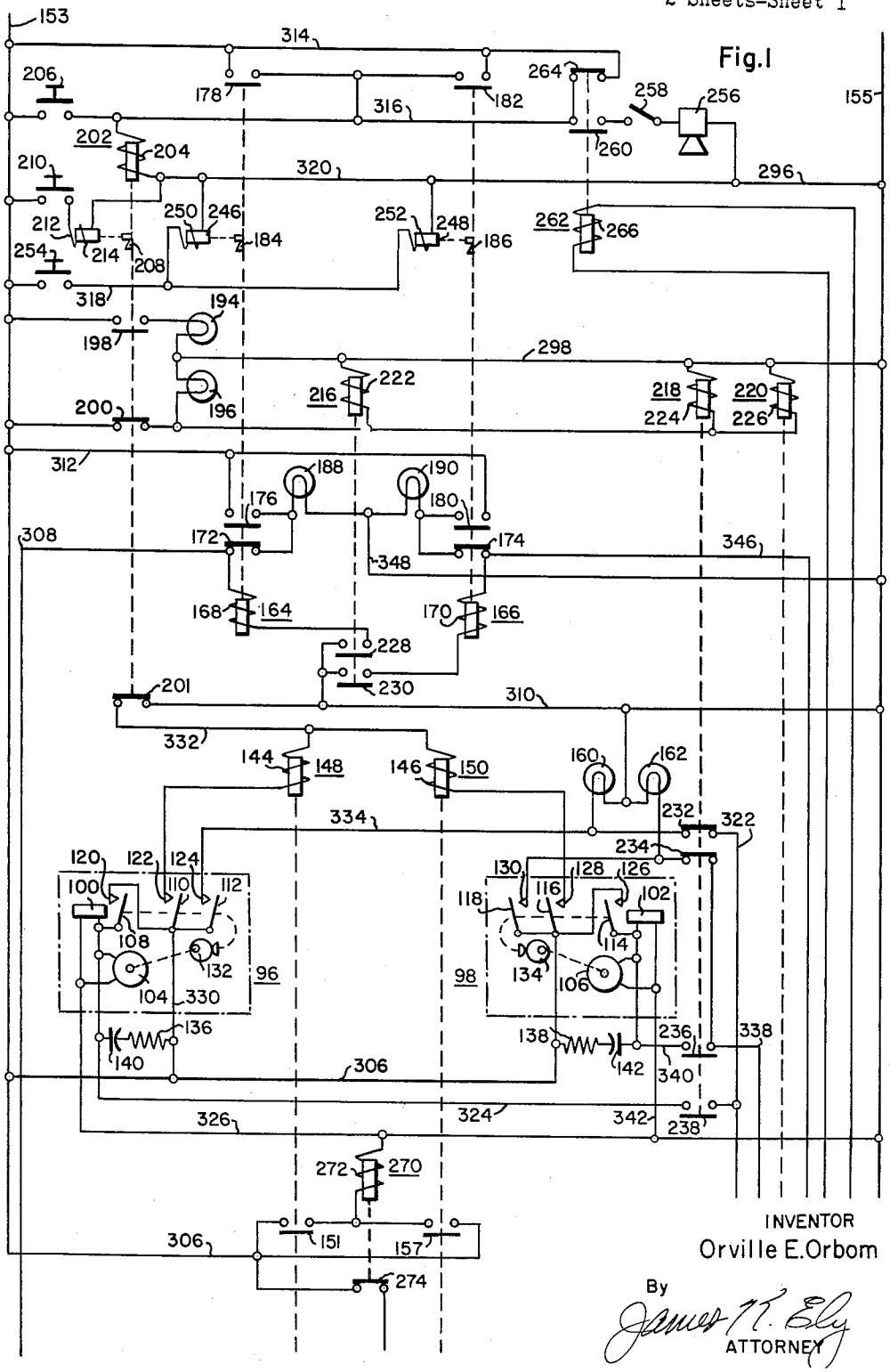
May 2, 1961 O. E. ORBOM 2,982,158

ELONGATION CONTROL SYSTEMS

Filed Aug. 26, 1957 2 Sheets-Sheet 1

Fig. 1



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ELONGATION CONTROL SYSTEMS

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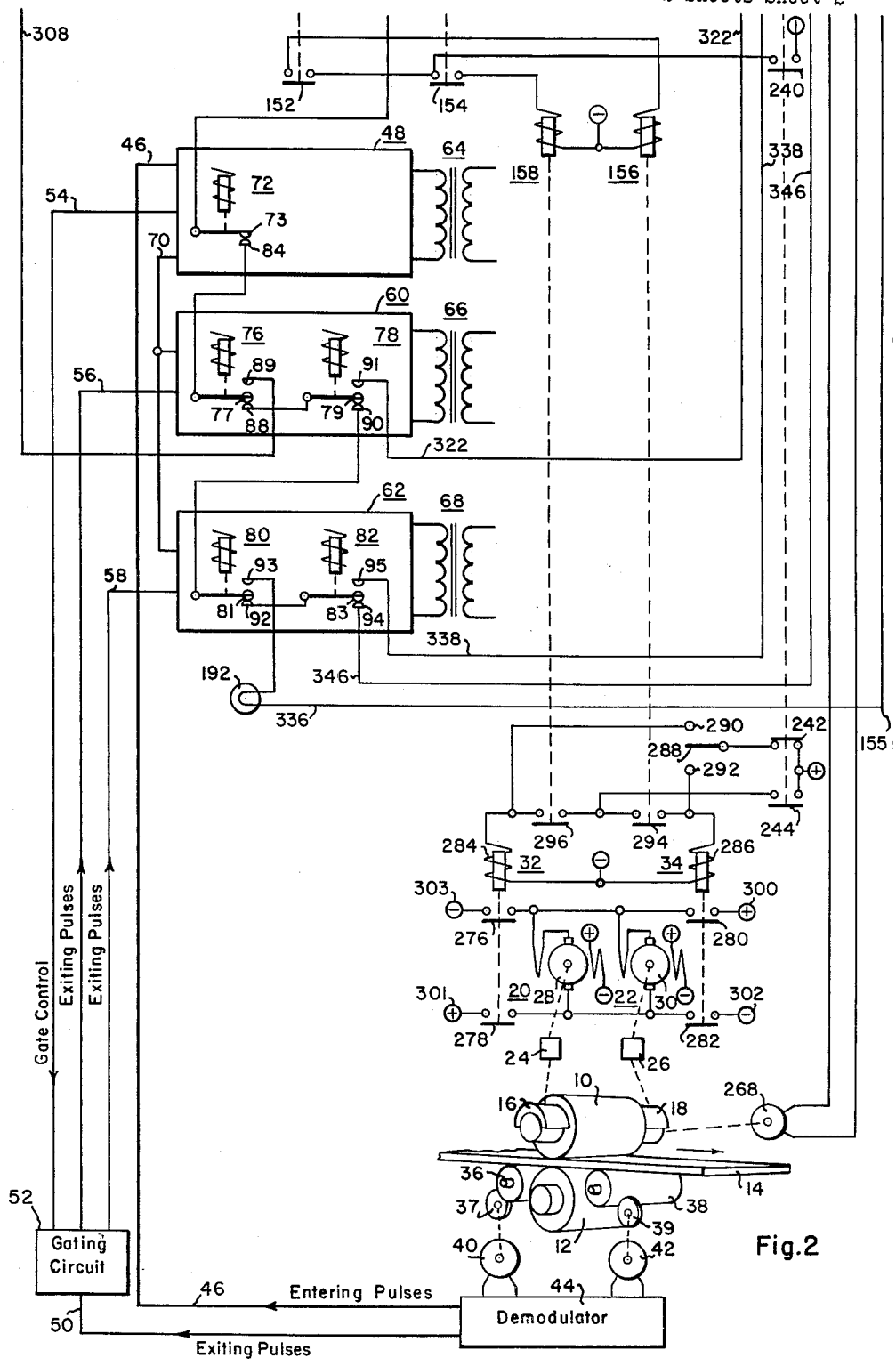


Fig.2

United States Patent Office 2,982,158 Patented May 2, 1961

2,982,158

ELONGATION CONTROL SYSTEMS

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4 Claims. (Cl. 80—56)

This invention relates to control systems and in particular to control systems for controlling the elongation of strip material as it is reduced in a rolling mill.

Many systems have been devised heretofore in an attempt to control the operation of rolling mills to automatically maintain predetermined elongation of strip material treated therein. All of the previously known control systems for controlling elongation have had the disadvantages of being not accurate enough or they were not of sufficiently wide range or had insufficient electrical output to control the rolling within sufficiently close tolerances.

An object of this invention is to provide a control system for a rolling mill for controlling the elongation of strip material as the strip is rolled in the mill.

Another object of this invention is to provide a control system for a rolling mill for automatically controlling the elongation of strip material as the strip is rolled in the mill.

A further object of this invention is to provide an automatic control system for a rolling mill for controlling the elongation of strip material in the mill, the control system having means for insuring an adjustment of the screw pressure on the mill in response to a predetermined signal before another signal is effective for initiating further adjustment of the screw pressure.

Another object of this invention is to provide in a control system for a rolling mill, means for comparing the length relationship of the entering strip and the exiting strip and means for measuring such length relationship to provide a measure of the elongation of the exiting strip, which measure is a visible measure having a definite display time.

A more specific object of this invention is to provide a control system for controlling the elongation of a strip as it is rolled in a rolling mill, the control system being automatically responsive to predetermined measurements of the elongation of the strip to adjust the screw pressure applied to the rolls to maintain the elongation within predetermined limits and to give a visual indication of the elongation maintained and being manually responsive under predetermined operating conditions of the mill, the control system having interlocking means for preventing the automatic response when the system is set for manual response and for preventing manual response when the system is set for automatic response.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawings in which:

Figures 1 and 2 form a composite drawing when disposed with the upper edge of Fig. 2 butting the lower edge of Fig. 1, the composite drawing illustrating diagramatically the circuits and apparatus embodying the teachings of this invention.

Referring to the compositie drawings, this invention is illustrated as applied to a steel mill having work rolls **10** and **12** for reducing the thickness of a strip **14** of metal as the strip passes between the rolls. In the embodiment

illustrated pressure pads **16** and **18** are applied to the necks of the upper roll **10** for applying pressure thereto, such pressure being controlled by motors **20** and **22**, respectively, which are mechanically connected as through gear boxes **24** and **26**, respectively, for controlling the operation of the holddown screws (not shown) for applying pressure to the pads **16** and **18**, respectively. The motors **20** and **22** are disposed with their armatures **28** and **30**, respectively, connected in parallel circuit relation and disposed to be selectively connected as by means of the selective operation of control relays **32** and **34** to a suitable source of direct current power represented by the positive and negative terminals shown at **301—303** and **300—302**, respectively, for controlling the direction of operation of the parallel connected motors.

In order to obtain a measure of the elongation of a given length of the strip **14** as it passes through the mill between the rolls **10** and **12**, a pair of idler rolls **36** and **38** are positioned on opposite sides of the lower roll **12** and in engagement with the strip **14** so as to be disposed to be rotated by the input and output movements of the strip **14** as the strip enters and leaves the rolls **10** and **12**. The rotation imparted to the rolls **36** and **38** is thus a measure of the surface speed and consequently the length of the strip **14** as the strip passes over the idler rolls, and since the strip is elongated as it passes through the mill, the speed of roll **38** relative to the speed of the roll **36** will reflect such elongation for a given length of strip material passing over the roll **36**. Pick-up rolls **37** and **39** are disposed to be driven by the idler rolls **36** and **38**, respectively, and are connected to drive pulse generators **40** and **42**, respectively, which are connected to a suitable demodulator unit **44** for supplying suitable electronic pulses having a frequency that can be counted. In practice, where idler rolls **36** and **38** are not available, the pick-up rolls **37** and **39** can be disposed to be driven directly by the strip.

The pulse generators **40** and **42** may be of any suitable type such as, for example, the pulse generators made and sold by the Telecomputing Corporation and identified as Type #20A and covered by Patent 2,765,459. The demodulator unit **44** utilized in conjunction with the pulse generators **40** and **42** actually incorporates two demodulator circuits, one for each of the pulse generators **40** and **42**. As in usual practice, the pulse generators **40** and **42** reflect a measure of the strip length in terms of revolutions of the respective pulse generators, the angular motion of the pulse generators being converted into representative electrical signals. Each of the pulse generators **40** and **42** receives an R-F signal from its demodulating circuit in the demodulator unit **44** and modulates such signal so that when the signal is returned to the demodulator unit and demodulation is accomplished, the demodulator unit output circuits constitute a measure of the frequency of the pulses as determined by pulse generator **40** on the entering side of the strip **14**, and a measure of the frequency of the pulses as determined by pulse generator **42** on the exiting side of the strip **14**, each of the generators **40** and **42** supplying a predetermined number of electrical pulses per revolution of the respective pulse generators, 500 electrical pulses per generator revolution being a convenient measure to utilize for such purposes.

In order to utilize the output of the demodulator unit **44** to provide a control function which can be translated to a useful quantity for controlling or initiating the operation of a control system to be described hereinafter, the output terminal of the demodulator **44** which is connected to reflect the output of the pulse generator **40** is connected as by means of conductor **46** to supply the pulses generated by the entering strip to a base counter **48**, whereas the output terminal of the demodulator unit

44 which is connected to reflect the output of the pulse generator 42 is connected as by means of conductor 50 to supply the pulses generated by the exiting strip to a suitable gating circuit 52, the operation of which is triggered by the controlled operation of the base counter 48 connected thereto through conductor 54, the output of the gating circuit 52 supplying the exiting pulses being connected as by means of conductors 56 and 58 to output counters 60 and 62, respectively. Each of the counters 48, 60 and 62 is connected to a suitable source of power represented by the transformers 64, 66 and 68, respectively, and the reset circuits (not shown) of the counters are connected as by conductor 70.

In practice any suitable counter responsive to the input pulses may be utilized, the Berkeley Dual Preset Counter, Model 5445 as manufactured and sold by the Berkeley Division of Beckman Instruments, Inc. of Richmond, California being entirely satisfactory in use as the base counter 48 and the output counters 60 and 62, respectively. For simplification of this description, only the coincidence relays of the counters utilized in this system are illustrated, the details of the electronic circuits involved in the base counter 48 and output counters 60 and 62 being omitted as such counters and electronic circuits and the operation thereof are well known as shown and described in instruction manuals published by the Berkeley Division of Beckman, Inc., and available to the public. As is well known, each of the counters 48, 60 and 62 of the Berkeley Dual Preset Counter is provided with five rows of numbers ranging from zero to nine for giving a visual indication of a number in five figures as the electrical pulses supplied thereto are counted and is provided with suitable control circuits for selectively de-energizing the coincidence relays in the counters as the counters reach coincidence with the predetermined counts which may be preset in the counters. The coincidence relays of the different counters 48, 60 and 62 are utilized in this invention for controlling the operation of a control system utilized for controlling the operation of the motors 20 and 22 of the mill to obtain an automatic control of the elongation of the strip 14; thus the coincidence relays 72, 76—78 and 80—82 of the counters 48, 60 and 62, respectively, are illustrated. Each of the relays 72, 76, 78, 80 and 82 is provided with a movable contact member 73, 77, 79, 81 and 83, respectively, disposed to engage a fixed contact member 84, 88, 90, 92 and 94, respectively, when the associated relay is de-energized. In addition, the relays 76—78—80 and 82 are provided with an opposed fixed contact member 89, 91, 93 and 95, respectively, disposed to be engaged by the movable contact member 77, 79, 81 and 83, respectively, when the relay associated therewith is energized.

The relays 72, 76, 78, 80 and 82 of the counters are normally disposed to be energized during a predetermined counting operation of the counters and are selectively de-energized as predetermined pulse counts are registered in the respective counters, such predetermined pulse count limits for the operation of the coincidence relays being manually set by the operator as in normal practice. Thus relay 72 is de-energized when a count such as, for example, 10,000 electrical pulses or any other multiple of ten depending upon the degree of precision and measuring time desired is registered by the base counter 48, such count being a measure of a predetermined length of the strip 14 as fed to the mill. When multiples of ten are used for establishing the base count, direct reading of percent elongation is available for display. Any other counting base other than multiples of ten may, however, be used for control purposes where visual indications are not necesesarily required. In utilizing the counters in the system of this invention, the base counter 48 is connected to the gating circuit 52 as by conductor 54 so that upon the occurrence of such a selected base count of 10,000 electrical pulses, a signal is applied to the gating circuit 52 and the gating circuit 52 is closed to prevent the gating circuit from feeding the output pulses initiated by the pulse generator 42 through conductors 56 and 58 to the counters 60 and 62, respectively, and thereby prevent the further counting operation of such output counters. Although the relay 72 of base counter 48 is de-energized upon an occurrence of the predetermined base count of 10,000 electrical pulses, the base counter 48 will continue to operate to count additional pulses supplied thereto to an arbitrarily established higher count such as, for example, 20,000 pulses, at which time the reset circuits of the counters connected as by conductor 70, reset all of the counters 48, 60 and 62 to zero and the counter 48 functions to remove the signal from the gating circuit 52 to open the gate so that the gate again supplies the exiting pulses to counters 60 and 62 and the counters 48, 60 and 62 again function to record the count of the pulses supplied thereto, the period of time between the registry of the base count of 10,000 and the higher selected count of 20,000 pulses or whatever the upper selected count might be in counter 48 being the actual display time of the count registered by the counters 60 and 62.

As the base counter 48 is accumulating the selected base count of 10,000 pulses, the counters 60 and 62 are accumulating the pulse counts of the pulse generator 42 in the same period of time to, in effect, measure the length of the strip 14 exiting from the rolls in the same period of time it takes the predetermined length of the strip entering the rolls to register the 10,000 pulse count on the base counter 48 to thereby, in effect, measure the elongation of such strip after reduction in the mill. For this purpose the counters 60 and 62 have preset limits manually adjusted so that when a predetermined count constituting the lower limit of acceptable elongation is obtained, such as, for example, 10.00% elongation or a count of 11,000 pulses, relay 76 of counter 60 is de-energized and when a preferred low limit of elongation, such as, for example, 11.00% elongation or a count of 11,100 pulses is obtained, relay 78 of counter 60 is de-energized whereas with a preferred upper limit of elongation of 12.00% or a count of 11,200 pulses, relay 80 of counter 62 is de-energized, and with an extreme upper limit of 13.00% elongation or a count of 11,300 pulses, relay 82 of counter 62 is de-energized. The figures given hereinbefore with respect to the percent elongation and the respective counts are merely representative of preset limits to be used for automatically controlling the elongation between the extreme limits of 10.00 to 13.00% with a preferred elongation limit of 11.00 to 12.00%, it being understood that variations in such limits can be readily established in the counters by presetting the count at which the different coincidence relays are de-energized. The operation of the coincidence relays of the output counters 60 and 62 is utilized in the system of this invention to determine if the control system for the motors 20 and 22 should be manual or automatic, and if automatic, to control such automatic operation.

In order to utilize the output of the counters 60 and 62 for effecting an automatic control of the motors 20 and 22 and to insure that an adequate time is permitted in which to effect a predetermined operation of such motors, suitable timer switching means 96 and 98 are utilized being disposed to be connected by the operation of predetermined coincidence relays of the counters 60 and 62 for giving definite times for the selective directional operation of such motors 20 and 22 before the counters 60 and 62 are again effective for initiating an automatic adjustment in the controls. The timer switching means 96 and 98 may be of any suitable type such as, for example, the Microflex Timer Model HA-10-A6 as sold by the Eagle Signal Corporation of Moline, Illinois and as disclosed in Patents 2,175,864 and 2,175,865. Each of the timers 96 and 98 is provided with a clutch sole-

noid 100 and 102, respectively, and a synchronous motor 104 and 106, respectively, connected in parallel therewith for simultaneous operation, and a plurality of movable contact members 108—110—112 and 114—116—118, respectively, disposed to be actuated into engagement with fixed contact members 120—122—124 and 126—128—130, respectively. In the embodiment of the timers illustrated, the motors 104 and 106 are disposed to actuate a cam 132 and 134, respectively, for actuating the movable contact members of the respective timer switching means to a circuit interrupting position after a predetermined period of time. The timers 96 and 98 are also provided with resistors 136 and 138, respectively, and a capacitor 140 and 142, respectively, such resistors and capacitors being connected in series circuit relation in conjunction with the circuits to the motor solenoid and movable contact members for the purpose of arc suppression and attenuation of electrical noise. The timer switching means 96 and 98 are utilized, as will be described hereinafter, for controlling the selective energization of the energizing windings 144 and 146, respectively, of relays or controllers 148 and 150, respectively, which are provided with movable contact members 151—152 and 157—154, respectively, the contact members 152 and 154 being disposed when in circuit establishing position to control the energization of relays 156 and 158, respectively, for controlling the energization of the control relays 32 and 34. A power source for the timer switching means 96 and 98 and for the different control relays to be described hereinafter, is represented by alternating current conductors 153 and 155. Associated with the timer switching means 96 and 98 and disposed to be controlled by certain of the operations of the coincidence relays of counters 60 and 62, as will be explained hereinafter, are two indicating lamps 160 and 162 disposed to be connected to indicate visually predetermined operating conditions of the mill.

Under other predetermined operating conditions of the system as indicated by the counters 60 and 62, relays 164 and 166 are disposed to have their energizing windings 168 and 170, respectively, energized to actuate contact members 172 and 174, respectively, to circuit interrupting positions and contact members 176—178 and 180—182, respectively, to circuit closing positions and latches 184 and 186, respectively, into a latched position to hold the contact members in such described positions. Associated with the relays or controllers 164 and 166 are lamps 188 and 190, respectively, disposed to give visual indication of certain predetermined operating conditions of the system as indicated by the counters 60 and 62 as will be described hereinafter. Likewise, a lamp 192 is associated with counter 62 to give a visual indication as to another operating condition of the system as will be described hereinafter.

In order to give a visual indication as to whether the system is on manual or automatic operation, lamps 194 and 196, respectively, are disposed to be selectively connected to the power supply represented by conductors 153 and 155 by the contact members 198 and 200, respectively, of a relay 202 having an energizing winding 204 disposed to be energized by operation of a manual control switch 206. The relay 202 is provided with a latch 208 disposed to maintain the relay in its energized position until a switch 210 is actuated to a circuit establishing position to place the system in condition for automatic operation and to energize a relay 212 having an energizing winding 214. When the switch 210 is actuated to place the system in condition for automatic operation, relay controllers 216, 218 and 220 having energizing windings 222, 224 and 226, respectively, are actuated to their energized positions. The relay controller 216 is provided with contact members 228 and 230, whereas the relay 218 is provided with contact members 232, 234, 236 and 238 and the relay controller 220 is provided with contact members 240, 242 and 244, the purpose of such relays and contact members being explained more fully hereinafter.

In order to provide for resetting the system after a manual operation, as will be described hereinafter, latching relays 246 and 248 having energizing windings 250 and 252, respectively, are disposed to be energized by the manual actuation of a reset switch 254 so as to release the latches 184 and 186 of the relays 164 and 166, respectively. Such a resetting operation cannot, however, be accomplished to return the system to automatic operation until relay 164 or 166 and relay 202 are de-energized, as will be described hereinafter. In order to sound an audible alarm under predetermined operating conditions of the mill, a horn 256 is disposed to be connected as by means of a manually operated switch 258 and contact member 260 of a relay 262 under predetermined operating conditions to be energized from the alternating current supply conductors 153 and 155. The relay 262 is also provided with a contact member 264 and an energizing winding 266, the latter being connected to be energized by operation of a tachometer 268 disposed to be driven by the roll 10 so that for all speeds above a predetermined lower speed the relay 262 will be energized and its contact member 264 will be in a circuit interrupting position and its contact member 260 will be in a circuit establishing position. If the speed of the roll 10 is below the predetermined lower speed, relay 262 remains de-energized and its contact member 264 maintains an energizing circuit for relay 202 to maintain the system in condition for manual control.

In order to control the flow of alternating current through the contact members of the coincidence relays of the counters 48, 60 and 62, a relay 270 having an energizing winding 272 and a contact member 274 is disposed to be energized when the relays 148 and 150 are selectively energized by the operation of the timers 96 and 98, respectively.

Again referring to the control circuits for the motors 20 and 22, the parallel connected armatures of the motors are disposed to be connected across a direct current source of supply by the selective operation of contact members 276—278 and 280—282 of the motor controllers 32 and 34, respectively. Each of the motor relay controllers 32 and 34 is provided with an energizing winding 284 and 286, respectively, disposed to be selectively energized either manually or automatically depending upon the energization of relay 220 and the relays 158 and 156. Thus if relay 220 is de-energized and its contact member 242 is in a circuit establishing position, the energizing windings 284 and 286 of relays 32 and 34, respectively, may be selectively energized as by the manual operation of a movable switch member 288 into engagement with fixed contact members 290 and 292, respectively. On the other hand, if the system is under automatic control and the relay 220 is energized whereby contact member 242 thereof is in a circuit interrupting position and contact members 240 and 244 thereof are in circuit establishing position, the selective operation of relays 156 and 158 to actuate their contact members 294 and 296, respectively, to a circuit establishing position will determine the direction of operation of the motors 20 and 22.

For purposes of illustrating the operation of the system of this invention it will be assumed that the coincidence relays of counters 48, 60 and 62 have been set to be de-energized as described hereinbefore based on the counts indicated which represent an elongation of the strip 14 in the extreme limits of 10.00 to 13.00%, and a preferred range of 11.00 to 12.00%, and that the operation of the output counters 60 and 62 will be stopped when a count of 10,000 pulses is reached by the base counter 48 and that the output counters 60 and 62, as well as the base counter 48, will be reset to zero and the gate 52 will be opened when the base

counter 48 has counted 20,000 pulses. Under such operating conditions the tachometer 268 is driven to energize the winding 266 of relay 262 to actuate its contact member 260 to a circuit establishing position and its contact member 264 to an open circuit position. It will also be assumed that the manual switch 258 has been operated to a circuit establishing position. The switch 206 is then actuated to a circuit establishing position to establish a circuit from conductor 153 through switch 206, contact member 260 of relay 262, manual switch 258, horn 256 and conductor 296 to conductor 155. The horn will then blow to give an audible signal that the control system is on manual control. At the same time a circuit is established from power conductor 153 through switch 206, energizing winding 204 of relay 202 and conductor 296 to the power conductor 155 whereby relay 202 is energized to actuate its contact members 200 and 201 to a circuit interrupting position and its contact member 198 to a circuit establishing position to establish a circuit which extends from power conductor 153 through contact member 198 of relay 202, the lamp 194 and conductor 298 to the power conductor 155 to give a visual indication by means of the lamp 194, that the system is under manual control. At the same time the relay 202 is latched in its energizing position by means of the latching relay 212 engaging the latch 208 to thereby prevent energization of the relays 148 and 150 associated with the timers 96 and 98, respectively. Under such conditions with relay 220 in its de-energized position, manual control of the directional operation of the motors 20 and 22 may be had by operating the switch member 288 into selective engagement with contact members 290 and 292, depending upon whether it is desired to release pressure on the pads 16 and 18 or to apply pressure thereto.

If it is desired to apply additional pressure to thereby increase the elongation of the strip, the switch 288 is moved into engagement with contact member 292 to establish a circuit which extends from the positive terminal of a direct current power source represented by the positive symbol through contact member 242 of relay 220, switch 288, contact member 292, energizing winding 286 of relay 34 to the negative terminal of the direct current source of power. Under such conditions relay 34 is energized and its contact members 280 and 282 are actuated to circuit closing positions to connect the parallel connected armatures 28 and 30 of motors 20 and 22, respectively, across the source of power represented by the positive and negative symbols 300 and 302, respectively. Under such conditions the motors operate through the gear boxes 24 and 26, respectively, to apply additional pressure to the pads 16 and 18 to thereby effect a greater elongation of the strip 14.

On the other hand, if it is desired to decrease the pressure on the pads 16 and 18 and thereby decrease the elongation of the strip, switch 288 is actuated into engagement with the contact member 290 to establish a circuit extending from the positive terminal of the source of power through contact member 242 of relay 220, switch 288, contact member 290, the energizing winding 284 of relay 32 to the negative terminal of the source of power. Under such conditions relay 32 is energized to actuate its contact members 276 and 278 to circuit establishing positions to connect the parallel connected armatures 28 and 30 of motors 20 and 22, respectively, to the positive terminal 301 and negative terminal 303 of the direct current source of power to reverse the direction of operation of the motors 20 and 22 to release the pressure applied to the pads 16 and 18 whereby the elongation of the strip 14 is reduced.

Under such conditions of manual operation, the counters 48, 60 and 62 being connected as previously described to the pulse generators 40 and 42 function to give a visual indication of the pulses counted so that the operator by watching the count recorded on the output counters 60 and 62 or signal lamps 188, 160, 192, 162 and 190 can determine when the pressure on the rolls has been adjusted to effect an elongation within the desired control band. As soon as the elongation has been adjusted to within the extreme limits desired, the system is placed in condition for automatic operaton by actuating reset switch 254 and the switch 210. Reset switch 254 establishes a circuit extending from power conductor 153 through switch 254, conductor 318, parallel connected energizing windings 250 and 252 of latching relays 246 and 248, respectively, and conductors 320 and 296 to power conductor 155 to return relay 164 or 166 and relay 202 to their de-energized position.s At the same time switch 210 establishes a circuit which extends from the power conductor 153 through contact member 210, the energizing winding 214 of latching relay 212 and conductor 296 to the other power conductor 155.

Under such conditions the relay 212 is actuated to release the latch 208 of relay 202 to actuate contact member 198 to a circuit interrupting position, thereby extinguishing the lamp 194, and to actuate contact members 200 and 201 to circuit establishing positions. When the contact member 200 is in its circuit establishing position, a circuit is established which extends from power conductor 153 through contact member 200, lamp 196 and conductor 298 to the other power conductor 155 to give a visual indication that the system is on automatic control. At the same time, the contact member 200 also establishes a circuit from power conductor 153 through contact member 200, the energizing windings 222, 224 and 226 of the parallel connected relays 216, 218 and 220, respectively, and conductor 298 to the other power conductor 155 to effectively energize the relays 216, 218 and 220 and actuate them to their energized positions. When thus energized the contact members 228 and 230 of relay 216 are actuated to circuit establishing positions, contact members 232 and 234 of relay 218 are actuated to circuit interrupting positions while contact members 236 and 238 thereof are actuated to circuit establishing positions, and the contact members 240 and 244 of relay 220 are actuated to circuit establishing positions while contact member 242 thereof is actuated to a circuit interrupting position. The actuation of the relay 218 functions to connect the timers 96 and 98 in circuit relation with predetermined coincidence relays of the counters 60 and 62, whereas relay 216 functions to connect relays 164 and 166 in circuit relation with other predetermined coincidence relays of the counters 60 and 62, and relay 220 places the motor control circuit in condition for automatic response.

Under such conditions of operation with the pressure on the roll 10 being sufficient to maintain elongation of the strip 14 within the predetermined band of operation, the base counter 48 is effective for counting the predetermined base count up to 10,000 pulses before relay 72 thereof is de-energized to actuate its movable contact member 73 into engagement with the fixed contact member 84. At the same time that the base counter 48 is counting the 10,000 pulses, counters 60 and 62 are counting the pulses generated by pulse generator 42 which count is, in effect, a measure of the elongation of the strip 14. If during the time that the base counter 48 counts the first 10,000 pulses less than 11,000 pulses are counted by the output counter 60, the coincidence relay 76 of counter 60 is maintained energized and when the relay 72 of counter 48 is de-energized at the time of the predetermined count of 10,000 pulses, a circuit is established which extends from power conductor 153 through conductor 306, contact member 274 of relay 270, the movable contact member 73 and fixed contact member 84 of coincidence relay 72 of the counter 48, movable contact member 77 and fixed contact member 89 of the coincidence relay 76 of counter 60, conductor 308, contact member 172 of relay 164, lamp 188 and conductor 348 to the other power conductor 155 to give a visual

indication by reason of the lamp **188** that the elongation of the strip **14** is lower than the predetermined lower limit desired.

At the same time that lamp **188** is lighted, the energizing winding **168** of relay **164** is energized by a circuit extending from conductor **308** of the circuit just described through the energizing winding **168** of relay **164**, contact member **228** of relay **216** and conductor **310** to the other power conductor **155**. When relay **164** is thus energized, contact member **172** thereof is actuated to a circuit interrupting position and contact members **176** and **178** thereof are actuated to circuit establishing positions and the relay is held in such energized position by reason of the latch **184** thereof latching over the latching relay **246**. Contact member **176** of relay **164** thus provides a circuit to effect the energization of lamp **188**, which circuit extends from the power conductor **153** through conductor **312**, contact member **176**, lamp **188** and conductor **348** to the other power conductor **155** to give a visual indication that the elongation is lower than the lowest limit desired. Since the output circuits from the counters **60** and **62** to the timers **96** and **98** are not energized under such operating conditions, an automatic operation of the system will not occur to change the force applied to the roll **10**. At the same time contact member **178** of relay **164** establishes a circuit which extends from power conductor **153** through conductor **314**, contact member **178**, conductor **316**, contact member **260**, switch **258**, the horn **256** and conductor **296** to the other power conductor **155** to give an audible signal that the elongation is below the desired lower limit. Simultaneously therewith a circuit is energized to remove the automatic control for the motors **20** and **22** and to return the system to a manual control status. This circuit is established by contact member **178** of relay **164** and extends from the power conductor **153** through conductor **314**, contact member **178** of relay **164**, conductor **316**, energizing winding **204** of relay **202** and conductor **296** to the other power conductor **155**. Under such conditions the relay **202** is automatically energized and its contact members **200** and **201** are actuated to circuit interrupting positions and contact member **198** is actuated to a circuit establishing position to again establish the circuit through the lamp **194** to give a visual indication that the system is in manual control. When the relay **202** is thus energized, is latch **208** is engaged by the latching relay **212** to maintain the contact members of relay **202** in the described circuit positions. It is to be noted that under such conditions, the system cannot be placed in automatic control by manually operating the switch **210** as long as the relay **202** is thus energized and that relay **202** will be so energized as long as relay **164** is energized or latched in the energized position with contact member **178** in a circuit establishing position. Under such conditions the operator can proceed to effect a manual control of the operation of the motors **20** and **22** in a direction to apply more pressure to the pads **16** and **18** as described hereinbefore and thereby increase the elongation of the strip **14** to a point where the visual showing of the count of counters **60** and **62** indicates that the elongation is within the established limits of elongation.

It is to be noted that if the elongation is within the established limits of elongation, that is, the visible count of counter **60** is greater than 11,000 but less than 11,100, indicating an elongation of between 10.00% and 11.00%, coincidence relay **76** of counter **60** is de-energized while coincidence relay **78** of counter **60** is maintained energized. When the relay **76** is thus de-energized, the circuit to the energizing winding **168** of relay **164** is interrupted so that when the operator actuates switches **254** and **210** to return the system to automatic control, the latching relay **246** disengages the latch **184** of relay **164** with the result that contact members **178** and **176** of relay **164** are actuated to circuit interrupting positions and contact member **172** thereof is again actuated to the circuit establishing position previously described, and the latching relay **212** is energized to release the latch **208** and thereby actuate contact member **198** of relay **202** to a circuit interrupting position and contact members **200** and **201** thereof to the circuit establishing position previously described. With the coincidence relay **76** de-energized and the coincidence relay **78** energized as described hereinbefore when the count recorded by counter **60** is at least 11,000 but less than 11,100, a circuit is established extending from power conductor **153** through conductor **306**, contact member **274** of relay **270**, the movable contact member **73** and fixed contact member **84** of coincidence relay **72** of counter **48**, the movable contact member **77** and fixed contact member **88** of coincidence relay **76** of counter **60**, the movable contact member **79** and fixed contact member **91** of coincidence relay **78** of counter **60**, conductor **322**, contact member **238** of relay **218**, conductor **324**, parallel connected solenoid **100** and synchronous motor **104** of timer **96** and conductor **326** to the other power conductor **155**. When the solenoid **100** is thus energized, the movable contact members **108**, **110** and **112** of timer **96** are actuated into engagement with the fixed contact members **120**, **122** and **124** of the timer **96**, and the motor **104** is operated to drive the cam **132** in a direction to actuate the movable contact members of the timer switching means **96** to an open circuit position. During the period of time required before the cam actuates the contact members, the counters **60** and **62** are ineffective even though reset to begin another count, to initiate another operation of the timer **96** until after a definite operation of the motors **20** and **22** to apply more pressure to the roll **10**. Thus with the movable contact members of the timer switching means **96** in the circuit establishing positions, contact member **110** establishes a circuit which extends from the power conductor **153** through conductor **306**, conductor **330**, contact members **110** and **122** of timer **96**, energizing winding **144** of relay **148**, conductor **332**, contact member **201** of relay **202** and conductor **310** to the other power conductor **155** to effect the energization of relay **148**. At the same time movable contact member **112** of the timer **96** engages the fixed contact member **124** thereof to establish a circuit extending from power conductor **153** through conductor **306**, conductor **330**, movable contact member **112** and fixed contact member **124** of timer **96**, conductor **334** and lamp **160** to the other power conductor **155** to give a visual indication as by means of the lamp **160** that the automatic system is operating in the medium low range of the predetermined limits of elongation.

When the relay **148** is thus energized its contact members **151** and **152** are actuated to circuit closing positions. Contact member **151** thus establishes a circuit extending from power conductor **153** through conductor **306**, contact member **151**, energizing winding **272** of relay **270** and conductor **326** to the other power conductor **155** to effect an operation of the relay **270** to actuate its contact member **274** to an open circuit position to interrupt the power supply to the coincidence contact members of the counters **48**, **60** and **62**. Simultaneously therewith, contact member **152** establishes a circuit which extends from the positive terminal of a direct current source of power indicated by the positive symbol through contact member **240** of relay **220**, contact member **152** of relay **148**, the energizing winding of relay **156** to the negative terminal of the direct current supply to effect the energization of relay **156** and actuate its contact member **294** to a circuit establishing position. Contact member **294** thus establishes an energizing circuit for relay **34** which extends from the positive terminal of a direct current source of supply through contact member **244** of relay **220**, contact member **294** of relay **156**, the energizing winding **286** of relay **34** to the negative terminal of a direct current source of power. When relay **34** is thus energized, its contact members **280** and **282** are actuated to their cir-

cuit establishing positions to establish the power circuit from terminals 300 and 302 for effectively driving the motors 20 and 22 in a direction to apply pressure to the pressure pads 16 and 18 of the roll 10 to effectively increase the elongation of the strip 14. It is to be noted that as long as the timer 96 is operating to maintain the energization of relay 148, relay 270 is energized to interrupt the power supply to the contact members of the coincidence relays of the counters 48, 60 and 62 so that, although counters 60 and 62 are still effective for giving a visual indication of the pulse count, that is, of the elongation of the strip 14, such count by the counters is ineffective for affecting an automatic change in the operation of the system until after the timer switching means 96 has completed its timed cycle of operation.

Assuming that the automatic operation just described has been effective for increasing the pressure applied to the roll 10 to produce an elongation in the strip 14 of between 11 and 12% whereby coincidence relay 78 of counter 60 is de-energized by reason of the preset count of 11,100 pulses but the coincidence relay 80 of counter 62 is still maintained energized since the count of 11,200 pulses has not as yet been reached, then the counters 60 and 62 are effective for establishing a circuit to indicate that the elongation is within the preferred range of elongation. This circuit extends from the power conductor 153 through conductor 306, contact member 274 of relay 270, the movable contact member 73 and fixed contact member 84 of coincidence relay 72 of counter 48, the movable contact member 77 and fixed contact member 88 of coincidence relay 76 of counter 60, the movable contact member 79 and fixed contact member 90 of coincidence relay 78 of counter 60, the movable contact member 81 and fixed contact member 93 of coincidence relay 80 of counter 62, the lamp 192 and conductor 336 to the other power conductor 155 to give a visual indication by reason of the lamp 192 that the elongation of the strip 14 is being maintained within the predetermined preferred limits of 11 to 12% and no adjustment of the system is required.

If for some reason the elongation of the strip 14 should vary from the preferred range of from 11 to 12% and should increase to between 12 and 13%, that is, a count of between 11,200 and 11,300 as registered on the output counters 60 and 62, coincidence relay 80 becomes de-energized upon reaching the count of 11,200. When thus de-energized coincidence relay 80 establishes another circuit which extends from the power conductor 153 through conductor 306, contact member 274 of relay 270, the movable contact member 73 and fixed contact member 84 of the coincidence relay 72, the movable contact member 77 and fixed contact member 88 of coincidence relay 76, the movable contact member 79 and fixed contact member 90 of coincidence relay 78, the movable contact member 81 and fixed contact member 92 of coincidence relay 80, the movable contact member 83 and fixed contact member 95 of coincidence relay 82, conductor 338, contact member 236 of the relay 218, conductor 340 and the parallel connected solenoid 102 and synchronous motor 106 of timer 98 and conductors 342 and 326 to the other power conductor 155 to effect an operation of the timer 98. Under such conditions contact members 114, 116 and 118 of the timer 98 are actuated into contact engagement with contact members 126, 128 and 130. Contact member 118 thus establishes a circuit extending from power conductor 153 through conductor 306, contact members 118 and 130 of the timer 98, conductor 344, lamp 162 and conductor 310 to the other power conductor 155 to give a visual indication as by reason of the lighting of the lamp 162 that the elongation of the strip 14 is within the permissible limits or band but higher than the preferred limits of elongation. At the same time contact member 116 of the timer 98 establishes a circuit which extends from the power conductor 153 through conductor 306, contact members 116 and 128 of the timer 98, energizing winding 146 of relay 150, contact member 201 of relay 202 and conductor 310 to the other power conductor 155 to actuate the relay 150 to its energized position. Under such conditions of operation contact member 157 of relay 150 establishes the energizing circuit for relay 270 which extends from the power conductor 153 through conductor 306, contact member 157 of relay 150, the energizing winding 272 of relay 270 and conductor 326 to the other power conductor 155 to actuate the relay 270 to its open circuit position where contact member 274 thereof interrupts the power supply to the contact members of the coincidence relays of the counters 48, 60 and 62. At the same time contact member 154 of relay 150 establishes the energizing circuit for relay 158, which circuit extends from the positive terminal of a direct current source of power through contact member 240 of relay 220, contact member 154 of relay 150, the energizing winding of relay 158 to the negative terminal of the direct current source of power. When the relay 158 is thus energized its contact member 296 is actuated to a circuit establishing position to establish a circuit which extends from the positive terminal of the direct current source of power through contact member 244 of relay 220, contact member 296 of relay 158, the energizing winding 284 of relay 32 to the negative terminal of the direct current source of power. The contact members 276 and 278 of relay 32 are thus actuated to a circuit establishing position to connect the parallel connected armatures of motors 20 and 22 to the source of power represented by the terminals 301 and 303 to effect an operation of the motors to release pressure from the pressure pads 16 and 18 of roll 10 to thereby effect a decrease in the elongation of the strip 14.

If, on the other hand, the elongation as measured by the counters 60 and 62 has reached the upper limit of the predetermined band of operation, that is, a count of not less than 11,300 representing an elongation in excess of 13.00%, then the coincidence relay 82 is de-energized and its movable contact member 83 is in engagement with its fixed contact member 94 to establish a circuit which extends from the power conductor 153 through conductor 306, contact member 274 of relay 270, the movable contact member 73 and fixed contact member 84 of coincidence relay 72, the movable contact member 77 and fixed contact member 88 of coincidence relay 76, the movable contact member 79 and fixed contact member 90 of coincidence relay 78, the movable contact member 81 and fixed contact member 92 of coincidence relay 80, the movable contact member 83 and fixed contact member 94 of coincidence relay 82, conductor 346, contact member 174 of relay 160, lamp 190 and conductor 348 to the other power conductor 155 to give a visual indication as by means of the lamp 190 that the elongation is above the predetermined upper limit of elongation desired.

Simultaneous with the initial lighting of the lamp 190, the relay 166 is energized by a circuit extending from the conductor 346 through energizing winding 170 of relay 166, contact member 230 of relay 216 and conductor 310 to the other power conductor 155. Relay 166 is thus energized whereby its contact member 174 is actuated to a circuit interrupting position and contact member 180 is actuated to a circuit establishing position to maintain lamp 190 lighted, such lamp circuit extending from power conductor 153 through conductor 312, contact member 180, lamp 190 and conductor 348 to the other power conductor 155. As the relay 166 is thus actuated, its contact member 182 is also operated to a circuit establishing position to establish an alarm circuit for the horn 266, which alarm circuit extends from power conductor 153 through conductor 314, contact member 182 of relay 166, conductor 316, contact member 260 of relay 262, switch 258, the horn 256 and conductor 296 to the other power conductor 155. At the same time contact member 182 of relay 166 establishes

the energizing circuit for the winding **204** of relay **202** to actuate such relay to its energized position where contact members **200** and **201** are in circuit interrupting positions and contact member **198** is in the circuit establishing position and the latch **208** is engaged by the latching relay **212**. The lamp **194** is thereby lighted as described hereinbefore to give a visual indication that the system has been removed from automatic control and again returned to manual control. It is to be noted that the system cannot be taken off manual control as long as relay **166** is energized or held by means of its latch **186** in its energized position so that the relay **202** cannot be released by operation of the switch **210** until after the elongation has been adjusted to again bring the elongation within the previously established limits of elongation.

With the relay **166** energized as previously described, a manual operation of the motors **20** and **22** is initiated by the operator for controlling the directional operation of the motors **20** and **22** to effect the release of the pressure on the pads **16** and **18** to thereby reduce the elongation to a point where such elongation is within the permissible limits previously described. Under such conditions as the count of the counter **62** again indicates a count of less than 11,300 indicating that the elongation is less than 13.00%, coincidence relay **82** of counter **62** is again energized so that the circuit to the energizing winding **170** of relay **166** is interrupted whereby an operation of the reset switch **254** will effect the release of latch **186** with the result that the holding circuit for relay **202** established by contact member **182** is interrupted so that the relay **202** is again returned to its de-energized position when the switch **202** is operated to place the system in condition for automatic operation.

During the manual operation it will be appreciated that relays **166**, **168**, **216**, **218**, **220** and **270** will be de-energized. Thus, because of the de-energization of relay **218**, its contact members **236** and **238** are in a circuit interrupting position so that the timer switching means **96** and **98** are inoperative. At the same time, since relay **270** is in its de-energized position, contact member **274** thereof connects the movable contact member **73** of coincidence relay **72** of counter **48** to the power conductor **153**. Likewise, since relay **218** is de-energized, its contact members **232** and **234** are in a circuit establishing position relative to lamps **160** and **162**, respectively. Since relays **164** and **166** are also de-energized and can be released by an operation of reset switch **254** to assume their de-energized positions, contact members **172** and **174**, respectively, thereof are in circuit establishing positions relative to lamps **188** and **190**, respectively. Thus, as the counters **48**, **60** and **62** are operated, as previously described, in response to the output of pulse generators **40** and **42**, the coincidence relays **72**, **76**, **78**, **80** and **82** will be operated, as previously described, to establish predetermined circuits through the indicating lamps **160**, **162**, **188**, **190** and **192**, depending upon the measured elongation as recorded by the counters. In practice the lamps **160**, **162**, **188**, **190** and **192**, as well as lamps **194** and **196**, are preferably located on the control panel so that the operator will have a light signal to indicate whether or not the system is in manual or automatic operation, and also as to the degree of elongation relative to the predetermined limits which it is desired to maintain.

As will be appreciated, a constant visible count of the percent elongation to within 1/100% will be obtained from the visual count as recorded by counters **60** and **62** and a close automatic control of the elongation can be obtained depending upon the preset conditions of coincidence established in the counters **60** and **62** at which points of coincidence the coincidence relays of such counters will become deenergized. Although this system has been described with reference to two dual preset counters **60** and **62** it will be appreciated that one counter can be substituted for the two counters where such one counter is a quadruplicate preset counter having four of the coincidence relays disposed to be de-energized as the counter reaches coincidence at each of the four predetermined counts preset in such counter. Further, by the simple addition of additional preset counters and timer switching means, the number of bands of control can be increased.

The system is entirely automatic within the predetermined limits established and gives a very fast response with visible lamp signals for indicating the condition, that is, manual or automatic, of the system and for indicating the bands of operation thereof relative to the elongation desired to be maintained. In addition, an accurate count of the measured pulses constituting a measure of the elongation of the strip is recorded by the counters **60** and **62** and can be readily read directly as a direct reading the percent elongation within 1/100% merely by reading the last four figures of the five-figure recorded count.

The system also includes means as provided by the timer switching means for effecting a positive adjustment of the pressure applied to the roll of the mill when the automatic control demands such an adjustment with interlocking between the automatic control and the manual control so that the system will return to manual control as soon as the extreme permissible limits of elongation are exceeded. Further, as this system uses separate timer switching means for controlling the application of pressure in two directions, correction for backlash of the pressure screw adjustment of the mill is inherent in the system. It is to be noted, however, that the system cannot be returned to automatic control until after the manual control has been effective to adjust the elongation to a value within the permissible limits of elongation.

As will be appreciated, with the system based on the time principle, flexibility is provided for the amounts of adjustment in the screw pressure necessary for any number of materials capable of being elongated in the mill. Once adjusted to automatic operation the system provides preset uniform control of elongation since it eliminates the human element completely. It will also be appreciated that instead of controlling the screw pressure as described, the control of the motors can be utilized to control reel tension which in turn controls elongation of the strip. This adaptation can be accomplished by simply utilizing motors **20** and **22** to control the field resistance of the reel motors. Further, the system of this invention utilizes standard components and therefore can be readily reproduced by anyone skilled in the art.

I claim:

1. In a system for controlling the elongation of strip material in a rolling mill having a pair of variable pressure rolls through which the strip is passed, the combination of a first means for producing electrical pulses representative of the rate of entrance of the strip into said rolls, a second means for producing electrical pulses representative of the rate of exit of the strip from said rolls, a first counter for pulses of said first producing means, a second counter for pulses of said second producing means, means for establishing a circuit while a predetermined number of pulses are counted by said first counter, and time controlled means regulated by the number of pulses counted by said second counter when said circuit is established for varying the pressure of the said rolls.

2. The invention set forth in claim 1 with the further provision that the time controlled means comprises preset timed switches selectively regulated by the number of pulses counted by the said second counter when the said circuit is established.

3. In a system for controlling the elongation of strip material in a rolling mill having a pair of adjustable pressure rolls through which the strip is passed, the com-

bination of a first means for producing electrical pulses representation of the rate of entrance of the strip into said rolls, a second means for producing electrical pulses representative of the rate of exit of the strip from said rolls, a first counter for pulses of said first producing means, a second counter for pulses of said second producing means, means for establishing a circuit while a predetermined number of pulses is counted by said first counter, and means comprising timed switches regulated by the number of pulses counted by said second counter when said circuit is established for adjusting said rolls according to predetermined settings.

4. In a system for controlling the elongation of strip material in a rolling mill having a pair of variable pressure rolls through which the strip is passed, the combination of a first means for producing electrical pulses representation of the rate of entrance of the strip into said rolls, a second means for producing electrical pulses representative of the rate of exit of the strip from said rolls, a first counter for pulses of said first producing means, a second counter for pulses of said second producing means, means for establishing a circuit while a predetermined number of pulses is counted by said first counter, and means regulated by the number of pulses counted by the said second counter when said circuit is established for indicating the relationship of the number of pulses counted in the respective said counters.

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