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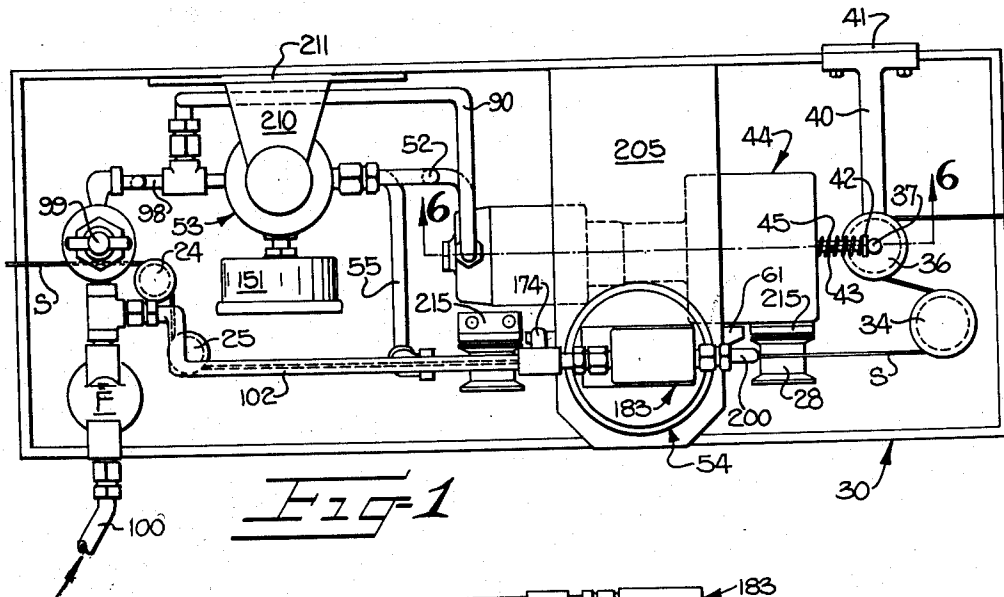
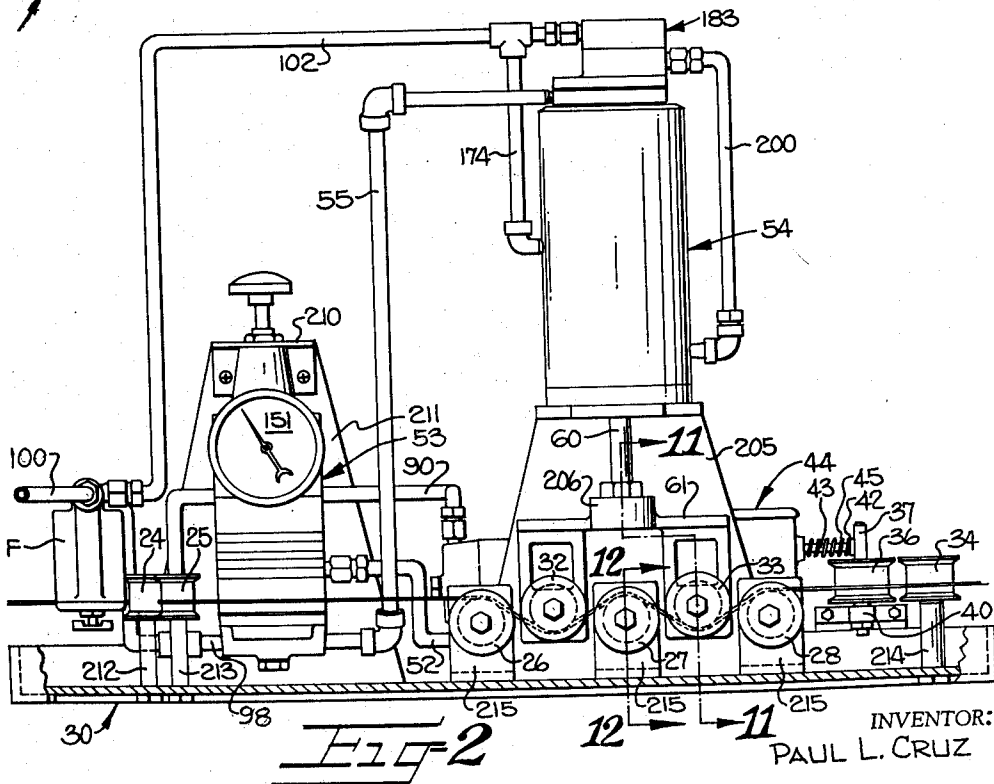
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TENSIONING APPARATUS FOR PLIABLE MATERIAL

Filed May 24, 1961

4 Sheets-Sheet 1



BY *Eaton, Bell, Hunt & Bell*

ATTORNEYS

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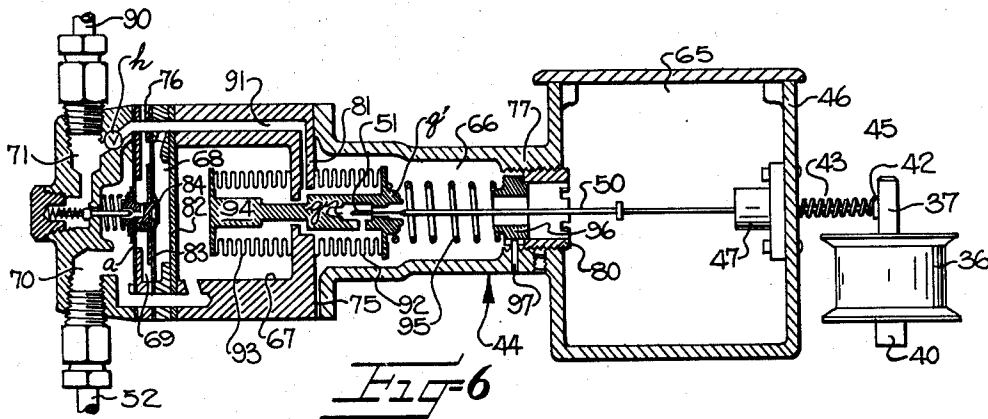
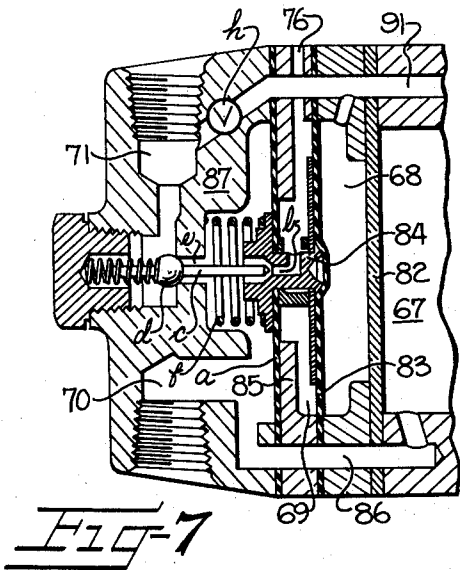
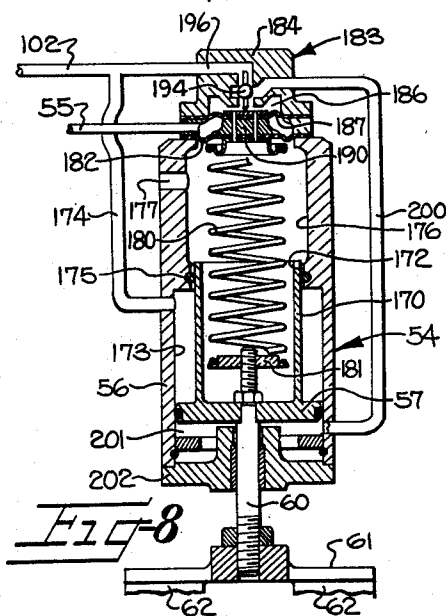
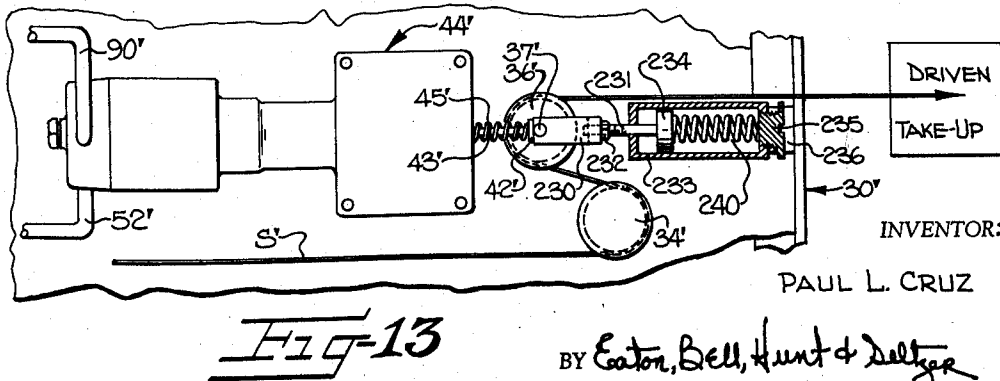
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TENSIONING APPARATUS FOR PLIABLE MATERIAL

Filed May 24, 1961

4 Sheets-Sheet 3



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TENSIONING APPARATUS FOR PLIABLE MATERIAL

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Filed May 24, 1961, Ser. No. 112,469
19 Claims. (Cl. 242—154)

This invention relates to apparatus for inducing and maintaining uniform tension in an indefinite length of strand, web or other pliable material, such as textile or metal strands, ropes, belts, fabrics, paper or plastic sheets, and the like.

It is a primary object of this invention to provide a tensioning apparatus capable of use with a wide range of sizes, shapes and weights of different pliable materials and capable of inducing and maintaining constant any of a wide range of different tensions in such pliable materials.

It is another object of this invention to provide an apparatus for maintaining tension in a moving pliable material of indefinite length comprising at least one first element and at least two spaced second elements straddling said first element, said first and second elements being engageable with opposite sides of the material to induce tortuosity in and apply friction to the material, and wherein actuator means is provided for varying the relative positions of said first and second elements independently of the tension in that portion of the material moving between said elements and thus serving to vary the tortuosity in and the friction applied to the material. A yieldable sensing element is spaced from said first and second elements and engageable by and biased by the material after it passes said first and second elements, and the sensing element is responsive to the tension in the material after it passes said first and second elements to cause said actuator means to vary the relative positions of said first and second elements whereby the tortuosity and friction induced in the material is varied in accordance with variations in the tension of the material leaving the first and second elements to maintain uniform tension in the material, without relying on the pressure of the material against the first and second elements for controlling the position thereof.

It is another more specific object of this invention to provide a tensioning apparatus including a device for applying frictional resistance to the movement of said material therethrough, which device includes means engaging substantially opposite sides of the material and causing the material to move in a tortuous path, with fluid-pressure-operated means operatively connected to the engaging means for varying the tortuosity of the material to vary proportionally the frictional resistance applied to the material. A movable sensing element is yieldably biased against the material after it passes said device, with means responsive to movement of said sensing device relative to an optimum position, at which optimum tension exists in the material, for varying fluid pressure in the fluid-pressure-operated means to an extent proportional to the movement of the sensing device to correspondingly vary the tortuosity of the material as it passes through said device and thereby vary the frictional drag or resistance to movement of the material therethrough.

It is another object of this invention to provide tensioning apparatus of the character described including means for applying a predetermined control point pressure to the fluid-pressure-operated means such that the sensing means must be biased a predetermined amount by the tension in the material in order to be in equilibrium with the frictional resistance applied thereto by the device so that said sensing device varies the pressure in the fluid

2

operated means relative to said control pressure with variation in the tension of the material above and below a predetermined optimum tension.

It is still another object of this invention to provide a tensioning apparatus of the character last described wherein means are provided for adjusting the control point pressure to thereby effect any of a wide range of optimum tensions in the moving pliable material.

Some of the objects of the invention having been stated, other objects will appear as the description proceeds, when taken in connection with the accompanying drawings, in which—

FIGURE 1 is a top plan view of a preferred embodiment of the improved tensioning apparatus;

FIGURE 2 is a side elevation of the apparatus of FIGURE 1 with portions of the base thereof broken away;

FIGURE 3 is a rear elevation looking at the left-hand side of FIGURES 1 and 2, with the base being shown in cross-section;

FIGURE 4 is a front or egress end elevation of the apparatus looking at the right-hand side of FIGURES 1 and 2;

FIGURE 5 is a schematic diagram of the preferred embodiment of the apparatus;

FIGURE 6 is a longitudinal sectional view taken substantially along line 6—6 in FIGURE 1 and showing a motion transmitter which converts mechanical movement of the sensing element into direct linear fluid pressure;

FIGURE 7 is an enlarged fragmentary view of the left-hand portion of FIGURE 6;

FIGURE 8 is a longitudinal vertical sectional view through an actuator or positioner for the friction applying device, and being taken substantially along line 8—8 in FIGURE 4;

FIGURE 9 is an enlarged fragmentary view of the upper portion of FIGURE 8;

FIGURE 10 is an enlarged somewhat schematic vertical and longitudinal sectional view through a controller for comparing a predetermined control point pressure with linear variations in pilot pressure effected by the motion transmitter for controlling the actuator in accordance therewith, and being taken substantially along line 10—10 in FIGURE 3;

FIGURE 11 is a fragmentary vertical sectional view taken along line 11—11 in FIGURE 2;

FIGURE 12 is a fragmentary vertical sectional view taken substantially along line 12—12 in FIGURE 2;

FIGURE 13 is a partially schematic view similar to the upper right-hand portion of FIGURE 5 and showing a second embodiment of the tension sensing device in association with the motion transmitter.

General Synopsis of the Invention

The present embodiment of the invention is shown as being particularly arranged for applying and maintaining uniform tension in a moving pliable element of indefinite length, which pliable element is shown in the form of a strand S drawn from a suitable source 20 by a suitable driven take-up mechanism 21 (FIGURE 5), with the friction applying device 22 and one embodiment of the sensing or detecting device 23 being serially arranged between source 20 and take-up mechanism 21. It is to be distinctly understood that the principles of the present invention may be readily adapted for applying and maintaining uniform tension in any type of pliable material of indefinite length in web or strand form.

The strand of pliable material S passes from source 20 successively partially around a pair of flanged guide pins or rollers 24, 25 to the friction applying device 22. Friction applying device 22 includes means contacting and producing a variable tortuous configuration in the

strand S passing therethrough and comprises a plurality of spaced, substantially parallel fixed pins or shafts 26, 27, 28, which are preferably fixed against rotation as well as being fixed with respect to the base or frame 30 of the tensioning apparatus.

A pair of laterally or vertically movable, preferably non-rotatable pins 32, 33 are provided which are so positioned as to be moved inwardly and outwardly or downwardly and upwardly in spaced intermeshing relation to and between the fixed pins 26, 27 and 28. Strand S passes between the upper and lower friction including pins 32, 33 and 26-28, from whence it passes partially around a roller 34. The pins 26-28, 32, 33, which may also be termed as friction applying elements, should have smooth arcuate surfaces engaging strand S and preferably the pins are circular in cross-section.

Roller 34 is offset forwardly with respect to a sensing element or roller 36 so as to form a loop in the strand S as it passes rearwardly from roller 34 and then substantially half-way around sensing roller 36, from whence the pliable material S passes forwardly to the take-up mechanism 21. Sensing roller 36 is journaled, on a shaft 37 fixed on the free end of a yieldable member, the first embodiment of which is shown in the form of a cantilever 40 suitably secured to a bracket 41 fixed to the base 30.

It will be observed in FIGURES 2, 4, 5 and 6 that the shaft 37, on which sensing roller 36 is mounted, is engaged by a follower 42 having a stem or shaft 43 extending therefrom. Follower 42 is a part of a motion transmitter broadly designated at 44 and may be pivotally or otherwise directly connected to the shaft 37 or the cantilever 40. It is preferred, however, that follower 42 is lightly urged into engagement with the rear surface of shaft 37, as by a compression spring 45, one end of which bears against follower 42 and the other end of which bears against the rear end of the housing 46 of motion transmitter 44. The motion transmitter may be of a type disclosed on opposite sides of a "Bulletin 1102A," copyrighted 1956, by Moore Products Co., H and Lycoming Streets, Philadelphia, Pennsylvania, for example.

Stem 43 is guided for longitudinal movement in a bearing 47 carried by housing 46 and has a longitudinally adjustable extension 50 on its inner end whose end opposite from stem 43 has a pilot valve 51 thereon which serves as a bleed-off valve. By means to be later described, pilot valve 51 is instrumental in converting any longitudinal mechanical movement of follower 42 into a given range of pilot air pressures, preferably of from 3 to 15 pounds per square inch gauge pressure. The range of pressure transmitted by motion transmitter 44 is in direct linear relationship with the range of movement of pilot valve 51 as effected by movement of the sensing roller 36.

The measured variable pilot pressure is transmitted from motion transmitter 44, through a pipe or conduit 52, to a controller broadly designated at 53. The controller 53 is a form of pressure relay into a portion of which a predetermined control point pressure is introduced and into another portion of which the variable pilot pressure from the motion transmitter is introduced. These pressures are compared to produce a signal pressure at the output of the controller 53.

The controller 53 operates in such a manner that, when pilot pressure is increased due to outward movement of the valve stem 43 in the motion transmitter of FIGURE 6, this increases the output signal pressure of the controller and, when the pilot pressure is decreased due to inward or right to left movement of the valve stem 43 in the motion transmitter, pressure escapes from the controller and is thus reduced at the output of the controller. The controller 53 may be of a type known as a "Nullmatic Controller-Model 55" disclosed in an instruction book No. SD 50-3, copyrighted 1958, by said Moore Products Company, for example.

The output side of controller 53 is connected to a control unit 183 of an actuator, broadly designated at 54, by a pipe or conduit 55. Actuator 54 is a form of air motor including a double-acting cylinder or housing 56 within which a piston 57 is positioned, and which piston has a piston rod or plunger 60 extending downwardly therefrom in FIGURES 2, 3, 4, 5 and 8. The cylinder 56 and piston 57 may be termed as relatively movable parts of actuator 54. The piston rod 60 has a bracket 61 adjustably secured on the lower end thereof. Bracket 61 has a pair of depending arms 62 thereon on which the vertically movable friction inducing or pressure pins 32, 33 are fixedly mounted. The actuator 54 may be of a type disclosed on pages 4 and 5 of a catalogue entitled "Annin Actuator Bulletin No. 1236ST," published by The Annin Company, 1040 South Vail Avenue, Montebello, California, for example.

The signal pressure transmitted to the actuator 54 from controller 53 controls the introduction and exhaust of compressed air from the main line into the cylinder 56 below the piston 57 in such a manner that any increase in the signal pressure transmitted from the controller 53 introduces high air pressure into cylinder 56 below piston 57 to cause piston 57 to move upwardly a distance determined by the signal pressure in pipe 55 and, upon any decrease in the pressure in pipe 55, air is exhausted from the lower end of cylinder 56 as high main line air pressure is effective above piston 57 to move piston 57 and piston rod 60 downwardly until the pressure exerted on a control element of the cylinder 56 is in equilibrium with the force exerted by the signal pressure from the output side of controller 53.

The control point pressure in controller 53 is pre-set such that the pull of strand S against sensing roller 36 must exert a predetermined amount of force such as to place the cantilever 40 under strain corresponding to the amount of tension to be maintained in the strand S when the entire fluid circuit is in equilibrium. When the entire fluid pressure circuit is in equilibrium, the movable friction applying pins 32, 33 occupy a predetermined intermeshing relationship with respect to the fixed pins 26-28 such as to maintain a frictional resistance to movement of the strand S through the friction applying device 22 which is in equilibrium with the amount of strain placed upon the cantilever 40 by the pull of the strand S against the sensing element 36.

Thus, upon any tendency for the tension in the strand S to be relaxed, such as to permit the sensing roller 36 to move rearwardly or from right to left in FIGURES 1, 5 and 6, the consequent inward or right to left movement of pilot valve 51 of FIGURE 6 produces a corresponding change or reduction in pilot pressure transmitted from the motion transmitter 44 through conduit 52 to controller 53. Thereupon, the controller compares the difference between the pre-established control pressure and the pilot pressure and correspondingly reduces the output signal pressure of controller 53. Consequently, the pressure in the control unit 183 of the cylinder 56 of actuator 54 is also reduced to exhaust air from the bottom of cylinder 56 as high main air pressure enters cylinder 56 above piston 57. This causes piston 57, piston rod 60 and movable friction applying pins 32, 33 to move downwardly in further intermeshing relationship to the fixed pins 26-28, thus increasing the frictional resistance to movement of the strand S through the friction applying device 22 to an extent such as to cause the sensing roller 36 to return to its optimum position due to the increased tension imparted to the strand S moving in engagement therewith.

Conversely, if the tension in strand S tends to become higher than the desired optimum tension, the vertically movable pins 32, 33 of friction applying device 22 move upwardly, because the stem 43 in transmitter 44 moves to the right with roller 36 and increases the pilot pressure transmitted from transmitter 44 to controller 53. Here again, the pilot pressure is automatically compared with

in conduits 100, 102, which pressure is preferably reduced to approximately 20 pounds per square inch gauge at the pressure regulator 99, this being a regulated supply pressure for the motion transmitter 44 and controller 53 which exceeds the maximum pilot pressure and signal pressure to be transmitted by the motion transmitter 44 and the controller 53.

Controller

As heretofore stated, controller 53 (FIGURES 1-5 and 10) is a form of relay which receives measured variable pilot pressures transmitted thereto through conduit 52 from motion transmitter 44 and these measured variable pilot pressures are compared with a pre-set control point pressure in the controller. The control point pressure is established so the movable friction applying pins 32, 33 and the plunger 60 and piston 57 of actuator 54 occupy pre-established positions relative to the fixed pins 26-28 when sensing roller 36 is biased to a predetermined position by the pull of the moving strand S thereagainst and the force of the pilot pressure is in balance with the control point pressure in controller 54. However, when there is any variation in the pilot pressure, due to fluctuations of the sensing roller effected by tendencies of the tension to vary in the strand S, such pilot pressure variations are compared with the control point pressure to effect corresponding changes in the signal pressure transmitted from the controller 53 to the control unit of the actuator 54.

The controller 53 includes a housing 107 of built-up construction which includes a control point setting regulator 110, a reset unit 111, a throttling unit 112, and a signal pressure unit 113. The housing 107 includes chambers 114-123. Chamber 114 is located in the control point setting regulator 110 and is vented to the atmosphere, as at 130. A manual adjustment screw 131, having a control knob 132 on its upper end, is threaded through the upper end of housing 107 and has a flanged spring seat 133 journaled on its lower end within chamber 114 and against which the upper end of a compression spring 134 is positioned.

The other or lower end of compression spring 134 bears against a built-up regulator base 135 which serves as a reinforcement for the central portion of a flexible diaphragm 136 mounted in housing 107 and serving to separate chambers 114, 115. The central portion of regulator base 135 bears against a nozzle seat plate 137 spaced above the corresponding portion of a lateral partition 140 which serves to separate chambers 115, 116.

A reduced lower portion of chamber 115 has a nozzle *i* therein which communicates with the atmosphere through a vent or port 141 formed in partition 140. The restricted upper end of nozzle *i* is adapted to be closed and opened by a throttling valve or nozzle seat *k* fixed to or formed integral with and depending from the central portion of nozzle seat plate 137. One side wall portion of housing 107 has a longitudinally extending passageway 142 therein which extends along partition 140 and communicates with chamber 115, at one end thereof. The other end of passageway 142 communicates with chamber 123.

The end of conduit 98 opposite from pressure regulator 99 is connected to housing 107 for communication with chamber 123. Thus, regulated supply pressure is admitted into chamber 123 and passageway 142. However, partition 140 has a reducing valve 143 therein which is interposed in passageway 142 so that the pressure admitted into chamber 115 may be substantially less than the regulated pressure admitted into chamber 123. Spring 134 in the control point regulator 110 is adjusted so as to constantly maintain a predetermined pressure in chamber 115, it being apparent that, when the pressure in chamber 115 exceeds the optimum desired control point pressure, diaphragm 136 and regulator base 135 move upwardly in FIGURE 11 and, since pressure is introduced into chamber 115 through passageway 142 at a point beneath the

nozzle seat plate 137, nozzle seat plate 137 also moves upwardly, raising throttling valve *k* out of engagement with nozzle *i* and permitting pressure to escape from chamber 115 through port 141.

Conversely, when the control point pressure in the chamber 115 is reduced below optimum pressure, the pressure of spring 134 against regulator base 135 is such that the regulator base 135 moves nozzle seat plate 137 and nozzle seat *k* into engagement with nozzle *i* to permit additional pressure to enter chamber 115 through passageway 142, thus completing the description of the control point setting regulator 110 of controller 53.

The chambers 116, 117 are separated by a transverse partition 144, and the chambers 117-120 are defined by spaced flexible diaphragms 145, 146, 147 which are interconnected by a built-up valve core *m*. It should be noted that the housing 107 is so constructed that the opposed sides of intermediate diaphragm 146 have substantially less effective surface area than opposed sides of the diaphragms 145, 147.

A diaphragm 116a is positioned in chamber 116 closely above partition 144. The space below diaphragm 116a is open to the atmosphere by a small passageway 116b in partition 144. Chamber 115 is in continuous communication with control point chamber 118 between the diaphragms 146, 145 by means of a conduit 150, to which conduit a suitable control point pressure indicating gauge 151 may be suitably connected. A pair of reducing valves 116c, 116d in partition 144 provides communication between passageway 142 and the bottom of chamber 116 and between chambers 116, 117, respectively.

The chambers 120, 121 are separated by a partition 152 having a nozzle 153 therein, whose restricted upper portion is positioned within a reduced lower portion of chamber 120, and which establishes communication between chambers 120, 121 whenever the lower end of valve core *m* is out of sealing engagement with nozzle 153 due to the control point pressure in chambers 115, 118 being greater than the pilot pressure in chamber 119. It should be noted that conduit 52 is connected to housing 107 for communication with chamber 119.

When the pilot pressure in chamber 119 tends to exceed control point pressure in chamber 118, diaphragms 145, 146, 147 and valve core *m* move downwardly to close the nozzle 153. Chambers 120, 122 are in continuous intercommunication through the medium of a passageway 155 formed in one side wall portion of housing 107.

A passageway *n* in partition 144 establishes continuous communication between chamber 117 and passageway 155, although a restricting valve *p* is shown interposed in the passageway *n*, which valve is manually controlled by a knob 156. Passageway 155 also communicates with chamber 116 through the medium of a manually operated restricting valve *q* which is controlled by a knob 157. However, since the chamber 116, diaphragm 116a and valves *p*, *q* are provided primarily for the purpose of delaying the action of diaphragms 145, 146, 147 in response to any sudden changes in the relative pressures in chambers 118, 119 and 120, which is not entirely necessary in the present embodiment of the invention, a detailed description of the function of valves *p*, *q*, diaphragm 116a valves 116c, 116d is deemed unnecessary.

To all intents and purposes, it is sufficient to state that the pressure in all the chambers 117, 120 and 122 and in passageway 155 is the same and is actually substantially equal to the signal pressure transmitted from chamber 122 to the control unit of actuator 54. It should be noted that conduit 55 is connected to housing 107 of controller 53 for communication with chamber 122. The signal pressure in chambers 120, 122 is varied relative to the control point pressure in direct relation to the pilot pressure in chamber 119.

The chambers 121, 122 are separated by a pair of closely spaced flexible diaphragms *r*, *s* defining an exhaust chamber *t* therebetween which is open to the atmosphere.

the pre-established control point pressure in controller 53 so that pressure is released from the output area of controller 53 and thus released from the control unit of actuator 54.

When pressure is released from the control unit of actuator 54, additional pressure enters cylinder 56 of actuator 54 below piston 57 to move piston 57, piston rod 60 and movable friction applying pins 32, 33 upwardly until the force exerted against the control unit 183 of actuator 54 is again in equilibrium with the force exerted by the signal pressure in the output side of controller 53, in conduit 55 and in the control unit 183 of actuator 54.

It is apparent that only very slight fluctuations of the sensing roller 36 may occur during travel of the strand or other pliable material through the tensioning apparatus and that, even though these fluctuations are caused by tendencies for the strand S to become slackened or over-tensioned, the biased cantilever 40 still maintains constant and uniform the tension in the strand S. This is due to the fact that the slightest movement of pilot valve 51 converts the linear mechanical movement of the follower 42 to a linear pressure change which is instantly compared with the control pressure and produces an instantaneous change in signal pressure in the control unit of actuator 54. This causes the movable pins 32, 33 of friction applying device 22 to move in such direction as to rectify any changes in the tension of the strand S and causes the sensing roller 36 to return to its optimum position under the pull of the loop formed of the strand S passing about the sensing element or roller 36.

It should be noted that the actuator 54 changes the position of pins 32, 33 with changes in signal pressure, but the pressure of pins 32, 33 against strand S may or may not be changed, since the pins 32, 33 simply vary the tortuosity of the strand to vary the angle of contact of the strand against pins 26-28, 32, 33 with consequent variation in the friction applied to the strand. Any increase or decrease in the pressure of pins 32, 33 against strand S is incidental and would generally occur during actual movement of pins 32, 33 relative to pins 26-28.

Motion Transmitter

The housing 46 of motion transmitter 44 is suitably secured to the base 30 rearwardly of the cantilever 40 and sensing roller 36, as will be later described.

The housing 46 of motion transmitter 44 is of hollow construction and is provided with a series of chambers 65-71 therein (FIGURES 6 and 7). The chamber 66 is open to the atmosphere by means of a vent or port 75 provided in the wall of chamber 66. The wall of chamber 69 also has a vent 76 open to the atmosphere. The chambers 65, 66 are separated by a restriction 77 in the wall of housing 46 and in which a tubular adjustment screw 80 is threadably mounted.

Chambers 66, 67 are separated by a partition 81 and chambers 67, 68 are separated by a partition 82. Chambers 68, 69 are separated by a flexible diaphragm 83 having a movable valve seat member 84 mounted in the central portion thereof. Chambers 69, 70 are separated by a partition 85 (FIGURE 7) through which valve seat member 84 loosely extends and which has a flexible diaphragm *a* connected thereto.

The left-hand portion of valve seat member 84 is connected to diaphragm *a* so the diaphragms 83 and *a* move in fixed relationship to each other. The valve seat member 84 is provided with a passageway *b* which provides communication between chambers 69, 70 when a needle valve *c* is out of engagement with valve seat member 84 for exhausting air from chambers 67 and 70 to the atmosphere through vent 76, it being noted that chambers 67 and 70 are connected by a passageway 86 so the pressure in both chambers 67, 70 is equal at all times. Needle valve *c* loosely extends through a partition 87 which separates chambers 70, 71.

A medial portion of needle valve *c* has a ball valve *d*

thereon which is normally yieldably urged or spring-pressed against a valve seat formed by a port or passageway *e* through partition 87. A compression spring *f* is positioned between valve seat member 84 and partition 87 and tends to urge member 84 away from needle valve *c*. The conduit 52 is connected to housing 46 of motion transmitter for communication with chamber 70, and a pipe or conduit 90 is connected to housing 46 for communication with air supply chamber 71. Conduit 90 is connected to a regulated supply pressure source, as will be later described, so that a pressure in excess of the maximum pressure transmitted by the motion transmitter is always present in supply chamber 71.

The portion of the wall of housing 46 of motion transmitter 44 adjacent compartments 67, 68, 70 has a passageway 91 therein which also extends inwardly within partition 81 and communicates with the interior of a pair of interconnected bellows 92, 93 disposed in the respective chambers 66, 67. The bellows 92, 93 are interconnected by a rigid core member 94. Core member 94 loosely extends through partition 81 and flanged opposite ends thereof are connected to the distal ends of bellows 92, 93.

The core member 94 has a chamber *g* therein which communicates with bellows 92, 93 and within which the pilot valve 51 is loosely positioned to serve as a bleed-off valve. The outer or right-hand end of chamber *g* is restricted, as at *g'*, and the adjacent end portion of the stem extension 50 is of reduced diameter relative to the diameter of pilot valve 51 so that movement of pilot valve 51 from left to right in FIGURE 6 further restricts and prevents the flow of air outwardly through restriction *g'*. Of course, inward or right to left movement of pilot valve 51 opens restriction *g'* so that a greater amount of air may pass outwardly therethrough and be bled to the atmosphere through the port 75 in the wall of housing 46.

It will be noted that passageway 91 also communicates with chamber 68 and supply chamber 71. However, the end of passageway 91 adjacent supply chamber 71 is provided with a throttling valve *h* so the pressure admitted into chamber 68 and bellow 92, 93 may be substantially less than the pressure admitted into supply chamber 71. Also, the pressure in chamber 68 and bellows 92, 93 is substantially less than the pressure in chambers 67, 70. It should be noted that passageway 91 is actually closed with respect to discharge port 76, and is shown extending through discharge port 76 only for purposes of clarity.

The core 94 within bellows 92, 93 is yieldably urged to the left in FIGURE 6, under relatively light pressure, by a compression spring 95, one end of which bears against the flanged right-hand or outer end of core 94, and the other end of which bears against a tubular spring seat or guide 96 which is keyed, as at 97, in the restriction 77 and is adjusted inwardly and outwardly by the adjustment screw 80.

As heretofore stated, a regulated pressure is introduced into the supply chamber 71 of motion transmitter 44. To this end, it will be observed in FIGURE 5, in particular, that conduit 90 is connected to a conduit 98, one end of which is connected to the controller 53 and the other end of which is connected to a manually operable pressure regulator valve 99 which serves to reduce the pressure transmitted to the controller 53 and the motion transmitter 44 from a main or high pressure pipe line or conduit 100 leading from a suitable source of compressed air or fluid pressure *P*.

A suitable filter *F* may be interposed in conduit 100 for removing any impurities or moisture from the air before its passage through pressure regulator 99. Also, a high pressure air line pipe or conduit 102 is connected to conduit 99 at a point between pressure regulator valve 99 and filter *F*, the other end of conduit 102 being connected to the actuator 54 in a manner to be later described.

The pressure source *P* preferably produces air pressure of approximately 100 pounds per square inch gauge

A suitable yieldable and porous member, such as a wire screen *u*, maintains diaphragms *r*, *s* in spaced relationship so these two diaphragms move in fixed relationship to each other. A flanged valve seat *v* penetrates and is suitably secured to the bottom diaphragms *s*, this valve seat being engageable and closable by a needle valve *w* which extends through a passageway *x* formed in a partition 160 separating chambers 122, 123.

The lower end of passageway *x* serves as a seat for a ball valve *y* formed integral with or secured to the stem of needle valve *w*. Ball valve *y* is normally urged to closed position by a relatively small, light compression spring *z* positioned in chamber 123. A passageway 161 is provided in partition 152 for establishing communication between passageway 142 and chamber 121. A suitable throttling or restricting valve 162 is positioned in passageway 161 so the pressure of the air in chamber 121 may be substantially less than the pressure in passageway 142. The operation of the controller 53 will be later described in conjunction with the operation of the actuator 54.

Actuator or Positioner

The actuator (FIGURES 1-5, 8 and 9) operates on the principle of application of a substantially constant high pressure to a small surface area at one side of a piston of a double-acting cylinder and application of a variable pressure against a substantially larger surface area at the other side of the piston, causing the piston to move in response to controlled variations in the amount of pressure applied against the larger surface area of the piston in opposition to the constant pressure applied to the relatively small area side of the piston.

As best shown in FIGURE 8, piston 57 of actuator 54 has a tubular portion 170, of lesser diameter than the piston 57, projecting upwardly therefrom and which moves in sealing engagement with a restriction 172 formed in a medial portion of cylinder 56, thus providing an annular chamber 173 above piston 57 into which pressure from the main line source *P* is constantly admitted through the medium of a conduit 174. A resilient annular seal 175 may be provided between tubular portion 170 and restriction 172. One end of a conduit 174 is connected to conduit 102 and the other end is connected to cylinder 56 for communication with chamber 173.

Since the tubular portion 170 of piston 57 is in sealing engagement with the restriction 172, it is apparent that the pressure in chamber 173 is effective upon a relatively small surface area of piston 57 as compared to the surface area of piston 57 which is exposed opposite from the tubular portion 170 thereof. The restriction 172 separates chamber 173 from a chamber 176 which is vented to the atmosphere, as at 177, and within which a compression spring 180 is positioned.

Plunger 60 is attached to piston 57, extends upwardly within tubular portion 170 and has a spring seat 181 adjustably mounted thereon, as by being threaded thereon. The lower end of spring 180 engages spring seat 181. The upper end of the chamber 176 of cylinder 56 is closed by a diaphragm 182 which is a part of actuator control unit broadly designated at 183 (FIGURES 8 and 9). Control unit 183 comprises a housing 184, of built-up construction, which is suitably secured to the upper end of cylinder 56 and serves to secure diaphragm 182 against the upper end of cylinder 56.

The housing 184 of control unit 183 is provided with a signal pressure chamber 185 and a venting chamber 186, the bottom of signal pressure chamber 185 being defined by diaphragm 182 and the top thereof being defined by a diaphragm 187 having lesser effective surface area than diaphragm 182. Diaphragm 187 also separates chambers 185, 186.

The central portions of diaphragms 182, 187 are separated by a spacing block 190 of greater diameter at its lower portion than at its upper portion. Block 190 is of

substantially lesser diameter than the opening at the upper end of cylinder 56 and the chamber 186, respectively. The diaphragms 182, 187 are suitably attached to respective upper and lower surfaces of spacing block 190, as by a plate or spring seat 192 and a plate 193. The upper end of spring 180 bears against spring seat 192. A reduced lower extension on a signal pilot valve 194, which serves as a bleed-off valve, engages the upper surface of plate 193.

Signal pilot valve 194 is positioned in a relatively small valve chamber 195 communicating with vent chamber 186 and defined at the juncture of a pair of passageways 196, 197 formed in the housing 184 of control unit 183. Conduit 102 is connected to control unit 183 for communication with passageway 196. A conduit or pipe 200 has one end thereof connected to control unit 183 for communication with passageway 197.

The other end of conduit 200 communicates with a chamber 201 defined in the bottom portion of cylinder 56 by the lower surface of piston 57 and a cylinder closure member 202 through which piston rod 60 extends. Vent chamber 186, and thus valve 194 communicating therewith is bled or vented to the atmosphere through one or more passageways *B* which extend through the plates 192, 193 and through the spacer block 190 between diaphragms 182, 187. The operation of actuator 54 and its control unit 183 will be later described.

Referring now to FIGURES 1, 2, 3 and 4, it will be observed that the closed lower end of cylinder 56 of actuator 54 is suitably secured to the horizontal upper portion of an inverted substantially L-shaped bracket 205 whose substantially vertical portion is suitably secured to and projects upwardly from base 30. Piston rod 60 loosely penetrates the horizontal upper portion of bracket 205 and is secured to a boss portion 206 integral with and projecting outwardly from bracket 61, so the center of plunger 60 may be substantially aligned with the center of pin 27.

Controller 53 may be suitably secured in fixed relation to the base 30 in any desired manner. In this instance, the upper end of housing 107 is fixed to an angle bracket 210 suitably secured to an upright plate 211 which projects downwardly and is suitably secured to base 30.

The rollers 24, 25 may be journaled or fixed on the upper ends of posts 212, 213, whose lower ends are suitably secured to base 30. The offset roller 34 also may be fixedly mounted or journaled upon the upper end of a post 214, whose lower end is suitably secured to base 30. In order to insure that the friction applying device 22 is effective to tension the pliable material *S*, particularly in instances in which relatively heavy tension is to be applied to the material *S*, it is desirable that the material *S* have some input tension therein, although such input tension may vary considerably and need not be controlled. Accordingly, rollers 24, 25 are preferably fixed on the upper ends of the posts 212, 213. Further, the rollers 24, 25 may be so positioned relative to each other that there is a greater angle of contact between material *S* and rollers 24, 25 than that shown in FIGURES 1 and 5, if desired, to increase the input tension of the material *S* entering the friction applying device 22.

In instances in which a relatively light output tension is to be applied to the strand as it leaves sensing device 23, it is apparent that the weight of the pliable material *S* may serve to induce sufficient input tension therein so the rollers 24, 25 may then be rotatably mounted on the posts 212, 213. Also, some input tension may be induced in the material at the source, since the source may be in the form of folds, layers or a roll of the pliable material, for example.

It is apparent that the base 30 of the apparatus must be secured in fixed relation to the driven take-up mechanism 21. Each stationary pin 26, 27, 28 is fixed to and

projects outwardly from the upright portion of a corresponding angle bracket 215 suitably secured to base 30 (FIGURE 12). It will be observed in FIGURE 11 that each pin 32, 33 is fixedly mounted on and extends outwardly from the bracket 61.

Method of Operation

As heretofore stated, the present tensioning apparatus may be used for applying tension to many different types of moving pliable materials of indefinite length and, for purposes of description, it is to be assumed that a tow or rope of synthetic filaments is to be drawn from a source at relatively little tension, say from $\frac{1}{2}$ to 1 pound tension, and is to have 15 pounds of tension applied thereto as it is taken up by the driven take-up mechanism, such as for the purpose of cutting the same into staple lengths, for example. It is to be further assumed that the pressure at pressure source P, which pressure may be produced by a suitable compressor, is approximately 100 pounds per square inch gauge and that pressure regulator 99 reduces this pressure to a regulated pressure of approximately 20 pounds per square inch gauge, this being the regulated pressure introduced into the supply chamber 71 of motion transmitter 44 (FIGURE 6) and the supply chamber 123 of controller 53 (FIGURE 10) through the respective conduits 90, 98.

In this example, it may be assumed that the valve *h* of FIGURE 6 reduces the pressure from supply chamber 71 to 1.5 pounds per square inch gauge in passageway 91, bellows 92, 93 and chamber 68, and that the pilot pressure in chambers 67, 70 of transmitter 44, pipe 52 and chamber 119 of controller 53 may vary from 3 to 15 pounds per square inch gauge.

Assume further that the average tortuosity required in the moving strand S is obtained when the control point setting regulator is adjusted to maintain a control point pressure of 10 pounds per square inch gauge in the chambers 115, 118 of controller 53, and that the pressure in the controller chambers 117, 120 and 122, and consequently the pressure in chamber 185 of the control unit 183 of actuator 54 may vary from 3 to 15 pounds per square inch gauge.

Now, in order for the entire pressure system or circuit to be in equilibrium, it is apparent that the pressure in the chambers 67, 70 of motion transmitter 44, and chambers 118, 119 of controller 53 must be equal to the control point pressure of 10 pounds per square inch gauge. Also, pressure in chambers 117, 120 and 122 of controller 53 and in chamber 185 of control unit 183 must be equal. Under equilibrium condition, the pressure level in chambers 67, 70, 118, 119 may or may not be equal to the pressure level in chamber 117, 120, 122 and 185, depending entirely upon the output tension inducing factors such as input tension and/or coefficient of friction between strand S and the pins 32, 33 and 26-28. Assuming that the free end of cantilever 40 is deflected .026 inch when the movable pins 32, 33 occupy the position in which they are shown in FIGURE 2 and the coefficient of friction between the pins 26-28 and 32, 33 and the strand S combined with the total angle of contact of the strand S with the pins is then such as to induce 15 pounds of tension in the moving strand S, this means that the pilot valve 51 is so positioned with respect to the restriction *g'* as to permit a predetermined amount of air to escape from the bellows 92, 93 through the restriction *g'* and outwardly through port 75 (FIGURE 6) such that the pilot pressure in chamber 70 applies an amount of left to right force to the relatively small area of diaphragms *a*, along with spring *f*, equal to the opposing force exerted on the relatively large surface area of diaphragm 83 by the pressure in chamber 68 so that that is a balance of forces within the motion transmitter 44.

Upon any tendency for the tension in the strand S to

increase, it is apparent that the deflection of cantilever 40 increases, permitting pilot valve 51 to move from left to right under the influence of spring 45 (FIGURE 6) and proportionally further restricting the outward flow of air from bellows 92, 93. Consequently, the pressure in chamber 68 increases, moving diaphragms 83 and *a* from right to left in FIGURE 7 to move valve seat 84 against needle valve *c* and close the same against the exhaust of air from chamber 70.

In so doing, valve seat 84 moves needle valve *c* and ball valve *d* from right to left, permitting air to flow from supply chamber 71 into chambers 70, 67 to increase the pressure in the latter chambers from said 10 pounds per square inch to, say, 11 pounds per square inch, for example. As the pressure increases in chamber 67, this pressure causes core 94 and bellows 92, 93 to move from left to right to again reduce the pressure within the bellows and chamber 68 to balance the forces of the pressure in chambers 70 and 68 acting upon diaphragms *a* and 83 and return the motion transmitter to a state of equilibrium while transmitting a pilot pressure of 11 pounds per square inch through conduit 52 to the chamber 119 of controller 53 (FIGURE 10).

Since the pressure in chamber 119 is then greater than control point pressure in chamber 118, and the pressures in chambers 117, 120 are each equal to the other, diaphragms 145, 146, 147 and valve core *m* move downwardly in FIGURE 10 to close nozzle 153 and thus increase the pressure in chamber 121 to such extent that the force applied against the upper surface of diaphragm *r* is greater than the opposing force applied against the diaphragm *s* by the signal pressure in chamber 122 and spring D.

It is apparent, therefore, that the valve seat *v* moves moves downwardly against needle valve *w*, moves ball valve *y* away from passageway *x*, and regulated air flows from supply chamber 98 through passageway *x* into chambers 122, 120 to increase the signal pressure in the latter chambers to, say, 11 pounds per square inch.

The increased signal pressure is transmitted to the chamber 185 (FIGURES 8 and 9) between diaphragms 182, 187 in control unit 183 through the medium of pipe 55. With an increase in pressure in chamber 185, since diaphragm 182 has a larger effective surface area than diaphragm 187, the diaphragms 182, 187, spacer 190 and plates 192, 193 move downwardly against spring 180. When plate 193 moves downwardly with the diaphragms 182, 187, signal pilot valve 194 moves downwardly therewith and establishes or increases communication between main air pipe 102 and pipe 200 through the medium of passageways 196, 197, thus increasing the pressure in chamber 201 beneath piston 57. This causes piston 57 to move upwardly, raise movable pins 32, 33 therewith, and increase the pressure exerted on the diaphragms 182, 187 by spring 180.

When piston 57 and movable pins 32, 33 move upwardly sufficiently to where the pressure of spring 180 exerts an upward force on the diaphragms 182, 187 which is equal to the force applied to the upper surface of diaphragm 182 by the signal pressure in chamber 185, the diaphragms 182, 187 move upwardly, raising plate 193 and valve 194 therewith and stopping the flow of air from pipe 102 into pipe 200 and chamber 201. As heretofore stated, the piston 57 moves upwardly with increased pressure in chamber 201 due to the relatively small area of the upper surface of piston 57 as compared to the lower surface thereof. The upward movement of piston 57 compresses the air in chamber 173 very slightly and this compression is merely absorbed in the pipe 102, 100 and pressure source P.

It is thus seen that the movable pins 32, 33 move upwardly or partially out of intermeshing relationship with fixed pins 26-28 to reduce the tortuosity in strand S, thus reducing the resistance to movement of the strand and the consequent tension in the strand so that the canti-

lever 40 and its sensing roller 36 return to the optimum position.

Now, when the sensing roller 36 returns to said optimum position, the entire fluid pressure circuit is returned to a state of equilibrium or steady state condition, because the pilot valve 51 moves inwardly or from right to left in FIGURE 6 relative to restriction g' to its original optimum position. The operation of the apparatus is then as follows:

(1) The exhaust of air from bellows 92, 93 increases. 10
(2) The pressure in bellows 92, 93 and chamber 68 of motion transmitter decreases.

(3) The valve seat 84 moves further away from needle valve c , permitting air to escape from chambers 67, 70 through port b , chamber 69 and exhaust port 76 and thus reducing pilot pressure therein. 15

(4) Pilot pressure is also reduced in pipe 52 and chamber 119 of controller 53 (FIGURE 11) to balance the same with the pressure in control point chamber 118.

(5) Balanced pressure in chambers 118, 119 then raises diaphragms 145, 146, 147 and valve core m to neutral position. 20

(6) Additional pressure released from chamber 121 through the then slightly open nozzle 153.

(7) Since pressure is reduced in chamber 121, the higher pressure then in chamber 122, along with spring D , raises valve seat v further away from needle valve w , permitting additional air to escape therethrough from chambers 122, 120 to the atmosphere. 25

(8) Signal pressure is reduced in chambers 120, 122, pipe 55 and chamber 185. 30

(9) Spring 180 of actuator 54 raises diaphragms 182, 187, spacer block 190 and plates 192, 193.

(10) Valve 194 raises to establish communication between passageway 197 and vent chamber 186, while at least partially restricting communication between passageways 196, 197, so that a balanced steady state condition exists between the forces applied by spring 180 and by piston 57 and the pressure within chamber 185, thus maintaining an equalizing pressure in conduit 200 and chamber 201. 35

It is apparent that, upon any tendency for the tension to decrease in the strand S , sensing roller 36 moves rearwardly or from right to left in FIGURES 1, 2, 5 and 6 as the deflection of cantilever 40 is reduced, thus causing pilot valve 51 to move further inwardly or from right to left in FIGURE 6 relative to the core 94. This will have substantially the same effect on the fluid pressure circuit as that which occurred when the cantilever 40 returned from an excessively deflected position to an optimum position. However, since less than the desired amount of deflection then exists in the cantilever 40, the pilot pressure in controller chamber 119 will then be less than the control point pressure in chamber 118, and this will result in a reduction in the signal pressure in chambers 120, 122 of controller 53, pipe 55 and chamber 185 of control unit 183. 40

As the pressure in chamber 185 is further reduced, spring 180 causes signal pilot valve 194 to move further upwardly, thus reducing or completely stopping the flow of air from pipe 102 into pipe 200 and permitting air to be exhausted from chamber 201 through pipe 200 into exhaust chamber 186, and thus through the passageways B , the chamber 175 and exhaust port 177 until the forces return to a state of equilibrium such that the valve 194 occupies an optimum position permitting the same amount of air to enter pipe 200 as may leave the same through exhaust chamber 186. Of course, when the pressure in chamber 185 was reduced in the manner last described, it is apparent that the force of the main line pressure in chamber 173 and the force of spring 180 on piston 57 then exceeded the force applied by the pressure in chamber 201 so that piston 57, plunger 60 and movable pins 32, 33 were moved downwardly and increased the tortuosity of and tension in strand S sufficiently to 45

return the sensing roller 36 and the free end of cantilever 40 to the optimum position.

It is apparent that all of these various pressure changes throughout the system act very quickly so that substantially simultaneously with any change in position of the sensing roller 36, a change is effected in the position of the movable pins 32, 33 to correspondingly vary the tortuosity of strand S and the tension thus induced therein.

It should be noted that, when the opposing forces acting upon the diaphragms a and 83 (FIGURE 7) by the pressures in chambers 70 and 68 of motion transmitter 44 are in equilibrium, the relationship of the needle valve c and ball valve d to the valve seat 84 and the passageway e is such that the exhaust of air through valve seat 84 from chamber 70 is equal to the inward flow of air from supply chamber 71 into chamber 70. This is also true with respect to the diaphragms 136, 145, 146, 147, r , s of FIGURE 10 and the diaphragms 182, 187 of FIGURES 8 and 9. 50

When the optimum or desired tension induced in the strand S is to be increased, the screw 131 of the control point setting regulator 110 of controller 53 (FIGURE 10) is adjusted to increase the pressure exerted by spring 134 against regulator base 135 so that a higher control point pressure must exist in chamber 115 in order to raise nozzle seat or throttle valve k out of engagement with the nozzle i . This increase in control point pressure in chamber 115 is also reflected in chamber 118 of the throttling unit of controller 53. 55

With an increase in control point pressure in chamber 118, the pressure therein becomes greater than it is in chamber 119 with the result that diaphragms 145-147 move upwardly along with valve core m . This releases pressure from chamber 121, permitting valve seat b to move upwardly and thus exhaust air from chambers 120, 122. In so doing, air is exhausted from chamber 185 in the control unit 183 of actuator 54 (FIGURES 8 and 9). It is apparent from the foregoing description of the operation of actuator 54 that this reduction in pressure in chamber 185 causes a reduction in pressure in chamber 201 below piston 57 so that spring 180 and the main line pressure in chamber 173 move piston 57, plunger 60 and pins 32, 33 downwardly to increase the tortuosity and tension in the strand S and cause the sensing roller 36 to occupy an optimum position in which greater deflection is imposed upon the cantilever 40 then was the case before the control point pressure was increased. 60

In so doing, pilot valve 51 will have moved from left to right in FIGURE 6, which, as heretofore stated, increases the pilot pressure in chambers 67, 70 of transmitter 44, pipe 52 and chamber 119 of controller 53. When the pressure in chambers 118, 119 is equalized, further increase in signal pressure in chambers 120, 122 is stopped and the entire fluid pressure circuit then operates in the same manner as that heretofore described with the exception that the tension induced in the strand S remains greater than it was in the first-described example. 65

In a third example, when the optimum tension in the strand S is to be decreased, control point pressure is reduced by turning screw 131 of the control point regulator 110 of controller 53 so as to decrease the pressure exerted by spring 134 against regulator base 135, thus decreasing the control point pressure in chambers 115, 118. Since the control point pressure in chamber 118 is then less than the pilot pressure in chamber 119, it follows from the foregoing description, that signal pressure in chambers 120, 122 of controller 53, in pipe 55 and in chamber 185 of the control unit 183 of actuator 54 is increased, causing diaphragms 182, 185 to move downwardly (FIGURES 8 and 9) and permitting additional pressure to enter chamber 201 in the lower end of cylinder 56. 70 75

Admission of additional pressure in chamber 201 of cylinder 56 raises movable pins 32, 33 to reduce the tortuosity of and tension in strand S. Thus, the deflection of cantilever 40 is decreased as the pull of the strand S against sensing roller 36 decreases and pilot valve 51 moves from right to left in FIGURE 6 relative to the core 94 within bellows 92, 93.

From the foregoing description, it is apparent that inward movement of pilot valve 51 relative to core 94 reduces the pilot pressure in chambers 67, 70 of motion transmitter 44, reduces the pressure in pipe 52, and reduces the pressure in chamber 119 of controller 53 to where it again equals the control point pressure in chamber 118 to maintain a higher pressure in chambers 120, 122, pipe 55 and chamber 185 (FIGURES 8 and 9) than was maintained in these chambers in the first example set forth herein.

It is thus seen that, with very little movement of the sensing roller 36 from right to left in FIGURES 5 and 6, such as to increase the length of the loop formed in the strand S passing thereabout, pilot pressure transmitted from motion transmitter 44 to controller 53 is decreased relative to control point pressure, causing a corresponding decrease in signal pressure transmitted from controller to chamber 185 of control unit 183 of actuator 54, thus decreasing the pressure in chamber 201 below piston 57 (FIGURE 8) and thereby increasing the intermeshing relationship of the pins 32, 33 with respect to the pins 26-28 and increasing the tortuosity of and tension in strand S.

It is seen further that, with the slightest movement of the sensing roller 36 from left to right in FIGURES 5 and 6, such as to reduce the size of the loop formed in the strand S passing thereby, pilot pressure transmitted from motion transmitter 44 to chamber 119 of controller 53 is increased, to cause a corresponding increase in signal pressure in chambers 120, 122 of controller 53, pipe 55 and chamber 185 of actuator control unit 183. This increases the pressure in chamber 201 below piston 57 and actuator 54 and reduces the intermeshing relationship between pins 32, 33 and pins 26-28, thus reducing the tortuosity of and tension in strand S to return the sensing roller 36 to its original optimum position.

It is apparent that, although the present embodiment of the present invention is particularly adapted for pneumatic operation, the motion transmitter, controller and actuator may be of types operated by hydraulic pressure, without departing from the spirit of the invention.

Second Embodiment of Sensing Device

The cantilever type of yieldable means for applying pressure to the sensing roller in opposition to the pull of the strand or other pliable material thereagainst is desirable from the standpoint of simplicity, ease of manufacture and installation, and the dimensions of the cantilever type of yieldable supporting means for sensing roller 36 may be easily calculated in order that its rate of deflection is directly proportional to the load or pressure applied thereto by the pull of the strand or other moving pliable material against the sensing roller. For example, one cantilever corresponding to the cantilever 40 was used in which deflection would start upon 5 pounds pressure being applied to the free end portion thereof, and said free end portion was deflected .078 inch upon 35 pounds pressure being applied thereto. Since the rate of deflection of the free end of the cantilever 40 was constant at least from zero deflection to .078 inch deflection, it follows that the free end of the cantilever was deflected .0026 inch with each additional pound of pressure applied thereto above 5 pounds.

Since there are instances in which the amount of tension induced in a moving strand or web of pliable material may be less than 5 pounds or substantially greater than 35 pounds, and might even be as much as 2,000 to 3,000 pounds, a second embodiment of means for apply-

ing yieldable pressure to the sensing roller, in opposition to the pull of the strand or web of pliable material, is shown in FIGURE 13 wherein those parts which are identical to or substantially the same as like parts shown in FIGURES 1 through 5 shall bear the same reference characters, with the prime notation added, in order to avoid repetitive description.

Referring to FIGURE 13, it will be observed that the shaft 37', on which sensing roller 36' is journaled, is fixed in a bifurcated block 230 which may be formed integral with a plunger 231, but is preferably threaded onto the free end of plunger 231 and locked in adjusted position by a nut 232. Follower 42' bears against bifurcated block 230. Plunger 231 slidably penetrates one end of an enclosure 233, shown in the form of a cylinder, and has a spring seat or piston 234 fixed on its inner end. The end of cylinder 233 opposite from that end through which plunger 231 extends is closed by an adjustment screw 235 threaded into cylinder 233.

The cylinder 233 is suitably secured to a bracket 236 which is suitably secured to the frame 30. A coil spring, in the form of a compression spring 240, is loosely positioned within cylinder 233, one end of which bears against piston 234 and the other end of which bears against screw 235 of cylinder 233. It is apparent that the size and type of the spring 240 may be varied, as desired, so that the pressure exerted by the spring 240 against the sensing roller 36' may be predetermined to apply any desired amount of tension to the moving pliable element or strand S'. Of course, the size of the spring may be readily calculated in order to obtain a given rate of deflection in accordance with the loads to be applied to the spring when certain variations in the tension of different strands or other pliable materials S' may be desired. Also, the pressure of spring 240 against piston 234 may be adjusted by adjusting screw 235.

It is apparent that the movable pins 32, 33 and/or the fixed pins 26-28 of the friction applying device 22 may be rotatably mounted, as may be desirable in tensioning plastic film materials or other materials which might be susceptible to damage due to the heat produced by frictional contact with a fixed pin or roll. Further, in the instance of any of the pins 26-28, 32, 33 being rotatably mounted, means may be provided for applying frictional resistance to rotation of such pins to provide further latitude in the selection of tensions to be applied to the material S, without departing from the spirit of the invention. Although the elements for applying tortuosity to the moving strand S are shown in the form of relatively small flanged pins, it is apparent that the principles of the present invention are also applicable wherein elongate rolls or shafts are used in place of the pins 26-28, 32, 33 so that the apparatus is readily adapted for applying predetermined uniform tension to moving web materials. In the latter instance, it may be desirable to support the pins 26-28 at each end thereof and to utilize two actuators, such as actuator 54, for supporting opposite ends of the movable pins 32, 33.

In instances in which relatively light tension is to be applied to the moving strand S, it is apparent that the two pins 26, 28 may be omitted, or a single one of the pins 32 or 33 may be used in combination with a corresponding pair of the pins 26-28. Further, if the tortuosity of and tension in the strand or other pliable material is to be increased beyond the capabilities of the three pins 26-28 and the two movable pins 32, 33 to do so, it is apparent that the number of fixed and movable pins may be increased without departing from the spirit of the invention.

In the drawings and specification there have been set forth preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of

limitation, the scope of the invention being defined in the claims.

I claim:

1. Apparatus for applying and maintaining uniform tension in a moving pliable material comprising a device for applying frictional resistance to the movement of said material therethrough, said device including means engaging substantially opposite sides of the material in a succession of spaced points along its path of travel and causing the material to move in a tortuous path, fluid-pressure-operated means including a first bleed-off valve operatively connected to said engaging means for varying the tortuosity of the material to vary proportionally the frictional resistance applied to the material, a movable sensing element engaging and forming a loop in said material after it passes said device, means for applying a predetermined control fluid pressure to said fluid-pressure-operated means such as to cause said engaging means to effect such tortuosity in the material that the frictional resistance so applied to the material induces an optimum tension therein, and means including a second bleed-off valve responsive to movement of said sensing element relative to an optimum position at which said optimum tension exists in the material for correspondingly varying the extent of bleed-off of pressure by said first bleed-off valve and to vary the pressure in said fluid-pressure-operated means with respect to said control fluid pressure.

2. In a structure according to claim 1; means for applying yieldable pressure to said sensing element in a direction tending to increase the size of the loop formed in said material, said last-named means comprising a bendable cantilever fixed at one end thereof in relation to said device, and said sensing element being carried by said cantilever at a point spaced from said one end thereof.

3. In a structure according to claim 1; means for applying yieldable pressure to said sensing element in a direction tending to increase the size of the loop in said material, and said last-named means comprising a coil spring operatively connected to and exerting pressure against said sensing element.

4. In a structure according to claim 3; means for adjusting said spring to vary the pressure exerted against said sensing element.

5. Apparatus for maintaining tension in a moving pliable material of indefinite length comprising at least one first pin, at least two spaced second pins straddling said first pin, said first and second pins being engageable with opposite sides of the material to induce tortuosity in and apply friction to the material, fluid-pressure-operated means including a first bleed-off valve for varying the relative positions of said first and second pins independently of the tension of the material moving between said second pins and serving to vary the tortuosity in and the friction applied to the material, a yieldable sensing element in spaced relation to said first and second pins and engageable by the material after it passes said first and second pins, means connecting said fluid-pressure-operated means to a source of fluid pressure, said sensing element being movable in response to variation in the tension in the material after it passes said first and second pins, and means including a second bleed-off valve interposed in said connecting means and being responsive to movement of said sensing element to vary the extent of bleed-off of pressure by said first bleed-off valve and to vary the pressure in said fluid-pressure-operated means to cause said first-named means to vary the relative positions of said first and second pins whereby the tortuosity and friction induced in the material is varied in accordance with variations in the tension of the material after it passes the first and second pins to maintain uniform tension in the material.

6. In an apparatus for tensioning a moving pliable material of indefinite length comprising a device for applying tension to the material, said device including at least one means engaging the moving material, and movable means operatively associated with said engaging

means for varying the tension applied to the material in accordance with the position of said movable means; the combination of fluid-pressure-operated means for imparting movement to said movable means and including first and second relatively movable parts, a yieldable sensing element engaging the material under yieldable pressure after it passes said engaging means, pressure converting means connected to a source of fluid pressure and including means responsive to movement of said sensing element for converting the pressure from said source to a measured pilot pressure varying in direct linear relation with the movement of said sensing element, means producing a predetermined control point pressure, means for comparing said measured pilot pressure with said control point pressure to produce a varying signal pressure corresponding to the comparison of said measured pilot pressure with said control point pressure, communicative means connecting said fluid-pressure-operated means to a source of fluid pressure, and means in said communicative means and being responsive to said varying signal pressure for varying the amount of fluid pressure effective in said fluid-pressure-operated means to cause relative movement between said first and second parts to thereby vary the position of said movable means such as to vary the tension applied to the material in response to variations in the position of said sensing element to maintain predetermined uniform tension in the material.

7. Apparatus for processing a moving pliable material of indefinite length comprising a device under control of the material, said device comprising fluid-pressure-operated means and including first and second relatively movable parts, a yieldable sensing element spaced from said relatively movable parts and engaging the material under yieldable pressure and being movable by engagement with the material, pressure converting means connected to a source of fluid pressure and including means movable with said sensing element for converting the pressure from said source to a measured pilot pressure varying in direct linear relation with the movement of said sensing element, means producing a predetermined control point pressure, means for comparing said measured pilot pressure with said control point pressure to produce a varying signal pressure corresponding to the comparison of said measured pilot pressure with said control point pressure, communicative means connecting said fluid-pressure-operated means to said source of fluid pressure, and means responsive to said varying signal pressure for varying the amount of fluid pressure effective in said fluid-pressure-operated means to cause relative movement between said first and second parts such as to vary the position thereof in response to variations in the position of said sensing element.

8. Apparatus for tensioning a moving pliable material comprising a device for applying frictional resistance to the movement of said material therethrough, said device including means engaging and imparting a tortuous configuration to the material and thereby applying frictional resistance to the movement of said material, fluid-pressure-operated means including a first bleed-off valve operatively connected to said engaging means, movable sensing means engageable by the material after it passes said device, means including a second bleed-off valve operatively interconnecting said first bleed-off valve and said sensing means and varying the extent of bleed-off pressure by said first bleed-off valve, said sensing means being responsive to the tension in the pliable material after passing said device for controlling said second bleed-off valve whereby the pressure in said fluid-pressure-operated means is varied by said first bleed-off valve in accordance with variations in the position of said sensing means caused by variations in the tension of the material, and said fluid-pressure-operated means being operable to vary the tortuosity of the material and the consequent frictional resistance to movement thereof in accordance with the pressure admitted to said fluid-pressure-oper-

ated means to maintain a uniform tension in the pliable material at all times.

9. Apparatus for applying and maintaining uniform tension in a moving pliable material comprising a device for applying frictional resistance to the movement of said material therethrough, said device including a plurality of pins engaging substantially opposite sides of the material and causing the material to move in a tortuous path, fluid-pressure-operated means including a first bleed-off valve operatively connected to said pins for varying the tortuosity of the material and the angle of contact of the material with said pins to vary proportionally the frictional resistance applied to the material, a movable sensing element engaging and forming a loop in said material after it passes said device, means for applying a predetermined yieldable force to said sensing means in opposition to the pull of the material thereagainst, means for applying a predetermined control point pressure to said fluid-pressure-operated means such as to cause said pins to effect such tortuosity in the material that the frictional resistance so applied to the material induces an optimum tension therein, and means including a second bleed-off valve responsive to movement of said sensing element relative to an optimum position at which said optimum tension exists in the material for correspondingly varying the extent of bleed-off of pressure by said first bleed-off valve and to vary the pressure in said fluid operated means with respect to said control point pressure.

10. Apparatus for tensioning a moving pliable material of indefinite length comprising first and second spaced means engaging opposite sides of the material and thus applying friction to the material, a fluid-pressure-operated actuator including a piston and a cylinder, means connecting said first engaging means in fixed relation to said piston, means applying a yieldable force against one side of said piston, a sensing element operatively connected to said actuator and engageable by the material after it passes said first and second engaging means, said sensing element being movable in response to variations in the tension in the material after it passes said first and second engaging means, means applying a predetermined opposing pressure against said piston in a direction opposite from said yieldable force when said sensing element occupies a predetermined optimum position and said material is under a consequent predetermined tension, and means responsive to movement of said sensing element in either direction relative to said optimum position for varying the opposing pressure applied to said piston relative to said predetermined opposing pressure to thereby change the position of said first engaging means relative to the second engaging means whereby the friction induced in the material by the first and second engaging means is varied in accordance with variations in the tension of the material after it passes the first and second engaging means to maintain uniform tension in the material.

11. Apparatus for tensioning a moving pliable material of indefinite length comprising a device for applying frictional resistance to the movement of said material therethrough, said device including first and second pin means engaging opposite sides of the material and imparting a tortuous configuration thereto, a fluid-pressure-operated actuator including a fixed part and a movable part, means connecting said first pin means in fixed relation to said movable part, means applying a predetermined fluid pressure to said movable part in one direction and thereby tending to move said first pin means in said one direction relative to said second pin means, a movable sensing element operatively connected to said actuator, said sensing element being adapted to engage and form a loop in said material after it passes said device, means for applying a predetermined, yieldable force to said sensing means in opposition to the

pull of the material thereagainst whereby said material passes said sensing element under tension after it passes said device, means applying a predetermined opposing fluid pressure force to said movable part of said actuator in the opposite direction from that in which said first-mentioned predetermined fluid pressure is applied, and means responsive to variations in the position of said sensing element due to changes in the tension in said material to vary the opposing fluid pressure force applied to said movable part in direct linear relationship to the movement of said sensing element and to thereby vary the position of said first pin means relative to the second pin means whereby the tortuosity and friction induced in the material is varied in accordance with variations in the tension of the material leaving the first and second pin means to maintain uniform tension in the material.

12. Apparatus for tensioning a moving pliable material of indefinite length comprising an actuator connected to a source of fluid pressure, a sensing element engaging and being movable in response to variations in the tension of said material, pressure converting means connected to said source and including means movable with said sensing element for converting said fluid pressure to a reduced pilot pressure varying in direct linear relation with the movement of said sensing element, a controller including first, second and third pressure chambers, manually adjustable means for maintaining a predetermined control point pressure in said second chamber, communicative means for transmitting pilot pressure from said converting means to said first chamber, means responsive to variations in the pilot pressure in said first chamber relative to the control point pressure for producing a concurrently varying signal pressure in said third chamber, said actuator comprising a fixed part and a movable part, first and second relatively staggered pin means engageable with opposite sides of and inducing tortuosity in the material in advance of said sensing element, means operatively connecting said first pin means to said movable part so said first pin means may move inwardly and outwardly relative to said second pin means, means applying a continuous yieldable force against one side of said movable part, valve means interposed between said pressure source and said actuator for directing fluid pressure against said other side of said movable part, and means responsive to variations in said signal pressure for controlling said valve means to vary correspondingly the pressure against said other side of said movable part whereby the position of said first pin means is varied to vary the tortuosity of and friction applied to said material in response to variations in the position of said sensing element to maintain uniform tension in the material.

13. Apparatus for tensioning a moving pliable material of indefinite length comprising a device for applying frictional resistance to the movement of the material therethrough, said device including first and second relatively movable friction applying means engageable with opposite sides of the material, fluid-pressure-operated means for imparting relative movement to said first and second friction applying means including first and second relatively movable parts, a yieldable sensing element engaging the material under yieldable pressure and forming a loop therein after it passes said friction applying means, pressure converting means connected to a source of substantially constant fluid pressure and including means movable with said sensing element for converting said substantially constant pressure to a measured pilot pressure varying in direct linear relation with the movement of said sensing element, means producing a predetermined control point pressure, means for comparing said measured pilot pressure with said control point pressure to produce a varying signal pressure corresponding to the comparison of said measured pilot pressure with said control point pressure, communicative means connecting said fluid-pressure-operated means to said source of fluid pres-

sure, and means in said communicative means and being responsive to said varying signal pressure for varying the amount of fluid pressure effective in said fluid-pressure-operated means to cause relative movement between said first and second parts and said first and second friction applying means such as to vary the frictional resistance applied to the material in response to variations in the position of said sensing element to maintain predetermined uniform tension in the material.

14. Apparatus for tensioning a moving pliable material of indefinite length comprising a device for applying frictional resistance to the movement of the material there-through, said device including first and second relatively movable and relatively staggered friction applying pins engageable with opposite sides of the material and causing the same to move in a tortuous path, fluid-pressure-operated means for imparting relative movement to said first and second friction applying pins including first and second relatively movable parts, a yieldable sensing element engaging the material under yieldable pressure and forming a loop therein after it passes said friction applying means, pressure converting means connected to a source of substantially constant fluid pressure and including means movable with said sensing element for converting said substantially constant pressure to a measured pilot pressure varying in direct linear relation with the movement of said sensing element, means producing a predetermined control point pressure, means for comparing said measured pilot pressure with said control point pressure to produce a varying signal pressure corresponding to the comparison of said measured pilot pressure with said control point pressure, communicative means connecting said fluid-pressure-operated means to said source of fluid pressure, and means in said communicative means and being responsive to said varying signal pressure for varying the amount of fluid pressure effective in said fluid-pressure-operated means to cause relative movement between said first and second parts and said first and second friction applying pins such as to vary the frictional resistance applied to the material in response to variations in the position of said sensing element to maintain predetermined uniform tension in the material.

15. Apparatus for tensioning a moving pliable material of indefinite length comprising an actuator connected to a source of fluid pressure, a sensing element engaging and being movable in response to variations in the tension of said material, pressure converting means connected to said source and including means movable with said sensing element for converting said fluid pressure to a reduced pilot pressure varying in direct linear relation with the movement of said sensing element, a controller including first, second and third pressure chambers, manually adjustable means for maintaining a predetermined control point pressure in said second chamber, communicative means for transmitting pilot pressure from said converting means to said first chamber, means responsive to variations in the pilot pressure in said first chamber relative to the control point pressure for producing a concurrently varying signal pressure in said third chamber, said actuator comprising a fixed part and a movable part, first and second friction applying means engageable with opposite sides of any applying frictional resistance to movement of the material in advance of said sensing element, means operatively connecting said first friction applying means to said movable part so said latter means may move inwardly and outwardly relative to said second friction applying means, means applying a continuous yieldable force against one side of said movable part, valve means interposed between said pressure source and said actuator and being arranged to direct fluid pressure against said other side of said movable part, and means responsive to variations in said signal pressure for controlling said valve means to vary correspondingly the

pressure against said other side of said movable part whereby the position of said first friction applying means is varied to vary the tortuosity of and friction applied to said material in response to variations in the position of said sensing element to maintain uniform tension in the material.

16. Apparatus for tensioning a moving pliable material of indefinite length comprising a motion transmitter, a controller and an actuator connected to a source of substantially constant fluid pressure, a sensing element engaging and being movable in response to variations in the tension of said material, means in said transmitter movable with said sensing element for converting said constant fluid pressure to a pilot pressure varying in direct linear relation with the movement of said sensing element, said controller including a first chamber, a second chamber and a third chamber, means for maintaining a predetermined control point pressure in said second chamber, communicative means for transmitting pilot pressure from said transmitter to said first chamber, means responsive to variations in the pressure in said first chamber relative to the control point pressure for producing a concurrently varying signal pressure in said third chamber, said actuator comprising a fixed part and a movable part, said movable part having a lesser effective surface area on one side thereof than that on the other side thereof, first and second friction applying means engageable with opposite sides of the material in advance of said sensing element, means operatively connecting said first friction applying means to said movable part so said first friction applying means may move inwardly and outwardly relative to said second friction applying means, said actuator being so connected to the pressure source that continuous yieldable fluid pressure is applied against said one side of said movable part, valve means connecting said source to said actuator for directing fluid pressure against said other side of said movable part, and means responsive to variations in said signal pressure for controlling said valve means to vary proportionally the pressure against said other side of said movable part whereby the position of said first friction applying means is varied to vary the friction applied to said material in response to variations in the position of said sensing element and thereby to maintain uniform tension in the material.

17. Apparatus for tensioning a moving pliable material of indefinite length comprising a motion transmitter, a controller and an actuator connected to a source of substantially constant fluid pressure, a sensing element engaging and being movable in response to variations in the tension of said material, means in said transmitter movable with said sensing element for converting said fluid pressure to a reduced pilot pressure varying in direct linear relation with the movement of said sensing element, said controller including a pilot pressure chamber, a control point pressure chamber and a signal pressure chamber, means for maintaining a predetermined control point pressure in said control point pressure chamber, communicative means for transmitting pilot pressure from said transmitter to said pilot pressure chamber, means responsive to variations in the pressure in said pilot pressure chamber relative to the control point pressure for producing a concurrently varying signal pressure in said signal pressure chamber, said actuator comprising a fixed part and a movable part, said movable part having a lesser effective surface area on one side thereof than that on the other side thereof, first and second relatively staggered pin means engageable with opposite sides of and inducing tortuosity in the material in advance of said sensing element, means operatively connecting said first pin means to said movable part so said first pin means may move inwardly and outwardly relative to said second pin means, said actuator being so connected to the pressure source that continuous sub-

stantially uniform pressure is applied against said one side of said movable part, valve means connecting said source to said actuator for directing fluid pressure against said other side of said movable part, and means responsive to variations in said signal pressure for controlling said valve means to vary the pressure against said other side of said movable part whereby the position of said first pin means is varied to vary the tortuosity of and friction applied to said material in response to variations in the position of said sensing element to maintain uniform tension in the material.

18. Apparatus for tensioning a moving pliable material of indefinite length comprising a pneumatic actuator connected to a source of air under substantially constant pressure, a sensing element engaging and being movable in response to variations in the tension of said material, pressure converting means connected to said source and including means movable with said sensing element for converting said air under pressure to a pilot air pressure varying in direct linear relation with the movement of said sensing element, a controller including first, second and third spaced diaphragms defining first, second and third pressure chambers, a valve core carried by an interconnecting said diaphragms, manually adjustable means for maintaining a predetermined control point air pressure in said second chamber, communicative means for transmitting pilot air pressure from said converting means to said first chamber whereby said diaphragms move in one direction when the pilot pressure is less than the control point pressure and in the opposite direction when the pilot pressure is greater than the control point pressure, means responsive to movement of the valve core with the diaphragms for producing a varying signal pressure in said third chamber, said actuator comprising first and second relatively movable parts, first and second relatively movable means engageable with opposite sides of and applying frictional resistance to the movement of the material in advance of said sensing element, means operatively connecting said first movable means to said first movable part, means applying a continuous yieldable force against one side of one of said relatively movable parts, valve means interposed

between said pressure source and said actuator for directing air pressure against the other side of said one of said movable parts, and means responsive to variations in said signal pressure for controlling said valve means to vary correspondingly the air pressure against said other side of said one of said movable parts whereby the relative positions of said first and second means are varied to vary the friction applied to said material in response to variations in the position of said sensing element to maintain uniform tension in the material.

19. Apparatus for applying and maintaining uniform tension in a moving pliable material comprising a tensioning device including at least one means engaging the moving material and movable means operatively associated with said engaging means for applying tension to the material varying in accordance with the position of said movable means, fluid-pressure-operated means including a first bleed-off valve operatively connected to said movable means to vary the position thereof relative to said engaging means to thereby vary the tension applied to the material, a movable sensing means engaging said material after it passes said tensioning device, means for applying a predetermined control pressure to said fluid-pressure-operated means so as to cause said movable means to effect a predetermined frictional resistance to the movement of the material and induce an optimum tension therein, and means including a second bleed-off-valve responsive to movement of said sensing means relative to an optimum position at which said optimum tension exists in the material for correspondingly varying the extent of bleed-off of pressure by said first bleed-off valve and to vary the pressure in said fluid-pressure-operated means with respect to said control pressure.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,072,360

January 8, 1963

Paul L. Cruz

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 6, for "adjusing" read -- adjusting --;
column 6, line 66, for "inteposed" read -- interposed --; column
7, line 51, for "atmospehre" read -- atmosphere --; column 8,
line 2, for "enagement" read -- engagement --; line 62, before
"valves" insert -- and --; column 9, line 10, for "intregal"
read -- integral --; column 10, line 35, for "intergal" read
-- integral --; column 11, line 73, for "that" read -- there --;
column 13, line 14, for "vlave" read -- valve --; column 16,
line 59, for "pins 32. 33." read -- pins 32, 33. --; column 21, line 63,
for "any" read -- and --; column 23, line 24, for "an" read
-- and --.

Signed and sealed this 9th day of July 1963.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents