May 20, 1941. G. P. LESSMANN 2,242,358

TENSIOMETER CONTROL

Filed Aug. 13, 1938 3 Sheets-Sheet 1

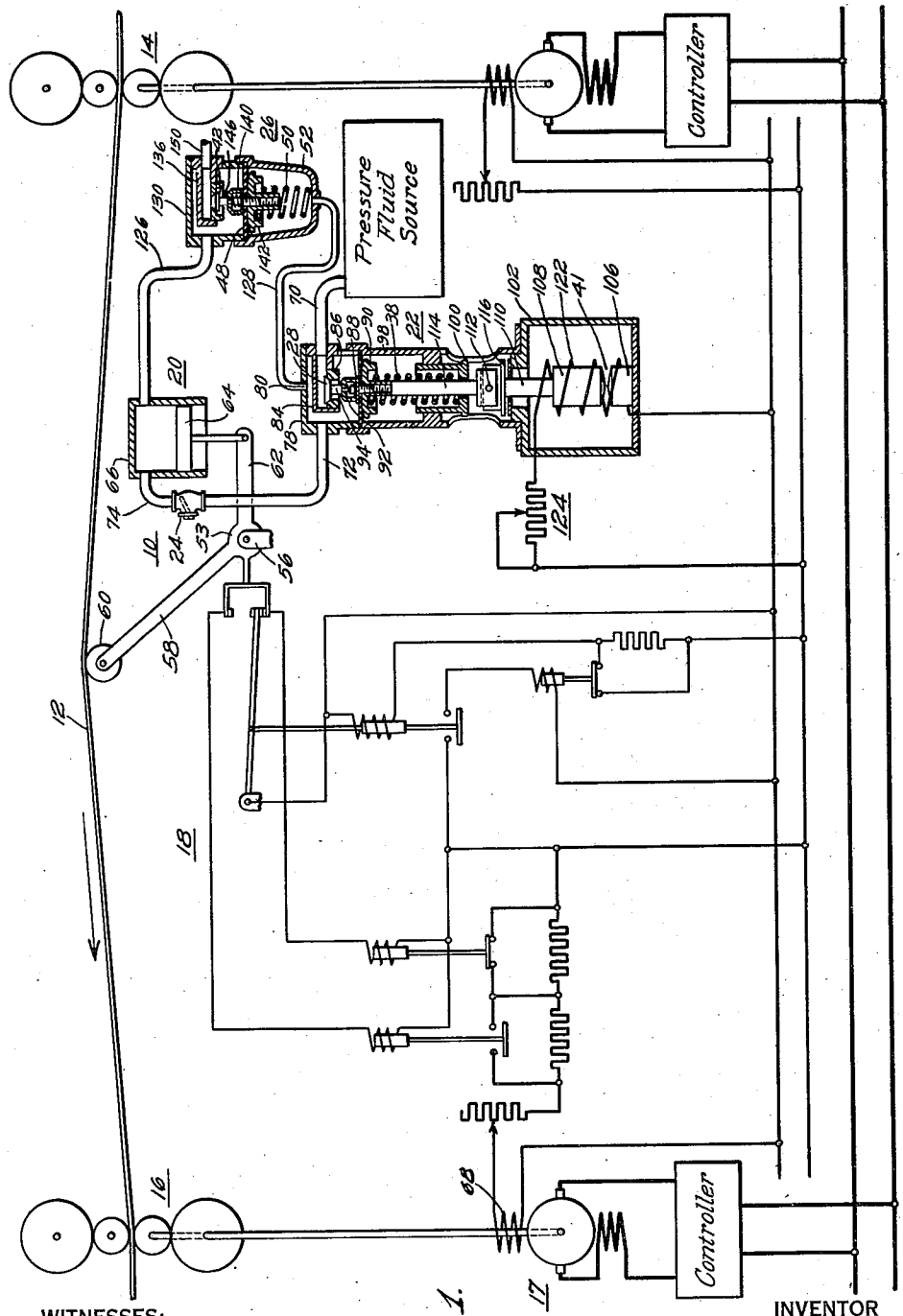


Fig. 1.

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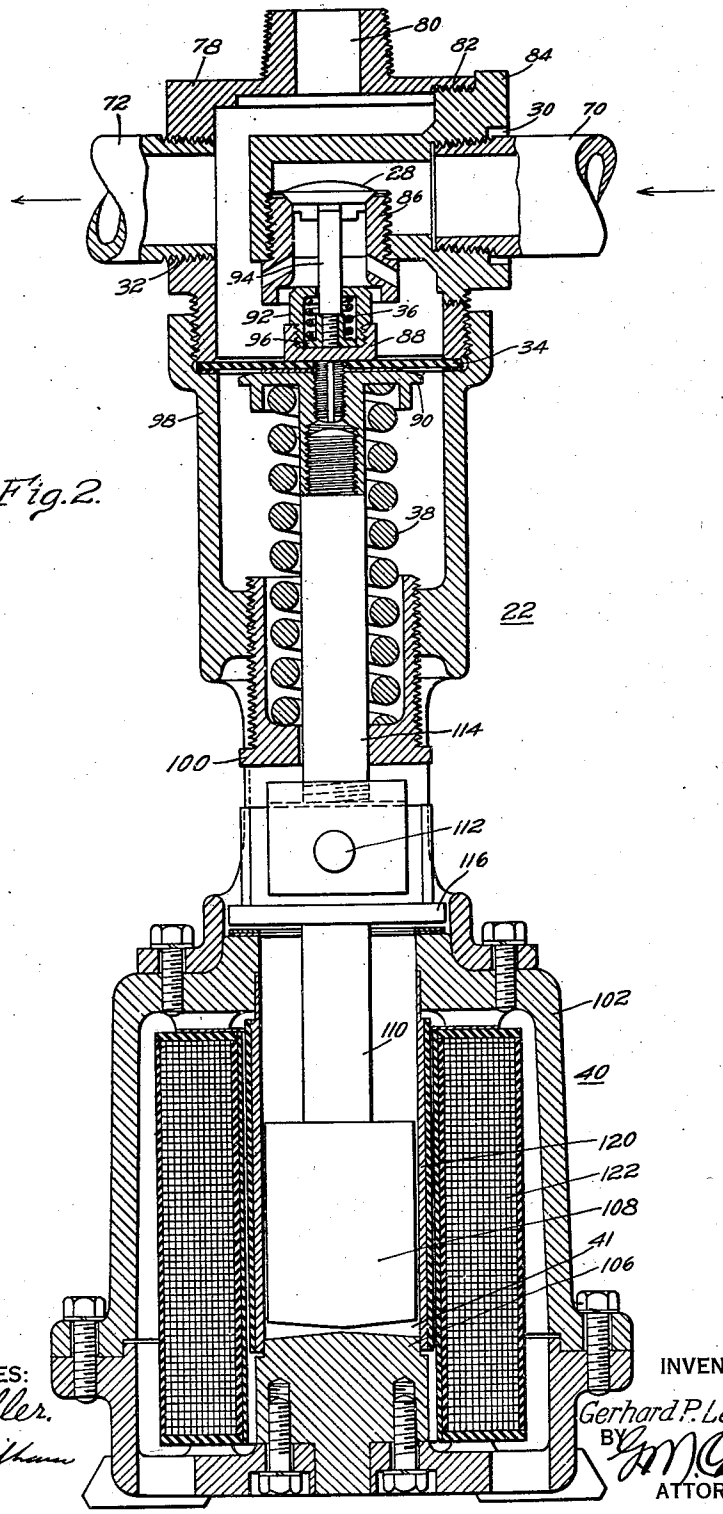


Fig. 2.

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TENSIOMETER CONTROL

Filed Aug. 13, 1938 3 Sheets-Sheet 3

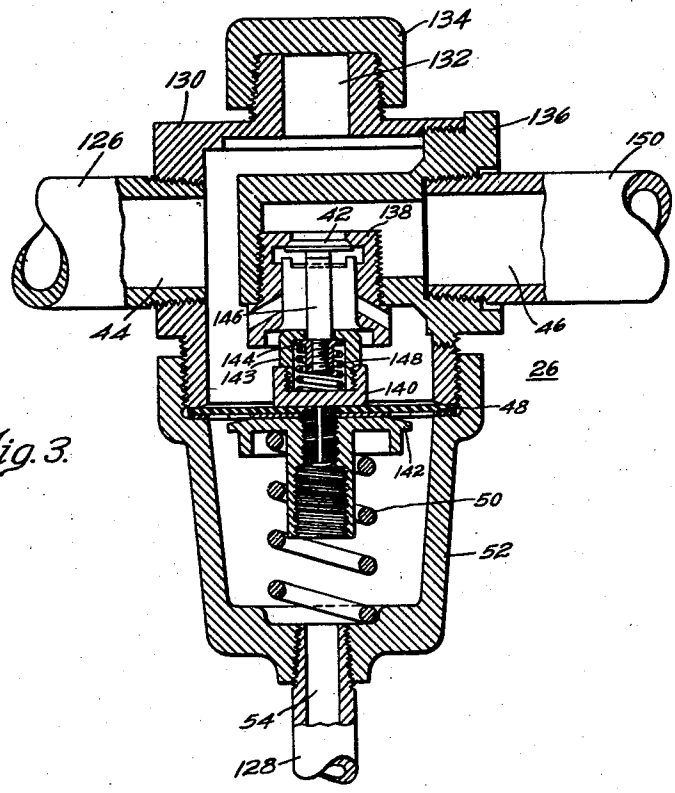
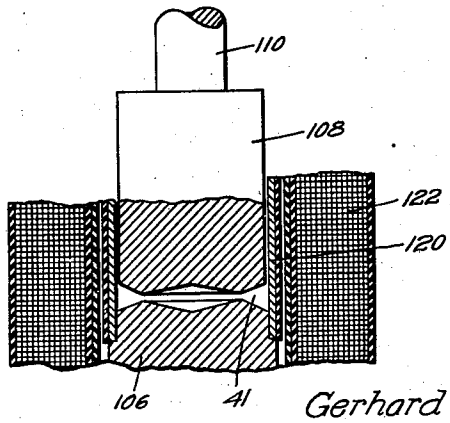


Fig. 3.

Fig. 4.



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2,242,358

TENSIOMETER CONTROL

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Application August 13, 1938, Serial No. 224,724

10 Claims. (Cl. 80—35)

My invention relates, generally, to devices for tensioning a length of material as it passes between adjacent work devices and, more particularly, to a control system for a fluid-pressure actuated strip tensioning device.

In the manufacture of sheet steel, it has become the practice to pass the steel in the form of a strip through a series of sets of reducing rolls simultaneously and to subject the strip to tension as it passes between adjacent roll stands by causes an idling roller to bear against the strip to deflect the strip from the normal pass line between adjacent roll stands.

Fluid-pressure operated pistons have been used for actuating strip tensioning devices and have been very successful because of the low inertia, flexibility, ease of regulation and wide range of regulation of the systems using fluid pressure as an operating medium. Such a fluid-pressure operated tensioning device is described in detail in my copending application Serial No. 133,419, filed March 27, 1937, now Patent No. 2,189,609, issued Feb. 6, 1940. In this application, an adjustable pressure-regulating reducing valve, having an electromagnetic adjustment, controls the fluid pressure applied to the actuating piston of the tensioning device.

The electromagnetically controlled pressure regulating valves used heretofore to regulate the pressure in tensioning systems, such as that described in detail in my copending application, above referred to, have had the disadvantage that occasional sticking of the control solenoid core hindered the proper operation of the valve. Another defect in these valves has been that the valve faces have been damaged by the sudden closing of the valve under the great force applied by the control magnet.

In the operation of such fluid-pressure actuated strip tensioning systems as I have described in my heretofore referred to copending patent application, it has been found that unusually high tension surges sometimes occur, particularly during the periods of acceleration and deceleration of the mill. These high tension surges are due to the sudden take-up of the slack in the strip between roll stands which tends to force the fluid-pressure operated piston back in the cylinder. It will be seen that, if the pressure in the cylinder could be lessened when these tension surges occur, the severity of the surges would be lessened and breakage of the strip due to these tension surges could be eliminated.

An object of my invention, therefore, is to provide a fluid-pressure operated tensioning system which shall function to accurately regulate the tension on a strip of material as it passes between two adjacent work devices and which shall function to reduce the amount of strip breakage by relieving tension surges on the strip.

Another object of the invention is to provide an improved electromagnetically adjustable fluid-pressure-regulating reducing valve which shall function to accurately and efficiently maintain a predetermined fluid pressure in a fluid-pressure actuated strip tensioning system.

A further object of the invention is to provide a fluid valve which shall be so constructed as to automatically protect its valve surfaces from damage due to sudden closure of the valve with great force.

Still another object of the invention is to provide a relief valve system for a fluid-pressure actuated strip tensioning device which shall function to relieve excess pressures in the system regardless of the value of the normal pressure acting in the system.

These and other objects and advantages of the invention will be apparent from the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of a strip tension control system embodying the principal features of my invention.

Fig. 2 is an elevational view in section of the pressure regulating valve of Fig. 1.

Fig. 3 is an elevational view in section of the relief valve of Fig. 1; and

Fig. 4 is a view of a section of a modification of the core structure of the solenoid of the regulating valve of Fig. 2.

In a general aspect, the invention comprises a tensioning device 10 which acts to apply a tension to a strip of material, such as sheet steel 12, as it passes between adjacent reducing roll stands or similar work devices 14 and 16 in the direction indicated by the arrow. A regulator 18, responsive to the degree of deflection of the strip 12, controls the speed of the driving motor 17 for the rolls of roll stand 16 to maintain the deflections of the strip within predetermined limits.

The tensioning device 10 is actuated by a fluid-pressure operated piston and cylinder device 20, the tension applied to the strip 12 by the tensioning device 10 being a function of the fluid pressure acting on the piston and cylinder device 20. An adjustable pressure regulating reduction valve 22 is connected between any suitable fluid-pressure source, as indicated, and the cylinder

and piston device 20 to maintain the desired strip tension through the regulation of the fluid pressure acting on the tensioning device 10.

A check valve 24 is connected in the conduit between the regulating valve 22 and the piston and cylinder device 20 to prevent reverse flow of pressure fluid from the piston and cylinder device 20 to the regulating valve 22 upon the occurrence of sudden tension surges which tend to cause the piston to compress the pressure fluid in the cylinder. A compensated relief valve 26 having a diaphragm actuated valve is connected to permit its diaphragm to be affected by the regulated fluid pressure on one side and the fluid pressure acting on the piston on the other side so that the relief valve will open to relieve tension surges when such surges cause a predetermined increase of pressure in the cylinder over the rgulated pressure.

As shown in Fig. 2, the pressure regulating valve 22 comprises a valve 28 disposed between inlet and outlet ports 30 and 32 respectively. The valve 28 is connected to be actuated by a diaphragm 34, on which the regulated pressure acts to close the valve through a spring 36, a regulatable biasing spring 38, which tends to move the valve to open position, and a solenoid 40 which partially counteracts the pressure of the spring 38. The air gap 41 of the solenoid is constructed to provide a self-centering action on the solenoid cores to prevent sluggish action of the valve due to the sticking of the core. An alternative form of self-centering core is shown in Fig. 4.

As shown in Fig. 3, the relief valve 26 comprises a valve 42 disposed between inlet and outlet ports 44 and 46, respectively, and actuated by a diaphragm 48. The diaphragm is acted upon on one side by the pressure existing in the cylinder of the tensioning device actuating means and on the other side by a spring 50 and the regulated pressure from the regulating valve 26 which is introduced into the chamber 52 through the orifice 54.

Referring to the drawings for a more detailed description of the invention, in Fig. 1, the tensioning device 10 comprises a bell crank 53 pivotally mounted upon a support 56 and having an arm 58 upon which there is rotatably mounted an idling roller 60. Another arm 62 of the bell crank 53 is acted upon by a piston 64, which is actuated by fluid pressure in a cylinder 66. This general arrangement of fluid-pressure operated tensioning device will maintain a tension upon the strip 12 dependent upon the fluid pressure acting in the cylinder 66 and will govern the speed of the motor 17 which drives the producing roll 16 by means of a regulator 18 which acts to control the current in the field winding 68 of the motor 17 to maintain the deflection of the strip 12 within predetermined limits. This general arrangement of the tensioning device and regulator is disclosed in my above referred to patent, to which reference is made for a more detailed description of the apparatus and its operation.

In order to maintain a constant pressure in the cylinder 66 to thus maintain a constant tension upon the strip 12, the fluid-pressure regulating valve 22 is provided having an inlet connected by a suitable conduit 70 to a source of fluid pressure and its outlet connected by suitable conduit 72 through a check valve 24 and a conduit 74 to the cylinder 66.

Referring to Fig. 2 of the drawings for a more detailed description of the structure and operation of the fluid-pressure regulating valve 22, the valve comprises a valve chamber 78 having openings 32, 80 and 82. A valve support 84 is inserted into the opening 82 and secured to the valve chamber 78 in any suitable manner, such as by screw threads as shown. A valve seat 86 is screw threaded into the valve support 84 and has the valve 28 cooperating therewith. The diaphragm 34 is secured between upper and lower diaphragm clamps 88 and 90 in any suitable manner as by screw threaded engagement between these two members, and a spring cage 92 is secured to the upper diaphragm clamp 88. The valve stem 94 extends from the valve 28 through an opening in the valve cage 92 and has screw threaded engagement with the valve nut 96. The spring 36 is disposed between the valve nut 96 and the spring cage 92.

The diaphragm 34 has its outer edge clamped between the valve chamber 78 and a spring housing 98. An adjustable spring support sleeve 100 is screw threaded into the spring housing 98 and a spring 38 is disposed between the sleeve 100 and the lower diaphragm clamp 90 to bias the valve 28 toward open position.

The housing 102 of the solenoid 40 is secured to an extension of the spring housing 98 and comprises upper and lower portions which are suitably clamped together, as shown. A fixed central solenoid core member 106 is secured to the lower section of the solenoid housing and a movable solenoid core member 108 is disposed adjacent the core member 106, cooperating therewith as a part of the magnetic circuit of the solenoid 40. The movable core section 108 is connected to the valve 28 through a stem 110, a coupling 112 and a stem 114, which has screw threaded engagement with the lower diaphragm clamp 90. A ring member of magnetic material 116 is secured to the stem 110 and is disposed to overlie the opening of the solenoid housing 102, through which the stem 110 extends, to thus provide a magnetic circuit including the fixed solenoid core 106, the air gap 41, the movable solenoid core section 108, the stem 110, the ring member 116, the air gap between the ring member 116 and the housing 102, and the solenoid housing 102. A sleeve 120 of non-magnetic material, such as brass, is disposed around and spaced from the movable solenoid core section 108 and the solenoid core 122 is disposed around the sleeve 120.

The adjacent cooperating faces of the solenoid core section 106 and 108 are cone shaped in form so as to provide a concentration of the magnetic flux at the apex of the cones to thus provide a centering force to keep the movable core section 108 centered in the sleeve 120, thus preventing sluggish operation of the valve due to frictional engagement of the movable core section 108 with the sleeve 120.

An alternative form of the cone sections 106 and 108 is shown in Fig. 4 where the oppositely disposed faces of the core sections are formed in the shape of V-shaped rings having their apexes centered and oppositely disposed. This form of core face will perform the desired centering function, and it will also permit the flow of a greater amount of flux through the air gap 41 than can be provided by the form of core section face shown in Fig. 2.

The pull of the solenoid 40 will provide a downward force acting against the spring 38, thus diminishing the amount of bias tending to move

the valve 28 to open position. The force applied by the solenoid 40 may be varied by suitable adjustment of the rheostat 124, shown in Fig. 1.

The operation of the regulating valve 22 to maintain an adjustable constant pressure in the cylinder 66 may be readily understood by reference to Figs. 1 and 2. It will be seen that the pressure acting in the cylinder 66 will also be acting in the valve chamber 78 against the diaphragm 34 tending to move the valve 28 to closed position. At the same time, the compression of the spring 38 minus the force exerted against the spring 38 by the solenoid 40 will be acting to move the valve 28 to open position. Thus, the valve 28 will be moved to open position to admit pressure fluid from the fluid-pressure source into the cylinder 66 until the pressure in the cylinder 66 and in the chamber 78 is such that this action on the diaphragm 34 will overcome the spring pressure upon the diaphragm and close the valve 28. It will be seen that any decrease in pressure in the cylinder 66 and the chamber 78 will again cause the valve 28 to open to bring the pressure up to the desired amount. The amout of pressure acting upon the cylinder 66 is thus determined by the amount of tension applied to the diaphragm 34 by the spring 38, and this tension may be adjusted by suitable adjustment of the spring support sleeve 100 and the degree of energization of the solenoid 40 by adjustment of the rheostat 124. Since the force applied to the valve 28 by the pressure on the diaphragm 34 and the pull of the solenoid 40 is applied to the valve 28 through the spring 36, the valve 28 will be cushioned against the valve seat 86 and the spring 36 to prevent damage to the valve 28 and its seat 86 by any pressure surge that might occur in the chamber 78 or any excess forces that might be applied by the solenoid 40 due to surges in the energizing current of the solenoid.

In order to relieve excess tension surges in the strip 12, which might be caused by sudden variations in the speeds of the rolls of the mill stands 14 and 16 or sudden variations in the hardness of the strip, or any other condition that would cause sudden decrease in the amount of slack in the strip 12 between the roll stands 14 and 16, the relief valve 26 is connected by a suitable conduit 126 to the cylinder 66 to relieve excess pressures in the cylinder 66 which would be caused by sudden decreases in the length of the strip 12 between the roll stands 14 and 16, forcing the pistons 64 upward in the cylinder 66. The relief valve 26 is also connected to the valve chamber 78 through the opening 80 by means of a suitable conduit 128 to provide pressure compensation for the relief valve 26, as hereinafter more fully explained.

Referring to Fig. 3 for a more detailed description of the relief valve 26, the valve chamber 130, similar to the valve chamber 78 of the pressure regulating valve 22, has an opening 132 closed by any suitable means, such as a cap 134 and has a valve support 136 inserted therein. A valve seat 138 is provided in the valve support 136 and a valve 42 cooperates therewith. A diaphragm 48 is secured between upper and lower diaphragm clamps 140 and 142, and a spring cage 143 is secured to the upper diaphragm clamp 140. A valve nut 144 is secured to the valve stem 146 and a spring 148 provides a biasing force between the valve nut 144 and the diaphragm clamp 140. The spring 148 performs the function of cushioning the seating force applied to the valve 42, thus protecting the valve 42 and its seat 138 from damage which might result from too great a seating force being applied thereto.

A housing 52 is suitably secured to the valve chamber 130, the diaphragm 48 being clamped between said housing and chamber. A spring 50 bears against the lower valve clamp 142 and against the housing 52. The housing 52 has an opening 54 to which the fluid conduit 128 is connected. The fluid conduit 126 hereinbefore referred to is suitably connected to the opening 44 in the housing 130 and a suitable conduit 150, opening to the atmosphere, is connected with the opening 46 in the valve chamber 130.

In the operation of the relief valve 26, it will be seen that the valve 42 will open when the pressure in the chamber 130, acting against the diaphragm 48, which is the pressure acting upon the piston 64 and the cylinder 66, exceeds the regulated pressure applied to the lower side of the diaphragm 48 through the conduit 128 plus the pressure of the spring 50 on the diaphragm 48, the check valve 24 preventing any back pressure from the cylinder 66 from being applied to the regulated valve 22. Thus, the relief valve 26 will not operate at a definite pressure, but will operate at a definite excess of pressure over the regulated pressure which the regulating valve 22 is adpusted to deliver to the cylinder 66. If it is desired, the relief valve 26 may be so constructed as to provide an adjustment for the spring 50 to provide thereby an adjustment of the excess pressure to which the relief valve is responsive.

In the operation of the system, it will be seen that the regulating valve 22 will provide a constant predetermined pressure in the cylinder 66, as determined by the adjustment of the rheostat 124, and this constant pressure will act through the tensioning device 10 and the regulating device 18 for the motor 17 to maintain a constant deflection of the strip 12 and the constant tension on the strip 12. If now, for any reason, there should be a sudden decrease in the deflection of the strip 12 due to a decrease in the amount of slack in the strip 12 between the roll stands 14 and 16, the piston 64 will be forced up in the cylinder 66 causing a sudden increase in the pressure in cylinder 66 and a sudden increase in the tension on the strip 12. This increase in pressure in the cylinder 66 will close the check valve 24, preventing flow of pressure fluid in the reverse direction toward the regulating valve 22 and if this resulting pressure in the cylinder 66 is sufficiently in excess of the regulating pressure provided by the regulating valve 22, the relief valve 26 will open to allow the pressure fluid to flow to atmosphere through the conduit 150, thus automatically decreasing the pressure in the cylinder 66 and relieving the excess tension on the strip 12.

If now it is desired to provide an increased tension on the strip 12 due to change in the dimensions of the strip, or for any other reason, the rheostat 124 may be adjusted to cause the regulating valve 22 to provide the desired constant pressure in the cylinder 66. This increase in pressure will not operate the relief valve 26 for the reason that this regulated pressure is applied to the lower side of the diaphragm 48 through the conduit 128 as well as to the upper side of the diaphragm 48 through the conduit 126, and the relief valve 26 will thus be compensated for any

regulated changes in fluid pressure, but will still relieve excess pressure generated in the cylinder 66 by sudden decreases in the deflection of the strip 12 to thus relieve tension surges in the strip 12.

It will be seen that I have provided a control system for a fluid-pressure actuated strip tensioning device which will function to efficiently and accurately maintain a predetermined tension upon the strip during normal conditions, which will function to relieve excess tensions on the strip by means of a relief valve which may be adjusted to provide any desired normal tension on the strip and which will automatically compensate the relief valves for change in regulated tension on the strip so that the relief valve will only act upon sudden increases of tension above the regulated tension on the strip.

In compliance with the requirements of the patent statutes, I have shown and described herein the preferred embodiments of my invention. It is to be understood, however, that the invention is not limited to the precise constructions shown and described but is capable of modification by one skilled in the art, the embodiments herein shown being merely illustrative of the principles of my invention.

I claim as my invention:

1. In a control system for a fluid-pressure actuated strip tensioning device, an adjustable fluid-pressure regulating valve for maintaining a predetermined normal fluid pressure on the tensioning device, a relief valve connected to relieve excess fluid pressure on the tensioning device and means for varying the operating pressure of said relief valve in accordance with variations in the normal pressure maintained on the tensioning device by said regulating valve.

2. In a control system for a fluid-pressure actuated strip tensioning device, an adjustable pressure regulating valve for maintaining a predetermined normal pressure on the tensioning device, a pressure actuated relief valve for relieving excess fluid pressure on the tensioning device and means for changing the relief valve operating pressure in accordance with changes in the normal pressure provided by said regulating valve for the tensioning device.

3. In a control system for a fluid-pressure operated piston-actuated strip tensioning device, an adjustable pressure regulating valve for maintaining a predetermined normal pressure on the actuating piston, a pressure operated relief valve for relieving excess fluid pressure on the piston, and means controlled by the regulated normal pressure for the actuating piston for varying the relief valve operating pressure in accordance with the adjusted variations of the regulated normal pressure.

4. In a system for maintaining a predetermined normal tension on a strip of material as it passes between adjacent work devices, an idling roller, means including a fluid-pressure actuated piston for causing said roller to deflect the strip from its normal pass line between the work devices to thus tension the strip, an adjustable pressure regulating valve for maintaining a predetermined normal pressure on the actuating piston, a pressure operated relief valve for relieving excess fluid pressure on the piston, and means controlled by the regulated normal pressure for the actuating piston for varying the relief valve operating pressure in accordance with the adjusted variations of the regulated normal pressure.

5. In a control system for a fluid-pressure actuated strip tensioning device, a source of pressure fluid, a pressure regulating valve connected between said source of pressure fluid and the strip tensioning device, said pressure regulating valve comprising a valve control means responsive to the pressure acting on the tensioning device biasing said valve to closed position, a continually energized electromagnet connected to apply a bias to said valve, means for selectively varying the energization of said electromagnet to thereby vary the fluid pressure applied to the tensioning device through said regulating valve thus varying the tension applied to the strip by said tensioning device; a relief valve connected to relieve excess fluid pressure on the tensioning device and means for varying the operating pressure of said relief valve in accordance with variations in the normal pressure maintained on the tensioning device by said regulating valve.

6. In a fluid-pressure regulating reduction valve for maintaining a predetermined selectively adjustable fluid pressure on a fluid-pressure actuated strip tensioning device, a valve, pressure responsive means for biasing said valve toward the closed position, means for biasing said valve toward open position and a selectively adjustable continuously energized solenoid having its core connected to continuously bias said valve to the closed position with a selectively adjustable force to thereby provide a selectively adjustable net valve biasing force, said solenoid comprising a fixed core and an axially movable core disposed in cooperative relationship as a part of the magnetic circuit of the solenoid, said cores having opposing faces of such contour as to concentrate the magnetic flux flowing therebetween substantially in the line of movement of the movable core to thereby confine the movement of the movable core to the desired axial movement.

7. In fluid-pressure regulating reduction valve for maintaining a predetermined selectively adjustable fluid pressure on a fluid-pressure actuated strip tensioning device, a valve, pressure responsive means for biasing said valve toward the closed position, means for biasing said valve toward open position and a selectively adjustable continuously energized solenoid having its core connected to continuously bias said valve to the closed position with a selectively adjustable force to thereby provide a selectively adjustable net valve biasing force, said solenoid comprising a winding disposed upon a sleeve, a fixed core and a movable core disposed in cooperative relationship within said sleeve as a part of the magnetic circuit of the solenoid, said cores having opposing faces so shaped as to cause a concentration of the magnetic flux flowing therebetween substantially in the line of movement of the movable core to thereby confine the movement of the movable core to the desired axial movement and preventing contact of the movable core with said sleeve.

8. In a fluid-pressure regulating reduction valve for maintaining a predetermined adjustable fluid pressure on a fluid-pressure actuated strip tensioning device, a valve, pressure responsive means for biasing said valve toward the closed position, means for biasing said valve toward open position and a continuously energized solenoid having its core connected to bias said valve to the closed position, said solenoid comprising a winding disposed upon a sleeve, a yoke of magnetic material disposed about said coil and having an opening coaxial with said

sleeve, a fixed core disposed within said sleeve and secured to said yoke, a movable core disposed within said sleeve in cooperative relation with said fixed core, said movable core being slidable axially of but spaced from said sleeve, a stem of magnetic material secured to said movable core and extending through said opening in said yoke, a plate of magnetic material secured to said stem overlying the opening in said yoke and so disposed with respect to said yoke as to form a part of the magnetic path of said solenoid, said fixed and movable cores having opposed faces so shaped as to cause a concentration of the magnetic flux flowing therebetween substantially in the axial line of said solenoid to thereby confine the movement of the movable core to the desired axial movement and preventing contact of the movable core with said sleeve.

9. In a control system for a fluid-pressure actuated strip tensioning device, an adjustable pressure regulating valve for maintaining a predetermined normal pressure on the tensioning device, a pressure relief valve for relieving excess fluid pressure on the tensioning device, said relief valve comprising a valve member, a first means biasing said valve member toward closed position, a second means biasing said valve member toward closed position with a force proportional to the regulated pressure provided by said regulating valve, and means biasing said valve member toward open position with a force proportional to the fluid pressure acting on the tensioning device.

10. In a control system for a fluid-pressure operated piston-actuated tensioning device, an adjustable fluid-pressure regulating valve for providing a predetermined selectable fluid pressure for the actuating piston, a check valve for preventing fluid flow from the piston toward said regulating valve, a pressure relief valve for relieving excess fluid pressure on the tensioning device, said relief valve comprising a first chamber, a valve member controlling an outlet from said first chamber, a second chamber, an imperforate flexible diaphragm forming a common wall between said first and second chambers, means connecting said valve member for operation by said diaphragm, means biasing said valve toward closed position, means connecting said first chamber to be affected by the fluid pressure acting on the piston and means connecting said second chamber to be affected by the fluid pressure provided by said regulating valve.

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