April 28, 1942. G. E. STOLTZ 2,281,083

CONTROL SYSTEM FOR ROLLING MILLS

Filed April 28, 1938 4 Sheets-Sheet 1

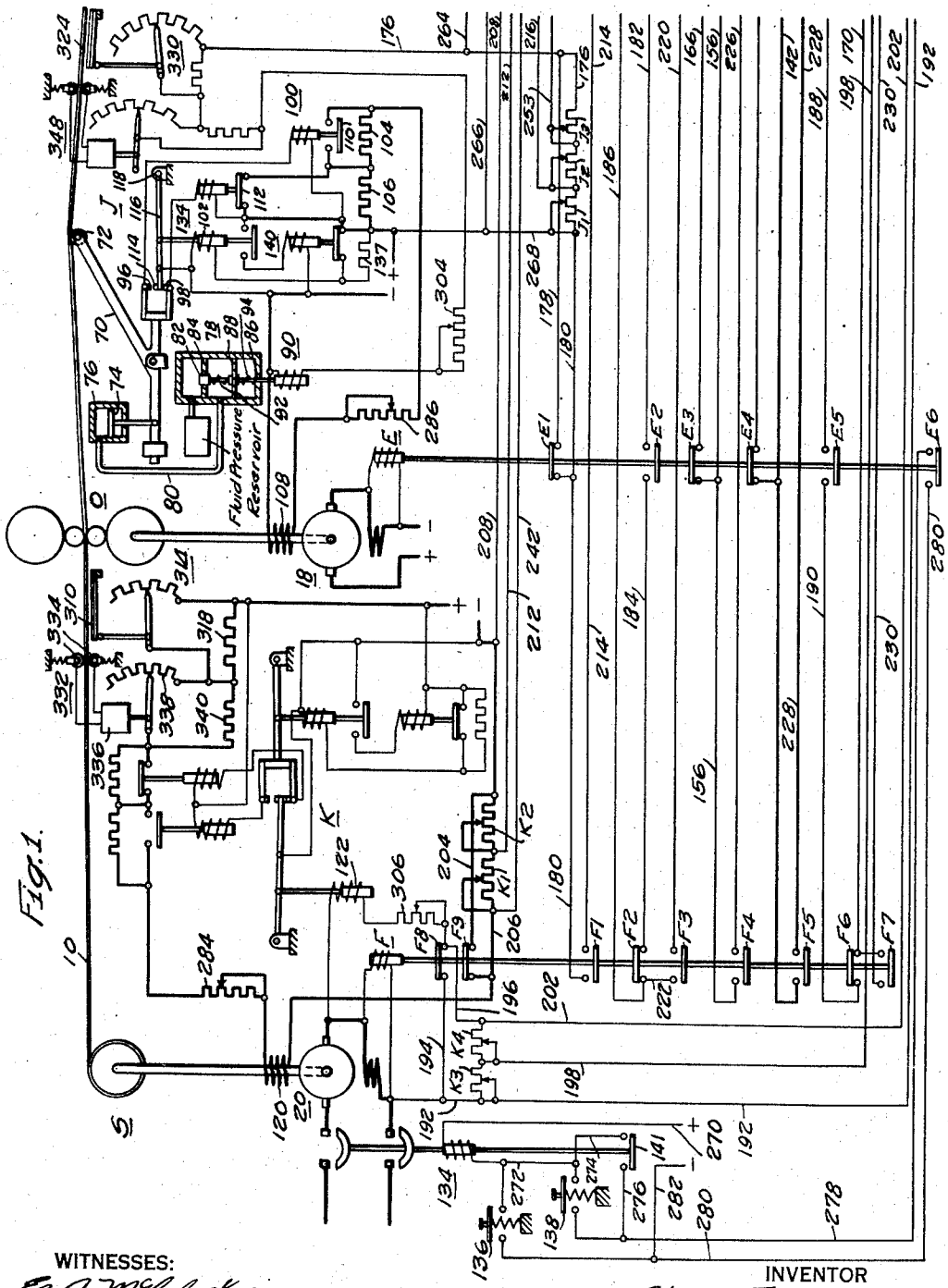


Fig. 1.

WITNESSES:
E. A. McCloskey.
Joe Weber

INVENTOR
Glenn E. Stoltz.
BY
G. M. Crawford
ATTORNEY

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Filed April 28, 1938 4 Sheets-Sheet 2

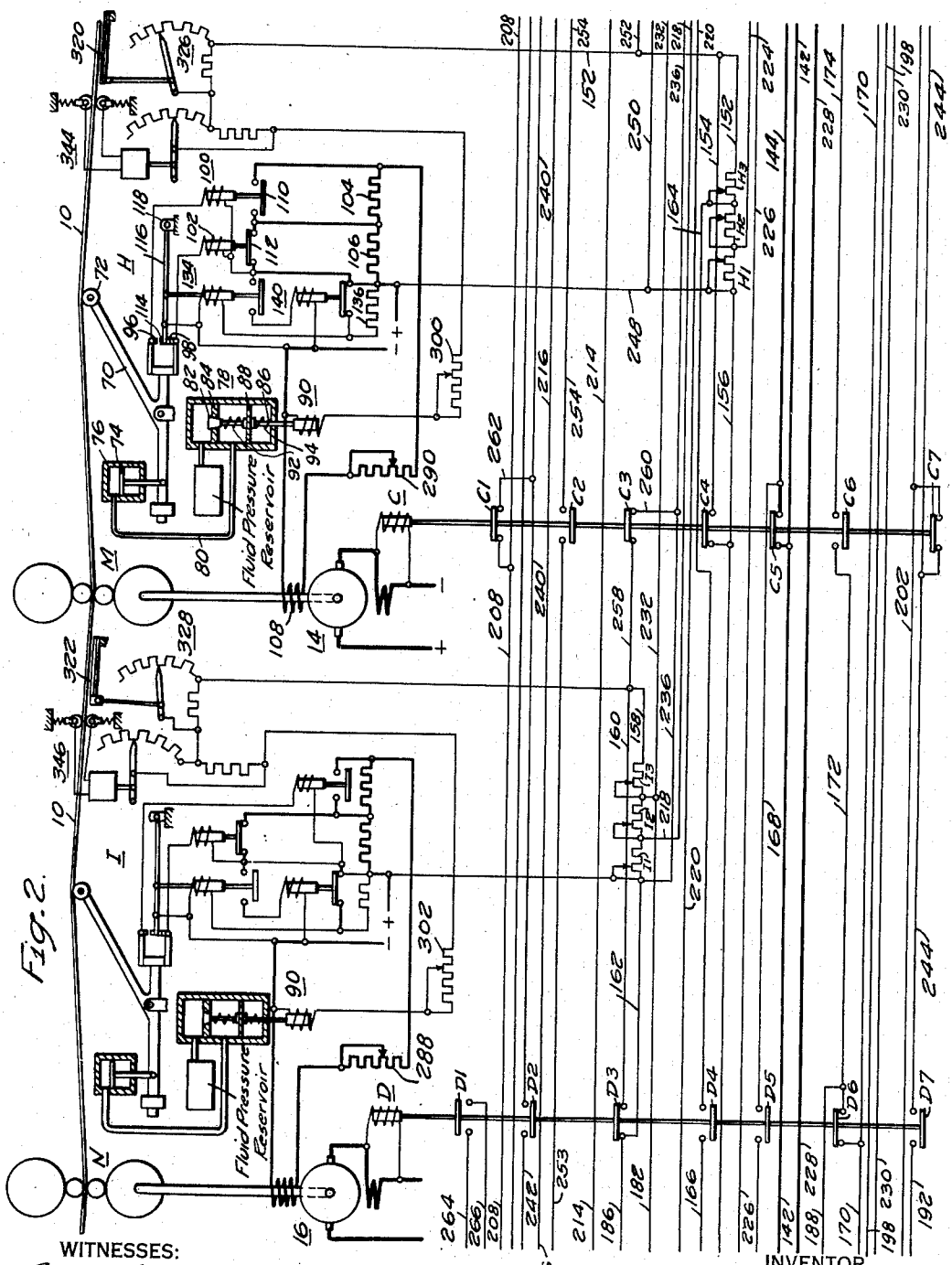


Fig. 2.

WITNESSES:
E. A. McCloskey.
Joe Weber

INVENTOR
Glenn E. Stoltz.
BY
G. M. Crawford
ATTORNEY

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CONTROL SYSTEM FOR ROLLING MILLS

Filed April 28, 1938 4 Sheets-Sheet 3

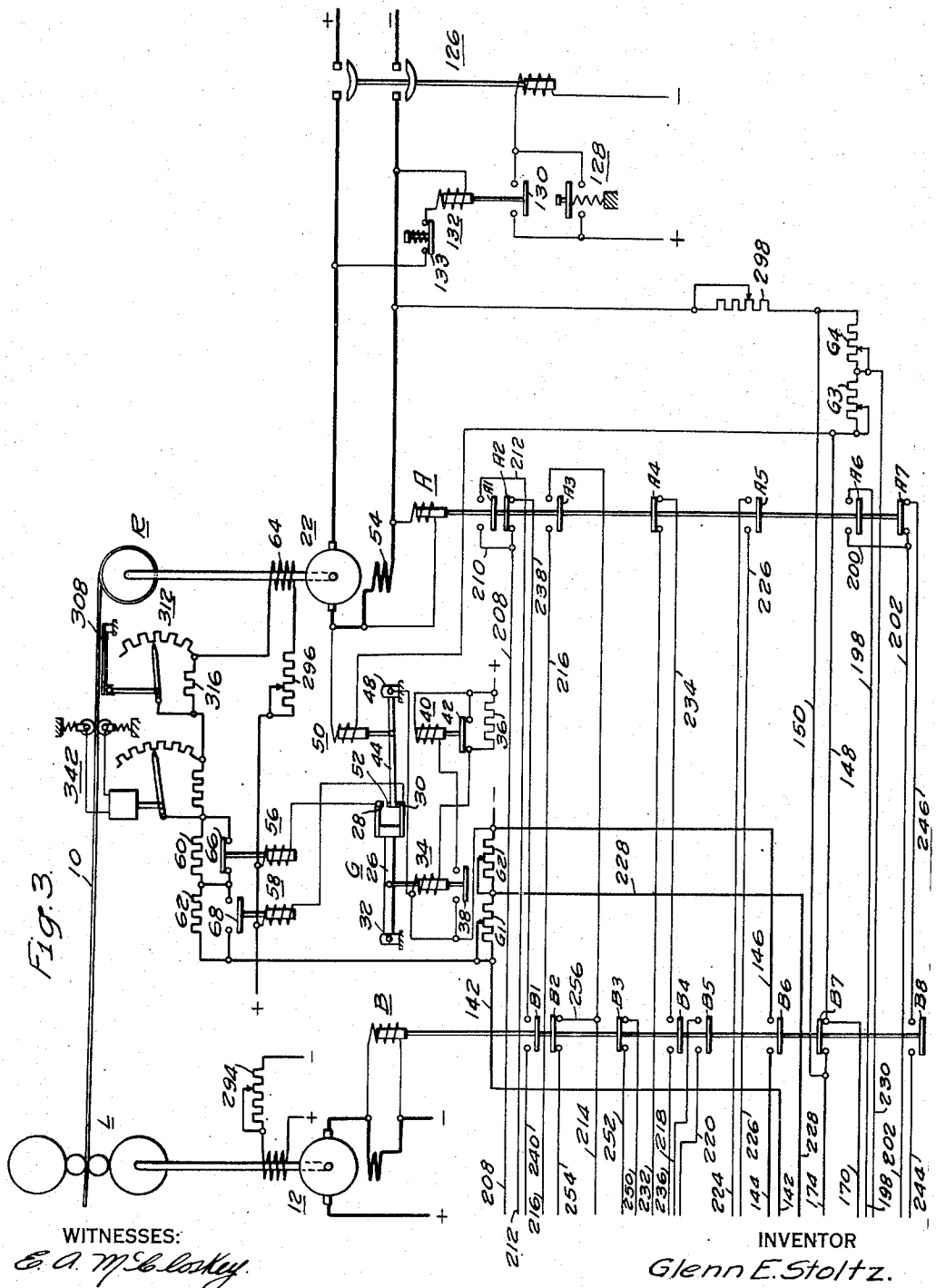


Fig. 3.

WITNESSES:
E. A. McCloskey.
Joe Weber

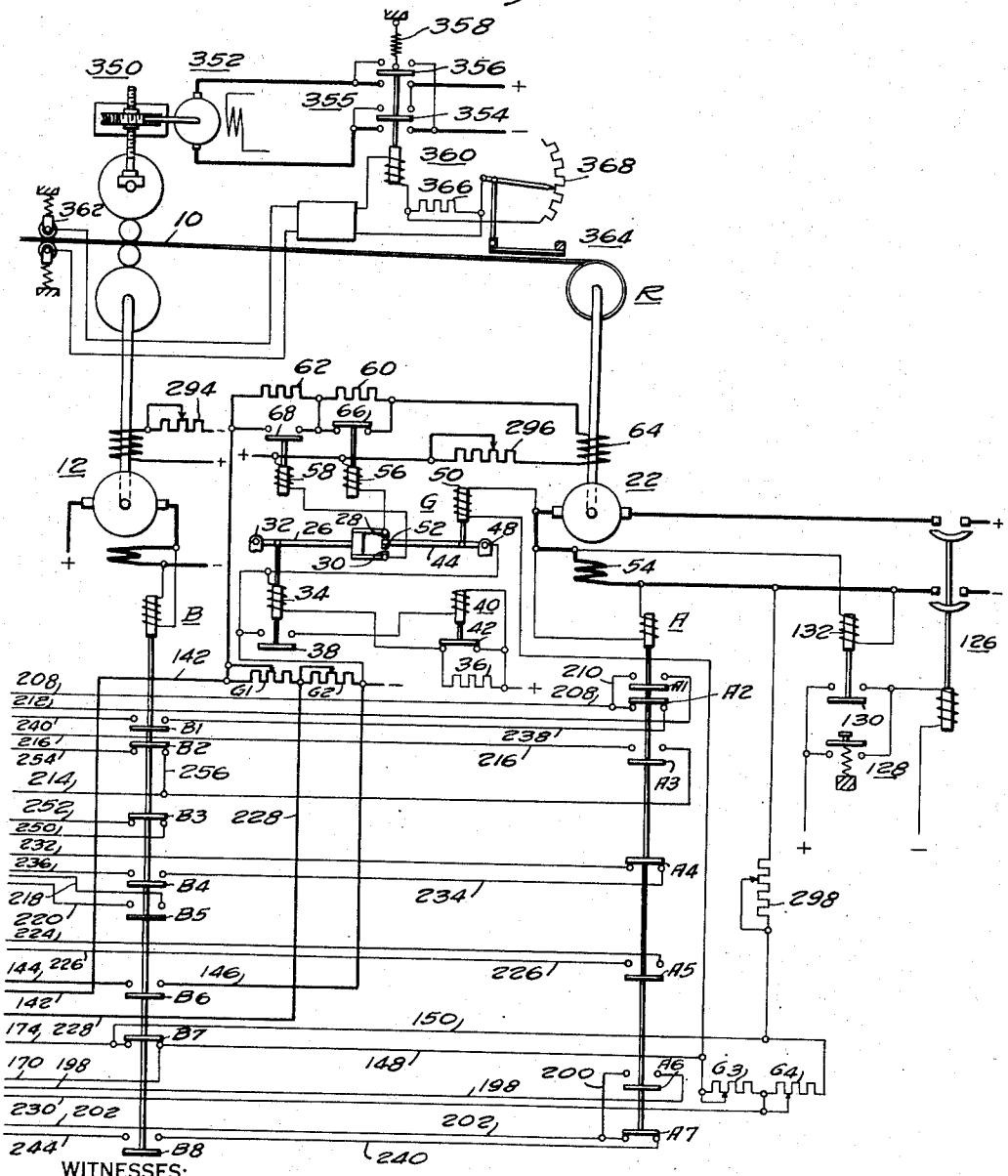
INVENTOR
Glenn E. Stoltz.
BY
G. M. Crawford
ATTORNEY

April 28, 1942. G. E. STOLTZ 2,281,083

CONTROL SYSTEM FOR ROLLING MILLS

Filed April 28, 1938 4 Sheets-Sheet 4

Fig. 4.



WITNESSES:

E. A. McCloskey.

Joe Weber

INVENTOR

Glenn E. Stoltz.

BY

G. M. Crawford

ATTORNEY

Patented Apr. 28, 1942 2,281,083

UNITED STATES PATENT OFFICE

2,281,083

CONTROL SYSTEM FOR ROLLING MILLS

Glenn E. Stoltz, Edgewood, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application April 28, 1938, Serial No. 204,711

25 Claims. (Cl. 80—32)

My invention relates, generally, to control systems and, more particularly, to control systems for single stand or tandem mills for rolling metallic strip.

In the operation of tandem mills for rolling strip material, devices have been provided for tensioning the strip material as it passes through the rolls. This tensioning of the material results in a greater reduction of the strip per roll stand so that fewer roll stands are necessary for a given amount of reduction in strip thickness than would be necessary if such tension were not provided. A further advantage of tensioning the material between the rolls is that the material is held firmly in position during the rolling process. Higher rolling speeds are sometimes also possible when this tensioning is used and the physical properties of the steel so produced may be improved.

The patent to W. G. Cook, No. 1,982,338, dated November 27, 1934, discloses a system for maintaining a predetermined tension on strip material between a reel from which the material is being unwound and the reducing roll which is operating on the material. The application of G. P. Lessmann, Serial No. 133,419, filed March 27, 1937, now Patent No. 2,189,609, issued February 6, 1940, discloses a system for maintaining a predetermined tension on a strip of material as it passes between two adjacent roll stands of a tandem mill. This provides front tension on the strip leaving the preceding roll stand and back tension on the strip entering the succeeding roll stand.

It will be seen that where tension on the strip material is provided by a device that bears on the strip as it passes between adjacent roll stands, a length of the leading end of the strip will be rolled without front tension as it is being threaded through the mill since such tensioning devices cannot operate to tension the strip until the strip is engaged by the rolls preceding and succeeding the tensioning device. In a like manner the winding reel cannot provide forward tension on the strip until the strip has passed from the last roll stand to the winding reel.

The same situation exists when the following end of the strip is passed between the unwinding reel and the first roll stand as back tension cannot be applied to the strip by the unwinding reel after it has left the unwinding reel. Likewise, back tension cannot be applied to the strip between adjacent roll stands while the following end is passing between the roll stands.

As a result of the failure to provide both front and back tensions on the ends of the strip, the ends are thicker than the rest of the strip since they are not reduced as much as that part of the strip which has received the proper front and back tensions while passing through the rolls.

It has been found in the operation of hot strip rolling mills that there is such a temperature gradient along the strip as it passes through the mill as to so affect the resistance-to-reduction of the strip as to result in increased thickness of rolled strip toward the following end of the strip.

These variations in thickness of the rolled material due both to lack of proper tensioning of the strip and to cooling of the strip make it necessary to sort the sheets cut from the finished strip, so that the gauge of the material may be kept within the tolerances permitted by the customer's specifications. If these variations are too great, it is necessary to scrap some of the material. Both scrapping of material and the process of sorting the finished material add considerably to the cost of production.

An object of this invention is to provide a control system for a single stand or a tandem mill for rolling strip or other rolled products such as rod wire or any sectional material where tension is applied to the material as it is being rolled, which shall function to produce a product of more uniform thickness and of predetermined physical characteristics.

A further object of the invention is to provide a control system for a tandem mill for rolling strip material which shall function to so adjust the tension on the strip of material between the roll stands and the winding and unwinding reels and between adjacent roll stands as to produce predetermined reducing forces upon the strip of material throughout the entire length of the strip as it passes through the mill.

A further object of my invention is to provide a control system for a single stand or tandem mill for rolling strip material which shall function to vary the roll spacing by screw down control in response to variations in temperature and/or thickness of the strip.

Another object of the invention is to provide a control system for a single stand or tandem mill for rolling strip material which shall function to vary the tension on the strip of material as it passes through the mill in response to variations of the temperature and thickness of the strip.

These and other objects and advantages of the invention will be apparent from the following detailed description taken in connection with the

accompanying drawings comprising Figs. 1, 2 and 3 on three separate sheets which, when placed in end to end relation constitute a diagrammatic view of a four stand rolling mill with one embodiment of my invention applied thereto showing the cooperative relationships of the invention with the rolling mill and,

Fig. 4 which is a diagrammatic view of a modification of the thickness and temperature responsive means for controlling the reducing forces on the strip. Fig. 4 includes most of the structure shown in Fig. 3 and is so drawn as to permit it to be substituted for Fig. 3 in the group of figures consisting of Figs. 1, 2 and 3, the system being complete and operative with the apparatus of either Fig. 3 or Fig. 4 used in connection with the apparatus of Figs. 1 and 2.

In carrying out my invention I provide means for causing the unwinding reel motor of a strip rolling mill to act as a braking generator to provide an abnormal back tension on a strip as the end of the strip passes between the first two roll stands. When the end of the strip is engaged by the rolls of the second roll stand a corrective abnormal tension is applied to the strip between the first and second roll stands and the back tension applied by the unwinding reel motor is reduced to a value below normal.

As the end of the strip progresses through the mill the tensions on the material are so adjusted by varying the tensions between adjacent roll stands and between the end roll stands and the reels as to provide an abnormal tension on the material at each roll stand as the leading end is threaded through the mill.

After the leading end is started on the winding reel the tensions between each pair of adjacent roll stands and between the end roll stands and the reels is automatically adjusted to a predetermined manually adjustable normal amount for each position. When the following end of the strip leaves the unwinding reel the tensions between the roll stands and between the winding reel and the last roll stand are varied to produce predetermined abnormal tensions on the material at each roll stand until the end leaves the last roll stand.

Temperature responsive means and thickness responsive means are provided for varying the strip tension in accordance with variations of strip temperature and gauge to compensate for the cooling of the strip when the system is used to control a hot strip mill and to compensate for varying physical characteristics of the strip material. Thickness responsive means are provided to correct varying thickness in metal coming to the mill as it is rolled.

Referring now to the drawings:

I have shown a four-stand strip rolling mill having roll stands L, M, N and O with the strip of material **10** being unwound from the unwinding reel R passing through the rolls of the four-roll stands and being wound on the winding reel S. The rolls of roll stands L, M, N and O are driven by motors **12**, **14**, **16** and **18**, respectively, and the winding and unwinding reels are driven by motors **20** and **22**, respectively. A vibrating regulator G is connected in the field circuit of the reel motor **22** and is controlled by the armature current of the motor **22** to regulate the back tension applied to the strip **10**.

Tension is applied to the strip **10** as it passes between adjacent roll stands by tensioning devices H, I and J which bear upon the strip between the stands L and M, M and N, and N and O, respectively. A vibrating regulator K is provided for so controlling the field current of the winding reel motor **20** as to maintain a constant adjustable tension on the strip as it is wound upon the reel S.

The vibrating regulator G comprises a vibrating arm **26** upon which are mounted contact elements **28** and **30** which are insulated from the arm. The arm **26** is pivoted at **32** and is connected to be actuated by the relay **34**. The coil of relay **34** is connected in series circuit relation with a resistance element **36** which has such a resistance value as to prevent sufficient current flow through relay **34** to cause it to actuate its armature. The contact element **38** of relay **34** is connected in series circuit relation with the coil of the relay **40**. Contact element **42** of relay **40** is connected in shunt relation with resistance element **36**. An arm **44** is pivoted at **46** and is connected to be actuated by the armature of solenoid **50**. Contact element **52** is mounted upon arm **44** and electrically connected therewith and is disposed between contact elements **28** and **30**. The coil of solenoid **50** is connected in parallel circuit relation with the series field winding **54** of the reel motor **22** in series circuit relation with the resistance elements G3 and G4.

The movable contact elements **28** and **30** of the regulator are connected in circuit with the coils of relays **56** and **58**, respectively. The resistance elements **60** and **62** are connected in series circuit relation with the shunt field winding **64** of reel motor **22** and with resistance elements G1 and G2. The contact element **66** of relay **56** is connected in shunt relation with resistance element **60** and the contact element **68** of relay **58** is connected in shunt relation with the resistance element **62** when relay **58** is energized.

It will be seen that the arm **26** will be caused to vibrate continuously because of the intermittent energization of the coil of solenoid **34**. When the coil of solenoid **34** is energized, contact element **38** will be closed to energize the coil of relay **40** which in turn moves its contact element **42** to the open circuit position to connect the resistance element **36** in series circuit relation with solenoid **34** to thus cause it to drop its armature. The dropping of the armature of solenoid **34** will cause contact element **38** to move to the open circuit position, thus deenergizing the coil of relay **40** and allowing the contact element **42** to drop to close circuit position, which, in turn, will cause an increase in current flow through the coil of solenoid **34** to again cause upward movement of the armature of solenoid **34**. The armature of solenoid **50** will occupy a position depending upon the current flow in its actuating coil which, in turn, will depend upon the current flow in the armature of the motor **22**. As the arm **26** vibrates contact elements **28** and **30** will intermittently engage contact element **52** and will remain in engagement with contact element **52**, and cause energization of the coils of relays **56** and **58** for periods of time during each vibrating movement of the arm **26** depending upon the position in which the contact element **52** is held by arm **44**.

It will be seen that if the current in the armature of machine **22** falls below that which is necessary to supply the required torque for the desired back tensioning of the strip **10** as it is being unwound from reel R, solenoid **50** will allow arm **44** to move downward, and this will permit contact element **52** to remain in contact with con-

tact element 30 for a longer period of time during each vibrating movement of arm 26 than with contact element 28. Thus, for each vibrating movement of arm 26 relay 58 will be energized longer than relay 56, and there will be an increase in the current in the shunt field 64 of machine 22 because of the decrease in the resistance in the field circuit. This increase in field current will increase the torque of motor 22 to increase the back tension on the strip 10.

The automatic tensioning devices H, I and J are similar and comprise a lever arm 70 on one end of which there is mounted a roller 72 which bears against the strip 10. A fluid pressure piston 74 operating in cylinder 76 is connected to actuate the lever 70 to move the roller 72 into a tensioning position with respect to the strip 10, the displacement of roller 72 being governed by the fluid pressure in the cylinder 76. The piston 74 and cylinder 76 are so dimensioned as to permit a leakage from the cylinder chamber to provide a continuous flow of fluid through the system. This leakage permits escape of pressure fluid, such as air, from the cylinder when it is desired to decrease the pressure in the cylinder, and prevents changes in tension by contraction or expansion of the air in the cylinder, thus providing a constant tension on the strip regardless of the movement of the tensioning roller and the piston. A fluid pressure reservoir shown is connected through a pressure regulating valve 78 and conduit 80 to the cylinder 76. The pressure regulating valve 78 comprises a valve member 82 and a valve seat 84 cooperating therewith, the valve member 82 being operated by stem 86 which is connected to diaphragm 88 and the core of solenoid 90. Spring members 92 and 94 bear against the diaphragm 88, the spring member 94 being of such dimensions as to tend to open the valve and to thus increase the pressure in the cylinder 76. The tension of spring 94 is opposed by the pull of the armature of solenoid 90 which pull varies with the current flowing through the coil of solenoid 90, so that the pressure in cylinder 76 and hence the tension applied to strip 10 by roller 72 will vary inversely with the current flowing in the coil of solenoid 90 and the regulator will tend to apply a constant tensioning force to the strip 10 so long as the constant current flows in the solenoid 90. It is to be understood that any suitable pressure regulating valve may be substituted for the valve 78. It is also to be understood that the pressure provided by spring 94 of valve 78 may be provided by an equivalent means such as a weight or a fluid pressure operated piston.

In order to prevent too great a displacement of the roller 72 as it bears against the strip, the regulator H includes a control means for the motor 14 which drives the rolls of roll stand M. This controller comprises contact elements 96 and 98 which are carried by and moved with the arm 70 and therefore change their positions with variations in the position in the arm 70. Contact element 96 is connected in series circuit relation with the coil of relay 100 and contact element 98 is connected in series circuit relation with coil of relay 102. The resistance elements 104 and 106 are connected in series circuit relation with the shunt field winding 108 of the motor 14 and in the energized position of relay 100 the contact element 110 thereof is connected in shunt relation with the resistance element 104. When relay 102 is deenergized its contact element 112 is connected in shunt relation with the resistance element 106.

A contact element 114 is carried by, and electrically connected to an arm 116 which is pivoted at 118, and the arm 116 is caused to vibrate by the solenoid 134 under control of relay 140 and resistance element 137 in the manner described in the discussion of the vibration of the arm 26 by the solenoid 34 and the control of relay 40 in connection with the regulator G.

Thus it will be seen that in the event that the arm 70 tends to be displaced too much to maintain a preferred predetermined position, the contact elements 96 and 98 will move to such a position as to cause a longer period of engagement of contact element 114 with one or the other of contacts 96 and 98 on each vibrating movement of the arm 116. This will cause longer energization of one or the other of relays 100 and 102 and will effect a change in the current flow in the field winding 108 of motor 14 which will tend to decrease or increase the speed of the motor. In this manner the tension roller 72 will be returned and maintained at a substantially fixed position.

When it is desired to increase the tension on the strip 10, the current flowing in the coil of solenoid 90 may be decreased by connecting the desired number of resistance elements H1, H2 and H3 in series circuit relation with this coil.

The tensioning reel motor 20 is controlled by regulator K to maintain an adjustable constant tension on the strip 10 as it is delivered from the last roll stand O. The regulator K comprises substantially the same elements as described hereinbefore in the discussion of the regulator G for the unwinding reel motor 22, except that in this instance the regulator K is connected to cause a decrease in the energization of the shunt field winding 120 of winding reel motor 20 in response to a decrease in the armature current of motor 20 to thus cause the motor 20 to tend to increase its speed and to thus increase the tension on the strip 10. The motor 20 is controlled to maintain the desired tensions on the strip 10 by connecting the desired number of resistances K1, K2 in series circuit relation with the field winding 120 of the motor 20 to control its shunt field current. The regulator K may be adjusted to maintain the selected tensions on the strip 10 by connecting the desired number of resistance elements K3, K4 in series circuit relation with the coil of its operating solenoid 122.

Relays A, B, C, D, E and F are connected in parallel circuit arrangement with the series field windings of motors 22, 12, 14, 16, 18 and 20, respectively, and are so designed as to be actuated when a load is carried by their respective associated motors. The relays A, B, C, D, E and F have the series of contacts shown which are connected in circuit to govern the tensions applied by the tensioning devices H, I and J, the back tension applied by the reel R and the front tension applied by the reel S. The detailed circuits governed by these relay contact elements will be described hereinafter.

The energization of motor 22 is controlled by a circuit breaker 126 which, when energized, connects motor 22 to the source of direct current power as shown. The operating coil of circuit breaker 126 is connected in circuit through the contact element of a manually operated push button switch 128. A holding circuit is provided for the operating coil of circuit breaker 126 comprising the contact element 130 of relay 132, the

contact element 130 closing a circuit in parallel circuit relation with the contact element of the push button switch 128. The coil of relay 132 is energized from the source of power for motor 22 and the contact element 130 is held in closed circuit position while the motor 22 is energized.

The motor 20 is connected to the source of direct current power by circuit breaker 134 which may be energized by the manually controlled circuit breaker 136 and which may also be energized by the manually controlled circuit breaker 138 through a circuit which includes the contact element E6 of relay E. The contact element 141 controls a holding circuit for the coil of circuit breaker 134, this holding circuit comprising a circuit in parallel circuit relation with the manually controlled circuit breaker 138.

In the operation of the system, the leading end of the strip 10 is unwound from the unwinding reel R and fed toward the first roll stand L when the motor 22 is started by momentarily closing the manually controlled push button switch 128. When motor 22 is energized to drive unwinding reel R, relay A is energized and lifts its contact elements A1, A2, A3, A4, A5, A6 and A7. When the leading end of the strip enters the rolls of the first roll stand L, a load is placed upon the roll motor 12 and this causes relay B to be actuated.

Since there is no front tension on the strip 10, as it is passed through the rolls of the first roll stand L, it is necessary that the back tension be higher than normal and of a predetermined amount in order that all portions of the strip 10 may receive substantially the same amount of reduction as it passes through the rolls of roll stand L. This predetermined higher-than-normal back tension is placed on the strip 10 by increasing the current flow in the shunt field winding 64 of motor 22. This increase in current in the shunt field winding 64 of motor 22 is effected by the movement of contact element B6 of relay B to closed circuit position to close the circuit which functions to short circuit the resistance elements G1 and G2 and which comprises the conductor 142 leading from one side of the resistance element G1 through the contact element C5, conductor 144, contact element B6 and conductor 146 to one side of the resistance element G2. At the same time, the regulator G is adjusted to maintain the higher-than-normal back tension on strip 10 by increasing the resistance in the coil of the operating solenoid 50 of regulator G. This is accomplished by the movement of the contact element B7 of relay B to open circuit position. It will be seen that the movement of contact element B7 to open circuit position opens a circuit which has a shunt relation with the resistance elements G3 and G4 and which comprises one side of the resistance element G3, conductor 148, contact element B7 and conductor 150 to one side of the resistance element G4. The strip 10 thus has applied to it a higher-than-normal back tension while it is passing through the rolls of roll stand L and until its leading end enters the rolls of second roll stand M.

As the leading end of strip 10 enters and passes through the rolls of roll stand M, it will be seen that the only tension that can be applied to the strip 10 is back tension, and in order to secure the proper reduction in all parts of the strip 10, it is necessary that this back tension be higher-than-normal. The required higher-than-normal back tension is applied to the strip 10 by the tensioning device H by decreasing the energization of the coil of solenoid 90 so as to increase the pressure on the strip 10 by increasing the pressure in the cylinder 76. This decrease in the energization of the coil of solenoid 90 is effected by the operation of relay C which is actuated when the increased load is placed on the roll motor 14 by the entry of the leading end of the strip 10 between the rolls of the roll stand M. It will be seen that when relay C is not actuated, a circuit which has a shunt relation to the resistance elements H1, H2 and H3 exists, and comprises conductor 152 from one side of resistance element H3, conductor 154, contact element C4 of relay C and conductor 156 to one side of resistance element H1. This higher-than-normal back tension will be maintained on the strip 10 by the tensioning device H which will automatically control the energization of the shunt field winding 108 of motor 14 and thus so regulate the torque of motor 14 as to maintain the desired tension of the strip 10.

With the higher-than-normal back tension maintained between the strip 10 and the rolls of the second roll stand M, it follows that the same higher-than-normal front tension will be applied between the strip 10 and the rolls of the first roll stand L, and in order to maintain the uniform reduction of the strip 10 at the roll stand L, it is necessary that the back tension between the strip 10 and the rolls of roll stand L as applied by the unwinding reel R be lower-than-normal. This lower-than-normal back tension between the strip 10 and the rolls of roll stand L is provided by decreasing the current flow in the shunt field winding 64 of motor 22. This decrease in the current flow in shunt field winding 64 is effected by connecting the resistance elements G1 and G2 in series circuit relation with the shunt field winding 64. The resistance elements G1 and G2 are connected in circuit with the shunt field winding 64 by opening the previously described shunting circuit comprising conductor 142, contact element C5, conductor 144, contact element B6 and conductor 146. It will be seen that this circuit is opened by the operation of relay C to move contact element C5 to open circuit position when the leading end of the strip enters the rolls of roll stand M. At the same time contact element C6 of relay 6 is moved to closed circuit position to close a shunting circuit for resistance elements G3 and G4 extending from one side of resistance element G3, conductors 148 and 170, contact element D6, conductor 172, contact element C6 and conductors 174 and 150 to resistance element G4. This shunting of resistance elements G3 and G4 decreases the resistance in the circuit of the coil of control relay 50 of regulator G to decrease the back tension on the strip 10. Thus it will be seen that a higher-than-normal tension is maintained on the strip 10 between roll stands L and M and a lower-than-normal back tension is maintained at roll stand L while the leading end of the strip 10 is passing from the roll stand M to the roll stand N.

As the leading end of the strip 10 enters and passes through the rolls of the third roll stand N and until it enters the rolls of the last roll stand O, it is necessary that a higher-than-normal back tension be applied to the strip in order that a uniform reduction in all parts of the strip 10 may be secured as the strip passes through the rolls of roll stand M. This higher-than-nomal back tension is applied to strip 10 by increasing

the resistance in the circuit of the regulating solenoid 90 of the tensioning device I to increase the pressure applied to the strip by the tensioning device I. This increase in the resistance in the circuit of the coil of regulating solenoid 90 is accomplished by opening a circuit which has a shunt relation to the resistance elements I1, I2 and I3 and which comprises conductor 158 from one side of resistance element I3, conductor 160, contact element D3 and conductor 162 to one side of the resistance element I1. This circuit is opened by the operation of relay D to move its contact element D3 to open circuit position when the leading end of the strip places a load upon the motor 16 as it enters the rolls of roll stand M.

In order to prevent too great a reduction of the strip 10 in the rolls of roll stand M, it is necessary that the back tension between the strip 10 and the rolls of roll stand M be decreased to lower-than-normal when the higher-than-normal front tension is established by the strip 10 and the rolls of roll stand M. This lower-than-normal back tension on the strip 10 is provided by connecting only resistance element H3 in circuit with the coil of the regulating solenoid 90 of the tensioning device H. It will be seen that when relay D operated, a circuit having a shunt relation with the resistance elements H1 and H2 was established comprising conductor 164, contact element D4, conductor 166, contact element E3, and conductor 156 to one side of the resistance element H1. With this adjustment of the energization of the coil of the regulating solenoid 90 of tensioning device H, a lower-than-normal back tension will be maintained between the strip 10 and the rolls of roll stand M and a lower-than-normal front tension will be maintained between the strip 10 and the rolls of the roll stand L.

In order to maintain the proper amount of tension on the strip 10 at the roll stand L, it is necessary that the back tension between the strip 10 and the rolls of roll stand L be increased to higher-than-normal at the time that the front tension between the strip 10 and the rolls of roll stand L is decreased to lower-than-normal. This higher-than-normal back tension is produced by increasing the current flow in shunt field winding 64 of motor 22 by applying a shunting circuit to resistance elements G1 and G2. This shunting circuit is completed by the movement of the contact element D5 to the closed circuit position and comprises conductor 142 from one side of the resistance element G1, contact element E4, conductor 167, contact element D5, conductor 168, conductor 144, contact element B6 and conductor 146 to one side of resistance element G2. At the same time, the current in the coil of regulating solenoid 50 is decreased to cause the motor 22 to maintain the higher-than-normal back tension on the strip 10 by connecting resistance elements G3 and G4 in series circuit relation with the coil of solenoid 50. The resistance elements G3 and G4 are connected in circuit with the coil of solenoid 50 by the movement of the contact element D6 to open circuit position to open a shunting circuit for the resistance elements G3 and G4 which comprises one side of the resistance element G3, conductor 148, conductor 170, contact element D6, conductor 172, contact element C6, conductor 174, and conductor 150 to one side of the resistance element G4.

Thus it will be seen that while the leading end of the strip 10 passes from the roll stand N to the roll stand O, a higher-than-normal back tension will be maintained between the strip 10 and the rolls of roll stand N; a higher-than-normal front tension will be maintained between the strip 10 and the rolls of roll stand M; a lower-than-normal back tension will be maintained between the strip 10 and the rolls of roll stand M; a lower-than-normal front tension will be maintained between the strip 10 and the rolls of roll stand L, and a higher-than-normal back tension will be maintained between the strip 10 and the rolls of roll stand L, thus ensuring the proper reduction due to tensioning at each of these roll stands.

Throughout this description, the terms lower-than-normal and higher-than-normal are used to designate tensions which when applied to the strip on opposite sides of the roll stand will produce a degree of reduction due to tension substantially equal to the reduction due to tension produced by normal tension on both sides of the roll stand. The lower-than-normal tension will be practically equal to no tension so far as its reducing effect on the strip is concerned. Where substantially constant total tensions are referred to in the specification and the claims the tensions which will produce constant reducing effects are meant. Constant total tensions at a roll stand are the tensions which will produce constant resulting reduction and may be either normal tension on both sides of the roll stand, higher-than-normal tension on one side of the roll stand with lower-than-normal tension on the other side or higher-than-normal tension on one side with no tension on the other side.

It is considered within the scope of this invention to provide fewer operations for correcting gauge than are described herein with each operation performing a greater degree of correction. It might be desirable, for instance, to provide increased tension between only two pairs of roll stands instead of between each pair of stands as herein described.

When the leading end of strip 10 enters the rolls of roll stand O and passes toward the reel S, it is necessary that a higher-than-normal back tension be applied between strip 10 and the rolls of roll stand O, since it is not possible to apply a front tension between the strip 10 and the rolls of roll stand O. This higher-than-normal back tension is applied and maintained by the tensioning device J when the contact element E1 is moved to the open circuit position by the operation of the relay E when the leading end of strip 10 places a load upon the motor 18 upon entering the rolls of roll stand O. The movement of contact element E1 to open circuit position removes a shunting circuit from the resistance elements J1, J2 and J3 which comprises one end of the resistance elements J3, conductor 176, conductor 178, contact element E1 and conductor 180 to one side of the resistance element J1. The tensioning device J automatically maintains this higher-than-normal tension between the strip 10 and the roll stands O and M while the leading end of the strip is moving from the roll stand O toward the winding reel S.

The application of higher-than-normal front tension between the strip 10 and the roll stand N makes it necessary that back tension between the strip 10 and the roll M be decreased to lower-than-normal, so that the reduction of all parts of the strip 10 at roll stand N may be uniform. The decrease in tension on the strip 10 by the tensioning device I to lower-than-normal is brought about by connecting only resistance element 13 in circuit with the coil of the regulat-

ing solenoid 90 of the tensioning device I. Resistance element I3 only is connected in circuit with the coil of solenoid 90 by applying a shunting circuit to the resistance elements I1 and I2 which comprises one side of resistance element I2, conductor 182, contact element E2 which was moved to closed circuit position by the operation of relay E when the leading end of the strip entered the roll stand O, conductor 184, contact element F2, conductor 186 and conductor 162 to one side of the resistance element I1. Thus a lower than normal tension is applied to the strip 10 between roll stands N and M.

With lower-than-normal front tension between strip 10 and roll stand M, it is necessary that the higher-than-normal back tension be applied between the strip 10 and the roll stand M. This higher-than-normal back tension is applied to strip between the rolls and the roll stands M and L by again connecting resistance elements H1, H2 and H3 in series circuit relation with the coil of regulating solenoid 90 of the tension device H. This decreased deenergization of the coil of solenoid 90 is effected by removing the shunting circuit, hereinbefore described, for resistance elements H1 and H2 by the movement of contact element E3 to open circuit position upon the operation of relay E.

With the establishment of the higher-than-normal front tension between the strip 10 and the roll stand L, it is necessary that the back tension between the strip 10 and the roll stand L be decreased to lower-than-normal. This is accomplished by again connecting resistance elements G1 and G2 in series circuit relation with shunt field winding 64 of motor 22 by removing the hereinbefore described shunting circuit for the resistance elements G1 and G2 by the movement of the contact element E4 to open circuit position upon the operation of relay E. At the same time, the regulator G is adjusted for the lower-than-normal back tension by applying a shunting circuit to the resistance elements G3 and G4. This shunting circuit comprises conductor 150 from one side of the resistance element G4, conductor 174, contact element C6, conductor 172, conductor 188, contact element E5, conductor 190, contact element F6, conductor 170 and conductor 148 to one side of the resistance element G3. Thus it will be seen that the higher-than-normal tension will be maintained between the strip 10 and each of the roll stands as the leading end of the strip moves from the roll stand O to the winding reel S.

After the leading end of the strip 10 has left the roll stand O and is started on the reel S, the load on the reel motor 20 will cause relay F to operate and move contact element F8 to the open circuit position to remove a shunting circuit from the resistance elements K1, K2, which comprises one side of resistance element K2, conductor 204, contact element F9 and conductor 206 to one side of the resistance element K1. With relay A energized a shunting circuit will be applied to the resistance element K2 which comprises one side of resistance element K2, conductor 208, conductor 210, contact element A1 and conductor 212 to the other side of resistance element K2. Thus resistance element K1 will be connected in series circuit relation with the field winding 120 of motor 20 to cause the motor to apply a normal tension to the strip 10 as it is wound on reel S. The operation of relay F will move its contact element F8 to open circuit position to remove a shunting circuit from the resistance elements K3 and K4 which comprises conductor 192 from one side of the resistance element K3, conductor 194, contact element F8 and conductor 196 to one side of the resistance element K4. It will be seen that with relay A energized, the contact element A6 thereof will close a shunting circuit for resistance element K4 which comprises one side of resistance element K4, conductor 198, contact element A6, conductor 200 and conductor 202 to the other side of the resistance element K4. This will leave such a resistance in circuit with the coil 122 of regulator K as to cause the regulator to maintain a normal front tension between the strip 10 and the roll stand O.

With normal front tension applied between strip 10 and roll stand O, it is necessary that normal back tension be applied between strip 10 and roll stand O in order to maintain the proper reduction due to tension at the roll stand O. This is done by applying a shunting circuit to resistance element J1 and leaving resistance elements J2 and J3 connected in series circuit relation with the coil of regulating solenoid 90 of tension device J. The shunting circuit for resistance J1 comprises conductor 180 extending from one side of resistance J1, contact element F1 which was moved to closed circuit position when the leading end of the strip 10 started winding on reel S, conductor 214, contact element A3 and conductor 216 to the other side of resistance element J1. With this adjustment of the circuit of the coil of the regulating solenoid 90, the tensioning device J will maintain a normal tension on the strip 10 between the roll stands O and M. It will be seen that this establishment of normal tension between adjacent roll stands and between the end roll stands and the reels will be necessary to maintain the proper tensions on the strip at each of the roll stands. The establishment of the normal tension between roll stands N and M will be accomplished by connecting resistance elements I2 and I3 in series circuit relation with the coil of the regulating solenoid 90 of tensioning device I. This is accomplished by applying a shunting circuit to the resistance element I1 under control of relay F, the shunting circuit comprising one side of resistance element I1, conductor 218, contact element B5, conductor 220, contact element F3, conductors 222, 186 and 162 to the other side of the resistance element I1.

The establishment of normal tension on the strip 10 between the roll stands M and L is effected by applying a shunting circuit to the resistance element H1 of the tensioning device H to regulate the current flow in the coil of solenoid 90 for normal tension. This shunting circuit comprises conductor 224 extending from one side of the resistance element H1, contact element A5, conductor 226, contact element F4 and conductor 156 to the other side of the resistance element H1.

The establishment of normal back tension between strip 10 and roll stand L is accomplished by connecting only resistance element G2 in circuit with the field winding 64 of motor 22 to provide a normal back tension and connecting only the resistance element G4 in series circuit relation with the coil of the regulator solenoid 50 to maintain the normal back tension on the strip 10. Resistance element G2 only is connected in series circuit relation with the field winding 64 for establishing a shunting circuit for resistance G1 which comprises one side of

the resistance element G1, conductor 142, contact element F5 and conductor 228 to the other side of resistance element G1. Resistance element G4 only is connected in series circuit relation with the coil of solenoid 50 for establishing a shunting circuit for resistance element G3 which comprises one side of resistance element G3, conductor 148, conductor 170, contact element F7 and conductor 230 to the other side of resistance element G3. Thus during the normal operation of the strip reducing mill, normal tensions will be applied to all parts of the strip.

When the following end of the strip leaves the reel R, there will be no back tension between the strip 10 and the roll stand L, and it is necessary to establish a higher-than-normal front tension between the strip 10 and the roll stand L so as to obtain the proper reduction of the part of the strip 10 between the roll stand L and the following end. To accomplish this, the tension applied to the strip 10 between the roll stands L and M by the tensioning device H is increased by decreasing the energization of the coil of regulating solenoid 90 of the tensioning device H. This decreased energization of the coil of solenoid 90 is accomplished by removing the shunting circuit for the resistance element H1, described hereinbefore, by the opening of the contact element A5 due to the deenergization of the relay A when the following end of the strip 10 leaves the reel R.

With the establishment of the higher-than-normal back tension between the strip 10 and the roll stand M, it is necessary that the front tension between the strip 10 and the roll stand M be decreased to lower-than-normal. This is accomplished by applying a shunting circuit to the resistance elements I1 and I2 of regulator I by the operation of relay A which closes its contact element A4 to close a circuit which comprises conductor 232, contact element A4, conductor 234, contact element B4 and conductor 236. Thus with only resistance element I3 connected in series circuit relation with the coil of solenoid 90, the tensioning device I will apply a lower-than-normal tension to the strip 10 between the roll stands M and N.

With the decrease in back tension between the strip 10 and the roll stand N, it is necessary that the front tension between the strip 10 and the roll stand N be increased to higher-than-normal. This is accomplished by connecting resistance elements J1, J2 and J3 in series circuit relation with the coil of operating solenoid 90 of the tension device J. Resistance elements J1, J2 and J3 are connected in this series circuit by the opening of the shunting circuit for the resistance element J1, hereinbefore described, due to the opening of contact element A3 of relay A. Thus a higher-than-normal tension will be applied to strip 10 between the roll stands N and O.

With the higher-than-normal back tension applied between strip 10 and roll stand O, it is necessary that a lower-than-normal front tension be applied between the strip 10 and the roll stand O. The lower-than-normal tension between the strip 10 and roll stand O is established by increasing the current flow in the field winding 120 of winding reel motor 20 by shunting the resistance elements K1 and K2 through a circuit which comprises one side of the resistance element K2, conductor 208, contact element A2, conductor 238, contact element B1, conductor 240, contact element D2, and conductor 242 to one side of the resistance element K1. At the same time, a shunting circuit is applied to the resistance elements K3 and K4 to so adjust the current strength in the coil of regulator solenoid 122 as to maintain the lower-than-normal tension on the strip 10. A shunting circuit for the resistance elements K3 and K4 comprises one side of the resistance element K3, conductor 192, contact element D7, conductor 244, contact element B8, conductor 246, contact element A7 and conductor 202 to one side of the resistance element K4. Thus it will be seen that the proper tensioning is maintained on the strip at each of the roll stands as the following end of the strip is moving between the unwinding reel R and the roll stand L.

The reel motor 22 may be stopped by operating the normally closed switch 133 to deenergize the holding circuit relay 132 which will, in turn, break the holding circuit of the circuit breaker 126.

When the following end of the strip 10 leaves the roll stand L, the decrease in the load on the roll motor 12 will permit the armature of relay B to drop. While the following end of strip 10 leaves the roll stand L and roll stand M, there can be no back tension applied between the strip 10 and the roll stand N. With the deenergization of relay B, it will be seen that contact element B3 will close a circuit having shunting relation with resistance elements H1, H2 and H3 which comprises one side of the resistance element H1, conductor 248, conductor 250, contact element B3, conductor 252 and conductor 152 to one side of the resistance element H3. This shunting out of the resistance from the circuit of the coil of the regulating solenoid 90 will permit such a current to flow in the coil of the solenoid 90 as will cause the constant pressure valve 78 to regulate the pressure in cylinder 76 to hold the idling roller 72 of tensioning device H in the idle position.

Since there is no back tension between the strip 10 and roll stand M after the end of the strip leaves roll stand L, it is necessary that the front tension between the strip 10 and the roll stand M be increased to higher-than-normal. This higher-than-normal tension is applied to the strip between roll stands M and N by increasing the resistance in series with the coil of the regulating solenoid 90 to decrease the current flow in the coil. The resistance element I1 is connected in series circuit relation with the coil of solenoid 90 by removing the hereinbefore described shunting circuit for resistance elements I1 and I2 by the opening of contact element B4 of relay B.

The establishment of a higher-than-normal back tension between the strip 10 and the roll stand M makes it necessary that a lower-than-normal front tension between the strip 10 and the roll stand M be established. This is effected by the closing of the contact element B2 of relay B to close a shunting circuit for resistance elements J1 and J2 which comprises conductor 253 extending from one side of resistance element J2, contact element C2, conductor 254, contact element B2, conductor 256, conductor 214, contact element F1 and conductor 180 to one side of resistance element J1. With only resistance J3 in series circuit relation with the coil of regulating solenoid 90, it will be seen that a lower-than-normal tension will be applied by the tension device J to the strip 10 between the roll stands N and O.

The establishment of lower-than-normal back tension between the strip 10 and roll stand N makes it necessary that the front tension between

the strip 10 and the roll stand O be increased to higher-than-normal. The higher-than-normal tension is applied to strip 10 by reel motor 20 by connecting resistance elements K1 and K2 in series circuit relation with the field winding 120 of motor 20 and connecting the resistance elements K3 and K4 in series circuit relation with the coil of the regulating solenoid 122. Both resistances K1 and K2 are connected in series circuit relation with field winding 120 by the opening of contact element B1 of relay B which opens the hereinbefore described shunting circuit for the resistance element K. Both resistances K3 and K4 are connected in series circuit relation with the coil of solenoid 122 by the opening of contact element B8 which breaks the hereinbefore described shunting circuit for resistances K3 and K4. Thus it will be seen that while the following end of strip 10 is moving between roll stands L and M higher-than-normal tension will be applied to the strip 10 between the roll stands M and N, lower-than-normal tension will be applied to the strip 10 between the roll stands M and O and higher-than-normal front tension will be applied to the strip 10 by the reel motor 20.

When the following end of the strip 10 leaves the roll stand M, the load will be removed from the roll motor 14 and the armature of relay C will be permitted to drop. With the contact element C3 in closed circuit position, a shunting circuit comprising conductor 258, contact element C3, conductor 260 and conductor 236 will be applied to the resistance elements I1, I2 and I3 to so increase the current flow in the coil of the regulating solenoid 90 so as to cause the roller of the tensioning device I to be held in idling position.

With no back tension between the strip 10 and the roll stand N, it is necessary that the tension on the strip 10 between roll stands N and O be increased to higher-than-normal. This higher-than-normal tension is obtained by the opening of the contact element C2 of relay C to break the hereinbefore described shunting circuit from resistance elements J1 and J2. This will cause resistance elements J1, J2 and J3 to be connected in series circuit relation with the coil of the regulating solenoid 90, thus causing tensioning device J to maintain a higher-than-normal tension on the strip 10.

With higher-than-normal back tension between the strip 10 and roll stand O, the front tensioning of strip 10 by reel motor 20 is decreased to lower-than-normal by the closing of contact element C1 of relay C to complete a shunting circuit for the resistance elements K1 and K2 which comprises one side of resistance element K2, conductor 208, contact element C1, conductor 262, conductor 240, contact element D2 and conductor 242 to one side of the resistance element K1. At the same time a shunting circuit is applied to resistance elements K3 and K4 which comprises one side of the resistance element K3, conductor 192, contact element D7, conductor 244, contact element C7 and conductor 202 to one side of the resistance element K4. This shunting of the resistance elements K1 and K2 and K3 and K4 establishes such current values in the field coil 120 of motor 20 and the coil of regulating solenoid 122 as to cause motor 20 to maintain a lower-than-normal tension on the strip 10.

As the following end of the strip 10 passes through the rolls of roll stand N, the roll motor 16 is relieved of its load and the relay D is permitted to drop its armature. The movement of contact element D1 to closed circuit position completes a shunting circuit for the resistance elements J1, J2 and J3 of regulator J comprising conductors 176, 264, contact element D1, conductor 266, and conductor 268 to thus cause tensioning device J to hold its tensioning roller in the idling position. Since there is no back tension applied between strip 10 and the roll stand O while the following end of strip 10 is moving from roll stand N to roll stand O, higher-than-normal tension is applied to the strip 10 by the reel motor 20. To cause motor 120 to apply and maintain this higher-than-normal tension to the strip 10, resistance elements K1 and K2 and K3 and K4 are connected in series circuit relation with the coil of solenoid 122 and the field winding 120 of motor 20, respectively. Resistance elements K1 and K2 are connected in series circuit relation with the field winding 120 by the opening of contact element D2 which breaks the hereinbefore described shunting circuit for the resistance elements K1 and K2. The resistance elements K3 and K4 are connected in series circuit relation with the winding of the relay 122 by the opening of contact element D7 to break the hereinbefore described shunting circuit for the resistance elements K3 and K4. Thus a higher-than-normal front tension will be applied between the strip 10 and roll stand O while the following end of the strip 10 is travelling from the roll stand N to the roll stand O.

It is understood that the normal lower-than-normal and higher-than-normal tensions referred to hereinbefore may have different values at the different tension applying points, since to secure the proper reduction of the strip, the tensions applied to the strip may have to be of different values as the strip progresses through the mill from stand to stand and is progressively reduced in thickness. These different values of tensioning may be secured and the desired predetermined tensions provided by properly selecting the values of the adjustable resistance elements G1, G2, G3, G4, 296 and 298, associated with reel motor 22, H1, H2, H3 and 300, associated with the tensioning device H, I1, I2, I3 and 302, associated with tensioning device I, J1, J2, J3 and 304, associated with tensioning device J, and K1, K2, K3, K4, 284 and 306 associated with reel motor 20.

When the following end of the strip 10 passes through the rolls of roll stand O, the load on the roll motor 18, will be decreased sufficiently to permit the armature of relay E to drop. The opening of contact element E6 of relay E will break the holding circuit for the coil of circuit breaker 134 which extends from the positive side of the source of power as shown through conductor 270, the operating coil of circuit breaker 134, conductor 272, conductor 274, contact element 141, conductor 276, conductor 278, contact element E6 and conductors 280 and 282 to the negative side of the source of power as shown. The deenergization of the operating coil of the circuit breaker 134 will permit the circuit breaker to open to deenergize the winding reel motor 20. The winding reel motor may then be inched by the manually controlled switch 126 to complete the winding of the strip 10 on the reel S.

The adjustable resistances 284, 286, 288, 290, 294 and 296 are connected in series circuit relation with the shunt field windings of the motors 20, 18, 16, 14, 12 and 22, respectively, so that manual adjustments for the proper operating conditions may be made. Likewise, variable re-

sistances 298, 300, 302, 304 and 306 are connected in series circuit relation with the regulating solenoids of the regulator G, the tensioning devices H, I and J and the regulator K, respectively, so that each of these regulators may be adjusted manually for the proper operating conditions.

When such a strip rolling system as hereinbefore described is used to roll hot strip, the strip gradually cools as it is fed through the mill and as its temperature decreases, its resistance to rolling increases, and, as a result, the thickness of the finished product gradually increases from the leading to the following end of the strip. In order to produce uniform thickness of the strip throughout the entire length of the strip, temperature responsive devices have been provided for varying the tensions applied to the strip as it passes through the mill, so that reducing tensions may be increased as the strip cools to compensate for the resistance to reduction of the strip due to the decrease in its temperature. These temperature responsive devices comprise thermostat elements 308 and 310 mechanically connected to rheostats 312 and 314, respectively. The rheostat 312 is connected in parallel circuit relation with resistance element 316 in the circuit of field winding 64 of motor 22 so as to increase the current flow therein and thereby increase the back tension in proportion to the decrease in temperature of the strip 10. While at the present time tension is not commonly applied to the strip at the feed and delivery ends of the mill in a hot strip mill, this invention includes means for so operating the hot strip mill and it is within the scope of this invention to omit the tensioning at these points if it is so desired.

The rheostat 314 is connected in parallel circuit relation with resistance element 318 in the circuit of field winding 120 of motor 20 so as to decrease the current flow therein in accordance with the decrease in temperature of the strip 10 to thus cause motor 20 to increase the tension on the strip 10.

Thermostat elements 320, 322 and 324 are connected to operate rheostats 326, 328 and 330, respectively, and are so connected in the circuit of the coils of the regulating solenoids 90 of the tensioning devices H, I and J, respectively, as to decrease the current flow in the coils of solenoid 90 with the decrease in temperature of the strip 10 to thus cause the tensioning devices H, I and J to increase the tension on the strip 10 in proportion to the decrease in temperature thereof. It is within the scope of this invention to use a smaller number of temperature responsive devices and adjust for temperature change on fewer tensioning devices if such operation is found more practicable.

Since the thickness of the strip as it is fed to the mill may vary, and therefore, require the application of variable reducing forces to produce the desired reduction in the mill and, since it is desired that the finished product have as near a uniform predetermined thickness as is possible, means responsive to the thickness of the strip at various stations along the strip are provided, for varying the tension on the strip at the various tensioning points so that the reducing forces may be so varied as to produce a finished strip of substantially uniform thickness. These thickness responsive devices may be of any well known construction.

The thickness responsive device 332 comprises a pair of conducting roller elements 334 biased to bear upon the strip 10. A resistance responsive device 336 which may be the usual Wheatstone bridge arrangement or any other electrical equipment responsive to the resistance of the strip between the rollers 334, is connected to rollers 334 and is caused to operate the rheostat 338. The rheostat 338 is connected in parallel circuit relation with the resistance element 340 which, in turn, is connected in series circuit relation with the field winding 120 of reel motor 20.

Variations in the thickness of the strip 10 at the point where the strip is engaged by conducting rollers 334 will cause the resistance responsive device 336 to vary the adjustment of the rheostat 338 to thus affect the field current of reel motor 20 to cause the motor 20 to vary the tension on the strip 10.

In like manner, a thickness responsive device 342 is utilized to vary the field current of unwinding reel machine 22 to vary the tension on strip 10 between the unwinding reel and the roll stand L. The thickness responsive devices 344, 346 and 348 likewise function to vary the current flow through the regulating solenoids 90 of the tensioning devices H, I, and J in response to variations in the thickness of the strip. Each of these thickness devices is so calibrated as to cause a change in the strip tension in response to any variation of the thickness of the strip from the predetermined desired thickness at the point where the thickness responsive device is located. It is understood that a smaller number of thickness responsive devices may be used for correcting gauge at any desired number of tensioning points.

In Fig. 4 there is shown a modification of the invention in which the draft taken by the rolls of the mill is varied in accordance with variations in thickness and temperature of the strip to thus vary the reducing effort with variations in strip thickness and strip temperature. It will be apparent that as the thickness of the strip increases the reducing effort must be increased to produce a given resultant strip thickness. Similarly as the temperature of the strip decreases, as it will when hot strip is being rolled, the resistance to reduction will increase and necessitate an increased reducing effort in order to produce a given resultant strip thickness. In the embodiment of the invention discussed hereinbefore in connection with Figs. 1, 2 and 3 of the drawings, the variations in reducing effort necessitated by changes in strip thickness and temperature are provided by an automatic screw down controlled by thickness and temperature responsive devices.

Referring to Fig. 4, a screw down device 350 is arranged to be driven by motor 352 to decrease or increase the spacing between the rolls and to thus vary the draft taken by the rolls. The contact elements 354 and 356 are the contact elements of reversing switch 355 and are biased in the upper closed circuit position by spring member 358 and are disposed to be actuated by the core of solenoid 360. A strip thickness responsive device 362, which may be any such device commonly used for determining material thickness, but which is shown as essentially the same as the thickness responsive devices 332, 342, 344, 346 and 348 discussed hereinbefore in connection with the system shown in Figs. 1, 2, 3, is provided for varying the energization of the solenoid 360 in accordance with variations in the thickness of the strip 10. A

thermal responsive device 364 is so positioned as to be responsive to temperature changes in the strip 10. A resistance element 366 is connected in series circuit relation with the coil of solenoid 360 and a rheostat 368 is connected in shunt circuit with it. The rheostat 368 is disposed to be actuated by temperature responsive device 364 so that variations in the temperature of the strip 10 will cause variations in the current flow in the coil of solenoid 360.

In the operation of the system, the thickness and temperature responsive devices 362 and 364 are so adjusted as to cause such current flow in the coil of solenoid 360 of switch 355 as will keep the contact elements 354 and 356 in the position shown in the drawings which is between the upper and lower closed circuit positions. If the thickness of the strip should change for any reason the thickness responsive device 362 will cause such a change in the current flow in the coil of solenoid 360 as will effect closure of the reversing switch contact elements to energize the motor 352 so as to cause the motor to operate the screw down device 350 in the necessary direction to correct the condition. The thickness responsive device will then respond to the changed thickness and return the reversing switch 355 to its neutral position.

When the mill is rolling hot strip and the strip cools, the temperature responsive device 364 will function to change the resistance characteristic of the solenoid circuit. As a result the motor 352 will be energized to actuate the screw-down device in such a direction as to increase the draft taken by the rolls of roll stand L.

The apparatus of Fig. 4 differs from that of Fig. 3 only in the substitution of screw down control in Fig. 4, for tension control in Fig. 3 in response to thickness and temperature. The apparatus of Fig. 4 is interchangeable with that of Fig. 3 and accordingly the same reference characters have been applied to the like elements and circuits. It is to be understood that the thickness and temperature responsive screw down system of Fig. 4 may be applied to any or all of the roll stands of the system shown in Figs. 1, 2 and 3. It is further to be understood that the system may be made to operate in accordance with the principles described herein so that both the draft and the tension on the strip may be varied in response to changes in strip thickness and temperature.

It is also to be understood that tensioning devises other than the particular ones shown and described may be used, that thermostat elements other than the ones shown and described may be used, and forward and back tension regulating devices for the reel motors other than those shown and described and any other equivalent devices may be used to accomplish the desired results without the exercise of invention.

It will be seen that I have provided a control system for a strip rolling mill which is reliable and efficient in operation, and which will so control the reducing forces on a strip of material as it is fed through the mill as to produce a strip of uniform thickness throughout the length of the strip.

In compliance with the requirements of the patent statutes, I have shown and described herein the preferred embodiment of my invention. It is understood, however, that the invention is not limited to the precise construction 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 strip rolling mill, a set of cooperating rolls, an unwinding reel and a winding reel for the strip material, means including said unwinding reel for applying back tension to the strip as it passes between said rolls, means including said winding reel for applying front tension to the strip as it passes between the rolls, means for causing said back tensioning means to apply an abnormal tension to the strip from the time at which the leading end of the strip enters the rolls until said leading end is attached to and tensioned by the winding reel, means for causing said front tensioning means to apply an abnormal tension to the strip from the time the following end of the strip leaves the unwinding reel until said following end passes through said rolls, and means for causing said front and back tensioning means to apply normal tensions to the strip while the strip is being simultaneously unwound from one reel and wound upon the other reel.

2. In a strip rolling mill having a winding reel for the strip material, means including said winding reel for applying front tension to the strip as the strip passes through the mill, and means for applying an abnormal back tension to the strip from the time the leading end of the strip enters the rolls until said end of the strip is started winding on said winding reel.

3. In a strip tensioning control system for a multi-stand rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing substantially constant total tensions on the strip at each roll stand while the strip is passing therethrough throughout substantially the entire length of the strip as it passes through the mill, and means responsive to the temperature of the strip and the thickness of the strip for varying the total tensions on the strip at the roll stands.

4. In a strip rolling mill, a winding reel and an unwinding reel for the strip material, means including said winding reel for applying front tension to the strip as it passes through the rolls, means including said unwinding reel for applying back tension to the strip as it passes through the rolls, and means for causing said back tensioning means to apply an abnormal tension on the strip while the leading end of the strip is passing from the rolls to winding position on the winding reel.

5. In a strip rolling mill, a winding reel and an unwinding reel for strip material, means including said winding reel for applying front tension to the strip as it passes through the mill, means including said unwinding reel for applying back tension to the strip as it passes through the rolls, and means for causing said front tensioning means to apply an abnormal tension on the strip while the following end of the strip is passing from the unwinding reel to and through the rolls.

6. In a strip rolling mill, a winding reel and an unwinding reel for the strip material, means including said winding reel for applying front tension to the strip as it passes through the rolls, means including said unwinding reel for applying back tension to the strip as it passes through the rolls, means for causing said back tensioning means to apply an abnormal tension on the strip while the leading end of the strip is passing from

the rolls to winding position on the winding reel, and means for causing both of said tensioning means to apply normal tensions to the strip while the strip is being both wound and unwound simultaneously.

7. In a strip rolling mill, a winding reel and an unwinding reel for strip material, means including said winding reel for applying front tension to the strip as it passes through the rolls, means including said unwinding reel for applying back tension to the strip as it passes through the rolls, means for causing said front tensioning means to apply an abnormal tension on the strip while the following end of the strip is passing from the unwinding reel to and through the rolls, and means for causing both of said tensioning means to apply normal tensions to the strip while the strip is being both wound and unwound simultaneously.

8. In a strip rolling mill, means for applying back tension to the strip as it passes through the rolls, means for applying front tension to the strip as it passes through the rolls, and means for causing said back tensioning means to apply an abnormal tension to the strip from the time the leading end of the strip enters the rolls until front tension is applied to the strip by the front tensioning means.

9. In a strip rolling mill, means for applying back tension to the strip as it passes through the rolls, means for applying front tension to the strip as it passes through the rolls, means for causing said front tensioning means to apply abnormal tension to the strip from the time the back tension is taken from the strip until the end of the strip passes through the rolls.

10. In a strip rolling mill, means for applying back tension to the strip as it passes through the rolls, means for applying front tension to the s ip as it passes through the rolls, means for causing said back tensioning means to apply an abnormal tension to the strip from the time the leading end of the strip enters the rolls until front tension is applied to the strip by the front tensioning means, and means for causing both of said tensioning means to apply normal tensions to the strip after front tension is applied to the strip.

11. In a strip rolling mill, means for applying back tension to the strip as it passes through the rolls, means for applying front tension to the strip as it passes through the rolls, means for causing said front tensioning means to apply abnormal tension to the strip from the time the back tension is taken from the strip until the end of the strip passes through the rolls, and means for causing both of said tensioning means to apply normal tensions to the strip while both front and back tensions are applied to the strip simultaneously.

12. In a strip tensioning control system for a multi-stand rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing substantially constant total tensions on the strip at each roll stand while the strip is passing therethrough throughout substantially the entire length of the strip as it passes through the mill, and means responsive to the thickness of the strip for varying the total tensions on the strip at one or more of the roll stands.

13. In a strip tensioning control system for a multi-stand strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing substantially constant total reducing tensions on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill, and means responsive to variations in the thickness of the strip for varying the screw down adjustment of the mill rolls.

14. In a strip tensioning control system for a multi-stand strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing substantially constant total reducing tensions on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill, and means responsive to variations in the temperature of the strip for varying the screw down adjustment of the mill rolls.

15. In a tensioning device for a multi-stand strip rolling mill, a winding reel and an unwinding reel for the strip of material, means for producing abnormal tensions in the strip on one side of each of the roll stands and subnormal tensions in the strip on the opposite side of each of the roll stands as the leading end of the strip of material passes from the first roll stand to winding engagement with the winding reel and as the following end of the strip of material passes from the unwinding reel through the last roll stand, and means for maintaining normal tensions on the strip on each side of each roll stand while the leading and following ends of the strip are on the winding and unwinding reels.

16. In a tensioning system for a multi-stand strip rolling mill having winding and unwinding reels, tensioning means bearing on the strip between adjacent roll stands and acting upon the reel motors for applying adjustable tensions to the strip between the roll stands and between the end roll stands and the adjacent reels, means for adjusting said tensioning means to apply normal tensions to all parts of the strip while both the leading and following ends of the strip are wound on the said reels, means responsive to the positioning of the leading end of the strip for adjusting said tensioning means to apply abnormal tension to the strip between the pair of roll stands which is engaging the strip immediately adjacent the leading end of the strip and between alternate pairs of roll stands engaging the strip while applying subnormal tension between intervening pairs of roll stands and applying an abnormal back tension on the strip between the unwinding reel and the first stand when the front tension on the strip at the first stand is subnormal, and a subnormal back tension on the strip between the unwinding reel and the first stand when the front tension on the strip at the first stand is abnormal, while the leading end of the strip is being threaded through the mill from the first roll stand to winding relation with the winding reel.

17. In a tensioning system for a multi-stand strip rolling mill having motor-operated winding and unwinding reels, tensioning means bearing on the strip between adjacent roll stands and controlling the reel motors for applying adjustable tensions to the strip between adjacent roll stands and between the end roll stands and the adjacent reels, means for adjusting said tension-

ing means to apply normal tensions to all parts of the strip as it passes through the rolls while both the leading and the following ends of the strip are wound on their respective reels, means responsive to the positioning of the following end of the strip for adjusting said tensioning means to apply abnormal tension to the strip between the pair of roll stands which is engaging the strip immediately adjacent the following end of the strip and between alternate pairs of roll stands engaging the strip while applying subnormal tension between intervening pairs of roll stands and applying subnormal tension on the strip between the winding reel and the last roll stand when the back tension on the strip at the last roll stand is abnormal and abnormal tension on the strip between the winding reel and the last roll stand when the back tension on the strip at the last roll stand is subnormal, while the following end of the strip is passing from the unwinding reel to and through the last roll stand.

18. In a tension control system for a strip rolling mill having winding and unwinding reels and first, second, third and fourth roll stands, individually adjustable tensioning means bearing on the strip between each adjacent pair of roll stands, adjustable tensioning means for applying a back tension on the strip between the unwinding reel and the first roll stand, adjustable tensioning means for applying a front tension on the strip between the winding reel and the last roll stand, means responsive to the entry of the leading end of the strip into the first roll stand for causing said back tensioning means to establish an abnormal back tension on the strip; means responsive to the entry of the leading end of the strip into the second roll stand for causing said tensioning means between the first and second roll stands to establish an abnormal tension on the strip between the first and second roll stands and for causing said back tensioning means to establish a subnormal back tension on the strip at the first roll stand; means responsive to the entry of the leading end of the strip into the third roll stand for causing said tensioning means between the second and third roll stands to establish an abnormal tension on the strip between the second and third roll stands, for causing said tensioning means between the first and second stands to establish a subnormal tension on the strip between the first and second roll stands and for causing said back tensioning means to establish an abnormal back tension at the first roll stand; means responsive to the entry of the leading end of the strip into the fourth roll stand for causing said tensioning means between the third and fourth roll stands to establish an abnormal tension on the strip between the third and fourth roll stands, for causing the tensioning means between the second and third roll stands to establish a subnormal tension on the strip between the second and third roll stands, for causing the tensioning means between the first and second roll stands to establish an abnormal tension on the strip between the first and second roll stands, and for causing said back tensioning means to establish a subnormal back tension on the strip at the first roll stand; means responsive to the establishment of winding relation between the strip and the winding reel for causing said front tensioning means to establish a normal front tension on the strip at the fourth roll stand, for causing the tensioning means between the first and second roll stands, the second and third roll stands and the third and fourth roll stands to establish normal tension on the strip between said pairs of stands, and for causing said back tensioning means to establish a normal back tension on the strip at the first roll stand; means responsive to the complete unwinding of the strip from said unwinding reel for causing the tensioning means between the first and second roll stands to establish an abnormal tension on the strip, for causing the tensioning means between the second and third roll stands to establish a subnormal tension on the strip, for causing the tensioning means between the third and fourth roll stand to establish an abnormal tension on the strip, and for causing said front tensioning means to establish a subnormal tension on the strip; means responsive to the passing of the following end of the strip through the first roll stand for causing the tensioning means between the second and third roll stands to establish an abnormal tension on the strip, for causing the tensioning means between the third and fourth roll stands to establish a subnormal tension on the strip, and for causing the front tensioning means to establish an abnormal front tension on the strip at the fourth roll stand; means responsive to the passing of the following end of the strip through the second roll stand for causing the tensioning means between the third and fourth roll stands to establish an abnormal tension on the strip, and for causing the front tensioning means to establish a subnormal front tension on the strip at the last roll stand; means responsive to the passing of the following end of the strip through the third roll stand for causing the front tensioning means to establish an abnormal front tension on the strip at the last roll stand, and means cooperating with the several tensioning means for maintaining the established tensions.

19. In a strip tensioning control system for a multi-stand metal strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing substantially constant total tensions on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill, and means responsive to variations in the temperature of the strip for varying the total tensions on the strip at the roll stands.

20. In a strip tensioning control system for a multi-stand metal strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing and maintaining substantially constant reduction-due-to-tension effects on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill.

21. In a strip tensioning control system for a multi-stand metal strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing and maintaining substantially constant reduction-due-to-tension effects on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill, and means responsive

to variations in the temperature of the strip for varying the reduction-due-to-tension effects on the strip.

22. In a strip tensioning control system for a multi-stand metal strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing and maintaining substantially constant reduction-due-to-tension effects on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill, and means responsive to the temperature of the strip and the thickness of the strip for varying the reduction-due-to-tension effects on the strip.

23. In a strip tensioning control system for a multi-stand metal strip rolling mill having winding and unwinding reels, means responsive to the positions of the leading and following ends of the strip with respect to the roll stands and winding and unwinding reels for establishing and maintaining substantially constant reduction-due-to-tension effects on the strip at each roll stand while the strip is passing therethrough throughout the entire length of the strip as it passes through the mill, and means responsive to the thickness of the strip for varying the reduction-due-to-tension effects on the strip.

24. A control system for material modifying apparatus and the like having a pair of elements operating successively on a length of material and individual dynamo-electric machines mechanically coupled to said elements comprising in combination, a current regulator for maintaining the armature current of one of said machines substantially constant, and means responsive to variations in the thickness of said material for controlling the other of said dynamo-electric machines to vary the tension of said materal to decrease the thickness variations of said material.

25. A control system for rolling mill apparatus and the like having a plurality of elements for successively operating on a length of moving material, and an electric motor for driving one of said elements and a second electric motor for driving another of said elements comprising in combination, a current regulator for maintaining the current input to one of said motors substantially constant, and means responsive to variations in the thickness of said material for controlling the speed of the other of said motors to vary the tension of said material to decrease the thickness variations of said material.

GLENN E. STOLTZ.