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CONTROL SYSTEM

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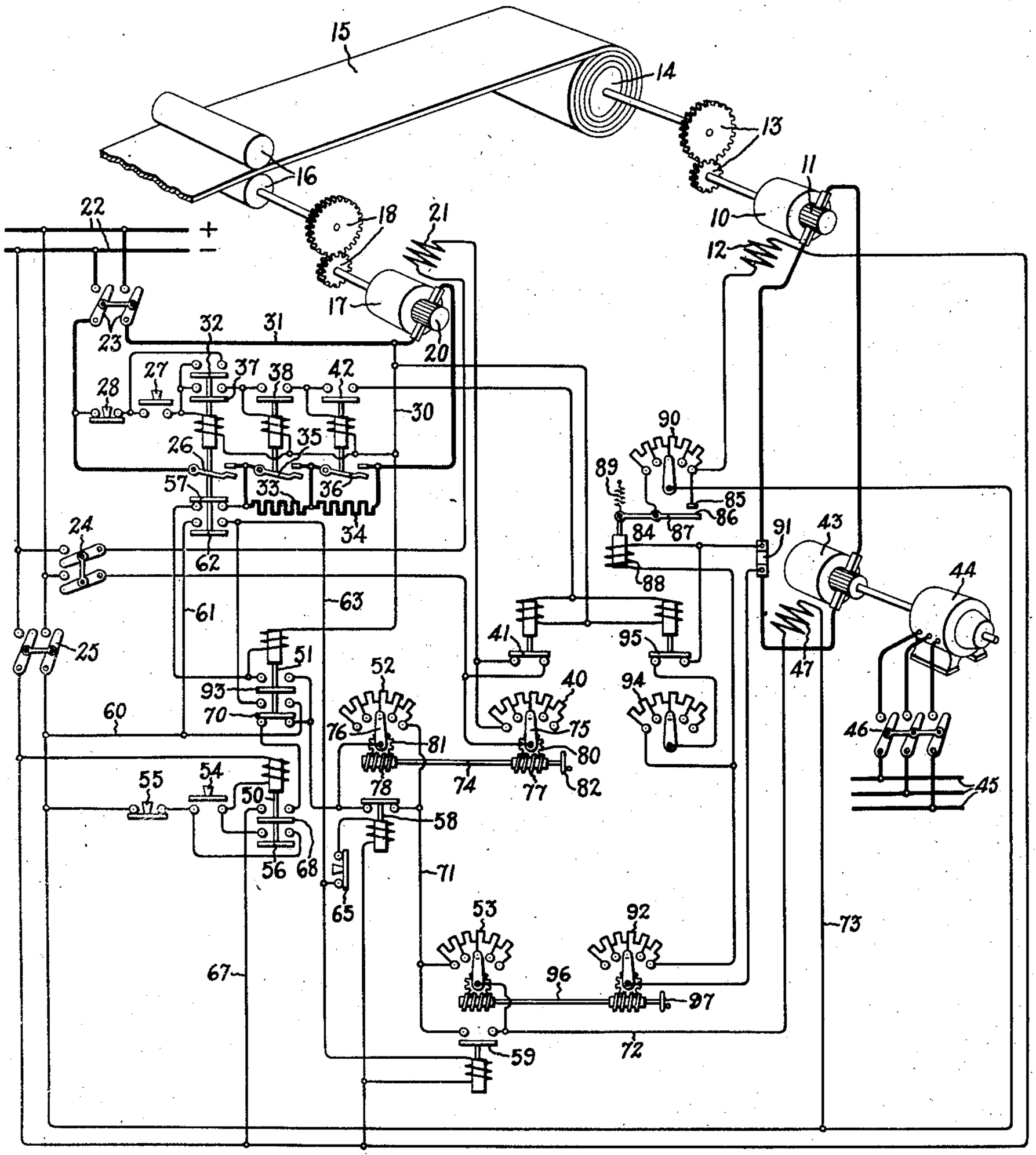

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CONTROL SYSTEM

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Our invention relates to control systems, more particularly to control systems for electric motors employed to drive reels for winding up strip materials, such as cold rolled strip steel, and has for its object the provision of an improved control system of this character.

In the manufacture of various sheet materials, such as cold rolled strip steel, it is usually the practice to wind the finished product on reels. In winding materials, such as strip steel, it is very desirable in order to improve the quality of the finished product that a substantially constant tension be maintained in the strip between the millstand and the reel regardless of the speed at which the material is being delivered to the reel. In some cases the ratio of the maximum to the minimum delivery speed of the strip material to the reel is as great as 3:1. In view of the fact that the active diameter of reel also changes greatly during the winding operation for any given mill speed, it is necessary in many instances that the reel driving motor have a speed range as great as 12:1 or more. In one of its aspects, our invention contemplates the provision of improved means for controlling the reel driving motor so that it can be controlled conveniently to operate through a very large speed range, such as 12:1, and so that it will maintain a constant tension in the strip throughout the speed range of the mill.

At times during the rolling process when the strip is in the mill and also in the reel it is necessary to bring the mill to rest, and then to restart the mill in order to continue the rolling operation. Another aspect of our invention is the provision of suitable means for controlling the reel driving motor so that it will operate to maintain a proper tension in the strip while the mill is being decelerated and accelerated, and also when the mill is at rest.

In carrying our invention into effect in one form thereof, we provide a suitable generator for supplying power to the reel driving motor, and control the generator excitation in accordance with the rate of feed of the strip material to the reel so that the speed setting of the reel motor is adjusted as the mill speed is changed. We also provide a suitable regulator for controlling the current input to the reel motor so that this motor will operate to maintain a substantially constant tension in the strip material being wound regardless of the rate at which the strip is being fed to the reel. Suitable means are provided for automatically changing the current regulator setting so that the current input to the reel motor will be increased during the accelerating period of the mill. This increase in the current input during the accelerating period tends to maintain the proper tension in the strip.

In order to maintain the tension in the strip while the mill is decelerating we provide suitable means for reducing the excitation of the generator, and consequently the electromotive force impressed upon the reel motor, in accordance with the rate of deceleration of the mill.

Our control system further includes suitable means for controlling the generator so that when the mill is stopped a limited excitation will be applied. The excitation applied when the mill is stopped will provide an impressed reel motor voltage sufficient to maintain a tension in the strip as long as the mill is at rest.

For a more complete understanding of our invention reference should be had to the accompanying drawing in which the single figure is a diagrammatic representation of a system of control embodying our invention.

Referring to the drawing, we have shown our invention in one form as applied to a direct current motor employed to drive the collecting reel of a cold rolled strip steel mill. As shown, a direct current motor 10, provided with an armature 11 and a separately excited field winding 12, is mechanically connected by means of a suitable gear train 13 to drive a reel 14 which serves to collect and wind in coil form the strip steel 15 passing from the main mill rolls 16. An adjustable speed electric motor 17, preferably of the direct current type, is provided for driving the main mill rolls 16. As shown, this motor is provided with an armature 20 and a separately

excited field winding 21. A suitable source of direct current supply 22, preferably of substantially constant potential, is provided for energizing the field and armature windings of the motor 17, and the field winding of the motor 10. It will be understood that these motors can be provided with separate electrical supply sources; however, in the interests of economy the common supply source shown is desirable. A control switch 23 is inserted in the connections leading from the source 22 to the armature of the motor 17, while a control switch 24 is inserted in the connections leading from this source to the field winding 21 provided for the motor 17. A switch 25 similar to the switches 23 and 24 is inserted in the connections leading from the source 22 to the separately excited field winding 12 provided for the motor 10.

The control system for the mill motor 17 includes a suitable line contactor 26. This contactor is controlled preferably by means of a suitable push button station. As shown, this station comprises a "start" push button 27 and a normally closed "stop" push button 28 electrically connected in series with the operating coil for the line contactor 26 so that when the start button 27 is depressed an energizing circuit will be completed for the operating coil. This circuit may be traced from the lower conductor of the supply source 22 through the switch 23, the stop button 28, the start button 27, the operating coil of the contactor, the conductor 30 and thence through the conductor 31 and the switch 23 to the upper conductor of the supply source 22. It will be observed that the contactor 26 in closing establishes a holding circuit for itself through the stop button 28 by means of its associated interlock 32. The control system for the mill motor 17 further includes suitable accelerating resistors 33 and 34 connected in series with the motor armature 20. These resistors are placed under the control of accelerating contactors 35 and 36 which are energized successively in response to the closing of the line contactor 26. It will be observed that the line contactor 26 in closing will close its associated interlock 37 so as to complete an energizing circuit for the operating coil provided for the accelerating contactor 35 to close, and that this contactor in turn in closing will complete an energizing circuit for the accelerating contactor 36 to close by means of its associated interlock 38. Thus, it is merely necessary to depress the start button 27 in order to energize and accelerate the main mill motor 17, the line contactor 26 in closing in response to the depression of the start button operating to cause the successive operation of the accelerating contactors 35 and 36 to close.

In order that the main mill motor 17 may be operated at various suitable speeds, a suitable rheostat 40 is connected in series with the motor field winding 21, this rheostat serving to control the motor from its basic to its maximum speed. It will be understood that by varying the effective resistance in the circuit of the field winding 21, the speed of the motor 17 and consequently the rate of feed of the strip 15 to the reel will be varied accordingly. In order to insure that the mill motor will accelerate from standstill to basic speed with maximum field excitation, suitable means are provided for short circuiting the speed controlling resistor 40 during this portion of the accelerating period, and for automatically reinserting the resistor after the motor has been accelerated to its basic speed. For this purpose, we have provided a suitable ccntactor 41 which when closed operates to shunt the resistor 40, and which is energized to open responsively to the closing of the last accelerating contactor 36. It will be observed that the accelerating contactor 36 in closing will close its associated interlock 42 which when closed will complete an energizing circuit for the contactor 41. It will be obvious in view of this arrangement that the energizing circuit for the contactor 41 will be open until the last accelerating contactor has been closed, and that as a result the speed controlling resistor 40 will not be included in the motor field circuit until the motor has been brought up to its basic speed.

Power is supplied to the reel driving motor 10 by means of a suitable separately excited generator 43. This generator preferably will be driven at a substantially constant speed by any suitable means. As shown, a suitable squirrel cage induction motor 44 directly connected to drive the generator 43 is provided for this purpose. The induction motor 44 is electrically supplied by means of a suitable three phase alternating current source of supply 45. A suitable control switch 46 is interposed in the connections leading from the power source 45 to the induction motor 44.

The separately excited generator field winding 47 normally is energized from the substantially constant potential direct current supply source 22, and is controlled by means of a pair of contactors 50 and 51, and by means of a pair of adjustable rheostats 52 and 53. The generator field contactor 50 is controlled by a suitable push button station comprising a start button 54 and a stop button 55 so that when the start button 54 is depressed, the contactor 50 will be energized to close through a circuit including the stop button 55. To deenergize the contactor 50 it is merely necessary to depress the stop button. It will be observed that when the field contactor 50 is in its closed position it will complete a holding circuit for itself through the stop button 55 and the interlock 56 which will have been closed when the

contactor 50 moved to its closed position. The contactor 51 is controlled by the line contactor 26 provided for the main mill motor 17 so that when the line contactor is deenergized to allow the mill to come to rest, the operating coil of the contactor 51 will be included in a local circuit with the armature 20 of the motor 17 through the interlock 57 which is operably associated with the contactor 26. By reason of this arrangement, the contactor 51 will be energized in accordance with the counter electromotive force of the mill motor when the motor has been deenergized so as to allow the mill to come to rest. The contactor 51, as will be pointed out in more detail hereinafter, thus operates, when the mill motor 17 is deenergized, to transfer the generator field winding 47 from the supply source 22 to a local circuit with the armature of the motor 17.

The rheostat 52 provided for adjusting the excitation of the generator 43 normally will be included in the circuit of the field 47, but under certain conditions of operation, as will be explained in more detail hereinafter, will be rendered ineffective by the closing of a suitable contactor 58. The rheostat 53 normally is excluded from the generator field circuit by means of a suitable contactor 59, but under certain conditions of operation will be included in the field circuit. The energizing circuits for the operating coils of the contactors 58 and 59 will be completed when the line contactor 26 closes by means of an energizing circuit which may be traced from the upper conductor of the direct current supply source 22 through the switch 25, the conductor 60, the conductor 61, the interlock 62 which will be closed when the line contactor 26 is closed, the conductor 63, thence through the operating coils provided for the contactors 58 and 59, connected in parallel, and thence through the switch 25 to the lower conductor of the direct current supply source 22. It will be observed by reason of these connections that during the normal operation of the mill, that is when the strip is being fed to the reel, the rheostat 52 only will be effective to control the excitation of the generator field 47, while when the mill motor 17 is deenergized and the feed of the strip has been stopped, the rheostat 53 only will be effective to control the excitation of the generator. During the normal operation of the mill, the rheostat 52 can be rendered ineffective at will so as to permit the application of the full electromotive force of the source 22 to the generator field by means of a suitable controlling push button 65 which as shown is connected in the energizing circuit for the operating coil of the contactor 58. It will be observed that when this button is depressed the energizing circuit for the contactor 58 will be interrupted and the contactor thereby allowed to move to its closed position so as to short circuit the resistor 52.

It will be observed in view of the foregoing that in order to energize the field contactor 50 it is merely necessary to depress the start button 54. Moreover, it will be observed that when the field contactor 50 is closed, an energizing circuit for the generator field winding 47 will be completed from the lower conductor of the direct current supply source 22 through the switch 25, the conductor 67, the upper interlock 68 of the field contactor 50, which will have been closed when the field contactor moved to its closed position, the lower closed interlock 70 of the contactor 51, the effective portion of the adjustable resistor 52, the conductor 71, the closed contactor 59, the conductor 72, the generator field winding 47, the conductor 73 and thence through the switch 25 to the upper conductor of the direct current supply source 22. In view of these connections it will be observed that the excitation of generator 43 and consequently, the value of the electromotive force impressed upon the armature of the reel driving motor 10 may be controlled by adjusting the rheostat 52. In other words, the speed setting of the motor 10 may be controlled simply by an appropriate adjustment of the rheostat 52.

We control the excitation of the generator 47 automatically and concurrently with changes in the speed setting of the main mill motor 17. As shown, we have provided an operating connection between the rheostat 40, provided to control the mill motor speed, and the generator field rheostat 52, which as shown is a mechanical connection, and comprises a suitable shaft 74 arranged to operate the movable elements 75 and 76 provided for the rheostats 40 and 52 respectively. As shown, this shaft is provided with worm gears 77 and 78 which mesh with worm wheels 80 and 81 provided for the movable elements 75 and 76 respectively so that when the shaft is turned, motion will be imparted to each of these movable elements whereby the effective resistances of their associated rheostats will be varied concurrently. The shaft is provided with a suitable hand wheel 82 whereby it may be conveniently operated. It will be observed by reference to the drawing that when the rheostat 40 is adjusted so that all of its effective resistance is cut out of the motor field circuit and the motor is thereby operating with maximum excitation and consequently at its basic speed, all of the effective resistance of the rheostat 52 will be included in the generator field circuit so that the motor 10 will be operating at its minimum speed setting. It will also be observed that when the rheostat 40 is adjusted so as to change the speed of the mill rolls, the rheostat 52 will be adjusted at the same

time so as to change the speed setting of the reel motor 10 accordingly.

As has been pointed out, it is very desirable to maintain a certain substantially constant tension in the strip material 15 between the main mill rolls 16 and the winding reel 14. It will be understood that as long as the lineal speed of the strip remains constant, the power input to the reel motor must be constant in order to maintain a substantially constant tension in the strip. Therefore, in order to maintain a substantially constant tension in the strip under all running conditions, the power input to the reel motor must increase or decrease proportionately as the speed of the mill rolls 16 increases or decreases, and further the speed of the reel motor must decrease and its torque increase as the effective diameter of the reel increases by reason of the strip being wound on. It will be evident that since the excitation of the generator 43 remains constant for any given speed setting of the mill motor 17, and since the generator excitation is varied in accordance with changes in the speed setting of the motor 17, the current input to the motor 10 must remain constant irrespective of the speed setting of the mill motor, in order to obtain a constant strip tension. Furthermore, it will be evident that for any given speed setting of the mill the field strength of the motor 10 must be increased as the effective diameter of the coil 14 increases in order to maintain the constant current input to the reel motor.

In order that the current input to the reel motor 10 may be so regulated that a predetermined constant tension will be maintained in the strip 15, suitable control means are provided for the motor 10. This control means comprises a suitable regulator 84, which as shown comprises a stationary contact 85, a movable contact 86 operated by a pivoted bar 87, an operating coil 88 having its core connected to the end of the bar opposite the contact 86, and a tension spring 89 connected to the bar, preferably at the same point as the core is connected, although this arrangement is not necessary. The regulator contacts 85, 86 are connected across a suitable adjustable rheostat 90 which in turn is connected as shown in the circuit of the reel motor field winding 12 so that when the contacts are open the resistance is included in the field circuit and when the contacts are closed the resistance is short circuited.

The coil 88 is energized responsively to the armature current of the motor 10. As shown, the actuating coil 88 is connected across a suitable shunt 91 connected in the motor-generator armature circuit. This coil may be energized by the voltage drop across a commutating field of either the motor 10 or its generator 43. The adjustment of the regulator 84 to obtain the desired value in the tension to be maintained in the strip being wound is effected by means of a suitable adjustable rheostat 92 which as shown is included in series with the regulator operating coil 88.

It will be understood in view of the foregoing discussion that the strength of the reel motor field 12 and consequently the current intake of the motor 10 will depend upon the relative pulls exerted by the winding 88 upon its core and by the spring 89 on the bar 87. The regulator is so adjusted by means of the rheostat 92 that when the current in the reel motor armature circuit is less than a predetermined value to be maintained to give the desired tension in the strip, the pull of the coil 88 will be overbalanced by the tension of the spring 89 and the contacts 85, 86 will be held in their open position, thus inserting the resistance 90 in the circuit of the field 12. The field will then be weakened which will cause more current to flow through the armature 11. When the current in the armature 11 increases to a value above the predetermined current to be maintained, the pull exerted by the coil 88 will be increased to such a degree that the spring force will be overpowered and the regulator contacts will be closed so as to short circuit the resistance 90 whereby the strength of the field 12 will be increased. As a result, the motor 10 will draw less current from the generator until when the armature current is less than the predetermined value, the spring will overpower the pull exerted by the coil 88 and the contacts will be opened to reinsert the resistance in the field circuit. The motor current will now increase and the cycle of operation will be repeated as previously described. The regulator 84 will thus be given a vibratory motion, alternately short circuiting and inserting the resistance 90 in the field circuit of the reel motor 10. As the contacts rapidly vibrate the effective resistance in the field circuit will depend upon the proportion of time that the contacts are in their open position, and assuming that the mill motor 17 runs at a constant speed, the vibrator 84 will maintain a constant current input to the reel motor 10 whereby this motor will apply a constant tension in the strip 15.

Even though the mill motor 17 runs at a constant speed, the speed of the reel motor 10 must gradually decrease since the effective diameter of the reel 14 gradually increases due to the winding of the strip 15. As the reel diameter increases the reel motor will tend to apply a torque of such increased value that unless suitably compensated for there would result an increase in the tension of the strip. This action of the motor, however, causes its armature current to increase whereby the regulator operates to close the contacts 85, 86 and thereby strengthen the motor field until the armature current has been reduced to the predetermined value. Thus, since the

reel is constantly increasing in diameter, and the armature current always tending to increase, the proportion of time that the vibratory contacts remain closed gradually increases. As a result of this action in maintaining the armature current constant, the effective field resistance will be gradually reduced and the motor field current thereby gradually increased with the result that the motor torque will be increased so as to maintain a constant tension in the strip. In this manner the regulator 84 operates to cause the motor 10 to maintain a constant tension in the strip regardless of the speed setting of the motor effected by the control of the generator excitation.

In order to change the tension maintained in the strip it is merely necessary to adjust the rheostat 92. By increasing the effective resistance of this rheostat, the regulator will cause the reel motor 10 to tend to increase its speed and thereby cause the motor to draw more current in order to produce the proper amount of current to balance the regulator. As a result, greater tension will be applied to the strip. Conversely, if this effective resistance be decreased the motor will necessarily have to draw less current to produce the proper balance in the regulator circuit whereby the tension maintained will be decreased.

Under certain conditions of operation, particularly during the accelerating period of the mill, it is desirable to change the current setting of the regulator so that the current input to the reel motor will be increased. It will be understood that the regulator limits the current input to the reel motor to a value just sufficient to maintain the desired tension in the strip 15. It is possible, therefore, that the regulator with its normal setting might so limit the current input to the reel motor that this motor would not accelerate at a rate sufficiently high to follow the acceleration of the mill with the result that the tension in the strip would not be maintained. We provide suitable means for automatically changing the regulator current setting so as to increase the current input to the reel motor during the accelerating period of the mill. For this purpose, we provide a second adjustable rheostat 94 for controlling the setting of the regulator 84. As shown, this rheostat is connected in parallel with the regulator operating coil 88. It will be clear that if this rheostat be included in the circuit of the operating coil 88, its effect will be to reduce the current flowing through the coil for a given armature current of the reel motor. In other words, the effect of the rheostat 94 on the regulator is to allow the reel motor to draw more current from its generator 43. Obviously, therefore, the current input to the reel motor will be increased as long as the rheostat is included in the regulator operating coil circuit. In order to include the rheostat 94 automatically during the accelerating period of the mill and to disconnect it when the mill has been brought up to speed, we provide a suitable controlling contactor 95 for the rheostat. As shown this contactor when closed operates to connect the rheostat, and when opened operates to disconnect the rheostat. The operating coil for this contactor is controlled by the last accelerating contactor 36 through the medium of its associated interlock 42. It will be observed by reference to the drawing that the contactor 95 will be deenergized so that the effective resistance of the rheostat 94 will be included in the regulator coil operating circuit as long as the accelerating contactor 36 is open, while when the contactor 36 is closed the contactor 95 will be energized to open so as to render the rheostat 94 ineffective. By adjusting the rheostat 94 it will be understood that various rates of acceleration of the reel motor can be obtained. By this means it is possible to insure the maintenance of the proper tension in the strip also during the accelerating period of the mill.

As has been pointed out in a previous portion of this specification, one of the features of our invention is the provision of suitable means for maintaining proper tension in the strip during the decelerating period of the mill. For this purpose, we have provided suitable means for controlling the excitation of the generator 43, and in consequence the electromotive force impressed upon the armature 11 of the reel motor 10, in accordance with the rate of deceleration of the strip 15. More specifically, we have provided suitable means for energizing the generator field 47 in accordance with the counter electromotive force of the main mill motor 17 after it has been denergized so as to allow the mill to come to rest. This is accomplished by means of the contactor 51 which as has been pointed out operates, when the mill motor 17 is deenergized, to disconnect the field winding 47 from the direct current supply source 22 and to connect the field winding in a local circuit with the armature 20 of the mill motor 17. It will be observed that when the main line contactor 26 has been deenergized, the interlock 57 associated with the contactor 26 will be closed so as to connect the operating coil of the contactor 51 across the armature 20 of the mill motor 17, the accelerating resistors 33 and 34 being connected in series with the operating coil of the contactor. The contactor 51, therefore, will be energized in accordance with the counter electromotive force of the mill motor 17. The voltage drop across the resistors 33 and 34 is negligible when carrying only the small current necessary for the generator field 47.

It will be observed that when the contac-

tor 51 is energized, the field winding 47 of the generator will be connected in a local circuit with the armature of the main mill motor 17. This circuit may be traced from the upper conductor of the direct current supply source 22 through the switch 23, the conductor 31, the armature 20 of the motor 17, the accelerating resistors 34 and 33, the interlock 57, which will have been closed when the line contactor 26 was deenergized, the interlock 93 which will have been moved upwardly to close its associated contacts in response to the energization of the contactor 51, the effective portion of the resistor 52, the conductor 71, the closed contactor 59, the conductor 72, the field winding 47 of the generator 43, the conductor 73, and thence through the switch 25 back to the upper conductor of the supply source 22. It is to be noted that the operating coils for the contactors 58 and 59 will be energized during this operation in spite of the fact that the line contactor has been operated to open its associated interlock 62 because the energizing circuit for these contactors will be completed through the middle set of contacts provided for the contactor 51, this set being closed by means of the interlock 70 which will have been moved upwardly to bridge them in response to the energization of the contactor 51.

With this arrangement of the circuits, the field excitation of the generator 43 dies down gradually as the mill motor 17 slows down and its counter electromotive force is gradually reduced. This causes the electromotive force impressed upon the reel motor to be reduced gradually and as a result the reel motor slows down practically in step with the mill motor 17. This operation together with the operation of the current regulator 84 insures the maintenance of tension in the strip during the decelerating period.

When the main mill motor 17 in slowing down has attained a very low speed and the strip is being brought to rest the counter electromotive force of the mill motor will not be sufficient to hold the contactor 51 in its upper position, and in consequence the contactor 51 will move to its lower position as shown in the drawing. This operation of the contactor will disconnect the generator field winding from the motor armature circuit and will reconnect it with the direct current supply source 22. Under these conditions the operating coils of the contactors 58 and 59 will no longer be energized since the interlock 62 of the line contactor 26 will be open and the interlock 70 of the contactor 51 will have been moved to its lower position, in which position the middle contacts of the contactor 51 will be open. Thus when the contactor 51 operates in response to the slowing down of the mill to reconnect the generator field winding 47 with the supply source 22, the rheostat 52 will be rendered ineffective, while the effective resistance of the rheostat 53 will be included in the generator field circuit. The rheostat 53 is proportioned so that but a relatively small current will flow through the field winding 47, the resulting excitation of the generator being just sufficient to allow the reel motor 10 to maintain a constant tension in the strip while it is at rest. It will be understood that the current regulator 84 may be disconnected if desired when the mill is stopped, although this is not necessary.

We have provided suitable means for adjusting the rheostat 53 concurrently with adjustments in the setting of the regulator 84 so that the tension maintained in the strip when stopped, i. e., the "stalling" tension, will be automatically determined when the tension to be maintained in the strip while being wound is set. For this purpose we have provided a mechanical connection between the rheostats 53 and 92 which connection may have a construction identical with the construction of the mechanical connection provided between the rheostats 40 and 52. Thus, the mechanical connection between the rheostats 53 and 92 may comprise a shaft 96 which is connected by means of suitable worm drives with the movable elements of the rheostats so that when the shaft is turned, the rheostats will be adjusted concurrently and proportionately. This shaft is provided with a suitable hand wheel 97 whereby it can be conveniently operated.

The operation of our control system is as follows:

It it be assumed that the mill is stopped, that the reel 14 is at a standstill and that it be desired to start up the mill and thread in a new coil of strip. The switch 46 will be closed so as to energize the generator operating induction motor 44. The switches 23, 24, and 25 will be closed and the start push button 27 for the mill motor 17 will be depressed. The motor 17 will be energized and accelerated in response to the depression of the start button 27 in a manner which has been described, and the strip 15 will be fed toward the reel. At this time the contactor 50 will be open so that there will be no excitation on the generator 43. After the end of the strip has advanced to the reel and has been inserted in the reel, the push button 54 for the field contactor 50 will be depressed, which operation, as has been pointed out, will effect the energization of the field contactor 50 to close and thereby excite the generator 43. The reel motor will start from rest in response to the excitation of the generator and will accelerate. In order to accelerate the reel at a high rate so as to take up the slack, which will have accumulated in the strip 15 during the threading process, as fast as possible, the operator will press the push button 65. As has been pointed out, this will cause the contactor 58 to close its contacts and thereby

short circuit the field controlling resistor 52. It will be obvious that this operation will effect the application of the maximum voltage of the supply source 22 to the generator field winding 47, and thereby will cause the reel motor to operate at its maximum speed. When the slack in the strip 15 has been almost taken up, the operator will allow the push button 65 to close which operation will effect the reenergization of the operating coil of the contactor 58. The contactor 58 will open in response to the completion of its energizing circuit, and thereby will reinsert the generator field controlling resistor in the generator field circuit. The speed setting of the mill drive including the motor 17 and the reel motor 10 will be controlled by a suitable adjustment of the hand wheel 82. The regulator 84 during the operation of the mill will operate to maintain a constant current input into the reel motor so as to maintain a predetermined constant tension in the strip. This tension, as has been pointed out, may be adjusted by means of the hand wheel 97.

If it be desired to allow the mill to come to rest it is merely necessary to depress the stop button 28, which operation, as has been pointed out, will effect a deenergization of the line contactor 26. This contactor in opening will effect not only the deenergization of the motor 17 but also will effect an operation of the contactor 51 to disconnect the generator field 47 from the supply source 22 and to connect it in a local circuit with the armature 20 of the motor 17. As the motor 17 slows down, the reel motor 10 slows down in step with it so as to maintain the proper tension in the strip during the decelerating period. After the mill has attained a very low speed, the generator field 47 will be reconnected with the source 22 in series with the stalling rheostat 53. The adjustment of the hand wheel 97 to set the tension to be maintained in the strip while being wound also will have effected an adjustment of the rheostat 53 so that a constant tension will be maintained in the strip when it is stopped proportionate to the tension maintained in the strip during the running period.

If it be desired to restart the mill the operator will press the start button 27, which operation will cause the mill motor 17 to accelerate in the manner previously described. The line contactor 26 in closing not only will effect an energization and acceleration of the main mill motor 17 but also will effect an energization of the contactors 58 and 59, the contactor 58 operating to reinsert the generator field controlling rheostat 52, while the contactor 59 operates to disconnect the stalling rheostat 53. The excitation of the generator 47 will build up, and the reel motor 10 thereby will be accelerated at the same time that the main mill motor 17 is being accelerated.

The regulator 84 remains in operation during this accelerating period but, as has been pointed out, its current setting will be increased by the inclusion of the rheostat 94 in the operating circuit of the regulator operating coil 88. As a result, the current input to the reel motor will be increased during the accelerating period so as to insure the maintenance of the proper tension in the strip. When the mill has been accelerated the rheostat 94 will be disconnected so that the regulator 84 will function with its normal setting to maintain the constant tension in the strip.

While we have shown a particular embodiment of our invention, it will be understood, of course, that we do not wish to be limited thereto since many modifications may be made, and we, therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of our invention.

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

1. The combination with a winding reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, an electric generator for electrically supplying said reel driving motor, means for controlling said reel motor so as to maintain a tension in said strip, means for adjusting the feed of said strip to said reel, and means dependent upon the setting of said feed adjusting means for controlling the excitation of said generator so that the magnitude of the electromotive force applied to said motor is changed concurrently with changes in the rate of feed of said strip.

2. The combination with a winding reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, an electric generator for electrically supplying said reel driving motor, means for controlling said reel motor so as to maintain a tension in said strip, means for adjusting the feed of said strip to said reel, means for adjusting the excitation of said generator and a single means for operating both of said adjusting means.

3. The combination with a winding reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, an electric generator for electrically supplying said reel driving motor, means for operating said generator at a substantially constant speed, means for controlling said reel motor so as to maintain a substantially constant current input thereto, means for adjusting the feed of said strip to said reel, and means dependent upon the setting of said feed adjusting means for controlling said generator so that the magnitude of the electromotive force applied to said reel motor is changed

concurrently with changes in the rate of feed of said strip whereby said reel motor operates to maintain said tension irrespective of the rate of feed of said strip.

4. The combination with a winding reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, an electric generator for electrically supplying said reel driving motor, means dependent upon the armature current of said reel motor for controlling said motor so as to maintain a substantially constant tension in said strip, means for controlling the rate of feed of said strip to said reel, means dependent upon the setting of said feed adjusting means for controlling said generator so that the magnitude of the electromotive force applied to said reel motor is changed concurrently with changes in the rate of feed of said strip, and means for rendering said latter controlling means ineffective.

5. The combination with a reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, an electric generator for electrically supplying said reel motor, means for controlling said reel motor so as to maintain a tension in said strip, means for adjusting the rate of feed of said strip to said reel, means for controlling said generator so that the magnitude of the electromotive force applied to said reel motor can be adjusted to the rate of feed of said strip and means for rendering said control means ineffective so that the speed of said reel motor can be increased irrespective of the setting of said control means.

6. The combination with a winding reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, an electric generator for electrically supplying said reel driving motor, electroresponsive means for controlling said reel motor so as to maintain a substantially constant tension in said strip, means for controlling the rate of feed of said strip to said reel, means dependent upon the setting of said feed adjusting means for controlling said generator so that the magnitude of the electromotive force applied to said reel motor is changed concurrently with changes in the rate of feed of said strip, and means for rendering said generator controlling means ineffective so that said reel motor can be driven at its maximum speed irrespective of the setting of said feed rate adjusting means.

7. The combination with a reel for a strip of material to be wound thereon of an electric motor for feeding said strip to said reel, an electric motor for driving said reel, a generator for electrically supplying said reel driving motor, means responsive to the reel motor armature current for controlling said reel motor to maintain a substantially constant tension in said strip, a resistor for controlling the excitation of said feeding motor, a second resistor for controlling the excitation of said generator, a common control means for operating said resistors so that the excitations of said feed motor and of said generator are changed concurrently whereby the speed setting of said reel motor is changed in accordance with changes in the rate of feed of said strip, and means operable at will for rendering said generator field controlling resistor ineffective so that said reel motor can be operated at its maximum speed irrespective of the setting of said common resistor control means.

8. The combination with a reel for a strip of material to be wound thereon, of an electric motor for feeding said strip to said reel, a generator provided with a field winding, a reel drive motor supplied from said generator, electroresponsive means for maintaining a substantially constant tension in said strip during the normal operation of said motor in feeding said strip to said reel, means for deenergizing said feed motor, and means responsive to the deenergization of said feed motor for connecting said field winding to the armature of said feed motor for maintaining a tension in said strip in accordance with the counter electromotive force of said feed motor after said motor has been deenergized and said strip is being brought to rest.

9. The combination with a reel for a strip of material to be wound thereon, of an electric motor for feeding said strip to said reel, an electric motor for driving said reel, means for controlling said feeding motor so that it can be energized to feed said strip to said reel and can be deenergized so as to permit said strip to come to rest, means for controlling said reel driving motor so as to maintain a substantially constant tension in said strip while said feed motor is energized so as to feed said strip to said reel, and means comprising a generator having a field winding energized by the counter electromotive force of said feeding motor for controlling said reel motor so as to maintain tension in said strip after said feeding motor has been deenergized and said strip is being brought to rest.

10. The combination with a reel for a strip of material to be wound thereon, of an electric motor for driving said reel, an electric generator for supplying said reel driving motor, means for feeding said strip to said reel, means for controlling said reel motor so as to maintain a tension in said strip while said strip is being fed to said reel, and means responsive to the operation of said feeding means to permit said strip to decelerate for controlling the excitation of said generator in accordance with the rate of deceleration of said strip so that said reel motor operates

to maintain tension in said strip during the deceleration of said strip.

11. The combination with a reel for a strip of material to be wound thereon, of an electric motor for feeding said strip to said reel, an electric motor for driving said reel, a generator for electrically supplying said reel driving motor, a regulator for controlling said reel motor so as to maintain a substantially constant tension in said strip while it is being wound, and means for controlling the excitation of said generator in accordance with the counter electromotive force of said feeding motor so that when said feeding motor is deenergized to permit said strip to come to rest, the magnitude of the electromotive force impressed upon said reel motor is reduced at a rate commensurate with the rate of deceleration of said strip whereby the maintenance of tension in said strip is insured during the decelerating period.

12. The combination with a reel for a strip of material to be wound thereon, of an electric motor for feeding said strip to said reel, an electric motor for driving said reel, a generator for electrically supplying said reel driving motor, a regulator for controlling said reel motor so as to maintain a substantially constant tension in said strip while it is being wound, speed controlling means for said feeding motor, means for controlling the excitation of said generator, means for effecting concurrent adjustments of both of said controlling means so that the magnitude of the electromotive force applied to said reel motor is changed in accordance with the rate of feed of said strip, and means for controlling the excitation of said generator independently of the adjustments of said speed and excitation controlling means in accordance with the counter electromotive force of said feed motor so that when said feed motor is deenergized to permit said strip to come to rest, the magnitude of the electromotive force impressed upon said reel motor is reduced at a rate commensurate with the rate of deceleration of said strip whereby the maintenance of tension in said strip is insured during the decelerating period.

13. The combination with a reel for a strip of material to be wound thereon, of an electric motor for feeding said strip to said reel, an electric motor for driving said reel, a generator for electrically supplying said reel driving motor, a current regulator for controlling said reel motor so as to maintain a substantially constant tension in said strip while it is being wound, switching means for controlling the energization and acceleration of said feed motor, a second switching means for connecting the field winding of said generator with a source of excitation, means for varying the excitation of said generator in accordance with the rate of feed of said strip, and a third switching means dependent upon the operation of said first switching means to deenergize said feeding motor for connecting said field winding in a local circuit with the armature of said feeding motor so that the excitation of said generator decays at a rate proportional to the deceleration of said feeding motor.

14. The combination with a reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, a motor for driving said reel, a generator for electrically supplying said motor, means for controlling said motor to maintain a tension in said strip while said strip is being fed to said reel, and means for controlling said generator so that the current supplied by said generator to said motor operates to maintain a tension in said strip after the feed thereof to said reel has been stopped.

15. The combination with a reel for a strip of material to be wound thereon, means for feeding said strip to said reel, a motor for driving said reel, a generator for electrically supplying said motor, means dependent upon the armature current of said motor for controlling said motor to maintain a substantially constant tension in said strip and means for applying limited excitation to said generator after the feed of said strip has been stopped so that said motor operates to maintain a tension in said strip when stopped.

16. The combination with a reel for a strip of material to be wound thereon, of a motor for delivering said strip to said reel, a motor for driving said reel, a generator for supplying said reel motor, means for controlling said reel motor so as to maintain a substantially constant tension in said strip, means for controlling the speed of said delivery motor and the excitation of said generator concurrently so that the magnitude of the electromotive force applied to said reel motor is varied in accordance with the speed of said delivery motor and means for rendering said controlling means ineffective and for applying limited excitation to said generator after said delivery motor is deenergized, whereby said reel motor operates to maintain a tension in said strip after the delivery of said strip has been stopped.

17. The combination with a winding reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, control means for said feeding means, a motor for driving said reel, a generator for electrically supplying said motor, means dependent upon the armature current of said motor for controlling said motor so as to maintain a substantially constant tension in said strip, a source of excitation for said generator, an adjustable rheostat for controlling the excitation of said generator so that the magnitude of the electromotive force applied to said reel motor can be adjusted in accordance with the rate of feed of said strip, a second

adjustable rheostat for limiting the excitation of said generator, and means responsive to the operation of said feeding control means for disconnecting said first rheostat, and for connecting said second rheostat to limit said excitation after said feed control means has been operated so as to cause said feeding means to stop the delivery of said strip.

18. The combination with a reel for a strip of material to be wound thereon, of means for delivering said strip to said reel, a motor for driving said reel, a generator for electrically supplying said motor, means for controlling said motor so as to maintain a substantially constant tension in said strip, means for adjusting said controlling means so as to change the value of the tension maintained in said strip, means for controlling said generator so that said motor will maintain a tension in said strip after the delivery thereof to said reel has been stopped, adjusting means for said generator controlling means so that the tension maintained in said strip when stopped can be regulated, and a single means for operating both of said tension adjusting means.

19. The combination with a reel for a strip of material to be wound thereon, of means for delivering said strip to said reel, a motor for driving said reel, a generator for electrically supplying said motor, a constant current regulator for said reel motor electrically responsive to the armature current of said motor, means for adjusting the setting of said regulator so that the value of the tension maintained in said strip can be controlled, means for controlling the excitation of said generator so that said motor operates to maintain a tension in said strip after the delivery of said strip to said reel has been stopped, means for adjusting said excitation controlling means so that the value of the tension maintained in said strip when stopped can be adjusted, and a common operating means for both of said tension adjusting means so that when the tension to be maintained in said strip while being wound is set, said excitation adjusting means will be set so that a corresponding tension will be maintained in said strip when stopped.

20. The combination with a reel for a strip of material to be wound thereon, of a motor for delivering said strip to said reel, a motor for driving said reel, a generator for electrically supplying said reel motor, a regulator for controlling said reel motor so that said reel motor operates to maintain a substantially constant tension in said strip while it is being wound, means for controlling said delivery motor so that the rate of feed of said strip can be adjusted, means for adjusting the excitation of said generator, a common operating means for said feed adjusting and said excitation adjusting means so that the excitation of said generator is changed in accordance with changes in the rate of delivery of said strip, means for adjusting said reel motor regulator so that the value of the tension maintained in said strip while being wound can be varied, a second means for controlling the excitation of said generator so that said reel motor will maintain a tension in said strip after the delivery thereof to said reel has been stopped, and a common operating means for said reel motor regulator adjusting means and for said second excitation controlling means.

21. The combination with a reel for a strip of material to be wound thereon, of an electric motor for feeding said strip to said reel, an electric motor for driving said reel, a generator for electrically supplying said reel driving motor, a regulator for controlling said reel motor so as to maintain a substantially constant tension in said strip while it is being wound, means for controlling the excitation of said generator in accordance with the counter electromotive force of said feeding motor so that when said feeding motor is deenergized to permit said strip to come to rest, the magnitude of the electromotive force impressed upon said reel motor is reduced at a rate commensurate with the rate of deceleration of said strip whereby the maintenance of tension in said strip is insured during the decelerating period, and means dependent upon the counter electromotive force of said feeding motor for controlling the excitation of said generator so that when the speed of said feeding motor has been reduced to a predetermined low value an electromotive force of substantially constant value is applied to excite said generator so that said reel motor operates to maintain a substantially constant tension in said strip after the feed of said strip has been stopped.

22. The combination with a reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, means for adjusting the feed of said strip to said reel, a motor for driving said reel, a generator for electrically supplying said motor, a regulator for controlling said reel motor so as to maintain a substantially constant tension in said strip while it is being wound, a source of excitation for said generator, means for controlling said excitation source so that a substantially constant electromotive force is applied to excite said generator, the value of said electromotive force being dependent upon the feed adjustment of said strip, and auxiliary means for controlling said excitation source so that a substantially constant electromotive force is applied to excite said generator whereby said reel motor operates to maintain a substantially constant tension in said strip when the feed thereof to said reel has been stopped.

23. The combination with a reel for a strip of material to be wound thereon, of means for feeding said strip to said reel, an electric motor for driving said reel, means dependent upon a condition of operation of said motor for maintaining a substantially constant current input to said motor and means for adjusting said current controlling means so that the current input to said motor is automatically increased during the acceleration of said strip from rest.

24. The combination with a reel for a strip of material to be wound thereon, of a motor for feeding said strip to said reel, a motor for driving said reel, a regulator for controlling the current input to said reel motor, and means for changing the setting of said regulator so that the current input to said reel motor is automatically increased while said feeding motor is accelerating said strip from rest.

25. The combination with a reel for a strip of material to be wound thereon, of a motor for feeding said strip to said reel, a motor for driving said reel, switching means for controlling the energization and acceleration of said feeding motor, a regulator dependent upon the armature current of said reel motor for maintaining a substantially constant current input to said reel motor, and means dependent upon the operation of said switching means for changing the setting of said current regulator so that the current input to said reel motor is increased during the accelerating period of said feeding motor.

26. The combination with a reel for a strip of material to be wound thereon, of a motor for feeding said strip to said reel, a motor for driving said reel, switching means for controlling the energization and acceleration of said feeding motor, a regulator dependent upon the armature current of said reel motor for maintaining a substantially constant current input to said reel motor, means for controlling the speed of said feeding motor, means responsive to the operation of said switching means for rendering said speed controlling means ineffective during the acceleration of said feeding motor from rest, and means responsive to the operation of said switching means for changing the setting of said current regulator so that the current input to said reel motor is increased during the acceleration of said feeding motor from rest.

In witness whereof, we have hereunto set our hands this 19th day of August, 1930.

LEONID A. UMANSKY.
CLAUDE B. HUSTON.