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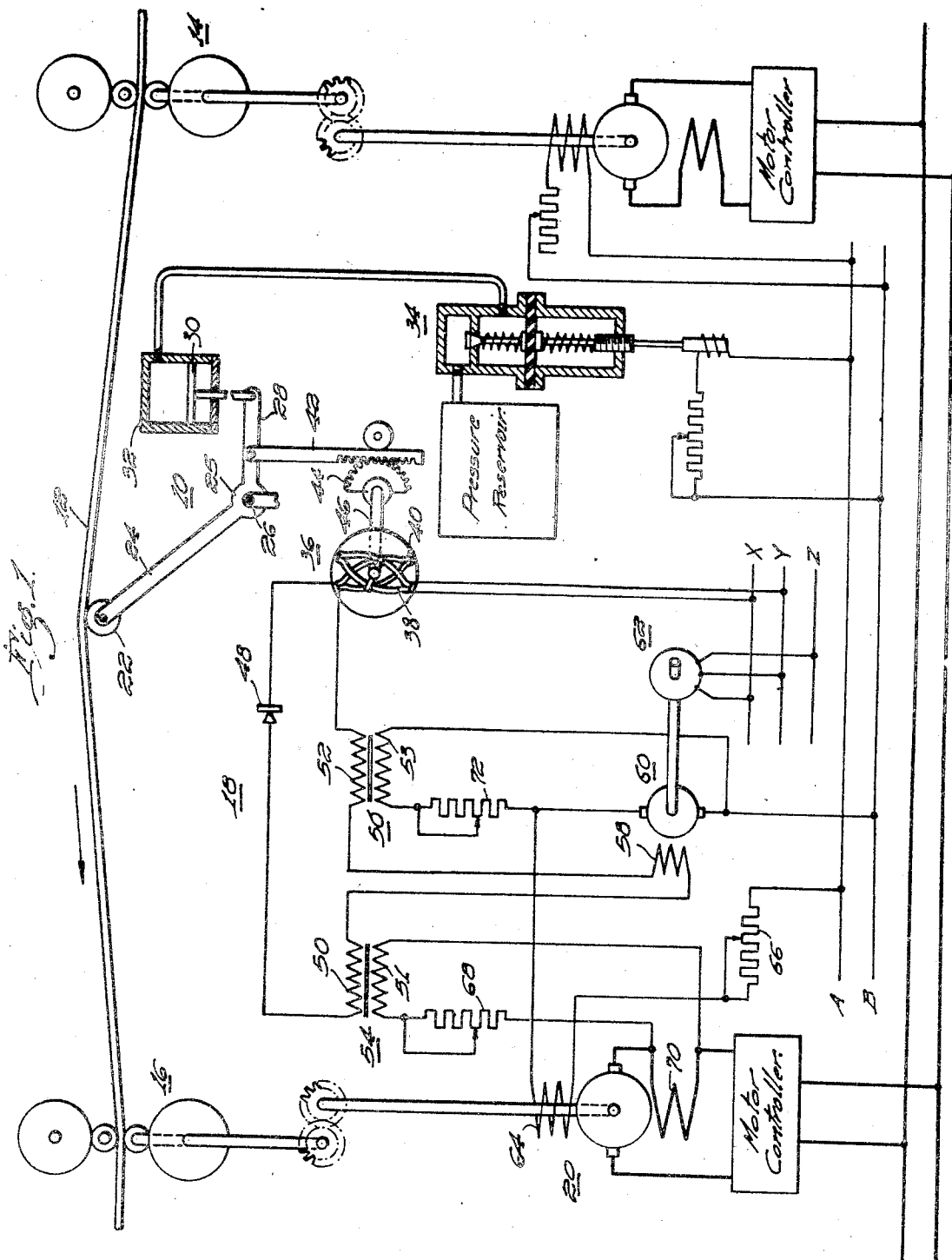
W. G. COOK

2,240,637

TENSIOMETER CONTROL SYSTEM

Filed July 28, 1938

2 Sheets-Sheet 1



WITNESSES:

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Joe Weber

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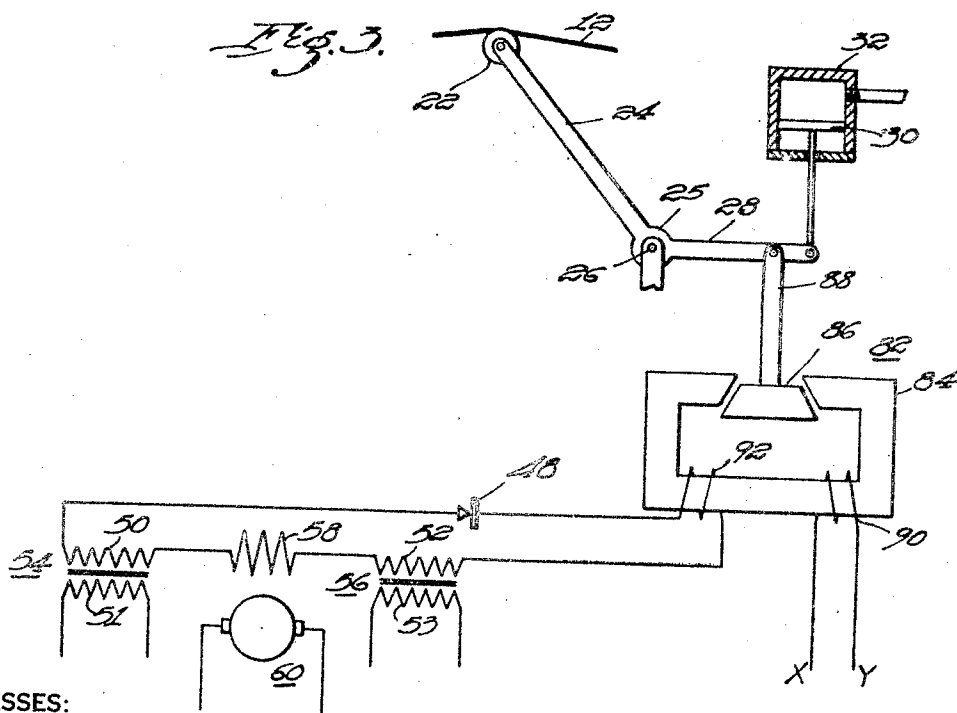
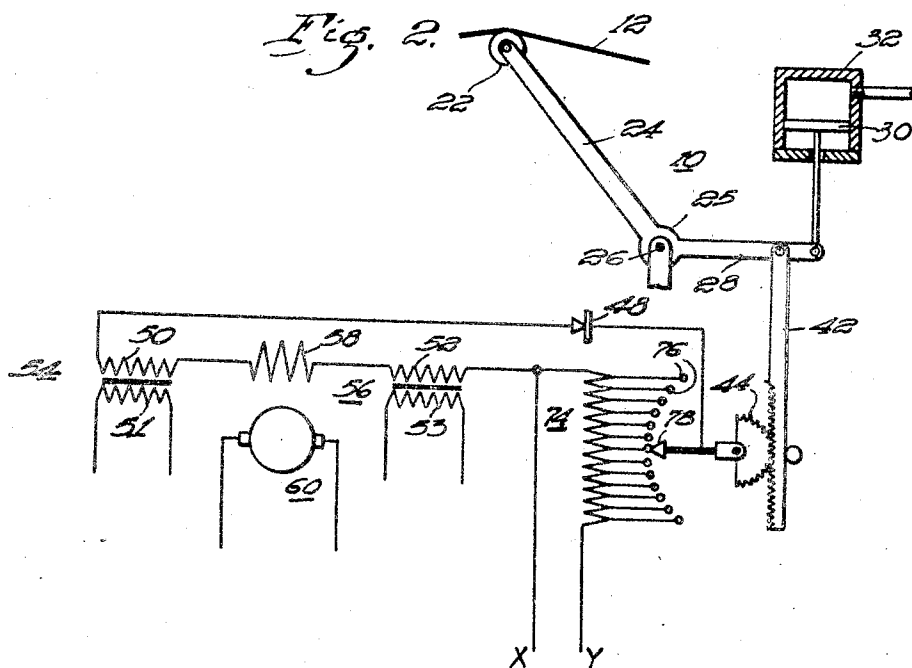
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2 Sheets-Sheet 2



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2,240,637

TENSIO-METER CONTROL SYSTEM

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10 Claims. (Cl. 86—35)

My invention relates, generally, to tensiometer control systems, and more particularly, to systems for controlling the tension on steel strip as it is being passed through a rolling mill.

In my patent application Serial No. 165,287 filed September 23, 1937, I have disclosed a tension control system in which tension is applied to a strip of material as it passes between adjacent roll stands, by a tensioning roller applying a transverse deflecting force to the strip. The deflection of the strip is maintained within predetermined limits by controlling the speed of one of the roll stand motors, preferably the motor of the leading stand, by means of a vibrating regulator which is controlled, through a synchro-tie system, in accordance with the position of the tensioning roller.

One object of my invention is to provide for simplifying the above-described tensiometer control system and improve its operation by eliminating the vibratory regulator, synchro-tie system, and other auxiliary relay devices and substituting apparatus therefor which is of more simple construction.

Another object of my invention is to provide a tension control system for a strip rolling mill which has a minimum of operating parts, which is simple in operation, and which is inexpensive to manufacture, install and maintain.

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

Figure 1 is a diagrammatic illustration of a tension control system embodying the principal features of my invention; and

Figs. 2 and 3 are diagrammatic views of modifications of that part of the control system shown in Fig. 1 which provides the proper energization for the booster generator.

In practicing my invention, I provide for controlling the excitation and speed of the leading roll stand motor by means of a booster generator connected in the field circuit of the motor and varying the excitation and voltage of the booster generator in accordance with the direction and amount of deflection of the strip from a predetermined position. Alternative systems are provided for properly varying the booster generator excitation, using different forms of variable ratio transformers.

Referring now to Fig. 1 of the drawings, I have shown a tensioning device 10 for acting on a strip of material 12, such as steel strip, to deflect the strip from its normal pass line, and to thus ten-

sion the strip as it passes in the direction shown by the arrow between adjacent roll stands 14 and 16 of a tandem rolling mill. In order to maintain the amount of deflection of the strip 12 from its normal pass line within predetermined limits, a regulating device 18 is provided for controlling the speed of the driving motor 20 of the leading roll stand 16 in response to the degree of deflection of the strip 12.

The tensioning device 10 comprises an idling or tension roller 22 supported by an arm 24 of a bell crank 25 having a pivotal support 26. The bell crank 25 has a horizontally extending arm 28 which is acted upon by a piston 30 operating in a cylinder 32. A predetermined fluid pressure is maintained on the piston 30 in the cylinder 32 by means of an automatic fluid pressure regulating valve 34 which is connected between the pressure reservoir shown and the piston 32. The operation of the tensioning device 10 to maintain a substantially predetermined constant tension on the strip 12 is explained in detail in the copending application of G. P. Lessmann, Serial No. 133,419, filed March 27, 1937, now Patent No. 2,189,609, issued February 6, 1940.

In this instance the regulator 18 may include a variable ratio transformer 36 having a primary winding 38 and a secondary winding 40. The primary winding 38 is mounted for rotation relative to the secondary winding 40, the angular displacement of the primary winding 38 with respect to the secondary winding 40 determining the ratio of transformation of the transformer 36, and thus determining the electromotive force induced in the secondary winding 40. The primary winding 38 may be rotated by a mechanism which includes a rack 42 connected to the arm 28 of the bell crank 25 so that the motion of the arm 28 will be transmitted to the rack 42. The rack 42 engages a pinion 44 to rotate the primary winding 38 through a shaft 46 which mechanically connects the pinion 44 with the primary winding 38. Thus the primary winding 38 of the transformer 36 is rotated in accordance with the displacement of the strip 12 by the idling roller 22 and the potential induced in the secondary winding 40 of the transformer 36 depends upon the degree of displacement of the strip 12 by the idling roller 22.

The primary and secondary windings 38 and 40 are so adjusted with respect to the operating mechanism of the tensioning device 10 as to have a relative displacement of approximately 45 electrical degrees when the strip 12 is displaced by the tensiometer 10 the desired normal amount.

Thus, when the deflection of the strip 12 increases above the desired normal amount, the angular displacement of the primary winding 38 with respect to the secondary winding 40 will be increased, and this will result in a decrease in the potential induced in the secondary winding 40. In a like manner, the potential induced in the secondary winding 40 will be increased when the displacement of the strip 12 decreases from the desired normal amount.

The secondary winding 40 of the transformer 36 is connected in series circuit relation with a rectifier 42, the secondary windings 50 and 52 of transformers 54 and 56 respectively, and the field winding 58 of a booster generator 60. By this connection it will be seen that the excitation of the booster generator 60 will vary with the amount of deflection of the strip 12 from the pass line of the mill.

The booster generator 60 may be continuously driven by a motor 20. The armature of the booster generator 60 is connected in series circuit relation with the field winding 54 of the mill motor 20, a rheostat 66 and any source of energization for the field winding 54 represented by the conductors A and B. The booster generator 60 is so connected in this series circuit as to normally add its potential to the potential of the source A—B so that the energization of the field winding 54 of the motor 20 depends upon the sum of the potentials of the source of energization A—B and the booster generator 60. The rheostat 66 is provided for adjusting the normal energization of the field winding 54 of the mill motor 20.

The transformer 54 hereinbefore referred to has a primary winding 51 which is connected in series circuit relation with the rheostat 68 and in shunt circuit relation with the interpole winding 70 of the mill motor 20. With this connection sudden increases or decreases in the armature current of the mill motor 20 will cause changes in the energization of the primary winding 51, which will induce impulses in the secondary winding 52 which will be proportional to the magnitude and duration of the changes in the current flow in the armature of the motor 20.

In a similar manner, the primary winding 53 of transformer 56 is connected in series circuit relation with a rheostat 72 and this series circuit is in turn connected in parallel circuit relation with the armature of the booster generator 60. Thus, any change in the output potential of the booster generator 60 will cause a change in the energization of the primary winding 53, which in turn will induce an impulse in the secondary winding 52, the magnitude and duration of which will depend upon the magnitude and duration of the change of the potential output of the booster generator 60. The rheostats 68 and 72 are provided to regulate the current flow in the primary windings 51 and 53 respectively, to secure the desired functioning of the transformers 54 and 56.

The secondary windings 50 and 52 of the transformers 54 and 56, respectively, being connected in series circuit relation with the field winding 58 of the booster generator 60, will cause changes in the excitation of the booster generator 60 when impulses are induced in them. A decrease in the potential output of booster generator 60 will cause a decrease in the excitation of the motor 20 and will thus cause an increase in the current flow in the armature of motor 20. The transformers 54 and 56 are so connected with respect to the interpole winding 70 and the booster generator 60 as to so change the excita-

tion of the booster generator 60 as to oppose the change in the current flow in the armature of the motor 20 and to oppose the change in the voltage output of the booster generator 60. Thus there is provided an anticipating system which will prevent the booster generator 60 from causing too sudden and too great changes in the speed of motor 20 in response to changes in deflection of the strip 12.

In the operation of the tension regulating system of Fig. 1, the tensioning device 10 will function as hereinbefore described to maintain a predetermined tension on the strip 12 by deflecting the strip from its normal pass line as it passes between the roll stands 14 and 16. If for any reason the strip should be deflected by the tensioning device 10 beyond a desired normal amount, the movement of the tensioning device will rotate the primary winding 38 with respect to the secondary winding 40 of the transformer 36 in the clockwise direction to decrease the potential induced in the secondary winding 40. The decrease in the potential induced in the secondary winding 40 will decrease the excitation of the booster generator 60 and this, in turn, will decrease the excitation of the motor 20. With the decrease in excitation of the motor 20, the motor will tend to increase its speed and this increase in speed will act through the rolls of roll stand 16 to take up the strip 12 between the roll stands 14 and 16 and thus decrease the amount of deflection of the strip 12 from the pass line and return this strip to its desired deflected position.

In order that the regulator 18 may not effect too great a decrease in the deflection of the strip and thus necessitate that the deflection be increased again, the anticipating system, comprising transformers 54 and 56 which act upon the field winding 58 of booster generator 60 in response to changes in the current flow in the armature of motor 20 and potential output of the booster generator 60, is provided to counteract the change in the potential output of the booster generator 60, as hereinbefore explained in detail.

In a like manner, the regulator 18 will function in response to a decrease in the deflection of the strip 12 by the tensioning device 10 to increase the deflection of the strip 12 by decreasing the speed of the motor 20 if for any reason the deflection of the strip 12 should decrease below the desired amount. In this event the anticipating system also functions as described hereinbefore to prevent the regulator 18 from effecting too great a correction.

In Fig. 2 of the drawings, there is shown a modification of that part of the system shown in Fig. 1 which has to do with changing the potential applied to the field winding 58 of the booster generator 60 in response to changes in the deflection of the strip 12. Like reference characters refer to the corresponding elements in Figs. 1 and 2 and the elements of Fig. 2 may be substituted for the corresponding elements of Fig. 1 to produce a completely operative system employing the modification of the invention shown in Fig. 2.

The variable ratio transformer of the embodiment of the invention shown in Fig. 2 may take the form of an auto-transformer 74 connected to a suitable source of alternating current, designated by conductors x and y, and having a plurality of voltage taps connected to stationary contact elements 76 which may be traversed by a

movable contact element 78 which is actuated by the rack 42 through the pinion 44 in accordance with the movements of the idling roller 22. The rack 42 is connected, as hereinbefore described in connection with the embodiment of the invention shown in Fig. 1, to the arm 28 of the bell crank 25 so that variations in deflection of the strip 12 will move the contact element 78 over the stationary contact elements 76 to change the ratio of transformation of the transformer 74, and thereby control the excitation of the booster generator 60.

The embodiment of the invention illustrated in Fig. 2 will function in the manner described in detail in connection with the embodiment of the invention shown in Fig. 1 with the ratio of transformation being changed by the movable contact element 76 traversing the stationary contact elements 78 to increase or decrease the excitation of the booster generator 60 depending upon the direction of movement of the movable contact element 78 from the normal position shown in Fig. 2.

The embodiment of the invention shown in Fig. 3 operates in substantially the same way as the systems shown in Figs. 1 and 2 with the exception that a transformer 82 of a different type is substituted for the moving coil transformer 36 of the embodiment of the invention of Fig. 1 or for the auto-transformer 74 of the embodiment of the invention shown in Fig. 2. The variable ratio transformer 82 has a fixed core 84 and a movable section of core 86 which may be moved in a vertical direction by an element 88 which is connected to the arm 28 of the bell crank 25 to vary the reluctance of the magnetic path of the transformer 82 when the deflection of the strip 12 from the normal position changes. This variation of the reluctance of the magnetic path of the transformer 82 will change the potential induced in the secondary winding 92 and will thus change the energization of the field winding 88 of the booster generator 60. The operation of this embodiment of the invention is substantially the same as that described in detail in connection with the embodiment of the invention shown in Fig. 1, the transformer 82 with its primary and secondary windings 90 and 92, being substituted for the transformer 36 and its primary and secondary windings 38 and 40 respectively.

It is within the purview of my invention to connect the booster generator 60 so that its potential will be opposite to the potential of the source of energy represented by conductors A—B, so that the effective potential in the circuit of the field winding 84 of the motor 20 will be the difference between the potential of the source A—B and the output potential of the booster generator. With this arrangement it will be necessary that the variable ratio transformers 36, 74 and 82 in the embodiments of the invention shown in the Figs. 1, 2 and 3 respectively, be arranged to increase the potential in their secondary circuits when the deflection of the strip increases, and to decrease the potential when the strip deflection decreases. Thus, the speed of the roll motor 20 will increase with increased deflection of the strip and decrease with decreases in the deflection of the strip since increases and decreases of the strip will cause decreases and increases, respectively, in the excitation of the roll motor 20.

It will be seen that I have provided a tensioning control system for a strip rolling mill which has a minimum of operating parts, which is

simple and efficient in operation, and which is inexpensive to manufacture, install and maintain.

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

I claim as my invention:

1. In a system for maintaining tension on a length of material as it passes between two work devices, tensioning means bearing on the material between the work devices and subjecting the material to a transverse force to thus deflect and tension the material, a variable speed motor connected to drive one of the work devices, a generator, circuit means connecting said generator to control the excitation of said motor in accordance with the output potential of the generator, a continuously energized variable ratio transformer, means controlled by the degree of deflection of the material from a predetermined position for varying the ratio of said transformer, means for rectifying the output of said transformer, and electrical circuit means connecting the field winding of said generator to be directly energized by the rectified output current of said transformer.

2. In a system for controlling the tension on a length of material as it passes between two work devices, tensioning means bearing on the material between the work devices and subjecting the material to a transverse force to thus deflect and tension the material, a variable speed motor connected to drive one of the work devices, a generator connected to control the excitation of said motor, a continuously energized variable ratio transformer, means controlled by the degree of deflection of the material from a predetermined position for varying the ratio of said transformer, a rectifier, a second and a third transformer, circuit means connecting said rectifier, the field winding of said generator and one winding of each of said second and third transformers in circuit with the secondary winding of said variable ratio transformer, circuit means connecting the other winding of said second transformer to be energized in accordance with the armature current of said motor, and circuit means connecting the other winding of said third transformer to be energized in accordance with the output potential of said generator.

3. In a control system for regulating the speed of a motor in accordance with the movement of a movable element, a continuously driven generator, circuit means connecting said generator to excite the motor in accordance with the output potential of said generator, a variable ratio transformer, means for varying the ratio of said transformer in accordance with the degree of movement of the movable element, a rectifier, and electrical circuit means connecting said rectifier and the field winding of said generator directly in electrical circuit with the secondary winding of said variable ratio transformer.

4. In a control system for regulating the speed of a motor in accordance with the movement of a movable element, a continuously driven generator connected to affect the excitation of the motor in accordance with the output potential of said generator, a variable ratio transformer,

means for varying the ratio of said transformer in accordance with the degree of movement of the movable element, a rectifier, a second and a third transformer, circuit means connecting one winding of said second transformer to be energized in accordance with the armature current of the motor, circuit means connecting one winding of said third transformer to be energized in accordance with the output potential of said generator, and circuit means connecting the other winding of said second and third transformers, said rectifier and the field winding of said generator in circuit with the secondary winding of said variable ratio transformer.

5. In a tandem strip rolling mill, tensioning means bearing upon the strip as it passes between adjacent roll stands of the mill subjecting the strip to a transverse force to thus deflect and tension the strip, a variable speed motor connected in driving relation with the rolls of one of the adjacent roll stands, a continuously driven generator connected to affect the excitation of said motor in accordance with the output potential of said generator, a transformer having its primary and secondary windings relatively movable to vary the transformer ratio, means controlled in accordance with the deflection of the strip by said tensioning means for producing relative movement of said transformer windings, a rectifier, and electrical circuit means directly connecting the secondary of said transformer, said rectifier and the field winding of said generator in series circuit relation.

6. In a tandem strip rolling mill, tensioning means bearing on the strip as it passes between adjacent roll stands of the mill subjecting the strip to a transverse force to thus deflect and tension the strip, a variable speed motor connected in driving relation with the rolls of one of the adjacent roll stands, a continuously driven generator connected to control the excitation of said motor in accordance with the output potential of said generator, a transformer having a core of variable reluctance, means controlled in accordance with the deflection of the strip for varying the reluctance of said transformer core, a rectifier, and electrical circuit means directly connecting the secondary of said transformer, said rectifier and the field winding of said generator in series circuit relation.

7. In a device for maintaining tension on a length of material as it passes between two work devices, tensioning means bearing on the length of material between the work devices and subjecting the material to a transverse force to thus deflect and tension the material, a variable speed motor connected to drive one of the work devices, a continuously driven generator connected to excite said motor, an auto-transformer having a series of taps intermediate the ends of its windings, a movable contact element for selectively engaging said taps, means for moving said contact element in accordance with the deflection of the material, a rectifier, and circuit means connecting said rectifier, the field winding of said generator, one end of said transformer windings and said movable contact element directly in series electrical circuit relation.

8. In a tandem strip rolling mill, tensioning means bearing upon the strip as it passes be-

tween adjacent roll stands of the mill subjecting the strip to a transverse force to thus deflect and tension the strip, a variable speed motor connected in driving relation with the rolls of one of the adjacent roll stands, a continuously driven generator connected to excite said motor, a first transformer having its primary and secondary windings relatively movable to vary the transformer ratio, means controlled in accordance with the deflection of the strip by said tensioning means for producing relative movement of said transformer windings, a rectifier, a second transformer having its primary winding connected to be energized in accordance with the armature current of said motor, a third transformer having its primary winding connected to be energized in accordance with the output potential of said generator, and circuit means connecting the secondary windings of said first, second and third transformers, said rectifier and the field winding of said generator in series circuit relation.

9. In a tandem strip rolling mill, tensioning means bearing on the strip as it passes between adjacent roll stands of the mill subjecting the strip to a transverse force to thus deflect and tension the strip, a variable speed motor connected in driving relation with the rolls of one of the adjacent roll stands, a continuously driven generator connected to excite said motor, a first transformer having a core of variable reluctance, means controlled in accordance with the deflection of the strip for varying the reluctance of said transformer core, a rectifier, a second transformer having its primary winding connected to be energized in accordance with the armature current of said motor, a third transformer having its primary winding connected to be energized in accordance with the output potential of said generator, and circuit means connecting the secondary windings of said first, second and third transformers, said rectifier and the field winding of said generator in series circuit relation.

10. In a device for maintaining tension on a length of material as it passes between two work devices, tensioning means bearing on the length of material between the work devices and subjecting the material to a transverse force to thus deflect and tension the material, a variable speed motor connected to drive one of the work devices, a continuously driven generator connected to excite said motor, an auto-transformer having a series of taps intermediate the ends of its windings, a movable contact element for selectively engaging said taps, means for moving said contact element in accordance with the deflection of the material, a rectifier, a second transformer having its primary winding connected to be energized in accordance with the armature current of said motor, a third transformer having its primary winding connected to be energized in accordance with the output potential of said generator, and circuit means connecting said rectifier, the secondary windings of said second and third transformers, the field winding of said generator, said movable contact element and an end of the winding of said auto-transformer in series circuit relation.

WILLARD G. COOK.