United States Patent

[11] 3,613,975

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[54] **MATERIAL TRANSPORT TENSION CONTROL SYSTEM AND APPARATUS**
10 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **226/25,** 226/195, 226/42, 226/111, 318/7
[51] **Int. Cl.** **B65h 23/22**
[50] **Field of Search** 226/25, 44, 42, 30, 111; 318/195, 6, 7

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Attorney—Watson, Leavenworth & Kelton

ABSTRACT: A system for controlling tension in transported material in continuous form involving detection of positional displacement and last sense of movement of a tension roller in continuous contact with the material and generation of tension control signals compensatingly affecting material supply or takeup rate, said control signals being generated only upon occurrence of particular conditions of roller displacement and last sense of movement. The system also includes means for generating said tension control signals in digital steps of time duration controlled by system tension correction performance.

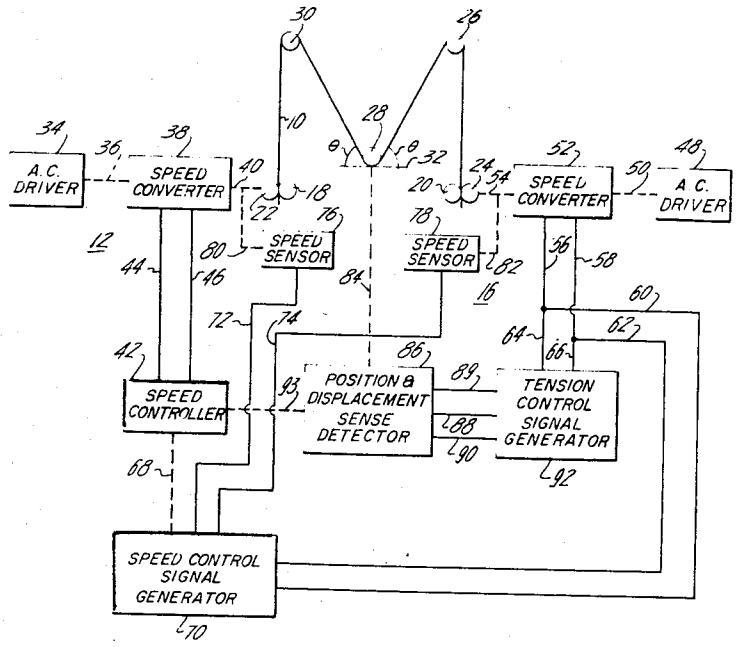


FIG. 1

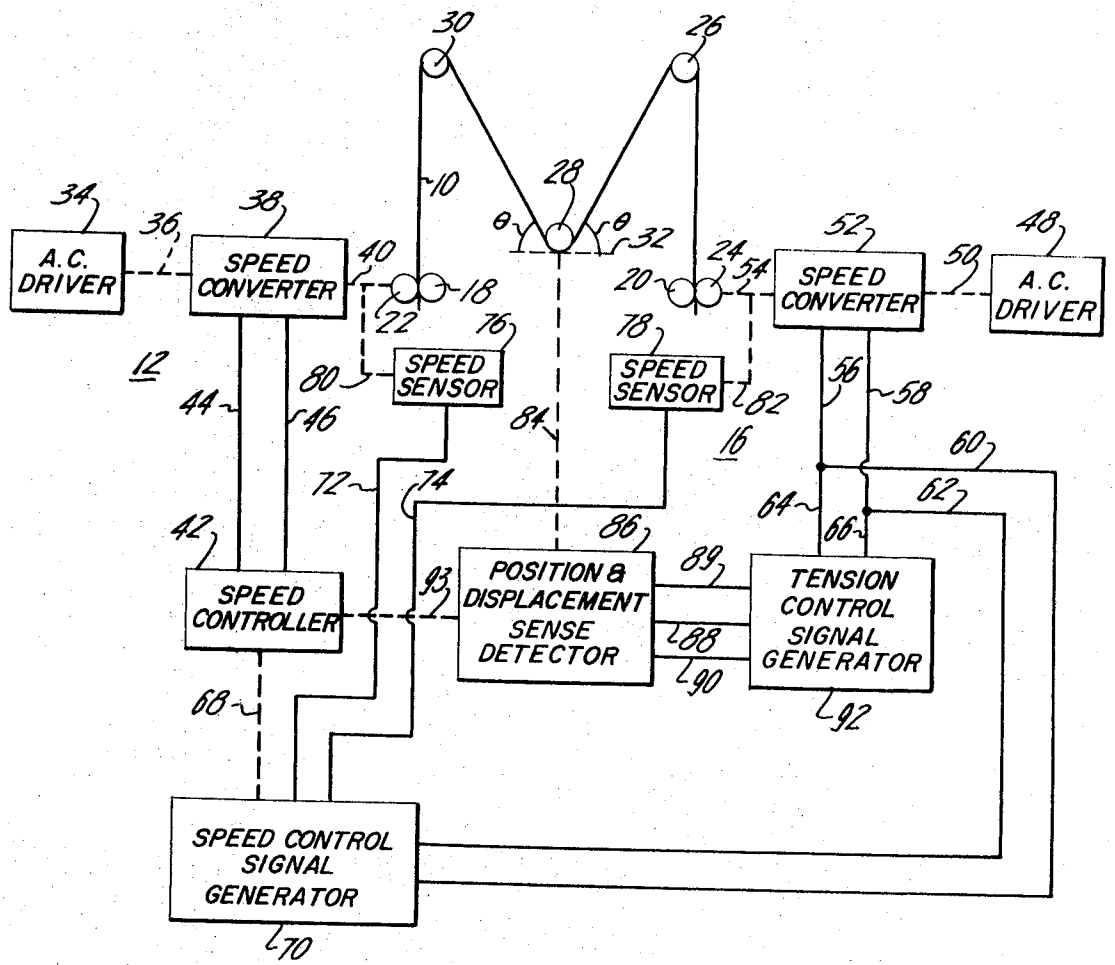

30
26
34
36
38
10
28
θ
θ
32
52
48
A.C. DRIVER
SPEED CONVERTER
40
18
22
20
24
54
SPEED CONVERTER
50
A.C. DRIVER
12
76
78
SPEED SENSOR
SPEED SENSOR
80
82
56
58
44
46
84
16
60
72
74
64
62
42
86
66
POSITION & DISPLACEMENT SENSE DETECTOR
89
TENSION CONTROL SIGNAL GENERATOR
SPEED CONTROLLER
93
88
90
92
68
SPEED CONTROL SIGNAL GENERATOR
70

FIG. 2

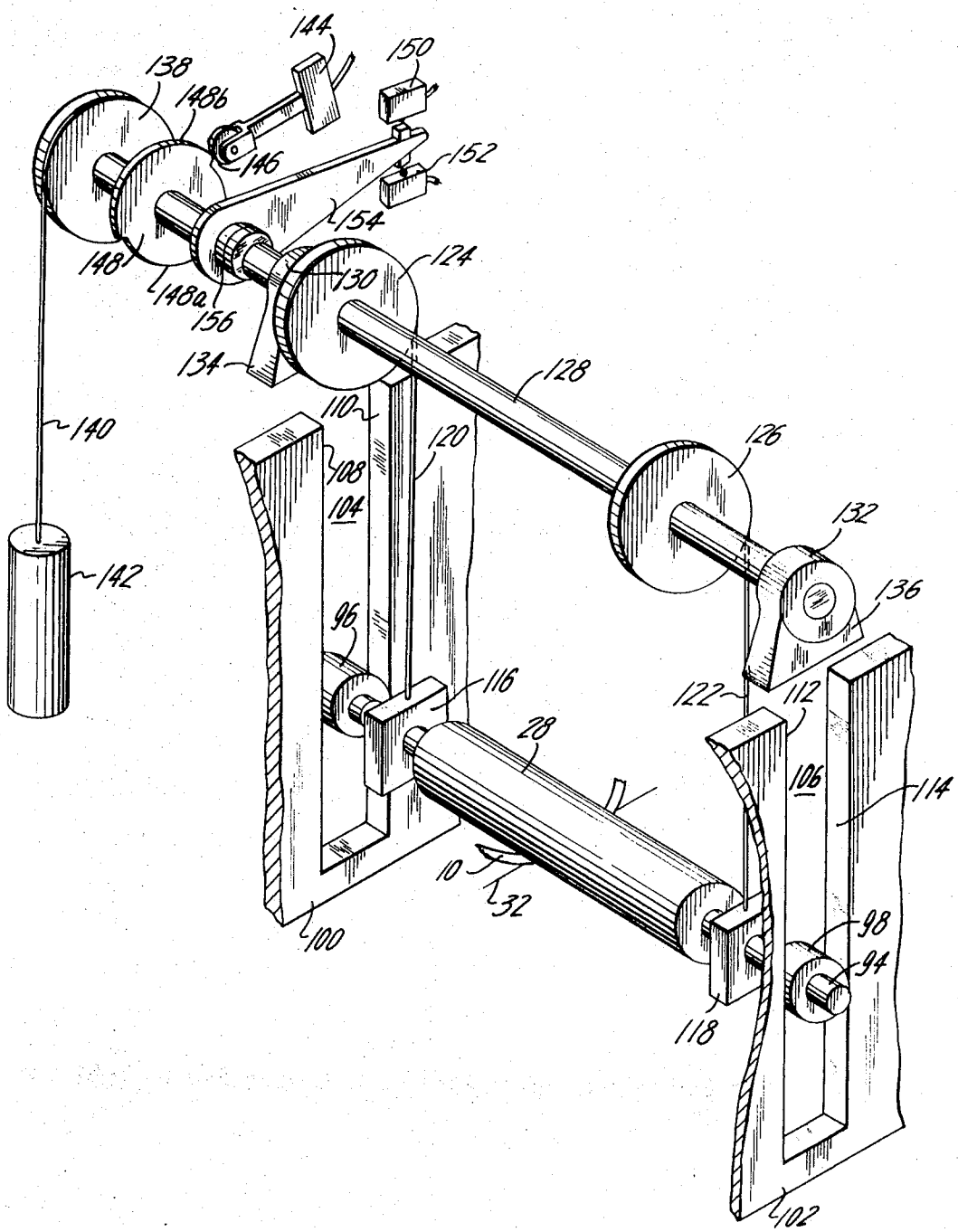

144
150
138
148b
146
152
154
148
148a
156
130
124
134
128
110
140
120
126
108
104
132
142
136
96
116
122
112
28
106
114
10
32
98
94
100
118
102

FIG. 3

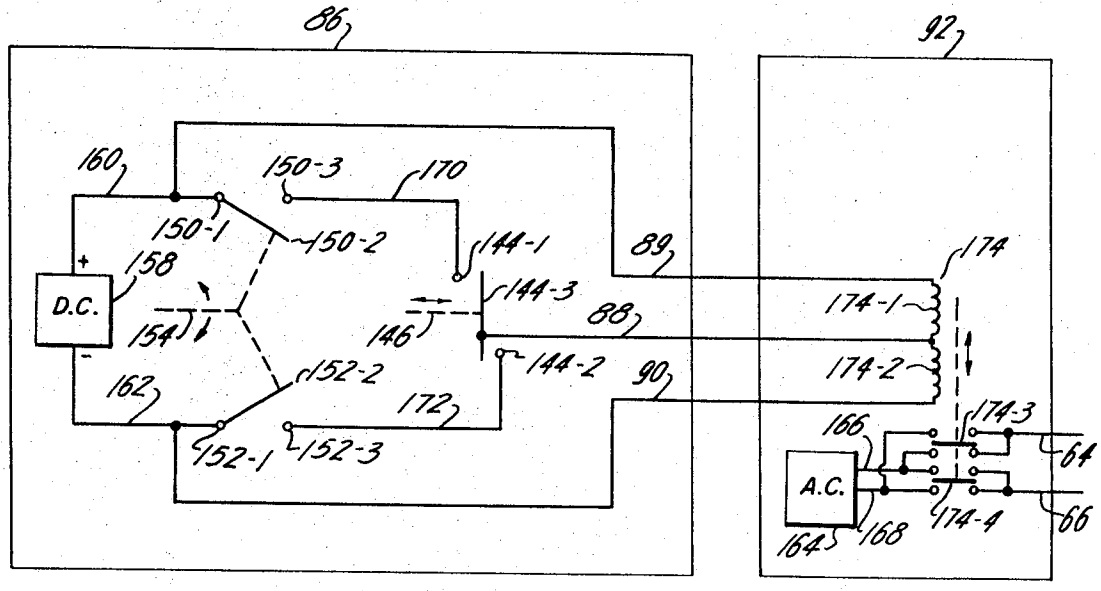

86
92
160
150-3
170
150-1
150-2
144-1
89
174
158
D.C.
144-3
174-1
154
146
88
174-2
144-2
90
162
152-2
172
174-3
166
152-1
152-3
64
A.C.
174-4
66
164
168

FIG. 4

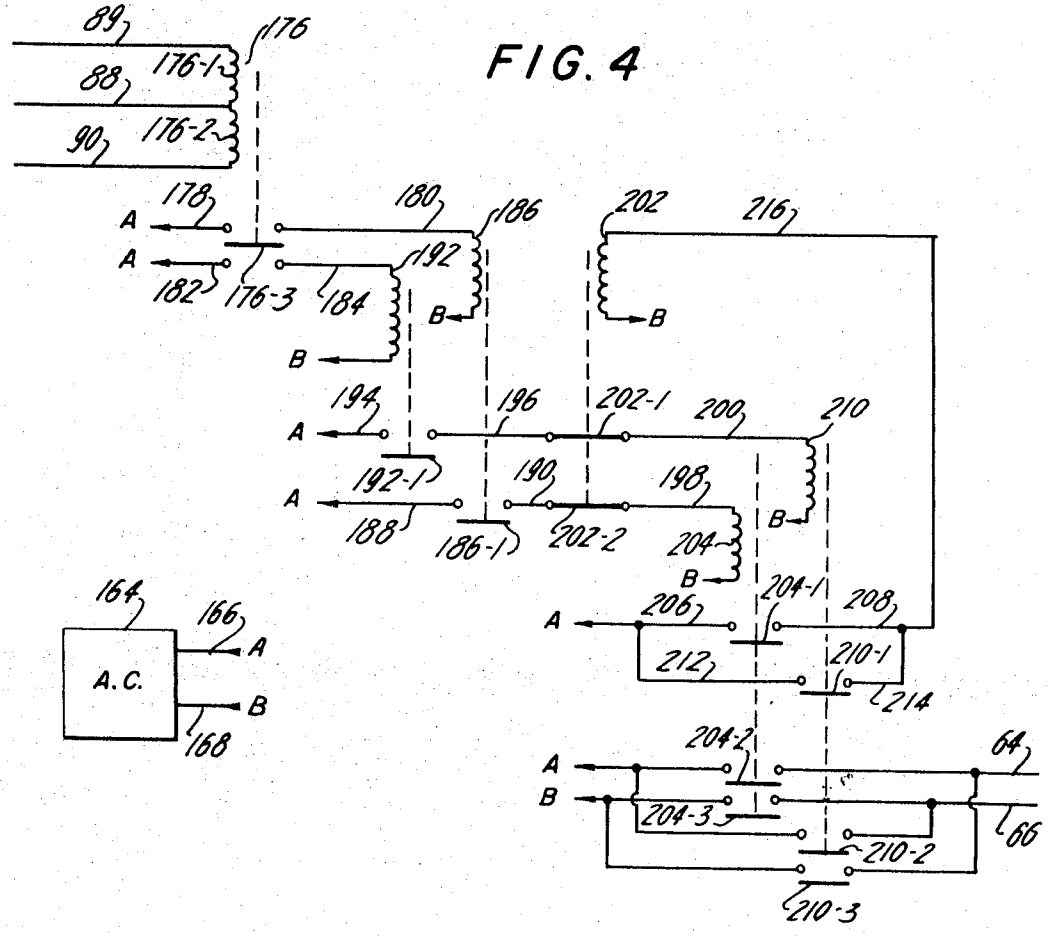

89
176
176-1
88
176-2
90
178
180
186
202
216
A
A
182
176-3
184
192
B
B
B
194
196
202-1
200
210
A
192-1
190
198
A
188
186-1
202-2
204
B
B
164
166
204-1
206
208
A
A.C.
A
212
210-1
214
B
168
204-2
64
A
B
204-3
210-2
66
210-3

FIG. 5

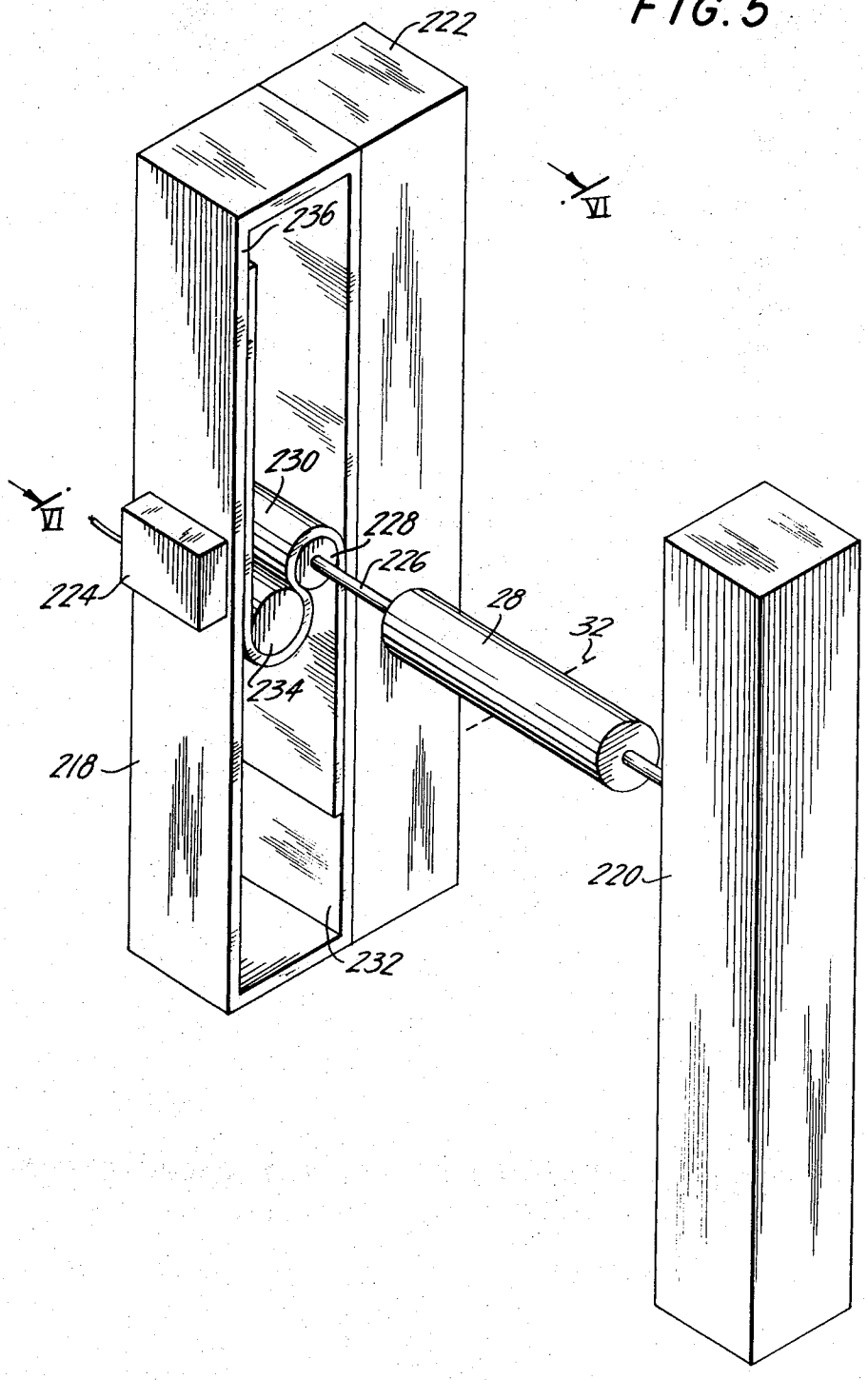
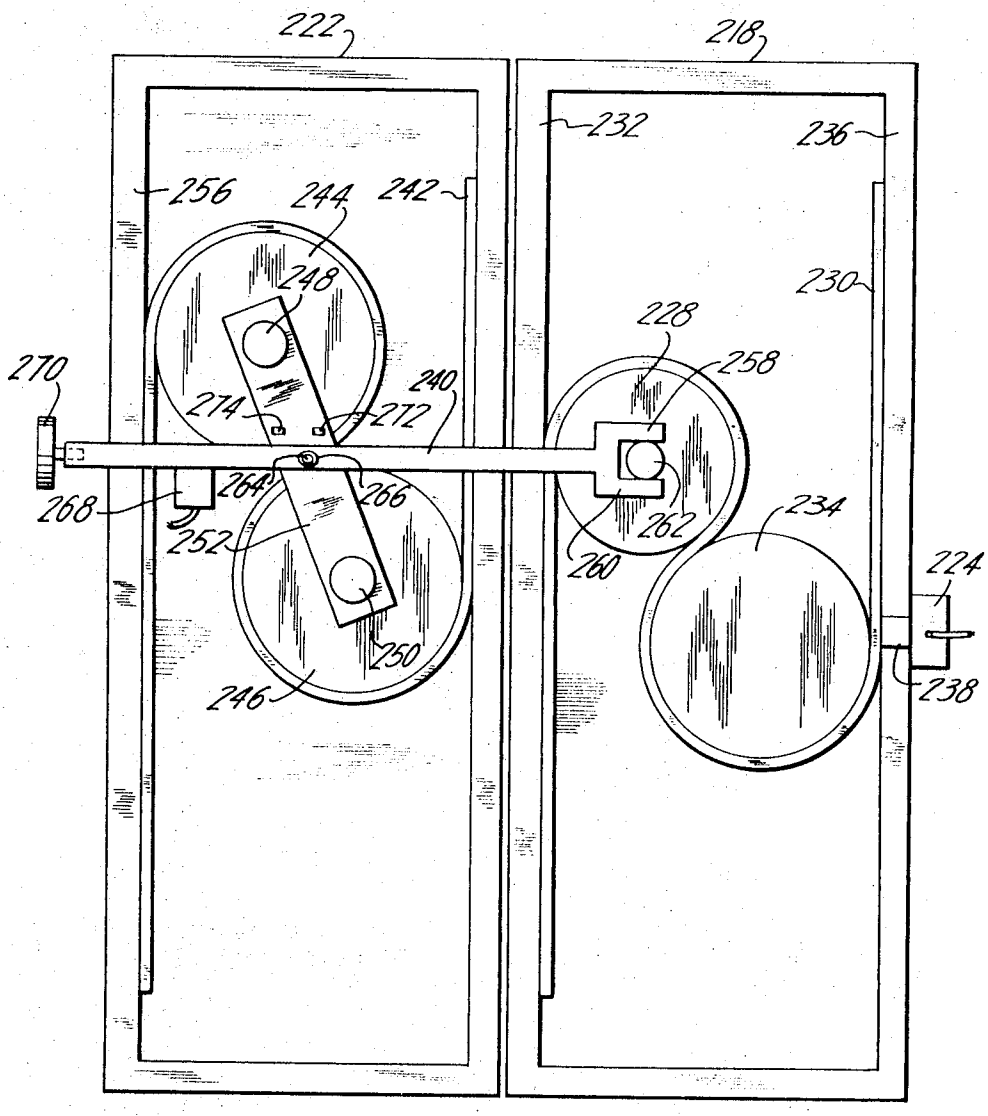


FIG.6


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224
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246
238

MATERIAL TRANSPORT TENSION CONTROL SYSTEM AND APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to material processing in continuous form and more particularly to systems for controlling material transport to provide constant tension in the material during processing thereof.

In various industrial applications, raw material is transported from a feed station to a work station wherein a characteristic of the material is modified and is further transported to a takeup station which feeds material utilization apparatus. In many such applications, it is necessary that the material characteristic be modified under conditions of constant tension in the material. Typical applications requiring such constant tension material transport are the treatment of yarn in cloth weaving in the textile industry, the finishing of paper in the paper-making industry and the feeding of tow to form filter plug rods in the cigarette-making industry. The importance of constant tension transport of raw material is particularly seen in the last-mentioned application. In accordance with a common type of cigarette filter, a tow comprising a bundle of several thousand continuous filaments is shaped into a continuous rod form, an outer sheath is applied, and the rod is ultimately severed into individual filter sections. The tow is first passed through a processing chamber in which the filaments are spread out and a plasticizer applied and then through a collection horn and finally to the sheath applying means. The sheath may be a paper wrapper or according to one specific form a plastic tube which is formed by extrusion with the tow directed into the hollow interior of the tube concurrently with the casting of the tube. It is important that the tow be supplied to the sheath applying means under a predetermined tension best suited to result in the desired characteristics including dimensional and functional characteristics.

In material processing systems of the foregoing general type, it is customary to employ what is designated as a tension roller or dancer to apply tension to the material and associated dancer position monitoring apparatus for generation of signals controlling material feed and/or takeup speed to maintain tension within certain limits. The dancer element is generally in the form of a cylindrical roller interposed between the feed means and the takeup means, the transported material being passed about the dancer in such a manner that variations in the tension desired in the material give rise to displacements of the dancer and consequently of the position of the plane of contact between the dancer and the material, and correspondingly the path of the material between the feed and the takeup mechanism. The dancer is freely mounted so as to follow the material, being raised or lowered thereby upon tension increase or decrease therein. By suitable counterbalancing the dancer may itself exert no tensile force upon the material. Alternatively the dancer may, by virtue of its unbalanced weight, apply tension to the material. It may be readily shown that dancer-produced tension in the material is equal to one-half of the unbalanced dancer weight times the arc sine of the angle between the material and said perpendicular plane in which the dancer moves. Such dancer-produced tension may be maintained at a given level by maintaining said angle constant, i.e. by maintaining the dancer in a particular contact plane which may be described as the plane tangent to the dancer surface within the arc of contact by the material strip and perpendicular to the direction of bodily movement of the dancer. The predetermined desired contact plane will hereinafter be referred to as the datum plane.

In certain known systems using relatively inexpensive alternating current transport apparatus it is customary to provide a control system operatively responsive only to dancer displacement and hence tension variation to modify the speed of the material takeup means. Arrangements of these control systems as are presently known to exist provide relatively coarse tension control, there being an inherent tendency to

provide constant or analog control in one or the other direction at all times resulting in continuing variation of the contact plane and oscillatory tension in the material. Close tension error tolerance is beyond the capabilities of such systems and in situations where close tolerance is essential, such as the above-mentioned tobacco application, these known tension control systems are ineffective.

Other control systems are presently known which provide appropriate tolerance control but such systems are characterized by relatively high cost since they are DC systems throughout in contrast to the known coarse control systems which permit the use of less expensive variable speed AC transport apparatus.

SUMMARY OF THE INVENTION

It is an object of this invention to provide an improved system for controlling tension in transported material.

It is a more particular object of this invention to provide a tension control system operatively responsive to a tension roller to provide close tolerance tension control with substantially no oscillatory tendency.

It is a further object of this invention to provide a tension control system permitting variable speed AC material transport with close tolerance of material tension.

It is an additional object of this invention to provide a tension control system wherein noncontinuous or digital tension correction is selectively initiated in response to tension roller movement.

It is a further object of this invention to provide improved tension roller movement sensors for constant tension control systems.

It is an additional object of this invention to provide an improved material transport system incorporating separately operative coarse speed and tension control.

In the efficient attainment of these and other objects there is provided in the present invention first means detecting tension roller position with respect to said datum plane and last sense of dancer displacement and generating distinct output signals upon occurrence of predetermined conditions of tension roller position and last sense of displacement and second means operatively responsive to said output signals to provide tension control signals which increase or decrease the speed of operation of material feed means upon occurrence of said conditions, thereby maintaining said tension roller in tensile-force applying contact with said material at said datum plane. Said predetermined conditions for generation of said output signals are that the tension roller have departed from said datum plane in a first or second direction respectively and not have exhibited a sense of displacement opposite to said first or second direction respectively. By such conditioned signal generation, the control system of the invention is effective to initiate tension correction only in instances in which no tendency toward self-correction has occurred and to continue tension correction only upon detecting need for correction beyond said initial correction.

In a particularly preferred embodiment of the invention, said second means incorporates circuitry for generating said tension control signals as a plurality of discrete pulses, each providing incremental speed variation in said transported material feed means and further circuitry adapted to continually determine the existence of said conditions intermediate generation of each said pulse.

Since system accuracy is dependent to a substantial extent upon frictionless support of said tension roller, there are disclosed in the present invention low friction embodiments of said tension roller position and sense of displacement detecting means, one of which embodies rolamite elements providing substantially friction-free displacement of said tension roller in said perpendicular plane.

The above and other objects and features of the invention will be evident from the following detailed description thereof and from the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram of a material transport system incorporating the tension control system of the invention and auxiliary coarse speed controlling apparatus.

FIG. 2 is a perspective view of a first embodiment of the tension roller position and sense of displacement detecting means of FIG. 1.

FIG. 3 is a schematic diagram of preferred circuitry for said detecting means and circuitry for use in the tension control signal generator of FIG. 1.

FIG. 4 is a schematic diagram of preferred circuitry for said tension control signal generator.

FIG. 5 is a perspective view of a preferred embodiment of the tension roller position and sense of displacement detecting means of FIG. 1.

FIG. 6 is a side elevation of the apparatus of FIG. 5 as seen from line VI—VI.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 raw material 10 is transported to material takeup station 12 from material feed station 16, stations 12 and 16 respectively including takeup rolls 18 and 22 normally maintained at constant speed and feed rolls 20 and 24 subject to adjustable fine speed control. The feed rolls draw continuous tow material 10 from a suitable supply coil, the material being passed through suitable processing means wherein a dimensional or like characteristic of the material is altered en route to the feed rolls, if desired. Material 10 is transported about guide roller 26, under tension roller 28 and about guide roller 30. The lower periphery of roller 28 is to be maintained in continuous contact with the material at datum plane 32 to exert a predetermined force upon the material and define a particular tensile force therein. Material 10 will thus be drawn through said processing means under constant tension as long as roller 28 contacts material 10 at datum plane 32.

Takeup station 12 comprises an AC driver 34, the output shaft 36 of which is rotated at a constant speed. Speed converter 38 is coupled to shaft 36 and provides variable coupling between same and its output shaft 40 in accordance with control signals applied from speed controller 42 over lines 44 and 46. The composite element grouping 34–46 may comprise a conventional variable-speed AC drive transport such as the Reeves Varidrive produced by the Reliance Electric Co., Cleveland, Ohio. In such arrangement unit 38 incorporates a small AC gear motor which is selectively connected to normal phase or reverse phase AC excitation through speed controller 42 which may comprise a simple bipolar switch. As the motor is excited with normal phase AC excitation mechanical coupling between shafts 36 and 40 is varied such that the speed of shaft 40 is reduced. Conversely, with speed controller 42 operated in the opposite manner to provide reverse phase AC excitation, the rotational speed of shaft 40 is increased.

A complementary arrangement is incorporated in material feed station 16 wherein AC driver 48 has an output shaft 50 coupled to speed converter 52, the output shaft 54 of which is speed-controlled in accordance with signals appearing on lines 56 and 58. In contrast to corresponding lines 44 and 46 of station 12, lines 56 and 58 of station 16 are connected with normal and reverse phase AC excitation either through lines 60 and 62 or lines 64 and 66. As will be presently clear, lines 60 and 62 provide such excitation, hereinafter speed control signals, for purposes of insuring equal feed and takeup of material 10. Lines 64 and 66 provide such excitation, hereinafter tension control signals, to direct unit 52 in modifying feed speed irrespective of material takeup rate. As will also be presently evident, lines 64 and 66 are integral with the normally operating tension control system of the invention whereas lines 60 and 62 are associated with the normally quiescent speed controlling apparatus employed in the FIG. 1 system.

In the generation of signals on lines 60 and 62, a mechanical interlink 68 is provided between speed controller 42 and speed control signal generator 70 such that unit 70 is operative to generate output signals only upon manual operation of unit 42. Instantaneous indication of the rate of takeup of material 10 by feed station 12 and of advance of the material by station 16 is provided to unit 70 over lines 72 and 74 respectively, same being connected to sped sensors 76 and 78 which receive input signals from shafts 80 and 82 respectively connected to shafts 40 and 54. Sensors 76 and 78 are typically tachometer generators providing direct current signals respectively proportional to the speeds of the input shafts thereof.

In operation of the system of FIG. 1, if it is desired at any time to increase or decrease material transport speed, or to perform a check of relative rates of feed and takeup, speed controller 42 is operated by manual actuation of switching assemblies thereof associated with increasing, decreasing or monitoring transport material speed. In the case of an increase or decrease in transport rate, AC excitation is applied at normal or reverse phase through lines 44 and 46 to variable speed unit 38 to provide speed variation in shaft 40. A signal indicative thereof is generated on line 72 and speed control signal generator 70 responds to said signal and the signal then provided on line 74 and indicative of the speed of shaft 54 to apply AC excitation to lines 60 and 62 of phase and time extent to set speed converter 52 such that shaft 54 speed is slaved to shaft 40 speed and the signals on lines 72 and 74 are equal. Such coarse speed adjustment is normally performed during system startup and at selected other times, the speed control apparatus described being generally inoperative during the normal course of material transport.

After such initial system setup and with feed rate tracking takeup rate, tension roller 28 is counterbalanced such that datum plane 32 defines the plane of contact of the roller with the transported material, the transported material defining the angles θ with plane 32. Mechanisms supporting roller 28 and providing such counterbalancing will be discussed in connection with FIGS. 2, 5 and 6. The tension roller is connected by mechanical linkage 84 with tension roller position and displacement sense detector 86. This unit contains a plurality of switch members operated by linkage 84 in accordance with both the positional displacement of roller 28 above or below datum plane 32, i.e. departures from the position illustrated in FIG. 1, and the last sense of displacement of the roller, i.e. upwardly or downwardly in FIG. 1. By suitable interconnection of said switch elements, predetermined signal generating conditions are established in unit 86 and signals are generated on lines 88 and 89 upon the occurrence of first conditions requiring an increase in feed speed for tension correction and on lines 88 and 90 upon the occurrence of second conditions requiring tension correcting reduction in the speed of operation of the feed apparatus.

Lines 88, 89 and 90 are connected to tension control signal generator 92 which includes circuitry operatively responsive to signals provided on said lines to apply AC excitation to lines 64 and 66 of phase and time extent sufficient to modify operation of variable speed unit 52 to direct variation in feed speed to initiate return of roller 28 to datum plane 32. Mechanical interlink 93 may be provided between speed controller 42 and detector 86 to discontinue excitation of unit 86, and hence interrupt tension control, during operation of the speed controller.

Referring to FIG. 2, wherein a first embodiment of tension roller 28, linkage 84 and tension roller position and displacement sense detector 86 is illustrated, the tension roller 28 is mounted on a shaft 94 seated in bearings 96 and 98. Side walls 100 and 102 define vertical tracks 104 and 106 having rails 108, 110 and 112, 114 which guide movement of bearings 96 and 98. Blocks 116 and 118 are secured to shaft 94 and mechanical linkage 84 takes the form of a pair of support cables 120 and 122 respectively connected to blocks 116 and 118 at first ends thereof and to pulleys 124 and 126 at the other ends thereof. The pulleys are fixedly mounted on shaft 128 which is seated in bearings 130 and 132 fixedly supported by arms 134 and 136. Shaft 128 fixedly supports a further pulley 138 to which is secured one end of cable 140, the cable

being connected at the other end thereof to a counterweight 142. As discussed above, counterweight 142 is selected in accordance with the unbalanced tension roller force desired to be applied to transported material 10 to develop a predetermined tensile force in the material during transport thereof.

The foregoing apparatus comprises tension roller support and guide means effective to impart rotation to shaft 128 in accordance with displacements of the tension roller from datum plane 32. A plurality of switch elements is associated with shaft 128 to provide signals on lines 88, 89 and 90 (FIG. 1) indicative of conditions of roller positional displacement and last sense of movement. A first switch 144 is actuated by a cam follower 146 operatively responsive to cam 148 to assume a first or a second state. Cam 148 is secured to shaft 128 and includes a cam contour having first and second continuous concentrically displaced sections 148*a* and 148*b* respectively engaging cam follower 146 when tension roller 28 departs upwardly or downwardly from the position thereof illustrated in FIGS. 1 and 2. Thus switch 144 assumes one state when the tension roller departs upwardly from datum plane 32 as a result of counterclockwise rotation of shaft 128 and assumes its other state when the tension roller departs downwardly through datum plane 32 whereupon shaft 128 is rotated in a clockwise direction. Second and third switches 150 and 152 are operated by actuating arm 154 which is connected to shaft 128 through a bidirectional slip clutch 156. Switches 150 and 152 are closely placed about actuator 154 and by reason of the slip clutch mounting of the actuator the switches, as operated, act as stop members, restricting total angular displacement of actuator 154 to a limited arcuate path of approximately 6° . As shaft 128 is rotated 3° counterclockwise, actuator 154 operates switch 150 and the switch will remain operated until clockwise rotation of shaft 128 occurs whereupon the actuator will operate switch 152 substantially immediately, i.e. upon about 6° of clockwise rotation. The converse situation will now be maintained, i.e. switch 152 will be maintained in its operated condition until the direction of rotation of shaft 128 again reverses. Evidently shaft 128 will be rotated in an initial counterclockwise direction upon any upward movement of tension roller 28 and switch 150 will be operated. Switch 152 will be operated by any downward movement of the tension roller.

The above-discussed predetermined conditions for generation of signals on lines 88, 89 and 90 of FIG. 1 by operation of switches 144, 150 and 152 by the mechanism of FIG. 2 will be evident from the switch interconnection circuitry of FIG. 3.

Two sources of supply potential are provided for the circuitry of the tension roller position and sense detection means 86 and tension control signal generator 92. A direct current potential is provided by supply 158 over lines 160 and 162 and alternating current potential is provided by supply 164 over lines 166 and 168. The former supply is provided only for low level signal generation in unit 86 whereas the latter supply is employed for generation of unit 92 control signals and for powering the AC drive apparatus of feed station 16. Terminal 150–1 of switch 150 is connected to line 160 and terminal 152–1 of switch 152 is connected to line 162. The switches include contact arms 150–2 and 152–2 operated as described above by actuator 154, movement of the actuator being clockwise or counterclockwise as illustrated. Switch 144 includes a first terminal 144–1 connected by line 170 to the remaining terminal 150–3 of switch 150 and a second terminal 144–2 connected by line 172 to terminal 152–3 of switch 152. The contact arm 144–3 of switch 144 is connected to output line 88, contact arm 144–3 being displaced by cam follower 146 in transverse directions as illustrated. Output lines 89 and 90 are connected respectively to supply lines 160 and 162.

While lines 89 and 90 are continually provided with positive and negative potentials respectively, output line 88 will be selectively energized by a positive or negative potential or will be unenergized depending upon the operation of switches 144, 150 and 152 by switch actuators 146 and 154. Referring to both FIGS. 2 and 3 if roller 28 assumes a position above datum plane 32, cam follower 146 assumes its leftward position placing contact arm 144–3 in engagement with terminal 144–1. Output line 88 will then receive a positive potential if switch 150 is closed or will be unenergized if switch 150 is open. Since switch 150 will be closed by actuator 154 upon upward movement of roller 28, the condition by which output line 88 will receive a positive potential is that the roller have assumed said position above datum plane 32 and have not initiated a return movement to the datum plane. Conversely, if roller 28 is positioned downwardly with respect to datum plane 32, cam follower 146 assumes its rightward position and contact arm 144–3 engages terminal 144–2. Line 88 will receive either a negative potential or will be unenergized depending upon the state of switch 152. Switch 152 will be closed with contact arm 152–2 engaging terminal 152–3 upon any downward sense of movement of roller 28 and will remain closed until upward movement of the roller occurs. Thus, the condition whereby line 88 will receive a negative potential is that the roller have departed downwardly with respect to datum plane 32 and not have initiated a return to the datum plane. Line 88 will be unenergized under all conditions other than the described conditions of continuity between said line and DC source 158 by said switches. Thus, control circuitry depending upon lines 88, 89 and 90 for operation will be operative only during the occurrence of said conditions and tension correction will occur only when the roller has been displaced from its desired position of registry with datum plane 32 and has not exhibited, by self-correction or like occurrence, a tendency to return to said datum plane position. By virtue of this system feature, the subject control system avoids the tendency to perform tension correction during the occurrence of self-correction or of system-initiated tension correction and the likelihood of overcorrection, repetitively directing roller 28 through and above and through and below the datum plane, is avoided rendering the system substantially oscillation-free.

A simplified version of tension control signal generator 92 is also shown in FIG. 3, comprising a bipolar relay 174. The relay incorporates a center tapped winding having sections 174–1 and 174–2, the former being connected across lines 88 and 89 and the latter being connected across lines 88 and 90. Evidently, when line 88 is interconnected with line 162, i.e. is negative, no potential difference exists between lines 88 and 90 and section 174–2 is unenergized. Under this condition, a potential difference does exist between lines 88 and 89 and section 174–1 is energized directing relay contact members 174–3 and 174–4 upwardly providing continuity between lines 168 and 64, and between lines 166 and 66. Conversely, if line 88 is interconnected with line 160, i.e. is positive, no potential difference exists between lines 88 and 89 and section 174–1 is unenergized. Under such conditions a potential difference does exist between lines 88 and 90 and section 174–2 is energized directing relay contact members 174–3 and 174–4 downwardly providing continuity between lines 166 and 64 and between lines 168 and 66. Thus, the phase of AC excitation provided on lines 64 and 66 will be reversed depending upon the polarity of energization of line 88, lines 64 and 66 being unenergized where line 88 is unenergized. Whereas relay 174 is illustrated as being of the center-tapped type, same may be comprised of a single winding without center tap, having a first terminal connected to line 88 and a second terminal connected through resistors to both lines 89 and 90. Current flow through such winding respectively in one or the other sense will provide first or opposite directional movement of the solenoid thereof.

In FIG. 4 there is illustrated a preferred embodiment of tension control signal generator 92 wherein the phase of tension control signals generated at lines 64 and 66 is provided in accordance with the polarity of energization of line 88, as in the unit 92 illustrated in FIG. 3, but wherein the periodicity of tension control signals is varied with respect to the periodicity of energization of line 88. To this extent, the arrangement of FIG. 4 includes a bipolar relay 176 having sections 176–1 and

176–2 selectively actuated in response to the polarity of energization of line 88 and directing relay contact member 176–3 to provide continuity respectively between lines 178 and 180 or between lines 182 and 184. Lines 178 and 182 are connected to line 166 of supply 164 as designated by the letter A. The letters A and B are employed throughout the circuitry of FIG. 4 to indicate respective connection of lines to either supply line 166 or 168. Relay 186 is connected to line 180 for energization and includes a contact member 186–1 adapted to provide continuity between lines 188 and 190. Similarly, relay 192 is connected to line 184 and includes a contact member 192–1 adapted to provide continuity between lines 194 and 196. Lines 190 and 196 are connected respectively to lines 198 and 200 through the normally closed contacts 202–1 and 202–2 of time delay on deenergization relay 202. Time delay on deenergization relay 204 is connected to line 198 and includes contact member 204–1, adapted to provide continuity between lines 206 and 208, and 204–2, 204–3, adapted to provide continuity between lines 166 and 64 and 168 and 66 respectively. Time delay on deenergization relay 210 is connected to line 200 and includes contact members 210–1 adapted to provide continuity between lines 212 and 214, and 210–2, 210–3 adapted to provide continuity between lines 166 and 66 and lines 168 and 64 respectively. Lines 206 and 212 are connected to line 166 and lines 208 and 214 are connected to line 216, the latter being connected to relay 202 for energization thereof.

In describing the operation of the circuit of FIG. 4, it will be assumed that line 88 has been energized with a negative potential, in turn energizing section 176–1 of relay 176 whereupon the upper relay contacts are closed by contact member 176–3 and relay 186 is energized through lines 166, 178 and 180. As the contacts of relay 186 are closed by contact member 186–1, relay 204 receives energizing voltage through lines 166, 188, 190, 198 and the normally closed contacts of relay 202. Upon energization of relay 204 lines 166 and 64 are connected through contact member 204–2 and lines 168 and 66 are connected through contact member 204–3 and a tension control signal of first phase is thereby generated. This control signal will persist on lines 64 and 66 until the time period for deenergization of relay 204 expires, irrespective of changes in state of relays 186 and 202 during such period. Concurrently with the generation of the tension control signal on lines 64 and 66, voltage energizing relay 202 is developed on line 216 by closure of contact member 204–1 and interconnection of lines 206 and 208. Upon energization relay 202 will remain energized until the time period for deenergization thereof expires, continuity between lines 190 and 198 being interrupted during such period by displacement of contact member 202–2 from its illustrated normally closed position. Since the energizing path for relay 204 is thereby interrupted, the relay will not be reenergized upon expiration of the time period thereof and the signal generated on lines 64 and 66 will terminate. Assuming relay 186 to be continued in its energized state at this time, the tension correction requirement signal being maintained on line 88 by virtue of the continuing need for correction as sensed by detector 86 (FIGS. 1 and 3), lines 188 and 190 of the energizing circuit of relay 204 will remain in continuity through contact member 186–1. Upon expiration of the time period of relay 202, contact member 202–2 will return to its normally closed position and energizing voltage will again be applied to relay 204 initiating the cycle of operation heretofore discussed and generating on lines 64 and 66 a second tension correction signal of the same phase. By appropriate selection of the respective time delays of relays 204 and 202, a plurality of pulses of desired duration and periodicity may be provided during the occurrence of the continuous tension correction requirement signal on line 88. Thus, in addition to the system feature providing for initiation of tension correction only upon the existence of the two above-discussed conditions implemented in circuit 86, the system is adapted, by virtue of the circuitry of FIG. 4, to generate noncontinuous or digital error correction signals thereby providing discrete conditioned correction having even less tendency toward oscillation than by use of circuit 92 of FIG. 3.

While the circuit of FIG. 4 has been discussed in connection with a first polarity signal appearing on line 88, it will be evident by virtue of the complementary symmetry in the control circuitry that actuation of relay 184, upon the generation of a reverse polarity signal on line 88, will given rise to like operation of relays 202 and 210, relay 210 providing for a reverse interconnection of lines 166, 168, 64 and 66 through contact members 210–2 and 210–3, thus generating tension control signals of opposite phase to those in the above discussed example. It will be further evident that the circuitry of FIG. 4 is adapted to generate continuing discrete pulses on lines 64 and 66 only upon continuing conditions for tension correction indicated by maintenance of signals of either polarity on line 88. Thus, where the system reacts promptly in initiating error correction, such conditions will not persist and a single and not a plurality of pulses may be generated.

In the arrangement illustrated in FIG. 2 for support of roller 28, various elements are in frictional engagement somewhat detractive of system performance. While such arrangement is useful in most applications, where a particularly high degree of system performance is desired, the arrangement of FIG. 5 is preferably employed. Therein roller 28 is supported by a pair of rolamite assemblies 218 and 220. A third rolamite 222 is included for tension roller sense of displacement detection. Rolamite assembly 218 has associated therewith a proximity switch 224 for detecting tension roller position relative to datum plane 32. Rolamite assembly 218 is shown in perspective section to illustrate the internal makeup thereof, it being understood that all rolamite assemblies 218, 220 and 222 are commonly structured. Roller 28 is rotatively supported on shaft 226, one end of which is supported by rolamite assembly 220 and the other end of which is supported by roller 228 of rolamite assembly 218. Disposed in nonslipping contact with a portion of the periphery of roller 228 is rolamite band 230 fixed at the lower end thereof to wall 232. Band 230 is further in nonslipping contact with a portion of the periphery of roller 234 and is affixed to wall 236 at the other end thereof. In accordance with rolamite kinematics, rollers 228 and 234 are selected to have diameters differing to an extent providing differential bending moments in band 230 yielding a net upward force on roller 228 equal to the weight of rollers 228 and 234 plus one-half of the weight of roller 28 and shaft 226 minus the desired force which roller 28 is to apply to transported material. Rolamite 220 is provided with a band of identical characteristics to band 230 and the rollers thereof corresponding to rollers 228 and 234 have identical corresponding diameters and weights. A full explanation of the kinematics and performance characteristics of rolamites per se may be found in U.S. Pat. Nos. 3,452,175 and 3,452,309 and reference thereto is hereby made. Since the rolamite is a substantially friction-free support bearing, the various frictional constraints on system performance, e.g. slip clutch 156, etc., present in the arrangement of FIG. 2 are avoided.

In order to derive positional information relating roller 28 position to datum plane 32 proximity sensor 224 incorporates a frictionless switch member actuated when metallic band 230 is within the switch field of view, i.e. when the band is positioned against wall 232 adjacent sensor 224. The switch member is unactuated when band 230 departs from wall 232, i.e. when roller 28 is displaced upwardly from datum plane 32. It will be evident that this switch performs an identical function to switch 144 of FIG. 2 in that it assumes alternate states depending upon the position of roller 28 with respect to the desired plane of contact between same and transported material.

In FIG. 6 sensor 224 is mounted in aperture 238 of wall 232, band 230 being shown in the sensor field of view. In such position roller 28 is in proper registry with datum plane 32, upward movement from such position withdrawing band 230 from the sensor field of view causing sensor 224 to indicate that roller 28 is disposed in a position above the datum plane.

Upward or downward last sense of movement of roller 28 is provided by signals generated in rolamite 222, same being connected by arm 240 to rolamite 218. Rolamite 222 incorporates a band 242 and rollers 244 and 246 having shafts 248 and 250 interconnected by member 252. As in the case of rolamite 218, band 242 is fixed to wall 254 at one end and to wall 256 at its other end. Arm 240 is bifurcated at one end thereof, arms 258 and 260 receiving shaft 262 of roller 228. Arm 240 is pivotally connected to member 252 by pin 264 and collar 266. The arm supports a switch member 268 which is tilt-sensitive, operated in a first state by clockwise rotation of arm 240 about pin 264 and in alternate state upon counterclockwise rotation of the arm about the pin. Such rotative movement of arm 240 is restricted in said two directions respectively by stop members 272 and 274 affixed to connecting member 252. A counterweight element 270 is variably seated in arm 240 for balancing the arm. The diameter differential of rollers 244 and 246 of rolamite 222 is selected such that the rolling cluster generates an upwardly directed force equal to the weight of the rollers 244 and 246 and the various elements connected thereto. With such diameter selection and counterbalancing of arm 240, it will be evident that in the neutral position illustrated rolamites 218 and 222 do not load one another.

Upon displacement of roller 28 upwardly or downwardly from said desired position of registry with datum plane 32, arm 240 will be freely pivoted about pin 264 over a defined arc as established by the position of stop elements 272 and 274. Such arc is preferably plus and minus three degrees from the neutral position and the tilt-sensitivity of switch 268 is similarly $\pm 3°$. Upon engagement of arm 240 with either of stop members 272 and 274, i.e. upon vertical travel of roller 28 in a substantial upward or downward direction, rolamite 222 will move in accordance with the movement of rolamite 218. Such movement will however be essentially nonloading as respects rolamite 218, rolamite 222 being self-supporting as discussed above.

It will be seen that switch 268 functions in identical manner as switches 150 and 152 of FIG. 2 constantly providing an indication of the last sense of displacement of roller 28. By interconnection of sensor 224 and switch 268, the aforementioned predetermined conditions for generation of tension correction control signals may be readily provided in accordance with the interconnection circuitry of FIG. 3.

While tension roller 28 has been illustrated to have vertical travel in response to tension variation in transported material 10, it will be readily evident that the apparatus of FIGS. 5 and 6 and the apparatus of FIG. 2 are equally adapted for use in providing the tension roller with horizontal travel. Furthermore, while the control circuitry has been illustrated as employing electromechanical elements, same may incorporate electronic devices in place of same, low power switching transistors being useful in circuit 86 of FIG. 3 and high power switching transistors or controlled rectifiers being useful in circuit 92 of FIG. 3 and the circuitry shown in FIG. 4.

While the control system herein has been illustrated in an application wherein tension control is required between first feed and first takeup apparatus, it will be evident that the system may be readily applied in cascade to multiple successive pairs of feed and takeup apparatus. In such application, the terminal or initial apparatus of each successive pair acts as a master respectively to the initial or terminal apparatus of the next successive pair as does apparatus 12 of FIG. 1 to apparatus 16 thereof.

In this connection, various changes and modifications as will be evident to those skilled in the art may be made in the preferred embodiments discussed in detail above without departing from the spirit and scope of the invention, such embodiments being intended in an illustrative and not in a limiting sense.

What is claimed is:

1. A system for maintaining a particular tension in material in continuous form transported between material feed mechanism and takeup material mechanism comprising:

a. force-applying means supported for movement in continuous contacting engagement with said transported material and producing said particular tension in said material upon contacting engagement therewith in a predetermined datum plane;

b. means detecting the position with respect to said datum plane and the last sense of movement of said force-applying means and generating output signals exclusively upon the occurrence of predetermined detected positions with respect to said datum plane and predetermined detected senses of movement of said force-applying means;

c. a tension controller operatively responsive to said output signals to vary the speed of operation of one of said mechanisms relative to the other said mechanism exclusively during occurrence of said output signals to maintain said force-applying means and said material in contacting engagement at said datum plane.

2. The system claimed in claim 1 in which said tension controller is connected to vary the speed of operation of said material feed mechanism, said takeup mechanism being maintained at a substantially constant speed.

3. The system claimed in claim 1 wherein said force-applying means comprises a shaft, a tension roller supported for rotation on said shaft and contactingly engaging said material, said shaft being supported by first and second rolamite assemblies for movement relative to said datum plane in accordance with movement of said material, said shaft being connected to first rollers of said assemblies.

4. The system claimed in claim 3 including further a third rolamite assembly having a member interconnecting a first roller thereof to said first roller of said first rolamite assembly, said means detecting the positions with respect to said datum plane and senses of movement of said tension roller including a first switch member actuated by said first rolamite assembly to one or another state by positioning of said tension roller on one or the other side of said datum plane and a second switch member actuated by said interconnecting member to on or another state in accordance with the last sense of movement of said tension roller.

5. The system claimed in claim 4 wherein said means detecting the positions and senses of movement of said tension roller further includes circuitry interconnecting a power supply and said first and second switches for generation of said output signals, first output signals being provided exclusively when both said first and second switches are actuated to said one state or when both said first and second switches are actuated to said other state.

6. The system claimed in claim 5 wherein said first switch comprises a proximity switch actuated by presence of the band of said rolamite within the switch field of view, and said second switch is an attitude-sensitive switch affixed to said interconnecting member.

7. The system claimed in claim 1 including a subsystem conforming the speed of operation of said feed mechanism to the speed of operation of said takeup mechanism comprising:

a. a first signal generator providing an output signal indicative of the speed of operation of said feed mechanism;

b. a second signal generator providing an output signal indicative of the speed of operation of said takeup mechanism; and

c. a speed controller operative alternatively to said tension controller upon demand to vary the speed of operation of said feed mechanism, and responsive to differences between said output signals of said first and second signal generators.

8. The system claimed in claim 1 wherein said position and sense detecting means provides a first or second output signal respectively upon the detection of first position with respect to said datum plane and first directional last sense of movement or second position with respect to said datum plane and second directional last sense of movement of said force-applying means, said tension controller increasing or decreasing the speed of operation of said feed mechanism respectively in response to said first or second output signals.

9. The system claimed in claim 8 wherein said tension controller includes means operatively responsive to said first or second output signal to respectively generate first or second successions of digital signals during occurrence of said output signals, each signal in said first or second succession of signals respectively providing incremental increase or decrease in the speed of operation of said feed mechanism.

10. The system claimed in claim 1 wherein said position and sense of detecting means comprises a first shaft, means supporting said first shaft for translation in a first plane, said shaft supporting a tension roller in contacting engagement with said transported material, a second rotatably supported shaft connected to said first shaft and operated thereby in one or the other rotational direction upon translation of said first shaft respectively in one or the other translational direction, a cam affixed to said second shaft for rotation therewith and having first and second cam surfaces respectively indicative of the position of said first shaft above or below a plane transverse to said plane of translation of said first shaft, cam follower means continuously contacting said cam, a signal generator connected to said cam follower and providing first or second output signals in accordance with said positions of said first shaft, a bidirectional slip clutch driven by said second shaft, an actuator connected to said slip clutch and second and third signal generators disposed on alternate sides of said actuator and respectively operated by said actuator upon clockwise or counterclockwise rotation of said second shaft and providing output signals respectively indicative of first or second senses of translation of said first shaft.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,613,975 Dated October 19, 1971

Inventor(s) Jack B. Knight

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Sheets 1 through 5 of the drawings, "3,513,975" should read --3,613,975--.

Column 4, line 5, "sped" should read --speed--.

Column 10, line 37, "on" should read --one--.

Signed and sealed this 1st day of August 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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