulator or electronic control to move the motor-operated rheostat in the proper direction to restore again a voltage balance therebetween.

The purpose and function of the transformer 63, the inductance 64, and the rectifier 65 arranged in the line 49^a in series with the tachometer generator 31 will now be described. It will be understood that it is the purpose of these three pieces of apparatus to constantly supply a source of direct current bias voltage to the control network for a purpose hereinafter to be described. While there is shown a transformer, a rectifier, and an inductance for supplying the direct current bias voltage to the control network, it will be understood that any other suitable means may be provided in the line for supplying such source of direct current voltage such as a bias battery. As has been previously stated, the electronic control or regulator is essentially a voltage matching regulator, i. e., electronic control regulates the heating voltage supplied to the conductor rolls 2 and 3 by utilizing the output voltage of tachometer generator 31 as a reference, or monitor, or in other words, the tachometer generator voltage is used as a standard or measuring stick.

As shown in the wiring diagram of Figure 2 of the drawings, the differential voltage at the points C—A, between the voltage supplied by the tachometer generator 31, points B—D, and rectified roll voltage, points A—D is applied to the electronic control or regulator. It will be seen that if the voltage A—D is greater than B—D, the differential voltage C—A between them causes the electronic control or regulator to operate to reduce the voltage supplied to the conductor rolls until the voltage C—A is zero or balanced. If voltage C—D is greater than A—D, the differential voltage C—A is of opposite polarity than above and causes the electronic control or regulator to raise the voltage applied to the conductor rolls until the voltage between the points C—A is zero.

Attention is now directed to the curves, as shown in Figures 3 and 4 of the drawings, in which the abscissa of each of these curves represents the speed of the strip in feet per minute and the ordinate represents voltage output. The curves shown in Figure 3 are not part of the present invention but merely show characteristic curves of voltage conditions when no constant source of direct current bias voltage is supplied to the control network. In other words, these curves represent the voltage conditions, if the line 49^b were connected directly to the electronic control and not thereto through the transformer 63, the rectifier 65 and the inductance coil 64 or through any other source of direct current bias voltage supply. In Figure 3, curve S represents the voltage output of the tachometer generator 31 and curve, curve W represents the ideal voltage supplied to the conductor rolls for good melting in the particular muffle or melting unit in the present instance which has hereinbefore been described. This curve also represents the voltage L—N or O—P as the ratio of transformer 28, as shown in Figure 2, if it were a standard transformer having a ratio of 1 to 1 instead of a tap transformer, as disclosed. In other words, the voltage on the primary and secondary windings of a standard 1 to 1 ratio transformer is of equal magnitude. The voltage difference between curves T and W represents the voltage loss in the full wave rectifier 29 and the choke coil 30 and capacitor 47.

For the purpose of explanation, it will be assumed that the speed of the strip is 300 feet per minute and it will be seen from curves S and T, in Figure 3, that these curves intersect each other at approximately 61.5 volts, and at this point curves S and T are equal. It will be understood that the electronic control or regulator is maintaining the voltage as shown in curve T, equal to the reference voltage as shown in curve S. It will now be assumed that the speed of the strip changes to 200 feet per minute and it will be seen from curve S that the tachometer generator 31 develops approximately 40 volts at this speed. However, in view of the fact that the electronic control is a voltage balancing regulator, it changes the voltage supply to the conductor rolls 2 and 3 until the rectified roll voltage A—D of the wiring diagram as shown in Figure 2, also equals 40 volts. Attention is now directed to curve T of Figure 3, and it will be found that 40 volts on this curve is only voltage enough to produce good melting on the strip at 160 feet per minute, consequently the coating will not be melted. In order to increase the voltage supply to the conductor rolls 2 and 3 so as to properly melt the coating at a speed of 200 feet per minute, it would be necessary to adjust the rheostat 44. From the above, it will be seen that while the electronic control will maintain the roll voltage correct for a good melting at any speed for which it is adjusted, it will require further adjusting each time the speed of the strip changes. While the electronic control will generally raise and lower the voltage supply to the conductor rolls as the speed of the strip accelerates and decelerates to prevent burning of the strip and consequent flowing of the coating therefrom, a large section of the coating on the strip will be unmelted when the strip starts moving from rest after it has been stopped until the proper speed is reached where the rheostat has been adjusted to produce good melting.

It will be seen from curve W of Figure 3 that when the strip is traveling at 4 feet per minute,

it requires approximately $17\frac{1}{2}$ volts to heat the strip sufficiently to melt the coating. In other words, in order to prevent an unmelted length of coating from emerging from the melting unit or furnace, $17\frac{1}{2}$ volts must be applied by the voltage regulator or electronic control to the conductor rolls the instant the strip starts its movement from rest through the melting unit and over the conductor rolls. The voltage is removed from the strip the instant the strip is arrested from movement through the melting unit.

According to the present arrangement, in order to permit the electronic control or regulator to apply the required $17\frac{1}{2}$ volts for properly melting the coating on the strip as soon as the same starts its movement through the melting unit, a source of direct current bias voltage is connected in series with the tachometer generator 31, as shown in the wiring diagram of Figure 2. As has been previously explained, this source of direct current bias voltage consists preferably of electrical apparatus including the transformer 63, the rectifier 55, and the inductance coil 64, or a bias battery may be substituted for this entire arrangement. By positioning such source of direct current in the line at this point it has the effect that when the strip is traveling at 4 feet per minute the voltage output of the tachometer generator 31 which would be approximately one volt but due to the source of direct current bias voltage in line which is $16\frac{1}{2}$ volts, the voltage from points C to D on the wiring diagram of Figure 2, will be $16\frac{1}{2}$ volts plus 1 volt or a total of $17\frac{1}{2}$ volts which is sufficient voltage to melt the coating on the strip at this speed. It will be assumed now that the voltage A to D, as shown in the wiring diagram of Figure 2, is zero at the instant the strip starts its movement, the voltage differential C—A of $17\frac{1}{2}$ volts is applied to the electronic control or regulator which immediately raises the roll voltage to the point where the voltage C—D equals A—D of Figure 2. Thus, it will be seen that when the speed of the strip is 4 feet per minute, the regulator is maintaining $17\frac{1}{2}$ volts on the conductor rolls 2 and 3.

Attention is now directed to curves shown in Figure 4 of the drawings, in which curve V represents the tachometer voltage, points B to D on the wiring diagram of Figure 2. It will be seen that by adding $16\frac{1}{2}$ volts to the voltage output of the tachometer by means of the source of direct current bias voltage supply, that the curve V will now start at approximately $16\frac{1}{2}$ volts at zero feet per minute, and as the speed of the strip increases, the voltage from points C to D increase along curve Y, as shown in Figure 4. Again in Figure 4, the curve X represents the voltage supplied to the conductor rolls 2 and 3 for good melting. Now it will be seen that if the voltage of curve X is applied at points A—D of Figure 2, and matched by the electronic control or regulator with the voltage of curve Y, as the reference or standard voltage, that throughout the speed range the roll voltage would always be equivalent to a higher speed than the speed of the strip and burning of the strip would result.

In order to insure that at all speeds that the voltage A—D of Figure 2, for a good melting exactly equals the voltage C—D of the tachometer plus the source of direct current bias voltage supply, the slope of curve X of Figure 4 must be changed so that the voltage A—D lies parallel to curve Y and substantially on top thereof. This is accomplished by providing a tapped transformer which is the transformer 28 shown in

the wiring diagram of Figure 2. It will be understood that when 60 volts are supplied to the conductor rolls, the transformer at points O to P develops 75 volts thus effectively changing the slope of the voltage A—D of Figure 2 from curve X, as shown in Figure 4, with a 60/60 volt transformer or standard transformer, to curve Z with a 60/75 volt transformer, which is another important aspect of the present invention. It will be seen from Figure 4 that if curve Z representing the voltage from wires O to P in Figure 2, then taking into consideration the voltage drop in the full wave rectifier 29 and the choke coil 30 and capacitor 47, curve Y becomes the direct current voltage at points A to D which represents the voltage impressed upon the conductor rolls. It will be understood that curve Y also represents the voltage output of the tachometer plus the source of direct current bias voltage supply. Therefore with the electronic control or regulator being a voltage balancing regulator and curve Y representing both the standard voltage, and the rectified roll voltage which represents the good melting characteristic of the melting unit, the electronic control or regulator will maintain the voltage impressed upon the conductor rolls 2 and 3 substantially correct for all speeds of the strip from rest to top speed without adjustment for all conditions, such as acceleration, deceleration, and any steady selected speed between rest and top speed that it is desired to operate the line. It will be seen that because of the retained balance between the voltage and speed curve, the variation or fluctuation in the strip speed causes the heating voltage to follow thus providing the required amount of heating current for suitably melting the coating on the strip for any particular speed thereof.

While we have shown and described a specific embodiment of our invention, it will be understood that this embodiment is merely for the purpose of illustration and description and that various other forms may be devised within the scope of our invention, as defined in the appended claims.

We claim:

1. In combination with a conductor roll for supplying current to a continuous metallic strip as it passes thereover, means for driving the strip so as to pull the same over the conductor roll, a transformer for supplying current to said conductor roll and the strip, means for controlling the power output of said transformer including a generator, a motor-controlled rheostat for controlling the power input to said generator whereby the voltage input to the conductor roll and the strip by said transformer may be varied, means for controlling the energization of the motor of said motor-controlled rheostat, and means responsive to the speed of said strip for controlling automatically the last named means whereby the voltage input to the conductor roll and the strip is adjusted automatically for the variations in speed and the cross-sectional area thereof.

2. In combination with a conductor roll for supplying current to a continuous metallic strip as it passes thereover, means for driving the strip so as to pull the same over the conductor roll, a transformer for supplying current to said conductor roll and the strip, means for controlling the power output of said transformer including a generator, a motor-controlled rheostat for controlling the current input to said generator whereby the voltage input to the conductor roll and the strip by said transformer may be varied, means for controlling the energization of the

motor of said motor-controlled rheostat, and a tachometer generator which is driven by said strip driving means for controlling automatically the last named means whereby the voltage input to the conductor roll and the strip is adjusted automatically for the variations in speed and the cross-sectional area thereof.

3. In combination with a melting unit of the class described having a pair of conductor rolls for heating a continuous metallic strip and the coating thereon by electrical resistance as it passes thereover, an electrical arrangement for supplying current to the conductor rolls and the strip including, a transformer connected to a source of power for supplying current to the conductor rolls and the strip, an exciter generator for controlling the power output of said transformer, a tachometer generator for controlling the voltage output of said transformer, a motor-operated rheostat for controlling the voltage output of said exciter generator, an electronic means for controlling the energization of said motor-operated rheostat, and means connected to the voltage output of said transformer as applied to said conductor rolls for supplying direct current voltage to said exciter generator, said tachometer generator arranged so as to have a voltage output directly proportional to the speed of the strip with the voltage output thereof continuously balancing that of the source of direct current supply whereby the power input to said conductor rolls and the strip is automatically controlled so that the power is continuously maintained in proper relation to the speed of the strip thereby properly melting the coating thereon at any particular operating speed.

4. In combination with a melting unit of the class described having a pair of conductor rolls for heating a continuous metallic strip and the coating thereon by electrical resistance as it passes thereover, an electrical arrangement for supplying current to the conductor rolls and the strip, as defined in claim 3, wherein the means connected to the voltage output of the transformer for supplying direct current bias voltage to the tachometer generator consists of a dry plate rectifier.

5. In combination with a melting unit of the class described having a pair of conductor rolls over which a continuous metallic strip passes for melting the coating thereon by electrical resistance, means for supplying a heating voltage to said conductor rolls and the strip for melting the coating thereon, means controlled by the speed of the strip for establishing a reference voltage for controlling the voltage output of said voltage supplying means, the voltage output of said second named means increasing when the strip speed increases and decreasing when the strip speed decreases, means for balancing the voltage of said voltage supplying means and said reference voltage, and means responsive to any unbalancing of said voltage supplying means and said reference voltage for varying said supply voltage for restoring the balance between said voltage supplying means and said reference voltage whereby the voltage output of said voltage supplying means is automatically adjusted for any given speed of the strip so that the coating thereon is properly melted.

6. In combination with a melting unit of the class described having a pair of conductor rolls over which a continuous metallic strip passes for melting the coating thereon, a transformer for supplying a heating voltage to said conductor

rolls and the strip for melting the coating thereon, a tachometer generator controlled by the speed of the strip for establishing a reference voltage for controlling the voltage output of said transformer, the voltage output of said tachometer generator increasing when the strip speed increases and decreasing when the strip speed decreases, an electronic means for balancing the voltage output of said transformer and that of said tachometer generator, and a motor-operated rheostat controlled by said last named means for controlling the voltage output of said transformer, said last named means adapted to actuate said rheostat to restore a balanced voltage between the said transformer and said tachometer when the voltage therebetween becomes unbalanced whereby the voltage output of said transformer is automatically adjusted for any given speed of the strip so that the coating thereon is properly melted.

7. In combination with a melting unit of the class described having a pair of conductor rolls over which a continuous metallic strip passes for melting the coating thereon by electrical resistance, a transformer for supplying current to said conductor rolls for heating the strip as it passes thereover, an electrical arrangement for controlling the supply of current to said conductor rolls by said transformer including a voltage regulating means, a tachometer generator actuated by the strip-driving means connected to said voltage regulating means, and means connected in series with said tachometer generator for supplying a bias direct current whereby said regulating means applies sufficient voltage to said conductor rolls so as to properly melt the coating on the strip the instant the same starts moving in the melting unit.

8. In combination with a conductor roll for supplying current to a continuous metallic strip as it passes thereover, means for driving the strip so as to pull the same over the conductor roll, means for supplying current to said conductor roll and said strip for resistance heating the same, a tachometer generator driven by said strip-driving means for establishing a reference voltage, the voltage output of said tachometer generator increasing when the strip speed increases and decreasing when the strip speed decreases, means for balancing the heating power voltage against the reference voltage and means responsive to the difference between the reference and heating power voltages for varying the voltage supplied to the strip as the speed of the strip varies.

9. In combination with a melting unit of the class described for melting the coating on a continuous metallic strip by means of resistance heating as it passes therealong, a pair of conductor rolls over which the strip passes for heating the strip by electrical resistance, bridle rolls for conveying the strip over said conductor rolls, means for supplying current to the conductor rolls and strip for resistance heating the same, a tachometer generator driven by said bridle rolls for establishing a reference voltage, the voltage output of said tachometer generator increasing when the strip speed increases and decreasing when the strip speed decreases, means for balancing the heating power voltage against the reference voltage and means responsive to the difference between the reference and heating power voltages for varying the voltage supplied to the strip as the speed of the strip varies.

10. In combination with a conductor roll for

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supplying current to a continuous metallic strip, means for supplying a heating voltage to said conductor roll and the strip, means controlled by the speed of the strip for establishing a reference voltage, the voltage output of said second named means increasing when the strip speed increases and decreasing when the strip speed decreases, means for balancing the heating power voltage against the reference voltage, and means responsive to the difference between the heating power and reference voltages for varying the voltage supplied to the strip as the speed of the strip varies.

11. In combination with a conductor roll for supplying current to a continuous metallic strip, means for supplying a heating voltage to said conductor roll and the strip, means controlled by the speed of the strip for establishing a reference voltage for controlling the voltage output of said voltage supplying means, the voltage output of said second named means increasing when the strip speed increases and decreasing when the strip speed decreases, means for balancing the voltage of said voltage supplying means and said

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reference voltage, and means responsive to any unbalancing of said voltage supplying means and said reference voltage for varying said supply voltage for restoring the balance between said voltage supplying means and said reference voltage whereby the voltage output of said voltage-supplying means is automatically adjusted for any given speed of the strip.

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Certificate of Correction

Patent No. 2,419,214.

April 22, 1947.

ROBERT W. HOLMAN ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Column 12, line 8, claim 6, strike out the words "an electronic"; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 12th day of August, A. D. 1947.

[SEAL]

LESLIE FRAZER,
First Assistant Commissioner of Patents.

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