Aug. 27, 1963 C. AARON ETAL 3,101,915

APPARATUS FOR CONTROLLING TENSION IN A RUNNING WEB

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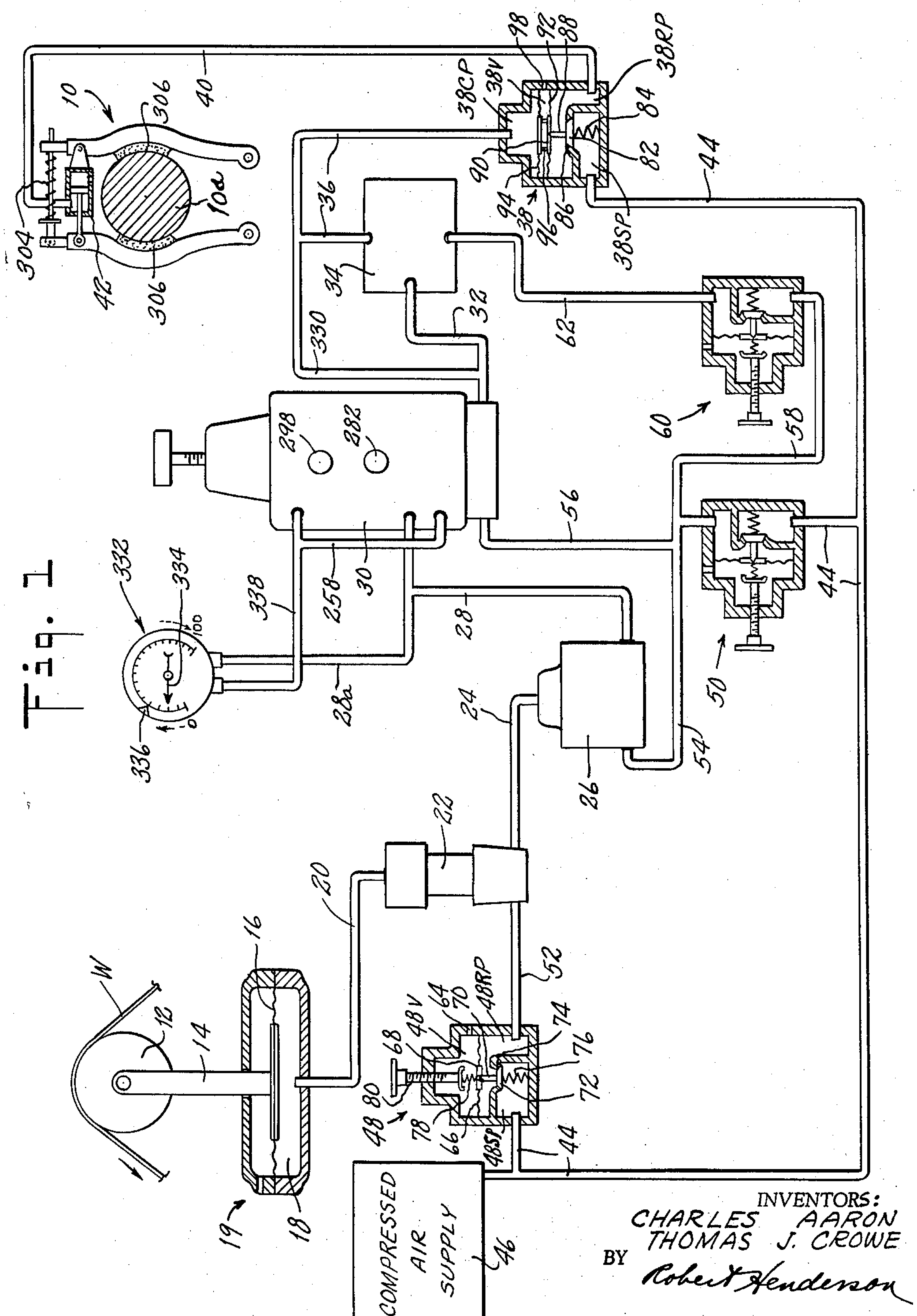

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Fig. 2.

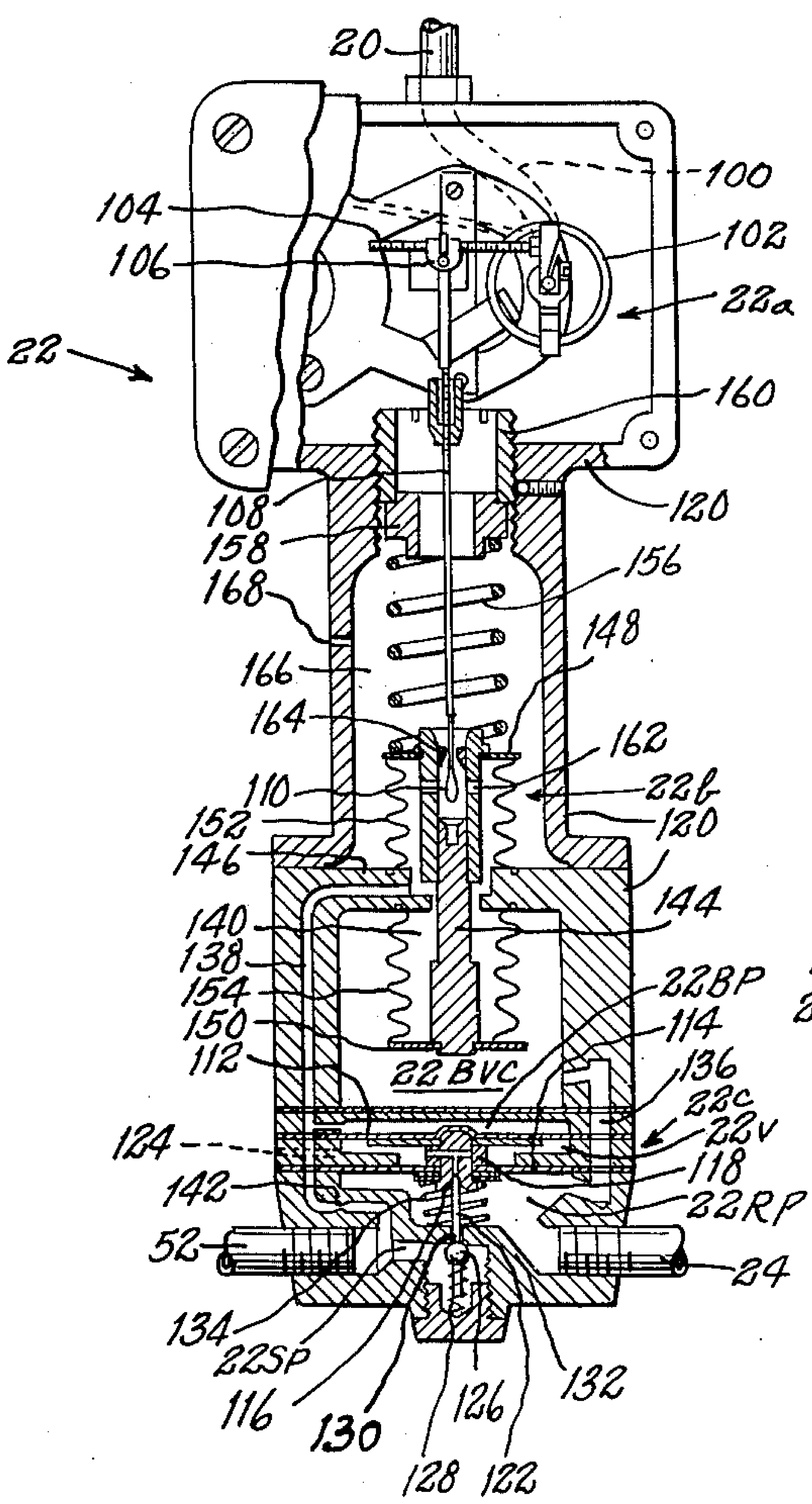

Fig. 3.

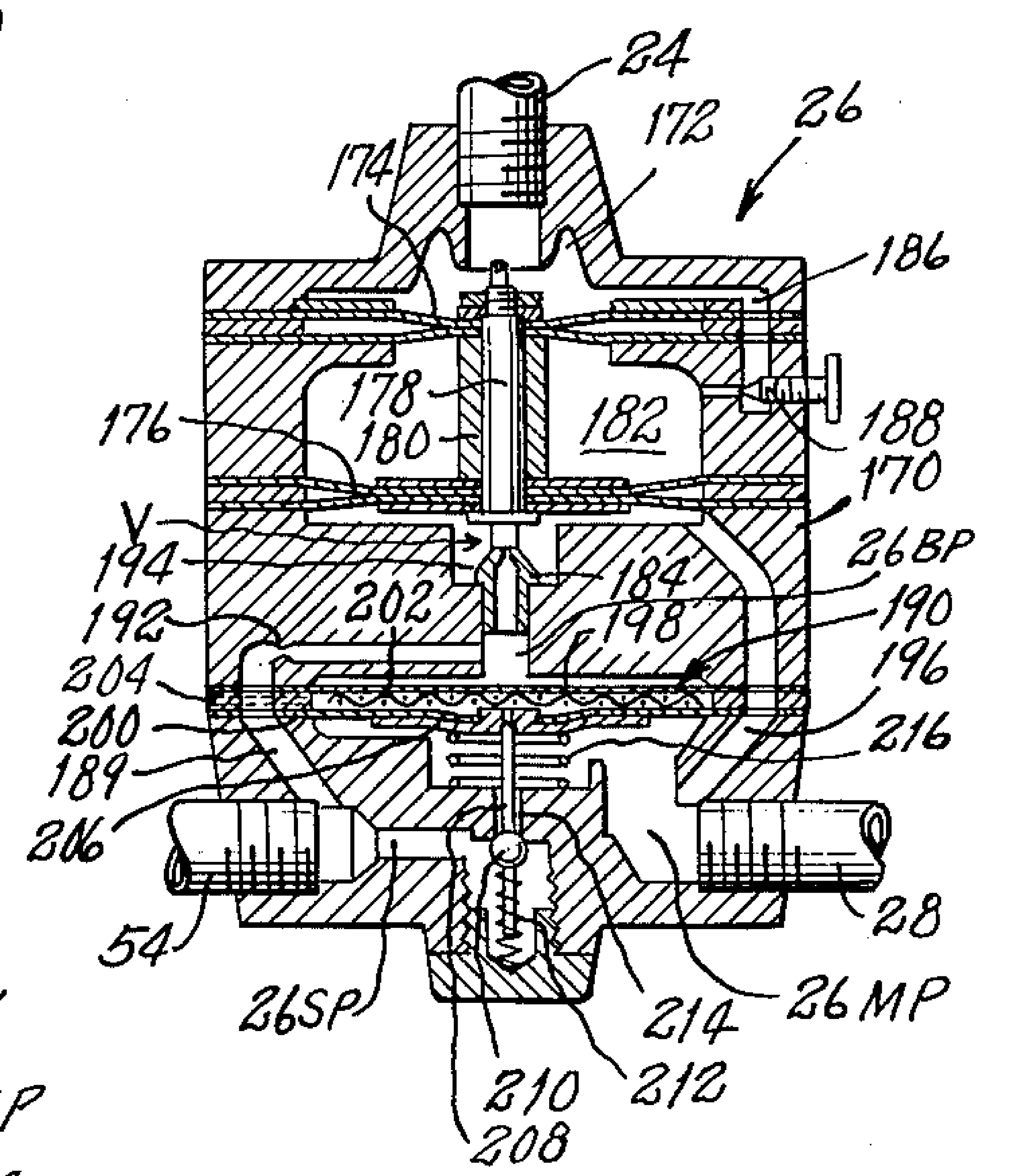

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Fig. 5.

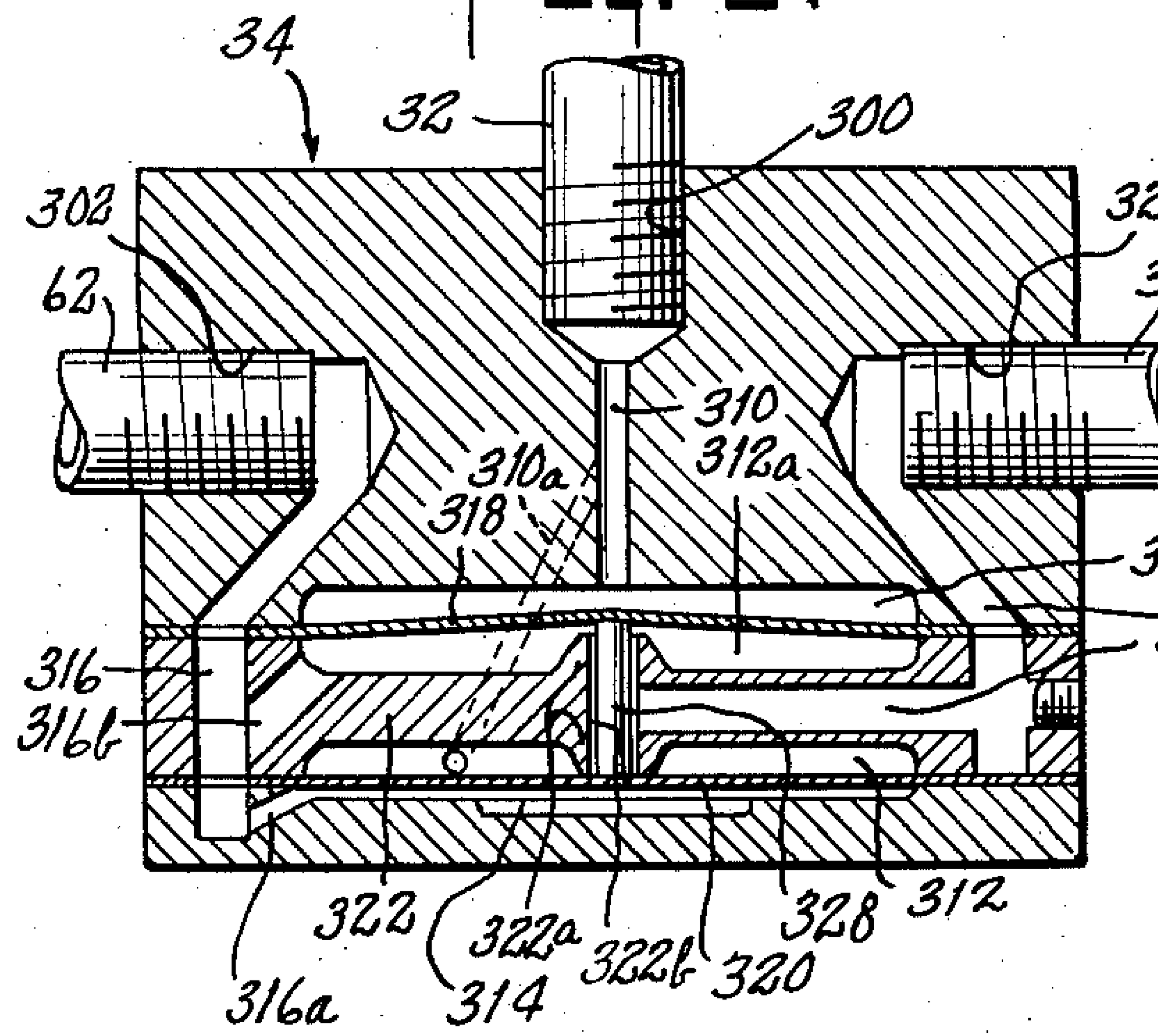
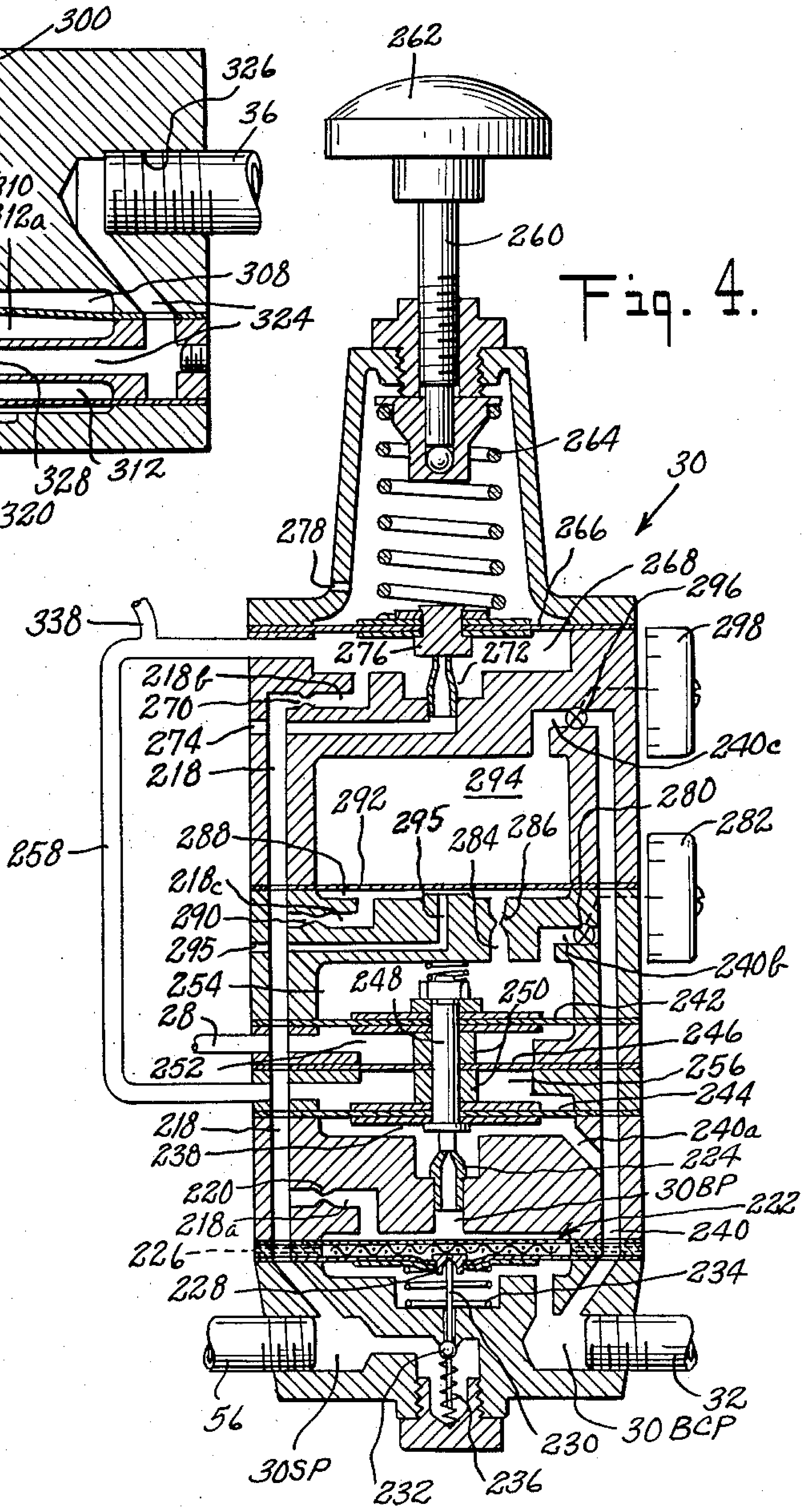


Fig. 4.



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3,101,915
APPARATUS FOR CONTROLLING TENSION IN A RUNNING WEB

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13 Claims. (Cl. 242—75.43)

This invention relates to improved web-tension control means for web-winding machines and, more particularly, for maintaining a substantially uniform tension in the running web. It amkes substantial use of the principle disclosed in Patent No. 2,974,893, dated March 14, 1961, covering the invention of Charles Aaron, but includes an improved combination of control means by which web-tension deviations are corrected more effectively and without undesirable hunting conditions which are sometimes encountered when the apparatus of said patent are employed.

The principal object of this invention is the provision of improved means for controlling the tension in a web being wound from one roll to another in a winding operation.

Another important object is the provision of such control means in which various control elements are of such light weight and limited to such minute movement that they do not develop inertia which could cause hunting or other undesirable conditions.

Another important object is the provision of such control means wherein a braking effect which controls web tension is varied, for correction of undesired web-tension deviations, to an extent dictated by the magnitude of said deviations.

Another important object is the provision of such control means wherein a braking effect, after having been varied to correct a web-tension deviation, is restored or reset automatically to reestablish and maintain control of the web at the desired tension thereof.

Another important object is the provision of such control means in which the mentioned automatic resetting of the braking effect occurs in a relatively gradual manner and with a diminishing magnitude of resetting effect.

Another important object is the provision of such control means which assure that a brake-operating fluid pressure will never drop below that which is necessary to prevent undesirable complete release of the brake which participates in control of the web tension.

Another important object is the provision of such control means which, despite possible violent fluctuations of web tension, assure the uninterrupted maintenance of sufficient fluid pressure to give continued operation of a ratio valve employed as an important instrumentality in control of the web tension.

Another important object is the provision of such control means which suppress rather rapid or high frequency variations set up in fluid in web-tension sensing means by web-tension variations which are so rapid as to require no corrections, leaving the variations of pressure in such fluid effective only with respect to more or less general or sustained tension variations which are generally referred to herein as tension deviations.

The foregoing and other more or less obvious objects are achieved by the present invention of which one preferred embodiment is shown, for illustrative purposes, in the accompanying drawings in which:

FIGURE 1 is a diagrammatic illustration of a tension-control system according to a preferred embodiment of this invention.

FIG. 2 is an approximately central, vertical sectional view of a hydraulically controlled tension sensing air valve which responds to tension variations in the running web and deilvers air pressure which varies in accordance with web-tension variations.

FIG. 3 is an approximately central, vertical sectional view of a modulating air valve which is controlled by the output air pressure of said tension-sensing valve and delivers air pressure which varies generally as the output of the tension-sensing valve, hence, as variations in web tension, but is modulated in that rapid pressure variations are substantially eliminated so that the pressure output of this modulating valve varies only in accordance with undesired web-tension deviations.

FIG. 4 is an approximately central, vertical sectional view of a ratio or brake control air valve which, in response to modulated, varying air pressure received from said modulating valve, delivers brake control or operating air pressure.

FIG. 5 is an approximately central, vertical sectional view of a pressure-selector relay which assures delivery of sufficient brake control or operating pressure to the brake to safeguard against free opening or complete release of the brake.

Referring to FIG. 1, the runing web W, in passing from a brake-controlled mill roll (not shown), the brake or brake assembly of which is generally indicated at **10**, is caused to pass over and press upon a guide member in the form of a roller **12** in passing to a rewind roll (not shown). The guide roller **12** may be supported as disclosed in said Patent No. 2,974,893, with one of its ends yieldably supported and rigidly connected by a stem **14** with a tension-sensing diaphragm **16** defining the top of a hydraulic chamber **18** in a rigidly supported hydraulic cylinder **19**. The chamber **18** is connected by pipe **20** to the top of a tension-sensing valve **22**. The pressure of liquid in chamber **18** and pipe **20** varies as the diaphragm **16** flexes slightly in response to variations in the downward force exerted by the web upon roller **12** caused by variations in the tension of said web; and said liquid pressure controls the operation of the valve **22**.

A pipe **24** connects the air pressure output of valve **22** to a modulating valve **26** to control the latter's operation.

A pipe **28** connects the modulated air pressure output of modulating valve **26** to a ratio valve **30** to deliver said modulated pressure to the latter valve to control its operation. This delivered modulated pressure is sometimes hereinafter referred to merely as "tension pressure."

A pipe **32** connects the air pressure output of ratio valve **30** to a pressure-selector relay **34** to deliver control air pressure to said relay.

A pipe **36** connects the air pressure output of relay **34** to a brake-supply valve **38** to deliver brake-control pressure to the latter to cause it to deliver controlled pressure for operating the brake.

The output of the valve **38** is connected by pipe **40** to brake-actuating fluid-pressure cylinder **42** which operates the brake **10**.

A pipe **44** connects a compressed air supply **46** to the brake-supply valve **38** and also to manually adjustable air-regulator valves **48** and **50**. Of these regulator valves, the output of valve **48** is connected by pipe **52** to tension-sensing valve **22**; and the output of valve **50** is connected by pipe **54** to modulating valve **26**, by pipe **56** to ratio valve **30**, and by pipe **58** to another, somewhat similar manually adjustable regulating valve **60**, the output of which is connected by pipe **62** to the relay **34** to provide, in the latter, one of two pressures to be selectively delivered, from said relay, to the brake-supply valve **38** to control the latter's operation. The other of these two pressures is the output pressure of ratio valve **30** delivered by pipe **32** to said relay.

The manually adjustable regulator valves **48**, **50** and

60 are all substantially similar, hence, the following description of valve 48 should suffice as a description, also, of each of valves 50 and 60.

The casing of valve 48 forms therein a supply-pressure chamber 48SP, a regulated-pressure chamber 48RP and a vent chamber 48V. The latter chamber is continuously open to atmosphere through a vent 64. The chambers 48RP and 48V are separated by a diaphragm 66, an integral central portion of which constitutes a centrally apertured valve seat 68 in the aperture of which seats the upper end of a valve stem 70 to control venting of air from chamber 48RP to atmosphere. The valve stem 70 has an integral valve member 72 at its lower end which seats in a valve seat 74 to control the movement of air between chambers 48SP and 48RP.

A compressed coil spring 76 urges valve member 72 and valve stem 70 upwardly, respectively, into or toward closing relation to valve seats 74 and 68. A compressed coil spring 78, the compressive force of which may be adjusted by a hand-operable screw 80, presses downwardly upon valve seat 68, valve stem 70 and valve member 72 in opposition to the force of spring 76.

The just-mentioned adjustment arrangement provides such spring biasing of the automatically operating parts of valve 48 that, if the regulated pressure in chamber 48RP exceeds the pressure which the valve 48 is set to deliver, the excess pressure flexes the diaphragm 66 upwardly, thereby unseating the upper end of valve stem 70 to permit the excess pressure to vent off through the aperture in valve seat 68, thence through chamber 48V and vent 64 to atmosphere.

If the regulated pressure in chamber 48RP drops below the pressure which the valve 48 is set to deliver, then, with the diminished pressure in chamber 48RP, the spring 78 suffices to push downwardly the diaphragm's valve seat 68, the valve stem 70 and valve member 72 to unseat the latter and thereby enable supply pressure to pass from chamber 48SP, through valve seat 74, into chamber 48RP, sufficiently to bring the pressure in the latter chamber to the pressure which the valve 48 is set to deliver.

Brake-supply valve 38 is similar to valves 48, 50 and 60 in having a supply-pressure chamber 38SP, a regulated-pressure chamber 38RP, a valve member 82, urged by spring 84 toward seating position in a valve seat 86, said valve member having an integral stem 88, the upper end of which functions as a valve, seating in a central aperture in a valve-seat member 90 which is an integral central part of a lower diaphragm 92.

Brake-supply valve 38 differs from valves 48, 50 and 60 in that it is controlled by air pressure rather than by manual adjustment. Thus, the pressure output from selector relay 34 enters a control-pressure chamber 38CP from pipe 36, the latter chamber being defined by an imperforate, upper diaphragm 94 which is fixedly spaced from diaphragm 92 by spacers 96. The space between the two diaphragms serves as a vent chamber 38V, through which air, passing from chamber 38RP through the valve-seat member 90 (when the aperture of the latter is open), may pass through vent port 98 to atmosphere.

The various pipe connections to and from the components 22, 26, 30 and 34 may be more fully and clearly understood by reference to FIGS. 2, 3, 4 and 5, the details of which will now be explained.

The tension-sensing valve 22 (FIG. 2) has three principal interacting sections, (1) a control section *22a*, (2) an air-bleed valving section *22b*, and (3) an air pressure regulating section *22c*.

The control section *22a* includes a tube 100 which connects liquid-containing pipe 20 to a Bourdon tube 102 to the closed end of which is fixed a substantially horizontal arm 104. On this arm is adjustably threaded a yoke 106 from which pivotally depends an adjustable-length rod 108 on the lower end of which is formed or fixed a valve element 110 which may be considered, also, as a part of the air-bleed valving section of valve 22.

The air pressure regulating section *22c* comprises a dual diaphragm arrangement having an upper, imperforate diaphragm 112, fixedly spaced from a lower diaphragm 114 by a valve-seat stud 116 and a spacing ring 118. The disposition of these diaphragms in casing 120 of the valve 22 is such as to provide a bleed-pressure chamber 22BP above the upper diaphragm, a vent chamber 22V between the two diaphragms, and a regulated-pressure chamber 22RP below the lower diaphragm.

The valve seat 116 and the spacing ring 118 have passages therethrough which, subject to control of a valve element 122, provide air communication from chamber 22RP to chamber 22V which is in constant communication with atmosphere through one or more vent ports 124. The upper end of valve element 122 functions with seat stud 116 as a vent-control valve. Said valve element has an integral ball-valve member 126 which is yieldably urged upwardly by compressed coil spring 128 toward a valve-seat passage 130 formed in a web 132 of the casing 120. The ball-valve member controls the passage of air from a supply-pressure chamber 22SP to the chamber 22RP. Another compressed coil spring 134 is disposed between the lower diaphragm 114 and the casing web 132.

There are two air passages, conveniently formed as ducts in the casing 120, which may be considered as parts of both the valve's sections *22b* and *22c*. One of these passages, numbered 136, uninterruptedly interconnects chamber 22RP with a bleed-valve control chamber 22BVC so that the air in the latter chamber is always at the same regulated pressure as in chamber 22RP. The other of the mentioned passages, numbered 138, is a bleed passage, uninterruptedly but constrictively interconnecting passage 22SP with a bellows chamber 140 and also with chamber 22BP. Between its two-mentioned connections to chamber 140 and 22BP, on the one hand, and chamber 22SP, on the other hand, the passage 138 is fixedly constricted to a predetermined extent by limitation or partial obstruction of its diameter by any suitable means; this constriction being indicated at 142 merely as a much reduced portion of said passage.

The air-bleed valving section *22b* of valve 22 comprises a stem-like bleed-valve seat element 144 which extends vertically, freely, through a transverse web 146 of the casing 120. The opposite ends of this valve-seat element are provided with plates 148 and 150 which are hermetically secured to said element; and these plates, in turn, are hermetically secured to metal bellows elements 152 and 154, both of the latter elements being hermetically fixed upon the web 146, thereby forming the bellows chamber 140. A compressed coil spring 156, disposed between a spring-seat ring 158 and the bellows plate 148 serves substantially to position the bellows and the valve-seat element 144 against the regulated air pressure in bleed-valve control chamber 22BVC. An adjustable bushing 160 supports the spring-seat ring 158 and permits adjustment of the force to be developed in the spring 156.

The upper portion of the bleed-valve element 144 is cylindrical and formed with one or more ports 162 therein. Above these ports a seat ring 164 is fixed within the element 144. The rod 108 extends through the ring 164 and the valve element 110, on said rod, is in valving relation to said ring. Raising of said rod causes the valve element 110 to diminish the flow of air through the seat ring 164 and lowering of said rod and valve element causes an increase in such flow.

Bleed air from passage 138 and chamber 140 passes through ports 162 and past valve 110, through seat ring 164 to spring chamber 166, thence through a vent port 168 to atmosphere.

The modulating valve 26 (FIG. 3) has a casing 170 which, like some other instrumentalities disclosed herein, may be fabricated of several parts which, before assembly, are formed with ducts, cavities and certain parts to provide a structure as now to be described.

The casing **170** of the valve **26** is formed with an upper air chamber **172** into which regulated but unmodulated air pressure is introduced through pipe **24** from tension-sensing valve **22**. The chamber **172** is partly defined by a relatively small area, uppermost diaphragm **174** of an assembly which includes another, larger area diaphragm **176**, these two diaphragms being rigidly interconnected centrally in spaced relationship by a connecting bolt **178** and a spacing sleeve **180**, thereby forming an intervening bleed-valve operating chamber **182**. Bolt **178** also operates as a bleed-valve member, having a flat, bottom end surface which closely overlies a central aperture in the upper end of a fixed nozzle **184** to control bleed communication of pressure through the latter. As the diaphragm **176** has a larger effective area than upper diaphragm **174**, air pressure in chamber **182** tends to urge the valve member **178** toward said nozzle to control the air-passing capacity of the latter.

Chambers **172** and **182** are maintained in constant fluid communication by a duct **186** having therein an adjustable throttle valve **188** which has the effect of maintaining a general equality of pressures in said chambers while preventing momentary pressure changes from passing from chamber **172** to chamber **182**.

Valve **26** is formed, at its lower end, with a chamber **26**SP, connected by pipe **54**, regulator valve **50**, and pipe **44**, to a source of compressed air and also connected by a duct **189** to a chamber **26**BP above a diaphragm **190**. A fixed constriction **192** is provided in duct **189**. Air may bleed from chamber **26**BP, through nozzle **184** into a chamber **194** underneath diaphragm **176**, thence through a duct **196** to a chamber **26**MP from which modulated pressure is carried by pipe **28** to ratio valve **30**.

The diaphragm **190** is constituted of two flexible plates **198** and **200**, spaced apart by some suitable spacing means such as a layer of metal mesh **202** which enables all open areas between said plates to communicate with atmosphere for venting purposes through one or more vent ports **204**.

Lower plate **200** is formed with a centrally apertured valve seat **206** into which seats the upper end of a valve element **208** which controls venting of pressure from chamber **26**MP to the area between plates **198** and **200** and, thence, through vent port **204** to atmosphere. The valve element has an integral ball-valve member **210** which is urged upwardly by a spring **212** into seating association with a valving passage **214** to control the movement of air from chamber **26**SP to chamber **26**MP. A spring **216** presses upwardly upon the diaphragm **190**.

Referring to brake-control or ratio valve **30**, the latter's general function is to control delivery, to brake cylinder **42**, of air at a pressure which is inversely proportional to the hydraulic pressure in hydraulic chamber **18** (which corresponds to tension in the running web), this hydraulic pressure having been converted into proportional air pressure in tension-sensing valve **22**, modulated in modulating valve **26**, and communicated (still proportional to said hydraulic pressure and web tension) into the valve **30** through pipe **28**. The parts of valve **30** which accomplish this general function will now be described.

It is first to be observed that the bottom part of valve **30** is identical or equivalent to the bottom part of valve **26**. Thus, pipe **56** connects a supply of air at controlled, relatively high pressure to a chamber **30**SP, thence through a duct **218**, constriction **220**, and duct **218***a*, to a chamber **30**BP, yieldably defined at its lower part by a dual-plate diaphragm **222** and at its upper part by a bleed nozzle **224**. The two plates of said diphragm are separated by a metal-mesh screen or other suitable separating means which enables the area between the two plates to vent to atmosphere through one or more vent ports **226**.

A valve seat **228**, valve element **230**, a ball member **232** of the latter and springs **234** and **236** function (similarly to corresponding parts of valve **26**) to control communication of air pressure between chamber **30**SP and a brake-control pressure chamber **30**BCP and between the latter chamber and atmosphere through the area between the two plates of the diaphragm and through vent port or ports **226**.

To maintain the desired brake-controlling pressure in chamber **30**BCP, air is either vented from the latter through valve seat **228** and port **226** or charged into said chamber by opening of the ball valve **232** to pass higher pressure air from chamber **30**SP into chamber **30**BCP and/or by opening of nozzle **224** to pass higher pressure air from chamber **30**BP into a chamber **238**, thence through ducts **240** and **240***a* to the chamber **30**BCP. The just-mentioned valving members **228** and **232** are controlled by flexing of the diaphragm **222**, similarly to the functioning of similar parts in valve **26**. The mentioned flexing is caused by variations in the throttling effect through nozzle **224** which variations are controlled by a differential between the pressures present in chamber **238** and a resultant or mean of the modulated air pressure derived from valve **26** and a desired tension air pressure separately established as that pressure needed for proper brake operation to maintain a desired web tension.

The mentioned resultant air pressure is made effective through the medium of a triple diaphragm assembly comprising an upper diaphragm **242**, a similar lower diaphragm **244** and an intermediate diaphragm **246** of smaller effective area than diaphragms **242** and **244**. These three diaphragms are centrally, rigidly interconnected and spaced, as illustrated, by a bolt **248** serving also as a valve element, and spacing sleeves **250**, the flat surface of the lower or head end of the bolt serving as a throttling control of the nozzle **224**. Diaphragm **242** defines the bottom of a proportional band-control chamber **254**, and, with diaphragm **246**, defines a chamber **252** which receives modulated tension pressure through pipe **28** from valve **26**. Diaphragm **244** defines the top of chamber **238** and, with diaphragm **246**, defines a chamber **256** which receives desired tension air pressure through a pipe or duct **258** (preferably formed as a duct in the valve casing), from pressure setting means now to be described.

The mentioned pressure setting means are designed to utilize pressure from chamber **30**SP and so throttle and controllably bleed it to atmosphere as to develop and maintain a desired tension pressure (hereinafter sometimes referred to for convenience as "set pressure") which is utilized in direct opposition to the modulated tension pressure received from valve **26** for control purposes as hereinafter explained.

The pressure setting means comprise an adjusting screw **260** having a manipulating knob **262** by which it may manually be turned up or down to adjust a spring **264** which bears downwardly upon a valve-controlling diaphragm **266**. This diaphragm defines the top of a set pressure chamber **268** which is connected by duct **258** to chamber **256**. Air is supplied to chamber **268** from chamber **30**SP through duct **218**, a constriction **270** and duct **218***b*. Air is vented from chamber **268** to atmosphere through a nozzle **272** and a venting duct **274**, the nozzle being controlled, to operate as a venting valve, by the flat undersurface of a valve member **276** carried by the diaphragm **266**. The area above the diaphragm **266** is suitably open to atmosphere, as, for example, through a vent port **278**.

Chamber **254** is connected with the output pressure (brake-control pressure) of valve **30** by duct **240** which communicates such pressure from chamber **30**BCP through a manually adjustable needle, throttling valve **280** and a supplemental duct **240***b*; the valve **280** being adjustable by a manually operable wheel **282**. Chamber

254 also is connected by a duct 284, having a fixed constriction 286 therein, with a chamber 288.

Chamber 288 is also connected with pressure in chamber 30SP by duct 218 and an auxiliary duct 218*c* having a fixed constriction 290 therein. The resultant of the pressures communicated to chamber 288 through ducts 284 and 218*c* tends to flex upwardly a diaphragm 292 defining the top of chamber 288 while pressure in a reset-controlling chamber 294, partially defined by the diaphragm 292, tends to flex the latter downwardly. This flexing, depending upon the relative values of the pressures in chambers 288 and 294, causes the diaphragm 292 to serve as a throttle of a vent duct 295 which controls venting of chamber 288 to atmosphere.

The reset-controlling chamber 294 is in communication with the brake-control pressure in chamber 30BCP through duct 240 and a supplemental duct 240*c* having therein a needle valve 296 which is manually adjustable by means of a hand wheel 298.

The brake-control pressure is communicated from valve 30 by pipe 32 to one inlet port 300 of pressure-selector relay 34 (FIG. 5). A second inlet port 302 of said relay receives regulated pressure by pipe 62 from the regulating valve 60. By manual adjustment thereof, valve 60 is regulated to communicate air pressure to relay 34, only slightly greater than the pressure needed in brake cylinder 42 to prevent brake spring 304 from causing the brake shoes 306 from disengaging and thus terminating their braking effect on brake drum 10*a*.

The brake-control pressure from valve 30 is communicated from inlet port 300 to an upper chamber 308 of the relay 34 by a duct 310 and to a first intermediate chamber 312 of the relay by duct 310 and a branch 310*a* thereof, the latter being diagrammatically indicated as a straight duct but actually being formed chiefly in outer wall portions of the relay. The regulated pressure from valve 60 is communicated to a lower chamber 314 of the relay by a duct 316 and a branch 316*a* thereof, and is communicated to a second intermediate chamber 312*a* of the relay by duct 316 and a branch 316*b* thereof.

A fluid-tight flexible diaphragm 318 separates chambers 308 and 312*a* and another similar fluid-tight flexible diaphragm 320 separates chambers 312 and 314. The chambers 312 and 312*a* are separated by a rather thick, rigid web 322 having an enlarged, central valving portion 322*a* with a central bore 322*b* extending completely therethrough. This bore is in fluid communication, through a duct 324, with an outlet port 326, whence air pressure is communicated by pipe 36 to brake-supply valve 38.

A spacing plunger 328, of a length greater than that of the bore 322*b* and of a diameter appreciably less than that of said bore, is disposed in the latter with its ends abutting the diaphragms 318 and 320 so that one or the other of chambers 312, 312*a* is always open to duct 324 and, hence, is open through pipe 36 to the brake-supply valve 38. It will be seen that the two diaphragms function as valve members at the ends of the bore 322*b*. When pressure in chambers 308 and 312 is lower than that in chambers 314 and 312*a* (an abnormal condition as indicated in FIG. 5), diaphragm 318 becomes unseated from the upper end of said bore so that at least minimum brake-controlling air pressure communicated from the regulator valve 60, to the chamber 312*a*, is communicated from the latter, through duct 324 and pipe 36 to brake-supply valve 38. Thus, valve 38 receives at least sufficient control pressure to cause the brake bands 306 to exert some braking effect on the brake drum 10.

Under ordinary operational conditions, however, the pressure in chambers 308 and 312 predominates that in chambers 314 and 312*a* and diaphragm 320 becomes unseated while diaphragm 318 becomes seated with respect to the bore 322*b*. Under these normal conditions, the pressure in chamber 312, derived from the ratio valve

30 is the pressure which controls the operation of brake-supply valve 38.

A feedback pipe connection 330 is provided to interconnect pipes 32 and 36, and functions, when the output pressure of valve 30 tends to drop below the set output pressure of valve 60, to maintain substantial equality of the pressures at the two input ports 300 and 302 of the relay 34. This feedback provides assurance against discontinuity of operation of ratio valve 30 by making certain that the pressure, in chamber 30BCP and duct 240 of the latter valve, will never drop below the minimum brake-control pressure supplied through regulating valve 60. The same minimum pressure suffices to keep ratio valve 30 in operation.

A dual-pressure gauge 332, functionally two gauges in comparative reading relationship, may be arranged, for example, so that a central pointer 334 is part of one gauge mechanism which, through pipes 28*a* and 28, is in fluid communication with chamber 252 of valve 30 to indicate the pressure in the latter chamber, which pressure may be referred to as actual tension pressure. The gauge 332 may have a peripheral pointer 336 as a part of another gauge mechanism which, through pipes 338 and 258, is in fluid communication with chambers 256 and 268 of the valve 30 to indicate the pressure in the latter chambers, which pressure may be referred to as desired tension pressure or set pressure.

The following description of the operation of the disclosed tension-control system should afford an understanding of the advantages of combining the various disclosed instrumentalities in accordance with this invention.

As satisfactory automatic control of the tension of the running web W depends upon providing for rapid compensation for variations of such tension, the tension-sensing valve 22 plays an important part in converting hydraulic pressure variations in hydraulic chamber 18 (variations corresponding to web-tension variations), into air pressure variations in output air pressure chamber 22RP of said valve. The valve 22 is highly sensitive and maintains its output air pressure proportional to its input hydraulic pressure. This sensitivity arises largely because of the already described arrangement whereby the output air pressure of the valve is controlled by throttling control by valve element 110 of only a bleed portion of its input air pressure and utilizing only the said bleed portion in chamber 22BP as the medium which operates valves 122, 126 to control transfer of air pressure between chambers 22SP and 22RP and between the latter chamber and atmosphere.

The high sensitivity of valve 22 causes its air pressure output to vary not only with respect to the more or less general variations in the tension of the running web but to include sharp, rapid variations corresponding to rapid, vibrating variations in the web tension. These vibratory variations are substantially self-compensating, hence, means for compensating them need not be provided; and, if such vibratory variations were reflected in air pressure employed to control the braking effect on brake band 10, they would cause needless, undesirable, vibratory brake operation.

Such vibrations are reflected in the air pressure output of valve 22 but that output, communicated by pipe 24 to valve 26 is modulated by the latter to eliminate the vibratory phase of the pressure leaving the latter variable only in relation to the general variations in the tension of the running web.

The modulating valve 26, like valve 22, is very sensitive because the operation of its valve members 208, 210 is controlled by a bleed pressure in chamber 26BP from which chamber, bleeding is controlled by nozzle 184 controlled by diaphragm 176 which, in turn, is controlled by pressure in chamber 182.

The modulating effect of valve 26 arises from the fact that the pressure in chamber 182 stays generally the same as the unmodulated pressure in chamber 172 but does not follow vibratory or rapid pressure changes in the latter chamber because the interconnection of chambers 172 and 182 is only through the throttle valve 188 in duct 186. This throttle valve is adjusted to prevent the vibratory or rapid pressure changes from passing from chamber 172 to chamber 182. It may thus be seen that modulated pressure in chamber 26MP of valve 26 is also present in chamber 252 of control valve 30 by reason of the interconnection of those two chambers by pipe 28. It may be well to remember that this modulated pressure varies with general web-tension variations but not with vibratory or rapid tension variations.

The control valve 30 plays an important part in avoiding hunting action of the brake 10 and in otherwise controlling the apparatus to maintain stable, satisfactory tension conditions in the web being wound. It does this in several ways, hereinafter explained, which more or less complement each other to bring about desired operational stability.

The control valve 30 provides means by which its valve element 248 and its related diaphragms may be conditioned to respond in a set ratio to the change required in the brake-control pressure in chamber 30BCP of said valve to so operate the brake 10 as to correct any operational departure of the running web's tension from the desired or set tension thereof. When any such departure occurs, correction thereof must arise from a change in said brake-control pressure to change operation of the brake to effect the desired change in the web tension.

Immediately prior to such correction, the brake-control pressure in chamber 30BCP reflects the differential or pressure change which must be effected in said pressure to effect the desired tension correction. That pressure, including said pressure differential, is communicated, unmodified, to chamber 238 through duct 240*a*, to bias the valve element 248 upwardly, while the brake-control pressure communicated to chamber 254 through at least partially closed needle valve 280 becomes somewhat modified by being partially vented off through constriction 286 and venting duct 295, thereby maintaining in chamber 254, a pressure somewhat less than the pressure in chamber 238 to bias the valve element 248 in an upward direction.

The pressure differential between chambers 254 and 238 remains in a substantially constant ratio to any correction required in the brake-control pressure in chamber 30BCP to effect correction of web tension. Thus, when any operational web-tension change creates an imbalance of the pressures in chambers 252 and 256, the reaction to such imbalance operates against the pressure differential existing in chambers 254 and 238. The corrective effect of such imbalance involves application of said imbalance against said pressure differential which continuously reflects the total corrective change needed in the brake-control pressure in chamber 30BCP and operates valve element 248 and valve element 230 or 232, in a manner already described, to cause such alteration of the brake-control pressure as will bring the web tension back to its desired tension. As the mentioned alteration and correction progresses, however, the net force of said pressure imbalance in chambers 252 and 256, upon valve element 248, either increases or decreases, depending on whether the brake-control pressure is undergoing a corrective increase or decrease. As the correction reaches completion, the absence of need for further correction of brake-control pressure brings the pressures in chambers 252 and 256 back into balance as when winding occurs without material web-tension variations. During this correction, the net force of said imbalance is of gradually diminishing effect, hence, the correction does not proceed to excess to cause a hunting condition in brake 10.

Upon completion of the just-described operation of valve 30 to vary the braking effect and thereby restore the desired web tension, and after discontinuance of the operational condition which caused web tension of undesired magnitude, the brake adjustment must be reset to its previous adjustment in order to cause the running web thereafter to be maintained at the desired tension. The valve 30 operates to cause such resetting.

While some temporary operational departure from the desired web tension has caused correction in the manner just described, the pressure condition established in chamber 256 remains constant at a pressure corresponding to the web tension desired to be maintained. The braking effect has been altered, however, by being decreased or increased, and, if left as altered, the web tension would remain lower or higher than desired. But upon termination of the operational disturbance which caused the undesired decrease or increase in the web tension, the undesired remaining lower or higher tension is reflected in the pressure in chamber 252 which operates to come into equilibrium with the pressure in chamber 256 through operation of valve element 248 in the manner already indicated.

The restoration of such equilibrium causes valve element 248 to operate oppositely to its previous correctional operation which caused the pressure change in chamber 30BCP to vary the operation of brake 10 to offset the previous undesired operational departure of web tension from the desired web tension. Such opposite operation of valve element 248 brings the brake-control pressure in chamber 30BCP back to that pressure which restores and maintains brake operation to maintain desired web tension. This restoration occurs relatively gradually and in diminishing manner, under influence of the pressure differential in chambers 238 and 254, in much the same manner as occurred in correction of an operational web-tension deviation. Here, again, a hunting condition is avoided.

The pressure in chamber 294 of control or ratio valve 30 operates to control the throttling action of diaphragm 292 upon the inner end of venting duct 295. The needle valve 296 may be set by wheel 298 so that pressure changes in chamber 30BCP and duct 240 will become effective in chamber 294 either relatively rapidly or relatively slowly, thereby controlling the speed of pressure change in chamber 254 and the resulting speed of a reestablishment of equilibrium of the pressure in chamber 252 with the constant, established pressure in chamber 256. Setting of the needle valve 280 by wheel 282, as already explained, operates in conjunction with the throttling actions of constriction 286 and venting duct 295 to establish in chamber 254 a pressure which with brake-control pressure in chamber 238 imposes operation on valve element 248 in proportion to any correction needed in the brake-control pressure.

The preceding description of pressure-selector relay 34 is sufficiently indicative of its mode of operation.

Summarizing operation of the described control apparatus; web-tension variations are hydrostatically communicated from chamber 18, through pipe 20, to tension-sensing valve 22, the output of which is modulated by modulating valve 26. The modulated pressure output of the latter valve operates ratio valve 30 to exert control upon brake-supply valve 38 in proportion to needed correction of web tension to cause controlled pressure from the latter to so operate brake 10 as to remedy any general web-tension departures from desired web-tension; control valve 30 also functioning to restore the braking effect needed to maintain the web tension at its desired value or magnitude.

It is worthy of note that, in addition to the mentioned anti-hunting effect derived from altering the brake-control pressure in proportion to the required web-tension correction, and with a gradual and diminishing effect, this invention also works against hunting conditions because any flexing of the various disclosed diaphragms is very slight and leads to no material inertia conditions which could operate to cause hunting. Also, the control of pressure outputs of valves **22**, **26** and **30** by having the control pressures imposed on said valves arranged to operate through pressure bleed arrangements, as described, leads to very sensitive operation of said valves.

It should be understood that the concepts of this imrpoved control apparatus may be employed in various other ways without, however, departing from the invention as set forth in the following claims.

We claim:

1. In apparatus for controlling tension in a running web, a combination comprising a fluid-pressure operated brake coacting with the web in opposition to a force lengthwisely actuating it, a guide member in engagement with the web and movable in response to tension variations therein, and a fluid-pressure system operatively arranged between said guide member and brake for operating the latter; said system comprising a tension-sensing element connected to and constrained to move with said guide member and partially defining a hydraulic chamber in a stationary hydraulic cylinder, a tension-sensing valve, a closed column of liquid interconnecting said chamber and said valve, causing the latter to operate in response to variations in the pressure of liquid in said column to establish proportionally similar variations in the output pressure of said valve, and a ratio valve coacting with said brake to control the latter's operation and coacting with said tension-sensing valve for deriving control of operation of the ratio valve from variations in the output pressure of the tension-sensing valve; said ratio valve comprising diaphragm means, for operating said valve, biased oppositely, on the one hand by the ratio valve's output pressure and on the other hand by a portion of the latter output pressure; and said diaphragm means also being partially under the control of the output pressure of said tension-sensing valve, whereby to operate said ratio valve in proportion to the differential of forces applied to said diaphragm means by said output pressure of the ratio valve and said portion of the latter output pressure.

2. A combination according to claim 1, said system further including means for imposing a selected control pressure upon said diaphragm means in opposition to the pressure imposed thereupon by the output pressure of said tension-sensing valve; the two latter opposing pressures normally exerting balanced forces upon said diaphragm but being adapted to coact to vary the operation of the ratio valve upon occurrence of any imbalance of said forces.

3. A combination according to claim 1, said system further including modulating means, connected between said ratio valve and said tension-sensing valve and adapted to suppress momentary pressure variations in the output pressure of the latter valve.

4. A combination according to claim 1, said system further including a pressure-selector relay connected to said ratio valve to have the output pressure of the latter communicated thereto, and means independent of the ratio valve for communicating separately controlled fluid pressure to said relay; said relay being connected to said brake and being adapted to communicate, to the latter, the higher of the pressures communicated to said relay.

5. A combination according to claim 4, further including a fluid communicating by-pass between output connections of said relay and said ratio valve to maintain the latter's output pressure at least as high as said separately controlled pressure.

6. A combination according to claim 1, said ratio valve further comprising manually adjustable means for varying the ratio of said portion of the ratio valve's output pressure to the latter valve's full output pressure, whereby to vary the magnitude of operation of the ratio valve arising from variations in the output pressure of the tension-sensing valve.

7. A combination according to claim 6, said adjustable ratio-varying means comprising a first pressure chamber partially defining said diaphragm means and having a substantially unimpeded connection to the output pressure of the ratio valve, and a second pressure chamber partially defining said diaphragm means and having an adjustable throttle valve connection to the ratio valve's output pressure and a throttled bleed connection to atmosphere; the different pressures in said first and second pressure chambers being effective in opposition to each other upon said diaphragm means and imposing a net force, upon said diaphragm means, which is operative in opposition to the output pressure of the tension-sensing valve.

8. A combination according to claim 1, said system further including a first pressure chamber arranged in operating relation to said diaphragm means, tension pressure setting means connected to said first chamber and adapted to establish and maintain a set pressure therein corresponding to the pressure desired to be derived from the tension-sensing valve, and a second pressure chamber arranged in operating relation to said diaphragm means and connected to said tension-sensing valve to receive the latter's output pressure; said first and second chambers being so arranged in relation to said diaphragm means as to impose their pressures oppositely upon the latter, whereby to operate the ratio valve in response to the difference in the forces applied to said diaphragm means by the pressures in said first and second pressure chambers.

9. In apparatus for controlling tension in a running web, a combination comprising fluid-pressure operated braking means opposing running motion of the web, a movable guide member coacting with the web to derive movement therefrom in response to tension deviations therein, a fixed hydrostatic cylinder, a movable element in said cylinder, constrained to move with said guide member and partially defining a pressure chamber in said cylinder, a tension-sensing valve having control means therein for controlling said valve's operation, a connection between said pressure chamber and said control means, a closed column of liquid in said pressure chamber and said connection, said control means being responsive to pressure in said column to control movement through said valve of fluid separately supplied thereto to cause the output of said valve to vary, as to pressure, in accordance with deviations in the tension of the running web, and a brake-control valve having a line pressure input chamber, a regulated pressure output chamber, a valve element in fluid-interchange relation between said input and output chambers, and diaphragm means including a diaphragm defining, at one face thereof, a tension-pressure chamber connected to said tension-sensing valve in fluid communication with the latter valve's output, and defining at the other face thereof, a set tension-pressure chamber having means associated therewith for maintaining a desired tension pressure therein, said diaphragm being adapted to flex in response to pressures in said two latter chambers and, through such flexing, to coact with and control operation of said valve element to control movement between said input and output chambers of fluid separately supplied to the brake-control valve, to cause the output of the latter valve to vary, as to pressure, in accordance with variations in the relative pressures in said tension pressure and set tension-pressure chambers; said braking means coacting with the regulated pressure in said output chamber of the brake-control valve to derive variation of the braking effect of said braking means in accordance with variations in the output pressure of the latter valve's said output chamber.

10. A combination according to claim 9, said diaphragm means including second and third diaphragms, rigidly interconnected with said first-mentioned diaphragm to constrain the three diaphragms to operate in unison, said second and third diaphragms being spaced from opposite faces of the first-mentioned diaphragm and defining, with the latter, said tension pressure and set tension-pressure chambers; said second and third diaphragms also defining, at their faces remote from said first diaphragm, a pair of oppositely acting ratio-control chambers in fluid communi-

cation with said regulated pressure output chamber; one of the ratio-control chambers being subject to the full pressure in said output chamber and the other of the ratio-control chambers having a constricted bleed passage therefrom to atmosphere to render the latter chamber subject to less than the full pressure in said output chamber, whereby to cause said ratio-control chambers to exert pressure upon said diaphragm means, effective in conjunction with the pressures in the tension pressure and set tension-pressure chambers, to so operate said valve element as to cause operation of the brake-control valve in a substantially fixed ratio to the pressure in said output chamber.

11. A combination according to claim 10, further including a separate diaphragm, coacting with said bleed passage as a valve for the latter, and defining a reset-controlling chamber, the latter being in controlled-restrictive fluid communication with said output chamber; said separate diaphragm being responsive to pressure in said reset-controlling chamber to vary the bleed capacity of the bleed passage and thereby control the brake-control valve's response to pressures in said tension-pressure chamber and said set tension-pressure chamber.

12. A combination according to claim 11, said brake-control valve including a manually adjustable needle valve, between said output chamber and said reset-controlling chamber to control the pressure in the latter chamber and thereby control the separate diaphragm's said valve action and the pressure maintained in said other ratio-control chamber.

13. A combination according to claim 11, said separate diaphragm also defining a bleed chamber constituting a part of said bleed passage and restrictively connected to said input chamber, said separate diaphragm constituting a valve, operative in said bleed passage between said bleed chamber and atmosphere.

References Cited in the file of this patent

UNITED STATES PATENTS

2,755,032	Justus	July 17, 1956
2,974,893	Aaron	Mar. 14, 1961
2,974,894	Aaron	Mar. 14, 1961
3,057,574	Justus	Oct. 9, 1962
3,071,300	Justus	Jan. 1, 1963
3,072,360	Cruz	Jan. 8, 1963