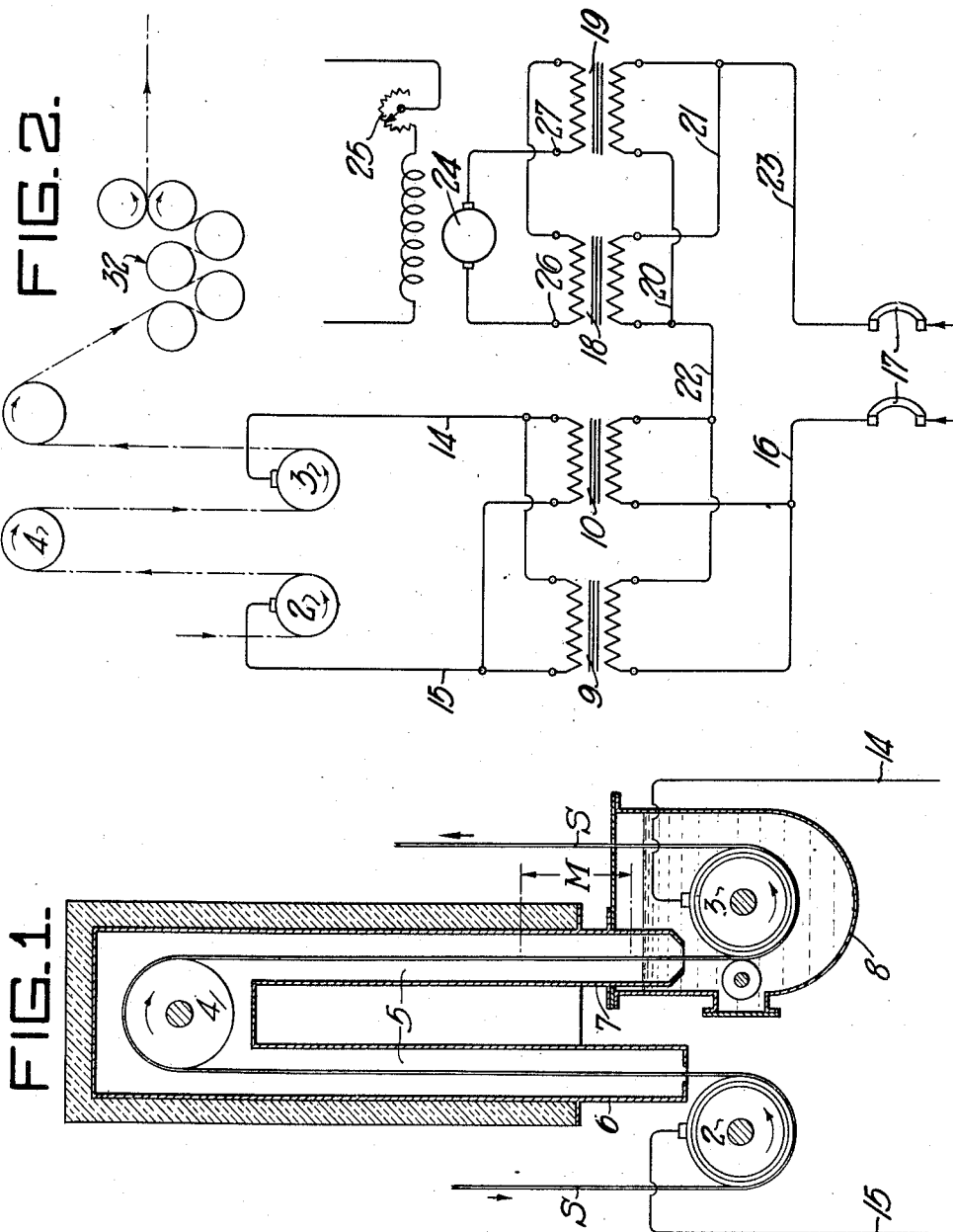


Dec. 16, 1947.

G. H. RENDEL
MEANS FOR UNIFORMLY ELECTRIC RESISTANCE
HEATING CONTINUOUSLY MOVING METAL STRIP
Filed June 28, 1943

2,432,801

2 Sheets-Sheet 1



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FIG. 3.

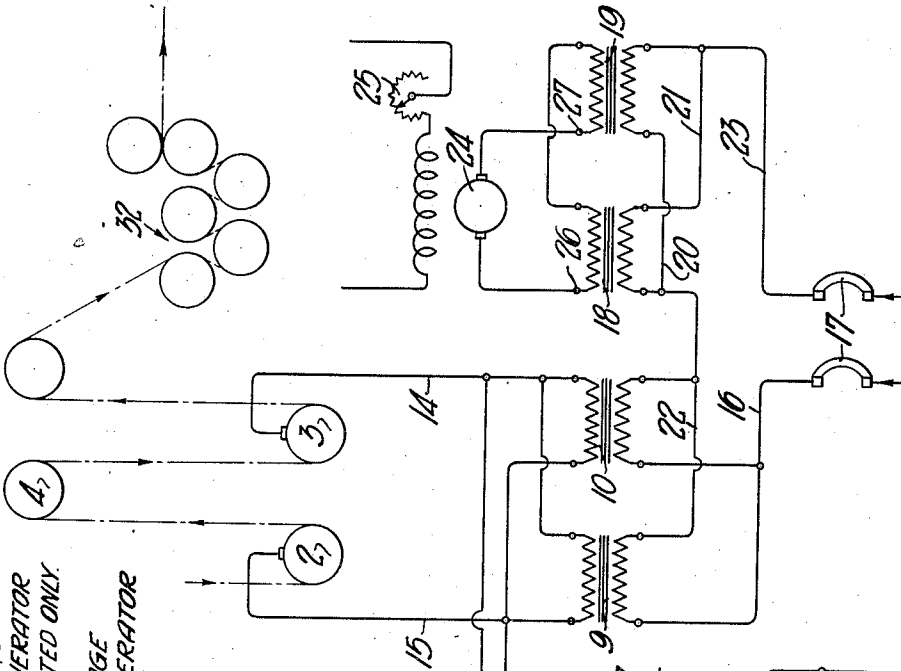
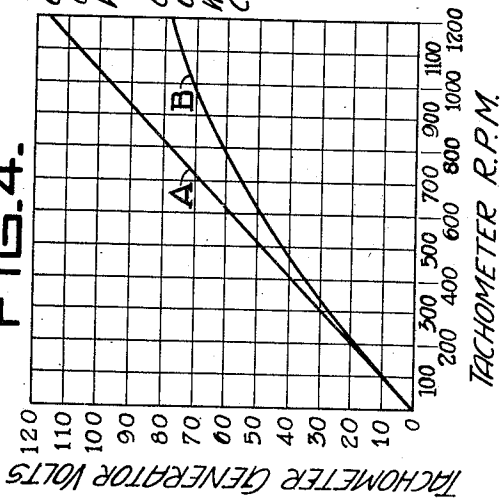


FIG. 4.



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UNITED STATES PATENT OFFICE

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MEANS FOR UNIFORMLY ELECTRIC RESISTANCE HEATING CONTINUOUSLY MOVING METAL STRIP

George H. Rendel, Gary, Ind., assignor to Carnegie-Illinois Steel Corporation, a corporation of New Jersey

Application June 28, 1943, Serial No. 492,625.

3 Claims. (Cl. 219—11)

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This invention relates to means for uniformly electric resistance heating continuously moving metal strip especially adaptable for use in controlling the voltage input to a continuous metallic strip and conductor rolls in the melting unit of an electrofinishing line.

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 deflection 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 rolls, 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 speed of the strip will change from time to time due to operating conditions. Also, the cross-sectional area of the strip changes from time to time due to difficult widths and thicknesses of the strip. 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 spoiling 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 operation.

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 the supply of power to the strip that the present invention re-

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lates. Various means and equipment have been suggested and used for such a purpose, 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.

In controlling the power input to the conductor rolls of the melting unit, it has been found that the most accurate and reliable control is obtained by accurately regulating the impressed heating voltage and maintaining the required voltage for any operating speed. The power (KW.) requirements for heating a strip of any given cross-sectional area is directly proportional to the speed at which the strip passes through the melting unit. By the formula, power (KW.) equals the current squared multiplied by the resistance, and since the resistance of the strip is unaffected by a change in operating speed, it will be seen that the voltage requirements for heating the strip must be varied with any change in speed thereof. However, it will be seen that the voltage is not directly proportional to the operating speed or the speed of the strip through the melting unit.

In order to obtain the correct heating voltage for all operating speeds, it is necessary to secure a reference voltage having the same characteristics as the heating power voltage requirements. This reference voltage can then be used by means of a voltage regulator to maintain the desired impressed heating power voltage for all operating speeds. To secure an accurate and reliable reference voltage, a compensated generator is employed from which the desired characteristics can be readily obtained. This generator is compensated so that its output voltage balances the heating power voltage, and consists of a conventional type tachometer generator having the fields thereof arranged so as to obtain the desired characteristics. This generator is mechanically connected to the drive bridge or master driving unit of the electrofinishing line and supplies reference voltage from which a voltage regulator is employed to control the heating power voltage input to the melting unit at the correct value to secure the desired heat therein over the entire operating speed range of the strip.

Accordingly, it is the general object of the present invention to establish a reference voltage for controlling the heating power voltage requirements of the metallic strip in a melting unit of

the class described so that the voltage characteristics thereof are substantially the same as those of the reference voltage whereby the voltage supplied to the conductor rolls and the strip is maintained at the required impressed power voltage for properly heating the strip for any given condition.

It is another object of the invention to provide a tachometer generator which has been specially compensated so as to obtain an accurate and reliable reference voltage having the same characteristics as the heating power voltage required by the strip as it passes through the melting unit.

It is a further object of this invention to improve a tachometer generator which is driven by the strip driving means for controlling the power input to the strip in the melting unit whereby the heating voltage supplied to the strip is varied as the speed of the strip varies.

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 my 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 my invention is incorporated;

Figure 2 is a wiring diagram showing an electrical arrangement for supplying a variable source of power to the conductor rolls of the melting unit as shown in Figure 1;

Figure 3 is a wiring diagram, similar to Figure 2 showing in addition the arrangement of the improved tachometer or compensated pilot generator of my invention together with the field windings thereof; and

Figure 4 is a curve showing the voltage generated by a tachometer generator in relation to the speed thereof.

Referring more particularly to 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 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 applied thereto by means of electrical

resistance 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 my invention comprises, preferably, a pair of transformers 9 and 10, although one may be used instead of two providing 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 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 the combined 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 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 motor operated 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 opposition with each other, it will be seen that no potential exists between the terminal 26 of the transformer 18 and terminal 27 of the trans-

former 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 potential 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 approximately 95 percent of rated output by changing the applied direct current voltage to the secondary windings of the transformers 18 and 19 by varying the power output of the generator 24 to the transformers.

As shown in Figure 3 of the drawing, there is connected to the lines 14 and 15 or the alternating current voltage output of the transformers 9 and 10, a transformer 28 to which there is connected a dry plate rectifier 29, preferably, of the "Rectox" type. According to the present invention, the rectifier 29 is connected 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 roll 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 through any suitable control or regulating means, such as an electronic control as shown in the Gerald R. Meyers application, Serial No. 497,691, filed August 6, 1943, and entitled "Electronic control."

In accordance with the teachings of the present invention, the tachometer generator 31 is provided with an armature 33 and two field windings 34 and 35. The field winding 34 is connected, preferably, through a resistor 36 to a source of direct current supply by means of the lines 37 and 38. One of the field windings, namely, the field windings 35 is arranged in the circuit of the armature 33 of the tachometer, preferably together with a resistor 40. In other words, the field winding 35 and the resistor 40 are connected in series with each other in the armature circuit so that the field winding 35 is energized by the armature or, in other words, self-excited. The tachometer generator 31 is constructed preferably from a 230 volt motor or generator from $\frac{1}{2}$ to $\frac{3}{4}$ horsepower in size. The field poles thereof are rewound so as to provide two separate field windings on each pole, namely, the windings 34 and 35 having approximately 70 percent of the number of turns of the same size wire as the original shunt field of the motor which was designed to provide full saturation at rated voltage. In other words, the two shunt fields 34 and 35 will be of the same value, differentially connected, each having 70 percent of the shunt field value of the original motor or an increase of 40 percent over the original total number of turns. It will be understood that the resistors 36 and 40 should be permanently fixed when a suitable characteristic has been achieved. Also, it will be understood that the line 443 connected to the rectifier 29 and the line 44 connected to the tachometer generator

31 are both in turn connected to the control means for the rheostat 25 or the motor thereof, or to any other suitable means for controlling the output of generator 24 or actuation of the rheostat 25, as has hereinbefore been explained.

By providing two field windings in the tachometer generator arranged in such a manner, it will be seen that when the fields are energized that the flux produced thereby oppose each other whereby the flux of these fields will balance each other so as to obtain the desired voltage output characteristic from the tachometer generator. In other words, by providing these two field windings, it will be seen that the generator is compensated so that its output voltage matches or balances the heating power voltage transmitted to the lines 14 and 15 and to the conductor rolls 2 and 3 and the strip S. That is to say, the tachometer generator 31 constructed in such a manner, establishes a reference voltage for controlling the heating power voltage requirements for the strip so that the voltage characteristic thereof is substantially the same as that of the reference voltage whereby the voltage supplied to the conductor rolls and the strip is maintained at the required value to properly heat the strip.

Attention is now directed to the curves shown in Figure 4 of the drawings, wherein the abscissa represents the revolutions per minute of a tachometer generator, namely, the tachometer generator 31 and the ordinate represents the voltage output thereof. The two curves shown represent the output voltage of the tachometer generator in relation to the speed thereof under two different conditions. Curve A shows the voltage output of the pilot or tachometer generator when only one field winding is used or energized, namely, field 34 as shown in Figure 3 of the drawings. It will be seen from this curve that the voltage increases in direct ratio to the speed of the tachometer and it will be understood that this curve corresponds to performance typical of a conventional type tachometer generator with a single field winding. As has been hereinbefore explained, since the voltage generated by the tachometer generator is used through the media of various controls to ultimately regulate the current for melting the coating on the strip, and furthermore since the melting current is not directly proportional to the speed of the strip, it will be seen that a standard or conventional type tachometer would not furnish a reference voltage for regulating the melting current efficiently.

In accordance with the present invention, in order to furnish a reference voltage with the desired characteristics which more nearly approaches melting current demands as indicated by the speed of the strip, a compensated pilot tachometer generator of the construction, heretofore described, has been provided. As has been explained, the flux produced by field 35 tends to cancel out or subtract from the effect of the flux produced by field 34. As a result, it will be seen that this opposition of the fluxes reduces the effective flux produced on the field poles, and the voltage output from the generator 31, then, will not be in direct proportion to the speed thereof, and this fact will be readily seen from curve B. In other words, field 34 constantly endeavors to increase the output voltage of the generator armature in direct proportion to the speed of rotation thereof, but the armature voltage causes current to flow through field 35 thus producing flux

in opposition to that produced by field 34, thereby resulting in a decrease in voltage from the armature. As the speed of the generator increases the resultant voltage increase will be somewhat less than in direct proportion to the speed increase, as will be readily seen from curve B. It will be understood that the exact relationship of generator operating speed to armature voltage output will be a result of the ratio of flux (ampere turns) produced by the combined field windings 34 and 35 as adjusted by resistors 36 and 40, respectively, in the field circuits.

It will be understood that the power output of the transformers 9 and 10, or, in other words, the power input to the load or conductor rolls 2 and 3, is controlled by the rheostat 25 through the action of tachometer generator 31 which controls the actuation of the same. In other words, it will be seen that as the speed of the strip is increased, the power input thereto by means of the transformers 9 and 10 is increased, and as the speed of the strip decreases, the power input to the conductor rolls and strip is decreased. It will be understood that such an electrical arrangement may be used for controlling the power input to a conductor roll in a plating bath, or a pickling or a cleaning tank, or in any case where it is desired to supply a variable source of power to a continuous moving metallic strip as it passes over a conductor roll.

As a result of my invention, it will be seen that there is provided an improved tachometer or compensated pilot generator which provides a reference for automatically controlling the voltage supplied to the conductor rolls depending on the speed of the strip thereover, and also a generator in which a reference voltage is established having the same characteristics as the voltage supplied to the strip so as to properly melt the coating thereon at any particular strip speed.

While I have shown and described one specific embodiment of my 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 my invention, as defined in the appended claims.

I 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, 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, said tachometer generator having two field windings with one of said fields having a constant flux connected to a source of direct current supply and the other connected to the armature circuit of the generator so that when the fields are energized the flux produced thereby oppose each other, the flux of said second field varying with the speed of said strip so as to obtain the desired voltage output characteristic from the generator, means for balancing the heating power voltage against the reference volt-

age 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.

2. 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, said tachometer generator having two field windings with one of said fields having a constant flux connected to a source of direct current supply and the other connected to the armature circuit of the generator so that when the fields are energized the flux produced thereby oppose each other the flux of said second field varying with the speed of said strip so as to obtain the desired voltage output characteristic from the generators, 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.

3. In combination with means for supplying current to a moving article, means for driving the article at variable speeds, a tachometer generator driven by said article-driving means for establishing a reference voltage, said tachometer generator having two field windings with one of said fields having a constant flux connected to a source of direct current supply and the other connected to the armature circuit of the generator so that when the fields are energized the flux produced thereby oppose each other, the flux of said second field varying with the speed of said article so as to obtain the desired speed-voltage ratio from the generator, means for balancing the supply voltage against the reference voltage, and means responsive to the difference between the reference and supply voltages for varying the voltage supplied to the strip as the speed of the strip varies.

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Certificate of Correction

Patent No. 2,432,801.

December 16, 1947.

GEORGE H. RENDEL

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 3, lines 14 and 15, for the word "improve" read *provide*; column 5, line 33, for "roll" read *rolls*; line 49, for "windings" read *winding*; line 74, for the numeral "443" read *43*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of April, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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