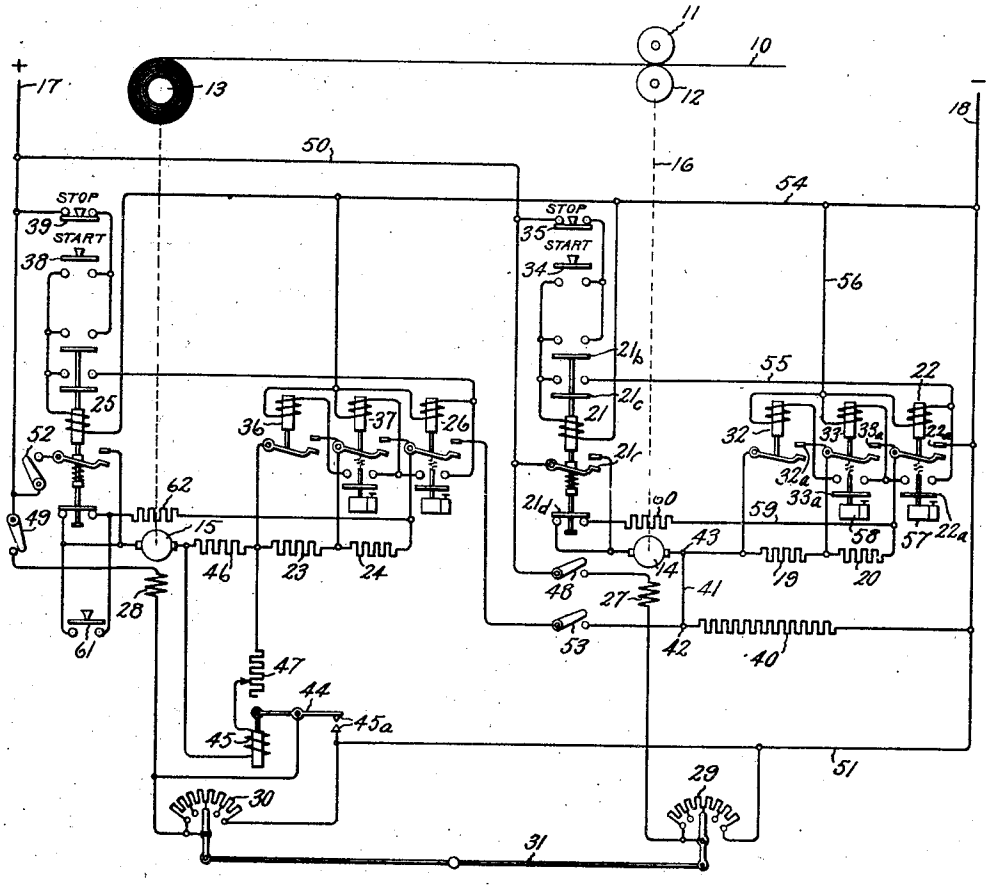
April 5, 1932. F. MOHLER 1,852,819

MOTOR CONTROL SYSTEM

Filed Ma 28, 1931



Inventor:
Francis Mohler,
by Charles E. Mullin
His Attorney.

Patented Apr. 5, 1932 1,852,819

UNITED STATES PATENT OFFICE

FRANCIS MOHLER, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

MOTOR CONTROL SYSTEM

Application filed May 28, 1931. Serial No. 540,685.

This invention relates to motor control systems, more particularly to motor control systems employed in carrying out predetermined operations upon a length of material, and has for an object the provision of a simple, reliable and efficient system of the kind.

More specifically, the invention relates to motor control systems for carrying out operations upon a strip of metal, such for example as a strip of steel, and a further object of the invention is the provision of means for effecting even acceleration of the rolling mill motor and the winding reel motor thereby to prevent undue stretching or wrinkling of the strip when starting from rest.

In the rolling of thin gauge cold steel strip such as tin-plate, precaution must be taken to prevent the formation of slack in the strip between the finishing rolls and the reel due to the tendency of the finished thin strip to buckle if tension is released.

It is, therefore, an additional object of the invention to maintain tension in the material while the mill is stopped and also during the stopping operation thereby to eliminate all tendency toward buckling or wrinkling the strip.

In carrying the invention into effect in one form thereof, a motor for performing work upon a length of material and the reel motor employed for winding up the finished strip are both supplied from a common source, and means are provided for equalizing the voltages applied to the motors during the starting period, thereby insuring even acceleration of the motors.

More specifically, both motors are connected to a supply source through a resistance device and an electrical connection between both motors is provided to equalize the applied voltage, together with means for rendering the resistance device ineffective at starting and means for separately interrupting the work motor circuit and again rendering the resistance device effective when stopping so that the reel motor is maintained connected to the supply source and sufficiently energized through the resistance device to maintain tension in the material when the mill operations are stopped.

In illustrating the invention in one form thereof I have shown it as applied in a control system for a rolling mill employed for rolling cold strip steel of a very thin gauge, such for example as commercial tin plate. Although the invention will be principally described with particular reference to the operation of rolling cold steel strip, it will, of course, be understood that the invention is by no means limited thereto.

For a better and more complete understanding of the invention, reference should now be had to the following specification and to the accompanying drawing, the single figure of which is a simple, diagrammatical illustration of one embodiment of the invention.

Referring now to the drawing, a length of material 10, such for example as a strip of cold steel is shown as being passed between the reducing rolls 11, 12 of the finishing stand of a cold strip mill and the delivered finished strip being wound upon a reel 13. The finishing rolls 11, 12 are driven by an electric motor 14 to the drive shaft of which they are connected by any suitable connecting means such as a reducing gearing (not shown); the connection being indicated in the drawing by the dotted line 16.

The winding reel 13 is likewise driven by an electric motor 15 and the driving connections between this motor and the reel are similarly indicated by means of a dotted line.

Although the motors 14 and 15 may be of any suitable type, they are illustrated as being of the direct current or shunt wound type and as being supplied from a suitable source of power such for example as that represented in the drawing by the supply lines 17 and 18. Suitable accelerating resistances 19 and 20 are connected in the circuit of the armature of the mill motor 14 and the armature is arranged to be connected to the supply source 17 and 18 by means of line contactors 21 and 22. Accelerating resistors 23 and 24 are likewise included in the armature circuit of the reel motor 15 and the line contactors 25 and 26 are provided for the purpose of connecting the armature of

the motor 15 to the source of supply 17, 18 with the accelerating resistances 23, 24 in circuit. As shown, the shunt field windings 27 and 28 of the motors 14 and 15 are also supplied from the supply source 17, 18. The respectively cooperating movable contacts of the field weakening resistances 29 and 30 are mechanically coupled by any suitable means such for example as the connecting rod 31, and the field weakening resistances 29 and 30 may be simultaneously varied to simultaneously vary the speeds of the motors 14 and 15 by manual operation of the connecting rod 31 in one direction or the other depending upon whether it is desired to increase or decrease the speeds of the motors.

The accelerating resistors 19 and 20 in the armature circuit of the motor 14 are respectively controlled by the accelerating contacts 32, 33 and the energizing circuits of the operating coils are in turn arranged to be controlled by any suitable means, illustrated in the drawing as manually operated "start" and "stop" push buttons 34 and 35 respectively.

It will likewise be seen that the accelerating resistances 23 and 24 in the armature circuit of the reel motor 15 are respectively controlled by contactors 36 and 37, the energizing circuits of the operating coils of which are similarly controlled by manually operated "start" and "stop" push buttons 38 and 39.

A current limiting device shown in the drawing as a resistance 40 is included in the armature circuit of the reel motor 15 and this resistance is preferably sufficiently large to limit the current passing through the armature of the motor 15 to approximately 20% of its normal value with the accelerating resistances 23 and 24 entirely short-circuited. The resistance 40 is effective in the armature circuit of the reel motor 15 only when the mill motor 14 is stopped and since this resistance limits the current flowing through the reel motor to a very small value, this motor will be just sufficiently energized to cause it to take up the slack in the strip 10 between the reel 13 and the finishing rolls 11, 12 after which the motor 15 will stall and maintain tension in the strip 10. The tension in the strip 10, however, will be limited to a permissible value since the resistance 40 limits the armature current of the reel motor 15 to a low value.

In order to equalize the voltages applied to the mill motor 14 and the reel motor 15 so as to insure equal and even acceleration of these motors from rest, an electrical connection 41 is provided from a point 42 in circuits between one terminal of the reel motor 15 and the stalling resistance 40 to a point 43 in circuit between a corresponding armature terminal of the mill motor 14 and the accelerating resistance 19. It will thus be observed that when the line contactor 26 for the reel motor is closed and the accelerating resistances 23 and 24 are short-circuited, the corresponding armature terminal of the mill motor 14 and reel motor 15 are connected together and that, therefore, the voltage applied to the armatures of these motors will be substantially equalized. It will also be observed that, with the accelerating resistances 23 and 24 of the reel motor short-circuited and the line contactor 26 closed, due to the presence of the equalizing connection 41 between the corresponding armature terminals of motors 14 and 15, the accelerating resistances 19 and 20 for the mill motor 14 will also serve as an accelerating resistance for the reel motor 15 thereby further insuring the even acceleration of these motors during starting.

A suitable tension regulator is provided for the purpose of maintaining constant tension of a predetermined value in the strip during the rolling operation. This tension regulator is shown as a constant current regulator 44 which is preferably of the well-known vibratory type having vibrating contacts 45a, a field weakening resistance 30 and having an operating coil connected across a resistance 46 of low value in the armature circuit of the motor 15; a suitable tension adjusting resistance 47 being included in the circuit of the operating coil 45 for the purpose of enabling the regulator to be adjusted to hold any one of a plurality of desired tensions in the strip.

With the above understanding of the elements and apparatus comprising an embodiment of the invention, the operation of the system will readily be understood from the detailed description which follows:

The apparatus is shown in its normal or prestarting condition. The respective manually operated line switches 48 and 49 for the shunt field windings 27 and 28 of the mill and reel motors are first operated to the closed position to connect the shunt field windings 27 and 28 to the supply source 17, 18, the circuits for the shunt field winding 27 being traced from the positive side of the supply source 17 through conductor 50, line switch 48, shunt field winding 27, field weakening resistance 29 and conductor 51 to the negative side of the supply source 18. The circuit for the shunt field winding 28 is similarly traced from the positive side of the supply source 17 through the line switch 49, shunt field winding 28, field weakening resistance 30, conductor 51 and thence to the negative side of the supply source 18.

The manually operated line switches 52 and 53 in the armature circuit of the reel motor 15 are also operated to the closed position and the system is then in readiness for starting.

Before commencing the rolling operation,

the mill must first be threaded, i. e., the strip must be run through the rolls of the succeeding mill stands and the ends of the strip clamped in the jaws of the reel 13. The threading of the mill may be performed either by the method known as "threading from stand-still" or the method known as "threading on the fly."

In the operation of "threading from stand-still", the strip is inserted in the rolls at the successive stands and as the end is inserted between the rolls the corresponding mill motor for that section of the drive is started. When the end of the strip reaches the finishing stand, the end of the strip is inserted between the rolls 11 and 12 and the start button 34 is depressed to the closed position in which it establishes an energizing circuit for the line contactor 21; this circuit being readily traced from the positive side of the supply source over the conductor 50, through the stop button 35, the start button 34 in its closed position, the operating coil of the line contactor 21 and conductor 54 to the negative side 18 of the supply source. Contactor 21 in responding to the energization of its coil closes its lower main contact 21_a and its upper auxiliary contacts 21_b and 21_c; the auxiliary contact 21_b, completing a holding circuit for its operating coil independently of the start button 34, which may then be released. The auxiliary contact 21_c completes an energizing circuit for the negative line contactor 22, which circuit may be traced from the positive side of the supply source 17 through the conductor 50, stop button 35, auxiliary contact 21_c, conductor 55, operating coil of contactor 22, conductor 56 and thence by conductor 54 to the negative side 18 of the supply source. Contactor 22 in responding to the energization of its operating coil closes its upper main contact 22_a thus completing the circuit for the armature of the motor 14 to the negative side of the supply source with the accelerating resistances 19 and 20 in series in the circuit. The motor 14 now starts very slowly due to the large amount of resistance in its armature circuit and after a predetermined time interval which may be adjusted as desired by means of the time-delay dash pot 57, the line contactor 22 closes its lower auxiliary contact 22_a establishing an energizing circuit for the operating coil of the contactor 33; this circuit being traced to the conductor 55 as before and thence through the auxiliary contact 22_a, the operating coil of contactor 33, conductor 56 and conductor 54 to the negative side 18 of the supply source. Contactor 33 immediately closes its upper main contact 33_a short-circuiting the portion 20 of the accelerating resistance thereby causing the speed of the motor 14 to increase in a well-understood manner. After a time interval which is determined by the setting of the time delay dash pot 58 with which contactor 33 is provided, contactor 33 closes its lower auxiliary contact 33_a to establish an energizing circuit for the final accelerating contactor 32; this energizing circuit being traced from the positive side of the supply source to the auxiliary contact 22_a as before and thence through the auxiliary contact 33_a, operating coil of contact 32, conductor 56 and conductor 54 to the negative side 18 of the supply source. Contactor 32 thereupon responds and closes its contact 32_a to short-circuit the final section 19 of the accelerating resistance whereupon the speed of the mill motor 14 increases to its normal operating value.

After a sufficient amount of the strip has been run through the rolls 11, 12 of the finishing mill to reach the reel 13, a stop button 35 is depressed thereby interrupting the energizing circuits of the line contactors 21 and 22 and the accelerating contactors 32 and 33. These contactors thereupon descend to their normal prestarting position in which the motor 14 is disconnected from the source 17, 18 and the accelerating resistances 19 and 20 are reinserted in the armature circuit. Contactor 21 in descending to its lower position causes its lower auxiliary contact 21_d to complete a dynamic braking circuit for the armature of the motor 14, which circuit may be traced from the armature terminal 43 of the motor through accelerating resistances 19 and 20, conductor 59, dynamic-braking resistance 60, auxiliary contact 21_d to the opposite armature terminal of the motor 14. The motor 14 is thereupon brought to rest rapidly in a well-understood manner.

The end of the strip 10 is then inserted in the jaws of the reel 13, after which the start button 38 for the reel motor 15 is depressed and the reel motor 15 is connected to the supply source 17, 18 with the stalling resistance 40 connected in series in the armature circuit. Since the circuits and the operation of the line contactors 25 and 26 and the accelerating contactors 36 and 37 are in all respects identical with the circuits of the line contactors 21 and 22 and the auxiliary contacts 32 and 33 for the mill motor, it is believed to be unnecessary to trace these circuits and describe the operation of these contactors since this will be entirely clear from the preceding description with respect to the starting and acceleration of the mill motor 14. It will be observed, however, that after the accelerating resistances 23 and 24 of the reel motor 15 have been short-circuited, the stalling resistance 40 will still be connected in series in the armature circuit and as previously pointed out, this resistance limits the current flowing through the armature of the reel motor 15 to a very low value, e. g., twenty percent of the normal full value. The reel motor 15 will thereupon cause the reel 13 to wind up the

strip 10 and after the slack between the reel 13 and finishing rolls 11, 12 has been taken up, the reel motor 15 will be stalled due to the effect of the stalling resistance 40, but will be sufficiently energized, however, to maintain tension in the strip 10 between the reel and the finishing rolls.

In the event that the winding up of the slack in the strip 10 by the reel 13 appears to be proceeding at too rapid a rate, the operator may depress "jog" button 61 to complete a dynamic-braking circuit for the armature of the reel motor 15; this dynamic-braking circuit being traced from the negative armature terminal through the accelerating resistances and the dynamic-braking resistance 62, thence through the contacts of the jog button 61 to the opposite armature terminal 15.

It will be observed that after the slack has been taken up in the strip and the motor 15 has been stalled, the accelerating resistances 23 and 24 are short-circuited by their respective accelerating contactors 36 and 37, and that the negative armature terminal of the mill motor 14 is directly connected to the negative armature terminal of the reel motor 15 through the equalizing connection 41.

The rolling operation may now be started simply by depressing the start button 34 of the mill motor. Since the positive armature terminal of the motor 15 is connected to the supply source through line contactor 25, it will be seen that when the line contactor 22 for the mill motor is closed in response to the operation of the start button 34 to start the mill motor, the negative armature terminal of the reel motor 15 will be connected to the negative side of the supply source 18 through the mill motor accelerating resistances 19 and 20. Consequently, when the accelerating resistances 19 and 20 are short-circuited by their respective accelerating contactors 32, 33, the mill motor 14 and the reel motor 15 will both be simultaneously accelerated and due to the presence of the equalizing connections 41 the voltage applied to both motors will be substantially equal and both motors will accelerate smoothly and evenly, thereby preventing any noticeable tendency to tear or unduly stretch the strip 10.

After the rolling operation has reached full speed, tension will be maintained in the strip 10 by means of the tension regulator 45 in a manner that is well understood by persons skilled in the art and which it is believed unnecessary to describe here in detail. It will be observed that the negative line contactor 22 for the mill motor 14 is interlocked with the positive line contactor 21, i. e., the auxiliary contacts 21_c of the positive line contactor are included in the energizing circuit of the negative line contactor 22 so that the energizing circuit of the negative line contactor cannot be established until the positive line contactor 21 has been first operated to the closed position. The ohmic value of the mill motor accelerating resistances 19 and 20 is small in comparison with that of the stalling resistance 40 and consequently if the negative line contactor 22 is closed before the positive line contactor 21 after the mill has been threaded, and the reel motor 15 is connected to the source through the stalling resistance 40 and with the accelerating resistances 23 and 24 short-circuited, there will be a heavy inrush of current through the mill motor accelerating resistances 19 and 20, the equalizing connections 41 and the reel motor 15 which will be sufficient to cause the reel motor 15 to start before the mill motor 14 and break the strip 10. This interlocking feature, however, by insuring the operation of the positive line contactor 21 prior to the operation of the negative line contactor 22 prevents this large inrush of current to the reel motor 15 and insures that both the mill motor 14 and the reel motor 15 will start simultaneously when the negative line contactor 22 finally closes, thus eliminating any tendency of the reel motor 15 to break the strip.

In the operation of "threading on the fly" the field weakening resistance 30 for the reel motor is initially adjusted so that the reel motor 15 tends to hold a slightly higher speed than that of the mill motor 14. The strip 10 after having been threaded through the rolls at the various stands is carried along by the operator and the end inserted in the finishing rolls 11, 12 and the mill motor 14 started and accelerated in a manner that is identical with that described in the operation of "threading from stand-still". After the strip is threaded through the finishing rolls 11, 12 it is carried along by the operator to the reel 13. Instead of stopping the mill motor 14 at this point as in the above-described operation, the end of the strip 10 is quickly inserted in the jaws of the reel 13 and the start button 38 for the reel motor pressed whereupon the reel motor 15 is connected to the supply source through accelerating resistances 23 and 24, the equalizing connection 41, and the negative line contactor 22 of the mill motor independently of the stalling resistance 40. The accelerating resistances 23 and 24 are short-circuited and the reel motor is accelerated in a manner that is identical with that previously described in connection with the threading of the reel in the operation of "threading from stand-still". Due to the slightly increased setting of the field weakening resistance 30 the reel motor 15 will accelerate quickly and take up the slack in the strip 10 between the reel 13 and the finishing rolls 11, 12 after which the rolling operation will proceed in the usual manner; the tension regulator 45 function-

ing to maintain a predetermined tension in the strip 10 between the reel and the finishing roll.

To stop the rolling operation, it is only necessary for the operator to depress the mill motor stop button 35 to interrupt the energizing circuit for the positive and negative line contactors 21 and 22 respectively and the accelerator contactors 32 and 33. As the positive line contactor 21 descends to its lower position in response to the deenergization of its coil, the lower auxiliary contact 21_d closes and establishes a dynamic-braking circuit for the mill motor 14 through the accelerating resistances 19 and 20 and the dynamic-braking resistance 60, which causes the mill motor to be brought to rest quickly. The opening of the negative line contactor 22 removes the short-circuit from about the stalling resistance 40 and renders this resistance effective in the armature circuit of the reel motor 15. It will thus be seen that when the mill motor 14 is disconnected from the source, the reel motor 15 is maintained connected to the supply source through the stalling resistance 40 and wholly independently of the mill motor accelerating resistances 19 and 20 and the mill motor negative line contactor 22. When the mill motor 14 comes to rest, the reel motor 15 will also come to rest since the maximum current which it can draw from the line through the stalling resistance 40 is but a small percentage of normal full value and thus, the mill motor will be stalled when the current through the reel motor 15 has reached this value. The reel motor 15, however, will be sufficiently energized through the stalling resistance 40 to maintain tension in the strip both during stopping of the mill motor 14 and while the latter is stopped.

Although in accordance with the provisions of the patent statutes, I have described this invention as embodied in specific apparatus and connections, I would have it understood that the invention is by no means limited thereto since alterations and modifications will readily suggest themselves to persons skilled in the art without departing from the true spirit of this invention or the scope of the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a motor for performing work upon a strip of material, a reel motor for winding finished strip, a common connection including a current limiting device between one terminal of each of said motors and one side of a supply source, means for starting said mill operations including means for completing connections from said motors to a common supply source and rendering said current limiting device ineffective, and means for stopping said operations including means for rendering said current limiting device effective and interrupting said work motor connections independently of said reel motor connections so that said reel motor is maintained connected to said source and energized through said current limiting device to maintain tension in the strip.

2. In combination, a motor for performing work upon a material, a reel motor for winding finished material, connections between said work motor and a supply source, means for connecting said reel motor to said supply source through said connections including a connection from said reel motor to said work motor for substantially equalizing the voltage applied to said motors and means comprising a separate electrical connection from said reel motor to said source for maintaining tension in the material when said work motor is disconnected from the source.

3. In combination, a motor for performing work upon a material, a reel motor for winding finished material, electrical connections between said motors and a supply source, means for connecting said reel motor to said work motor for substantially equalizing the voltage applied to said motors to provide even acceleration thereof, means for interrupting said connections to stop said working and winding operations and means including a separate electrical connection from said reel motor to said source and a current limiting device included therein for maintaining tension in the material when said operations are stopped.

4. In a mill, a mill motor for performing work upon a strip of material, a reel motor for winding finished strip, connections between said motors and a common supply source including a connection between said motors for substantially equalizing the voltage applied to said motors to provide even acceleration thereof, means for interrupting said connections to stop said mill operations, and means comprising a separate electrical connection including a resistance device for maintaining said reel motor connected to said source independently of said connections to cause said reel motor to maintain a predetermined tension in the strip during stopping.

5. In combination, a mill motor for operation upon a strip of material, a reel motor for winding up the finished strip, means for connecting said mill motor to a supply source, means for connecting said reel motor to said mill motor and to said source through said mill motor connecting means, and means comprising a separate electrical connection for connecting said reel motor to said source independently of said mill motor connecting means and a current limiting device included in said separate connections for causing said reel motor to stall and maintain a predetermined tension in the strip when said mill motor is disconnected from the source.

6. In a mill for operating upon a strip of

material, a mill motor, a reel motor, means for connecting said reel motor to a source of supply to wind up the finished strip, means comprising a current limiting device in circuit with said reel motor for causing said reel motor to stall and maintain tension in the strip after the slack has been taken up, means for connecting said mill motor to the source, and means for connecting said reel motor to said mill motor thereby to connect said reel motor to the source independently of said current limiting device and to equalize the voltage applied to said motors so as to provide for substantially equal acceleration of said motors.

7. In a mill having means for operating upon a strip of material and means for winding up the finished strip, a mill motor for driving said operating means, a reel motor for driving said winding means, separate connections between one armature terminal of each of said motors and one side of a supply source, a common connection between the opposite terminals of said motors and the opposite side of said supply source for equalizing the voltage applied to said motors so as to effect substantially equal acceleration of said motors, means for interrupting said separate connection for said mill motor and said common connection to stop said mill motor, and an independent connection including a resistance device between the opposite terminal of said reel motor and said opposite side of said source for causing said reel motor to stall and maintain tension in the strip after interrupting said common connection.

8. In combination, a work motor for operating upon a strip of material, a reel motor for winding up the finished strip, a switching device for connecting said mill motor to a supply source, an electrical connection between said reel motor and a point in circuit between said mill motor and said switching device for connecting said reel motor to said source through said switching device and to substantially equalize the voltage applied to said motors, and means comprising a separate electrical connection and a resistance device included thereon for maintaining said reel motor connected to said source and sufficiently energized to maintain tension in the strip upon operation of said switching device to disconnect said work motor from the source.

9. In combination, a work motor for operating upon a strip of material, a reel motor for winding up the finished strip, means for connecting said reel motor to a supply source, a sensitive device connected in circuit with said reel motor for causing said reel motor to stall and maintain tension in the strip after taking up the slack, means for connecting said work motor to a source of supply, an accelerating resistance in circuit with said work motor, an electrical connection from a point in circuit between said reel motor and resistance device and a point in circuit between said work motor and accelerating resistance for connecting said reel motor to said source independently of said resistance device and for substantially equalizing the voltage applied to said motors, and means for varying said accelerating resistance to accelerate both motors.

10. In combination, a work motor for operating upon a length of material, a reel motor for winding up finished material, electrical connections between a terminal of each of said motors and one side of a supply source, an electrical connection including a resistance device between the opposite terminal of said reel motor and the opposite side of said supply source for causing said reel motor to stall and maintain tension in the material after taking up the slack, electrical connections including an accelerating resistance between the opposite terminal of said work motor and the opposite side of said supply source, an electrical connection between said opposite terminals of said motor for connecting said reel motor to said source independently of said resistance device and for substantially equalizing the voltage applied to said motors, and means for controlling said accelerating resistance to accelerate said motors.

11. In a mill, a mill motor for operating upon a strip of material, a reel motor for winding finished strip, separate connections between one terminal of each of said motors and one side of a supply source, means comprising a current limiting device connected between the opposite terminal of said reel motor and the opposite side of said supply source for causing said reel motor to take up the slack in the strip and maintain a predetermined tension therein, an accelerating resistance and a switching device connected between the opposite terminal of said mill motor and the opposite side of said source, a second switching device included in the separate connection from said mill motor, an electrical connection from a point in circuit between said reel motor and said current limiting device to said opposite terminal of said mill motor for connecting said reel motor to the opposite side of said source through said accelerating resistance and for substantially equalizing the voltage applied to said motors upon operation of said switching devices, a third switching device for controlling said accelerating resistance to accelerate said motors and interlocking connections insuring the operation of said second switching device prior to the operation of said third switching device.

In witness whereof, I have hereunto set my hand.

FRANCIS MOHLER.