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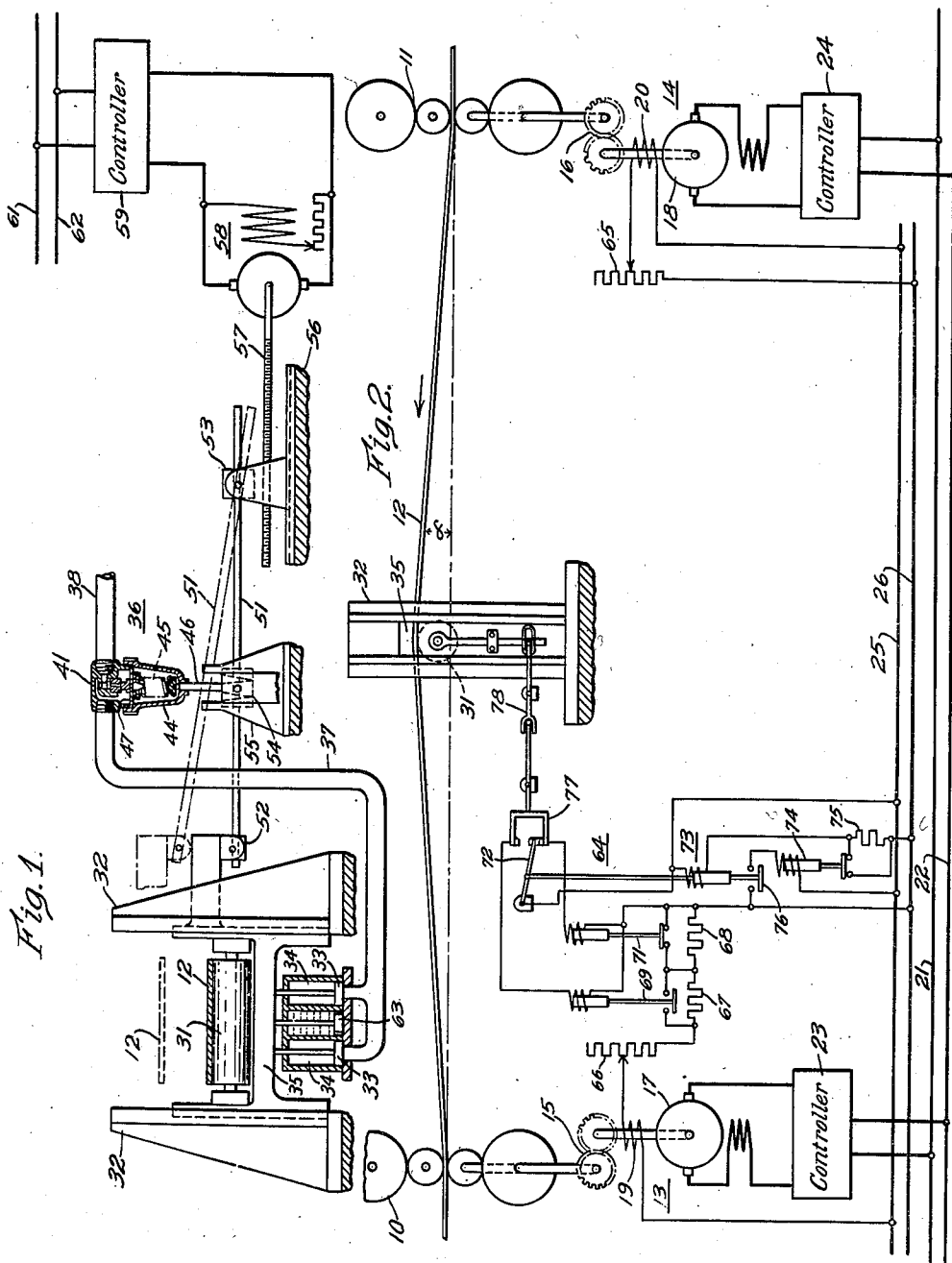
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2,221,592

TENSION CONTROL SYSTEM

Filed March 27, 1937

2 Sheets-Sheet 1



WITNESSES:

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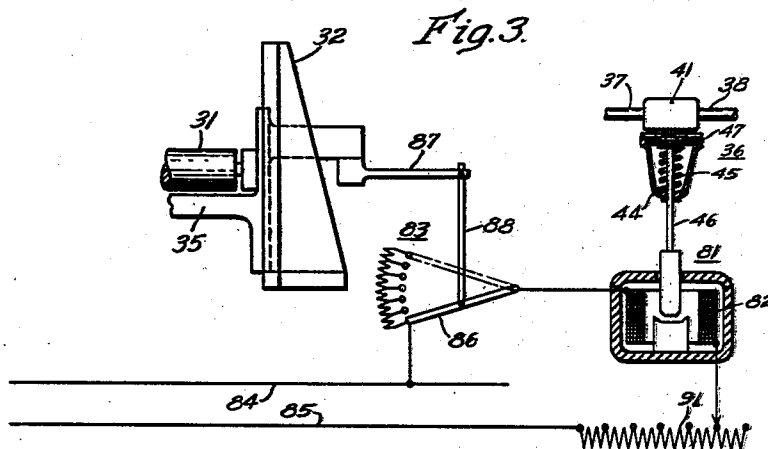
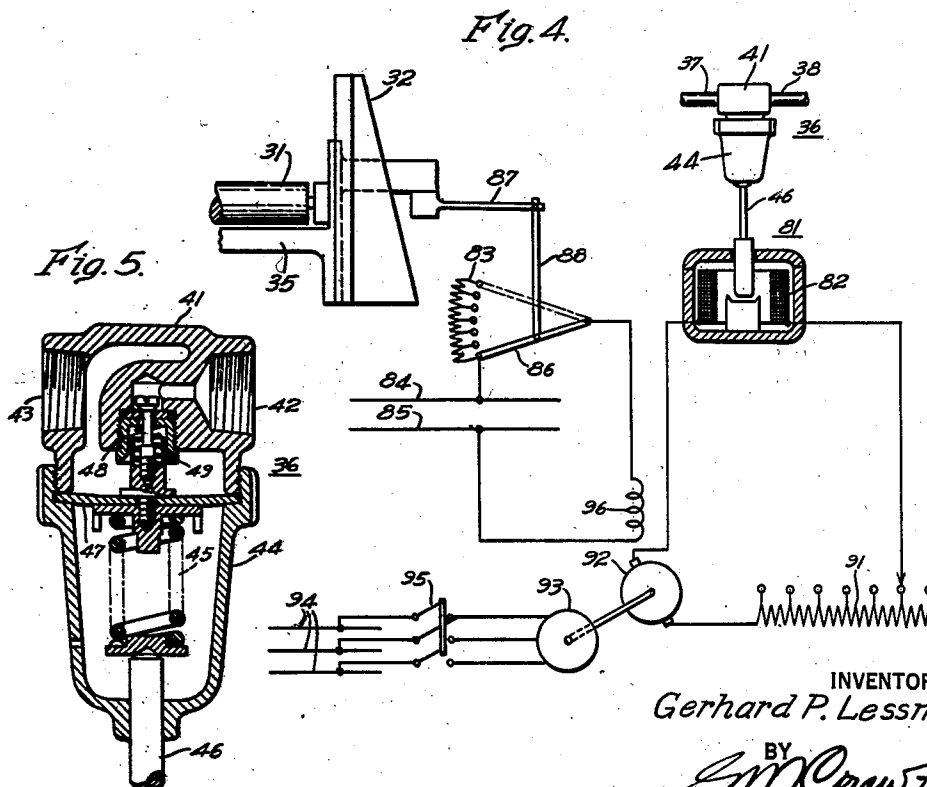
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2 Sheets-Sheet 2



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TENSION CONTROL SYSTEM

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Application March 27, 1937, Serial No. 133,418

21 Claims. (Cl. 80—35)

My invention relates, generally, to tension control systems and, more particularly, to fluid-pressure operated tensiometers for automatically maintaining a predetermined tension on the material being worked upon or handled by a plurality of work devices, such, for example, as between the rolls of a tandem or continuous mill.

Numerous methods have been proposed for maintaining a predetermined constant tension on the material extending between the rolls of a tandem mill. One prior method is to attempt to control the tension on the material by causing the motors driving the roll stands to assume a load somewhat greater than that required to actually reduce the material as it is passed through the rolls, the excess load being the tension load. This method has been found to be inadequate because of the difficulty of determining and controlling the amount of tension that is being applied, since the amount of power required for working the material may vary from time to time, thereby causing the tension to vary and it is difficult, if not impossible, to determine what percentage of the total motor load is being used to produce tension. Another method, previously utilized, is to subject the material to a tension by means of an idler roller mechanism disposed to apply a force transverse to the path of movement of the material which varies in accordance with the degree of deflection of the material between predetermined limits of movement. Compensation for variation in the degree of deflection of the material from its normal path of travel is provided by mounting the idler roller on a bell crank device having an angle between its arms which causes the tensioning device to be self-compensating over a certain range of operation and permits a limited amount of movement of the idler roller, resulting from variations in the length of material between roll stands, without appreciably changing the tension on the material. However, the range of operation over which devices of this character are self-compensating is relatively small and their application is limited to rolling mills in which the position of the idler roller does not vary over a wide range.

Therefore, an object of my invention, generally stated, is to provide a means for controlling and maintaining tension on translatable material being worked which shall overcome the foregoing disadvantages of prior systems and which may be economically manufactured and installed.

A more specific object of my invention is to

provide for maintaining a predetermined tension on translatable material over a wide variation in the position of the material from its normal path of movement.

Another object of my invention is to provide for continuously increasing the tension on a strip of material as it passes through the roll stands of a rolling mill.

A further object of my invention is to maintain tension on material passing between work devices by means of a device for applying a transverse deflecting force to the material and utilizing the movements of the force-applying device for maintaining the length of the material between the work devices within predetermined limits.

Other objects of my invention will be described fully hereinafter or will be apparent to those skilled in the art.

In accordance with one embodiment of my invention, which may be applied to a rolling mill where it is desired to maintain a predetermined tension on the material between any two roll stands, the material is subjected to a transverse force at a point between the roll stands by means of an idler roller which is raised by fluid-pressure operated pistons. In order to maintain a certain tension with various positions of the roll, the pressure in the cylinders containing the pistons which actuate the idler roller is so regulated that the pressure increases as the roller is raised, that is, for each position of the roller a definite pressure may be maintained. If desired, the tension on the material may be continuously increased as it passes through the rolls in order to compensate for the difference in temperature between the head of the sheet and the end of the sheet.

For a fuller understanding of the nature and objects of the invention, reference may be had to the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of a portion of a rolling mill embodying my invention;

Fig. 2 is another diagrammatic view of the embodiment of the invention illustrated in Fig. 1;

Fig. 3 is a diagrammatic view of a modification of the invention;

Fig. 4 is a diagrammatic view of another modification of the invention, and

Fig. 5 is a view, in section, of a regulating valve utilized in the invention.

Referring now to the drawings, and particularly to Fig. 2, the portion of the rolling mill

shown comprises roll stands 10 and 11 through which a strip of material 12, such as sheet steel, is passed. The roll stands 10 and 11 may be driven in any suitable manner, as by means of

motors 13 and 14, respectively, which are connected to their respective roll members through gear sets 15 and 16.

The roll motors 13 and 14 are provided with armature windings 17 and 18 and separately excited field windings 19 and 20, respectively. The armature windings may be energized from any suitable source of direct-current power (not shown) through conductors 21 and 22, the motors 13 and 14 being connected thereto by controllers 23 and 24, respectively. The field windings 19 and 20 are energized from power conductors 25 and 26, as will be explained more fully herein-after.

In order to provide for maintaining a predetermined tension on the material 12, there is utilized a tensioning device for exerting a transverse deflecting force on the material between the roll stands 10 and 11. If a deflecting force is applied to the material 12 midway between the two stands so as to move it from the plane of the straight pass line extending between the roll stands to a deflected position, the tension on the material will be a function of the sine of the angle of deflection alpha and the tension will remain substantially constant so long as the strip is maintained in this position under a constant force.

However, if the length of the material between roll stands increases and the same constant deflecting force is applied, the angle of deflection becomes greater and, therefore, the tension on the material is reduced. The opposite is true in the event that the length of the material between the roll stands decreases, thereby causing the tension on the material to increase.

In view of the foregoing, it will be understood that in order to maintain a predetermined tension on the material, provision must be made for not only maintaining the tensioning means which applies the force to the material as nearly as possible in a certain position, but provision must also be made for causing a variation to occur in the amount of force produced by the tensioning means depending upon the degree of deflection of the material from its normal path of travel. In general, the pressure characteristic must be such that the pressure increases with increasing height of the material above the pass line.

In the present invention, this result is accomplished by utilizing a tensioning device which comprises an idler roller 31 disposed to move up and down vertically in a pair of guides 32 between which the material 12 passes. The roller may be raised by a pair of fluid-pressure operated pistons 33 disposed in cylinders 34, located underneath the idler roller crosshead 35. In order to maintain a predetermined tension for various positions of the roll 31, the pressure in the cylinders 34 is so regulated that the pressure increases as the roll is raised. It will be understood that the weight of the idler roller 31 and crosshead 35 may be counter-balanced by suitable weights or springs or other well known devices.

The foregoing regulation may be accomplished by utilizing a regulating valve, shown generally at 36, to so vary the pressure ratio from inlet to outlet that with a constant inlet pressure a varying outlet pressure may be obtained. The outlet of the regulating valve 36 is connected to the

cylinders 34 by means of a pipe 37 and the inlet of the valve may be connected to an air pressure tank (not shown) by means of a pipe 38. If desired, other suitable working mediums, such as any other gas or a liquid, may be utilized in place of air.

The construction of the regulating valve 36 is illustrated in detail in Fig. 5. The regulating valve comprises a body 41 provided with an inlet opening 42 and an outlet opening 43 which may be connected respectively to the supply line 38 and the line 37 leading to the fluid pressure operated pistons 33. The body 41 is provided with a spring cover 44 that houses a compression spring 45, the compression of which may be varied by means of a plunger 46. As shown, the spring 45 is disposed to control the position of a diaphragm 47 which, in turn, controls the operation of a valve 48. The compression of the spring 45 is adjusted in accordance with the pressure it is desired to maintain through the outlet opening 43. Air is admitted through the inlet opening 42 past the valve 48 until the pressure within the body 41 as applied to the diaphragm 47 is sufficient to overcome the compressive force of the spring 45. The diaphragm 47 is then moved downwardly sufficiently to permit a spring 49 to close the valve 48, thereby preventing the further flow of air through the inlet opening 42. When the pressure within the body decreases to a value which is insufficient to maintain the diaphragm 47 in a position to permit the valve 48 to remain closed, the valve is opened slightly to permit air to flow through the inlet opening to increase the pressure in the body of the valve and the outlet pipe 37. Thus, it will be seen that the outlet pressure may be regulated by varying the compression of the spring 45. If the spring pressure is increased, the outlet pressure increases, and vice versa.

The vertical movement of the roll 31 may be transmitted to the spring 45 in the pressure regulator in several different ways. As shown in Fig. 1, a lever 51, having one end connected to the roll crosshead at 52 and the other end disposed in a fulcrum 53, has an intermediate point connected to a vertically movable slide 54 which is disposed in a guide member 55. The lower end of the plunger 46 is connected to the slide 54, thereby compressing the spring 45 as the roll 31 raises towards the position indicated by the broken lines.

It will be readily understood that the fulcrum 53 may be placed between the point 52 and the regulating valve 36, in which case it will be necessary to mount the valve 36 with the plunger 46 above the body member 41, that is, upside down from the position shown. However, this will not affect the operation of the valve and the same results may be accomplished as with the arrangement shown in Fig. 1.

In the foregoing manner, a constant tension may be maintained on the material 12 for various positions of the roll 31 by so regulating the pressure on the pistons 33 that the pressure increases as the roll is raised. In some instances, it is desirable to gradually increase the tension on a strip of material from the beginning of a pass to the end of the pass through the rolls 10 and 11 in order to compensate for the difference in the temperature of the material. If it be assumed that a sheet of material is of uniform temperature when it enters the finishing mill of a hot strip mill and that the duration of one pass is from one to two minutes, it is apparent that the

head of the strip leaves the last finishing stand at a higher temperature than the end of the strip.

The difference in temperature may have a detrimental influence on the gauge of the material which can be overcome by continuously increasing the tension on the strip of material as it passes through the roll stands. This can be effected by so moving the fulcrum 53 for the lever 51 that the compression of the spring 45 is continuously increased while the strip 12 is passing through the roll stands 10 and 11.

As shown in Fig. 1, the fulcrum 53 is slidably disposed on a base 56 and may be moved horizontally at a predetermined speed by a screw 57 driven by a motor 58, the operation of which may be controlled by a suitable controller 59 of a standard type. Power for operating the motor 58 may be supplied through conductors 61 and 62.

In this manner, the relative positions of the fulcrum 53 and the regulating valve 36 may be changed by operating the motor 58 at a speed to produce the desired change in tension while the material 12 is passing through the roll stands, thereby so changing the effect of the vertical movement of the end 52 of the lever 51 on the spring 45 that a continuously increasing tension is maintained on the material. It will be understood that the desired effect may be accomplished in other ways, as by utilizing another regulating valve unit which superimposes its pressure onto the working cylinders 34.

The position of the fulcrum 53 may also be changed to permit the device to be set for different pressures depending upon the size of the sheet going through the mill. Thus, the largest sheets require the highest pressure in order to maintain uniform tension on the material and the smallest sheets require the lowest pressure which may be readily adjusted by changing the position of the fulcrum 53.

As stated hereinbefore, air or any other suitable gas or liquid may be utilized as the working medium for actuating the pistons 33 in the cylinders 34. When air or a gas is utilized, it is desirable to provide a damper piston 63, in addition to the working pistons 33, to prevent bouncing of the cross-head 35.

As explained hereinbefore, the pressure regulator 36 and the idler roller 31 will maintain a predetermined tension on the material 12 over a wider range of operation than previously known tensioning devices. However, better results will be obtained if provision is made for maintaining the idler roller 31 in as near a predetermined operating position as possible. This may be accomplished by controlling the speed of at least one of the roll stand motors in accordance with the vertical movements of the tension roller 31 in such a manner that should the deflection of the material vary from a value considered as normal, the speed of at least one of the motors is varied in order to take up the excess length in the strip of material or to increase its length, as the case may be.

As illustrated in Fig. 2, provision is made for automatically controlling the speed of the motor 13 by means of a regulator device 64, the functioning of which is caused to be influenced in accordance with the position of the roller 31. As stated hereinbefore, the separately excited field windings 19 and 20 of the motors 13 and 14, respectively, are energized from the power conductors 25 and 26. The field circuit of the

motor 14 is provided with a variable resistance 65 which may be utilized to adjust the speed of the roll stand 11. Likewise, the motor 13 is provided with a field rheostat 66 which may be utilized to adjust the speed of the roll stand 10. In addition to the rheostat 66, the field circuit of the motor 13 contains resistors 67 and 68 which are controlled by shunting switches 69 and 71, respectively, which are, in turn, controlled by the regulator 64.

While the regulator 64 has been illustrated as a vibrating type, it will be understood that a regulator of any suitable type may be utilized. The vibrating contact element 72 is operated in a well known manner by means of an electromagnet 73 and an auxiliary relay 74. When the power conductors 25 and 26 are energized, the electromagnet 73 is energized and raises the contact element 72 to its uppermost position. The energizing circuit for the electromagnet 73 contains a resistor 75 which is shunted by the auxiliary relay 74. Upon the operation of the electromagnet 73, its contact members 76 are closed to energize the auxiliary relay 74 which opens its contact members to insert the resistor 75 in the circuit for the electromagnet 73. This increases the resistance of the circuit of the electromagnet 73 to such an extent that the vibrating contact element 72 is returned to its lowermost position. This cycle of operation is repeated, thereby causing the contact element 72 to vibrate.

The regulator is provided with an adjustable contact element 77 having upper and lower contacts which are positioned in any suitable manner in accordance with the position of the roller 31. As shown, the contact element 77 is connected to the roller cross-head 35 by means of a lever mechanism 78. However, it will be understood that the movement of the roller 31 may be transmitted to the contact element 77 in any other suitable manner.

In order to more clearly describe the functioning of the regulator 64 to control the speed of the motor 13 in accordance with the movements of the roller 31, it will be assumed that the material 12 is traveling in the direction indicated by the arrow. Under this condition, the speed of the motor 13 must be increased when the deflection increases, and decreased when the deflection decreases.

When the vibrating contact element 72 is in its lower position, it engages the lower contact of the adjustable contact element 77, and the shunting switch 71 is energized to remove the shunt connection from the field resistor 68, thereby decreasing the excitation of the motor 13 and increasing its speed accordingly. When the contact element 72 is in its upper position, the shunting switch 69 is energized to shunt the resistor 67 from the field circuit, thereby increasing the excitation of the motor, which causes its speed to decrease.

The regulator 64 is so disposed that when the tension roller 31 is in its normal operating position, the vibrating contact element 72 makes contact with the upper and lower contacts of the adjustable contact element 77 for equal periods of time. If, however, the deflection in the material 12 increases, the adjustable contact element 77 of the regulator 64 is so positioned that the vibrating element 72 engages the lower contact of the contact element 77 for a greater time than it engages the upper contact, thereby causing the shunting switch 71 to be maintained in its open

position over longer periods of time than the shunting switch 69, which causes the speed of the motor 13 to increase a sufficient amount to reduce the deflection of the material 12 to normal.

The opposite is true when the deflection decreases below its normal value, thereby causing the shunting switch 69 to be maintained energized over longer periods of time than the switch 71. In this manner, the speed of the motor 13 is decreased, and the deflection of the material 12 increased.

As an alternative to the mechanical connection between the idler roller 31 and the pressure regulating valve 36, hereinbefore described, an electrical connection may be utilized, if desired. As shown in Fig. 3, the pressure regulator 36 is of the same type as previously described. However, the spring 45 is normally compressed to an amount that will cause the maximum pressure to be maintained in the operating cylinders 34 which may at any time be required. The spring pressure is counteracted by the pull of a solenoid magnet 81, which is connected to the plunger 46 to reduce the pressure of the spring 45 on the diaphragm 47, thereby relieving the diaphragm of part of the pressure exerted on it by the spring 45. The force produced by the solenoid magnet 81 is so regulated that with the roller 31 in its lowest position the magnet 81 exerts its maximum force, practically balancing the force of the spring 45. As the roller 31 moves up, the current in the solenoid 81 is decreased a suitable amount to permit the spring pressure on the diaphragm to be increased. In this manner, a definite spring pressure is exerted on the diaphragm for each position of the roller, thereby producing a definite pressure on the pistons 33 which support the roller 31.

As shown in Fig. 3, the current in the coil 82 of the solenoid 81 may be controlled in accordance with the position of the roller 31 by means of a lever operated rheostat 83. The rheostat 83 is connected in series with the coil 82 which may be energized from power conductors 84 and 85. The lever arm 86 of the rheostat 83 may be connected to an extension 87 on the cross-head 35 by a link 88 to transmit the motion of the cross-head to the arm 86, thereby controlling the current in the solenoid coil 82.

In order to provide an adjustment for a variation in the size of the sheets of material being rolled, which requires a variation in the pressures necessary to maintain a constant tension in the material, as explained hereinbefore, a manually adjustable rheostat 91 may also be connected in the circuit for the coil 82 of the solenoid 81. In this manner, the current in the solenoid 81 may be so adjusted that it exerts a maximum force for the largest size of sheets, and a minimum force for the smallest size which are to be rolled through the roll stands 10 and 11.

In the modification of the invention shown in Fig. 4, the variable rheostat 83 is utilized to control the field excitation of a generator 92, which, in turn, energizes the coil 82 of the solenoid 81. The generator 92 may be driven by a motor 93 which may be connected to power conductors 94 by means of a switch 95. It will be understood that as the roller 31 is raised, the current in the field winding 96 of the generator 92 is decreased, thereby lowering the voltage of the generator 92 and decreasing the current in the coil 82, which decreases the pull exerted by the solenoid magnet and permits the spring 45 to increase the

pressure on the diaphragm of the regulating valve 36, thereby increasing the fluid pressure on the pistons 33 which actuate the roller 31 to maintain a predetermined tension on the material 12. As explained hereinbefore, a manually adjustable rheostat 91 may be connected in the circuit for the solenoid coil 82 to adjust the tension for different sizes of sheets of the material 12.

From the foregoing description, it is apparent that I have provided a tension regulating system which will operate satisfactorily over a wide range of movement of the tension roller. Furthermore, the system may be readily adjusted for various classes and sizes of material, and, if desired, provision may be made for continuously increasing the tension on the material to compensate for changes in the temperature of the material while it is being worked, in the manner hereinbefore described.

Since numerous changes may be made in the above described construction and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In a tension control system, in combination, a movable tensioning roller, fluid-pressure means for actuating said roller, and means responsive to the movement of said roller for controlling the operating pressure of the fluid-pressure means.

2. In a tension control system, in combination, a movable tensioning roller, fluid-pressure operated means for actuating said roller, and means responsive to the movement of said roller for regulating the pressure applied to the fluid-pressure operated means, thereby controlling the operation of said tensioning roller.

3. In a tension control system, in combination, a movable tensioning roller, fluid-pressure operated means for actuating said roller, and valve means controlled by the movement of said roller for regulating the pressure applied to the fluid-pressure operated means, thereby controlling the operation of said tensioning roller.

4. In a system for controlling the tension on a length of material, in combination, a movable tensioning roller, fluid-pressure operated means for actuating said roller into engagement with said material, and valve means actuated by the movement of said roller to vary the pressure applied to the fluid-pressure operated means, thereby controlling the tension on said material.

5. In a system for controlling the tension on a length of material extending between two points, in combination, a movable tensioning member, fluid-pressure operated means for so actuating said movable tensioning member as to cause the member to deflect the length of material from the line between the two points to thus subject the length of material to tension, and means responsive to the movement of said tensioning member for varying the pressure applied to the fluid-pressure operated means in accordance with the degree of movement of said member, thereby controlling the tension on the material.

6. In a system for controlling the tension on a length of material as it extends between two points, in combination, a movable tensioning member, fluid-pressure operated means for so actuating said tensioning member as to cause the

member to deflect the length of material from the line between the two points to thus subject the length of material to tension, and fluid-pressure regulating means actuated by the movement of said tensioning member for varying the pressure applied to the fluid-pressure operated means in proportion to the degree of movement of said member, thereby regulating the tension on the length of material.

7. In a system for controlling the tension on a length of material as it extends between two points, in combination, a movable tensioning member, fluid-pressure operated means for so actuating said tensioning member as to cause the member to deflect the length of material from the line between the two points to thus subject the length of material to tension, and fluid-pressure regulating means actuated by the movement of said tensioning member for increasing the pressure applied to the fluid-pressure operated means in direct proportion to the degree of movement of the member, thereby maintaining a predetermined tension on the length of material.

8. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, an idler roller disposed between said roll stands, fluid-pressure operated means for actuating said roller to apply pressure on the material to create a tension therein, fluid-pressure regulating means for regulating the pressure in said fluid-pressure operated means, and means responsive to the movement of said roller for adjusting said regulating means to vary the pressure in said fluid-pressure operated means, thereby maintaining a predetermined tension on said material.

9. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, an idler roller disposed between said roll stands, fluid-pressure operated means for actuating said roller to apply pressure on the material to produce a tension therein, fluid-pressure regulating means for regulating the pressure in said fluid-pressure operated means, and means responsive to the movement of said roller for adjusting said regulating means to vary the pressure in said fluid-pressure operated means in proportion to the movement of said roller, thereby maintaining a predetermined tension on said material.

10. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, means for driving each of said roll stands, a tension roller disposed between said roll stands, a fluid-pressure operated piston for moving said roller vertically to apply a transverse pressure on said material, a regulating valve for regulating the pressure on said piston, means for transmitting the vertical movement of said roller to said regulating valve to adjust the setting thereof, thereby varying the pressure on said piston in accordance with the position of said roller, and regulating means responsive to the vertical movement of said roller for governing the speed of the driving means for one of said roll stands.

11. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, a tension roller disposed between said roll stands, a fluid-pressure operated piston for moving said roller vertically to apply a transverse pressure on said material, a regulating valve for regulating the pressure on said piston, and a lever for adjust-

ing said regulating valve in accordance with the position of said roller, thereby varying the pressure on said piston in proportion to the movement of the roller to control the tension on said material.

12. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, a tension roller disposed between said roll stands, a fluid-pressure operated piston for moving said roller vertically to apply a transverse pressure on said material, a regulating valve for regulating the pressure on said piston, a lever for adjusting said regulating valve in proportion to the movement of said roller to vary the pressure on said piston, and means for changing the effect produced by said lever on said regulating valve.

13. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, a tension roller disposed between said roll stands, a fluid-pressure operated piston for moving said roller vertically to apply a transverse pressure on said material, a regulating valve for regulating the pressure on said piston, a lever for adjusting the setting of said regulating valve in accordance with the position of said roller to vary the pressure on said piston, and means for varying the effective length of said lever thereby changing the setting of said valve to vary the pressure exerted by said roller on said material.

14. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, a tension roller disposed between said roll stands, a fluid-pressure operated piston for moving said roller vertically to apply a transverse pressure on said material, a regulating valve for regulating the pressure on said piston, a lever for adjusting said regulating valve in proportion to the movement of said roller to vary the pressure on said piston, and means for changing the effect produced by said lever on said regulating valve while the material is passing through the roll stands.

15. In a system for controlling the tension on a strip of material, in combination, a pair of roll stands for rolling the material, a tension roller disposed between said roll stands, a fluid-pressure operated piston for moving said roller vertically to apply a transverse pressure on said material, a regulating valve for regulating the pressure on said piston, a lever for adjusting said regulating valve in proportion to the movement of said roller to vary the pressure on said piston and means for moving the fulcrum point of said lever while the material is passing through the roll stands, thereby continuously increasing the tension on said material.

16. In a system for controlling the tension on a length of material, in combination, a vertically movable tensioning roller, fluid-pressure operated means for actuating said roller, regulating means for controlling the pressure applied to said fluid-pressure operated means, electrically-energized means for adjusting said regulating means, and means for changing the effect of said electrically-energized means in accordance with the position of said roller, thereby controlling the tension on said material.

17. In a system for controlling the tension on a length of material, in combination, a vertically movable tensioning roller, fluid-pressure operated means for actuating said roller, a regulating means for controlling the pressure ap-

plied to said fluid-pressure operated means, electrically-energized means for adjusting said regulating means, and means actuated by the movement of said roller for controlling the energization of said electrically-energized means in accordance with the position of said roller.

18. In a system for controlling the tension on a length of material, in combination, a vertically movable tensioning roller, fluid-pressure operated means for actuating said roller, regulating means for controlling the pressure applied to said fluid-pressure operated means, electrically-energized means for adjusting said regulating means, means actuated by the movement of said roller for controlling the energization of said electrically-energized means in accordance with the position of said roller, and additional means for controlling the energization of said electrically-energized means to vary the tension on said material.

19. In a system for controlling the tension on a length of material, in combination, a vertically movable tensioning roller, fluid-pressure operated means for actuating said roller, regulating means for controlling the pressure applied to said fluid-pressure operated means, electrically-energized means for adjusting said regulating means, a generator for energizing said electrically-energized means, and means for varying the potential of said generator in accordance with the position of said roller.

20. In a system for controlling the tension on a length of material, in combination, a vertically

movable tensioning roller, fluid-pressure operated means for actuating said roller, regulating means for controlling the pressure applied to said fluid-pressure operated means, electrically-energized means for adjusting said regulating means, a generator for energizing said electrically-energized means, means for varying the potential of said generator in accordance with the position of said roller, and adjustable means for controlling the current in said electrically-energized means, thereby controlling the tension on said material.

21. In a system for controlling the tension on a length of material, in combination, a vertically movable tensioning roller, fluid pressure operated means for actuating said roller, a fluid pressure regulating reducing valve for controlling the pressure applied to said fluid pressure operated means, said regulating valve having an inlet opening and an outlet opening and comprising a diaphragm positioned to be displaced by the regulated fluid pressure, means whereby displacement of said diaphragm by the regulated fluid pressure tends to close the valve, means biasing said diaphragm in the direction of diaphragm movement which will open the valve, electromagnetic means acting in opposition to said biasing means, and means for controlling the energization of said electromagnetic means in accordance with the displacement of said roller by said fluid pressure operated means.

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