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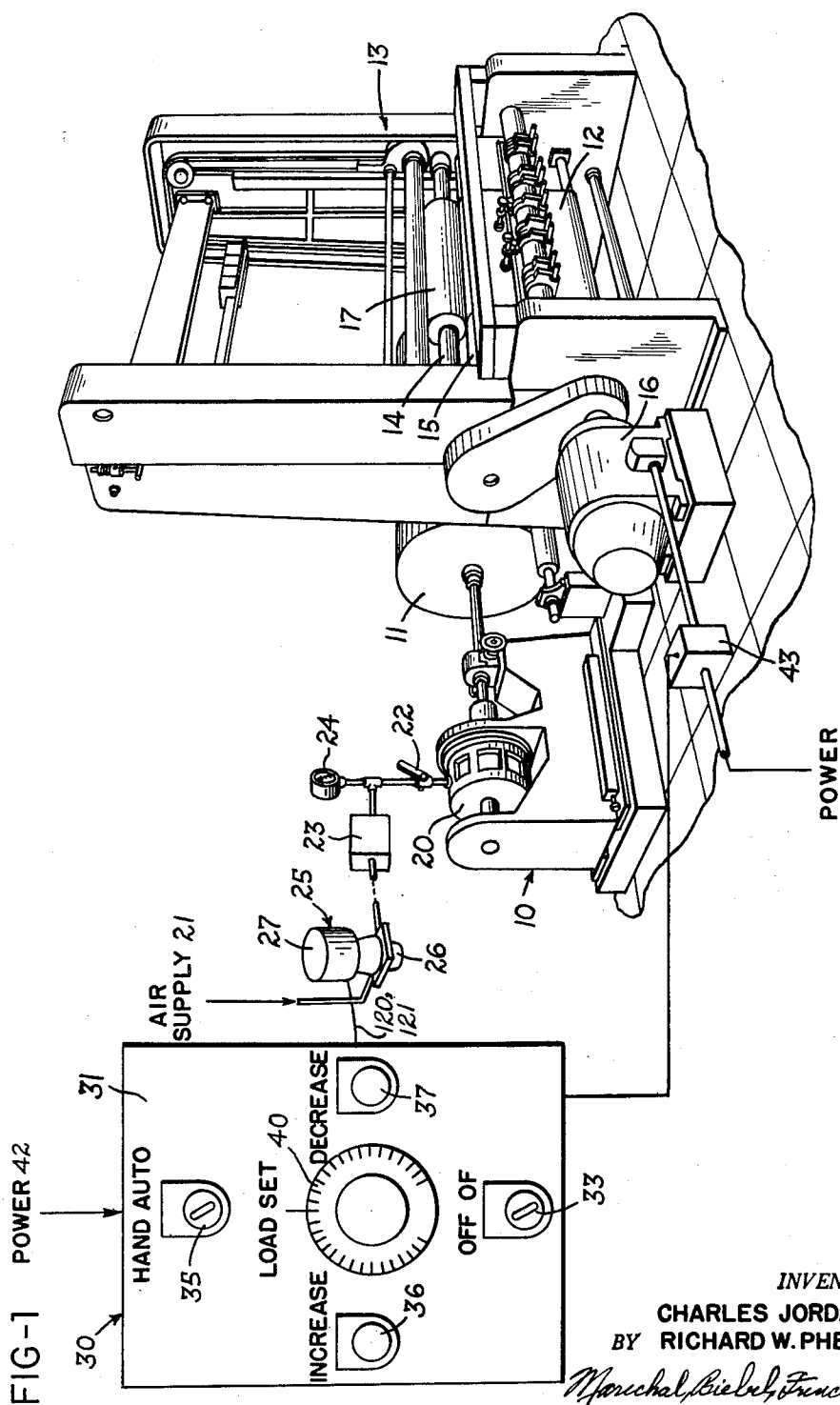
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3,049,313

WEB TENSION CONTROL SYSTEM

Filed July 27, 1959

3 Sheets-Sheet 1



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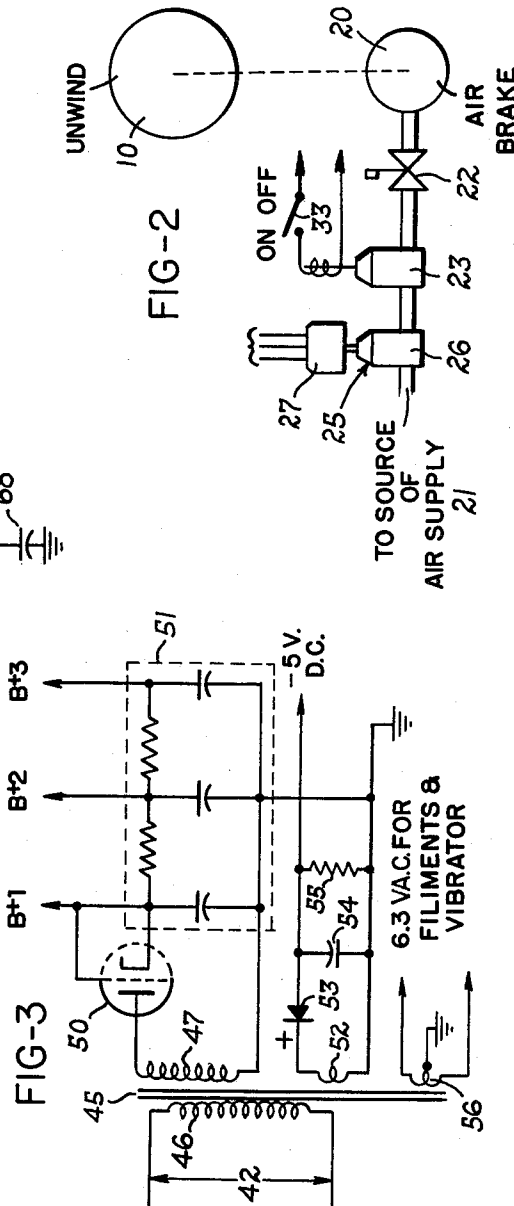
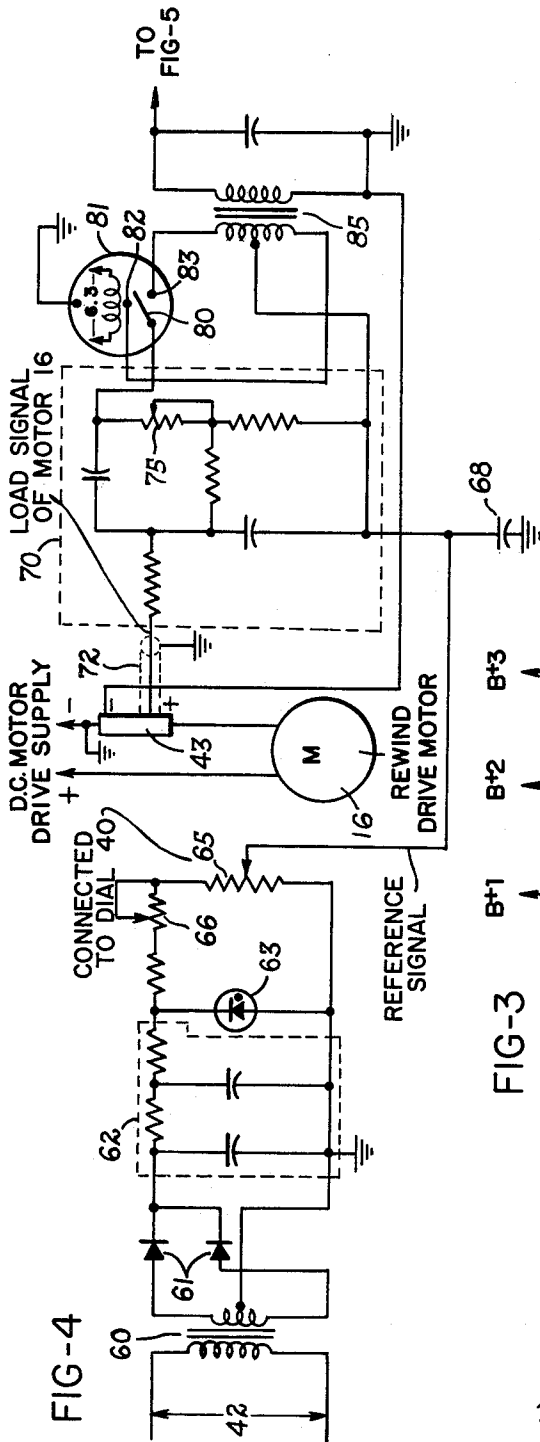
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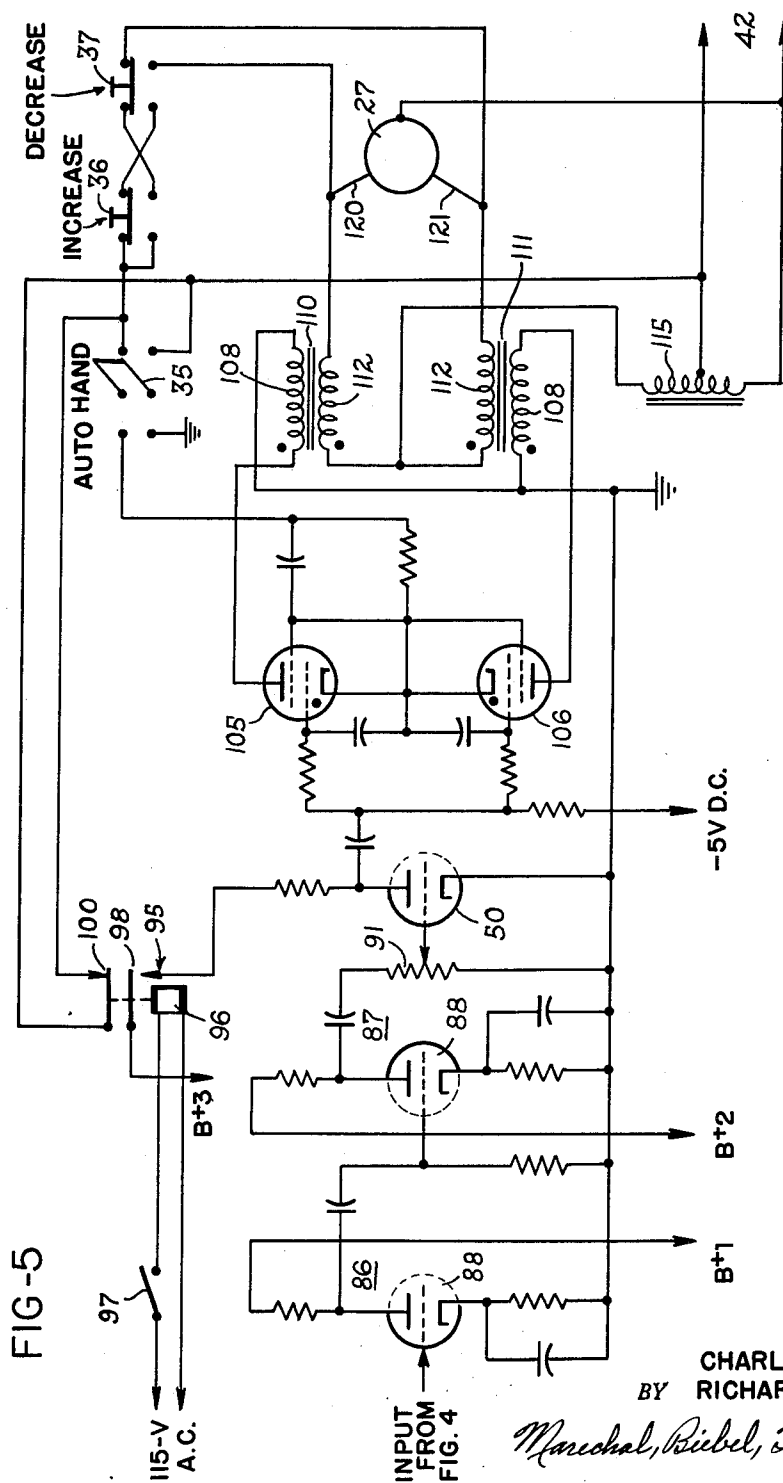
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3 Sheets-Sheet 3



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WEB TENSION CONTROL SYSTEM

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9 Claims. (Cl. 242—75.44)

This invention relates to a control system for regulating the tension in a moving web of sheet material.

Sheet material, such as paper, plastic film, foil, and the like is usually manufactured and supplied in large rolls. In the preparation for ultimate use, the material is taken as a web from the original roll through one or more forms of converting machinery, where it may be slitted, coated, laminated, or otherwise converted, and then rewound. During the unwinding and rewinding, it is desirable that a constant given tension be maintained within the moving web to prevent the breaking of the web and to assure a uniform surface speed according to the requirements of the converting processes involved.

This invention provides an automatic constant tension control system which eliminates any necessity for contacting the moving web between an unwind stand and a motor driven winder. The load on the winding motor is measured as an indication of the tension in the web and is compared to an adjustable standard representing the desired load. The compared difference between the standard and the actual load is applied to a servo amplifier for increasing or decreasing the drag of an adjustable friction brake on the unwind stand in such a direction as to bring the motor load into coincidence with the standard.

The system of this invention includes operator's controls for the selection of the tension which the system will automatically maintain, as described. Provision is also made for independently setting in a starting break-away tension which may be different from that set in for continuous running. The system includes a time delay to provide time for the winder to come up to speed on the presetting break-away tension with automatic transfer to automatic control. Also, the operator may at any time switch to fully manual control through which he may remotely increase or decrease the tension at will.

A principal object of this invention is to provide a tension regulating system as outlined above for the automatic control of tension in a moving web of sheet material, such as paper.

A further object of this invention is to provide a tension control system as outlined above through which the tension of a moving web of sheet material may be held at a preselected value.

Another object of this invention is to provide an automatic tension regulating system as outlined above wherein an adjustable brake on an unwind system may be varied either manually or controlled automatically through the system.

Another object of this invention is the provision of a closed loop tension regulating system as outlined above which continuously compares the load of a winder motor against a reference representing the desired load and controls an adjustable brake on an unwind stand according to the difference between the actual and desired loads. A rate network is included to improve accuracy and response.

A still further object of this invention is the provision of a constant tension control system as outlined above which operates without the necessity of contacting the surface of the moving web of paper.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings—

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FIG. 1 is a perspective view of the system of this invention as applied to a slitter-rewinder, a portion of the system being diagrammatically shown for the purpose of illustration;

FIG. 2 is a schematic of the air supply system; and

FIGS. 3, 4 and 5 are electrical schematic diagrams of the control system of this invention with FIG. 3 representing the power supply, FIG. 4 representing the reference voltage supply and the input to the servo amplifier including the differentiator, and FIG. 5 representing the servo amplifier and its interconnected relation to the operator's controls.

Referring to the drawings, which illustrate a preferred embodiment of the invention, an unwind stand is indicated generally at 10 as rotatably supporting a roll 11 of sheet material, such as paper. The material of the roll 11 is shown as being drawn as a web 12 into a converter consisting of a slitter-rewinder 13 which includes a mandrel 14 upon which the web 12 is rewound after being processed therein. The rewinder mandrel 14 is driven to rewind the web 12 through the winder drum 15 by an electric rewind motor 16 which causes the web 12 to be drawn from the supply roll 11 through the slitting apparatus contained within the slitter-rewinder 13 and wound onto the mandrel 14 in the converted state to form the new roll 17 on the mandrel 14.

The unwind stand 10 includes adjustable friction means for causing a drag which resists the unwinding of the roll 11 by the motor 16. This drag is transmitted to the motor 16 by means of tension through the web 12. The friction means preferably consists of an air actuated brake 20, which may be of any conventional type capable of causing a drag in response to the pressure of an air signal applied thereto. A source of air under pressure, indicated at 21 in FIGS. 1 and 2, supplies air for the operation of the brake 20 through a valve arrangement including a hand valve 22 and an electric solenoid valve 23. A gage 24 may be provided for the purpose of indicating the operative pressure at the brake 20.

Means for varying the amount of air pressure applied from the source 21 to the brake 20 to vary the braking effort and the tension applied by the brake 20 to the web 12 includes a motor-positionable air pressure control valve indicated generally at 25. The valve 25 includes a controllable pressure regulator valve body 26 connected between the source 21 and the solenoid valve 23 and an example of a commercially available valve of this description is the Model H-3 of the Westinghouse Air Brake Company of Wilmerding, Pennsylvania, sold under the trade name of Controlair. A reversible electric drive motor 27 is mounted in direct driven relation to the valve body 26 for causing the body 26 to increase or decrease the pressure applied to the brake 20 according to the requirements of the system of this invention. The drive motor 27 may consist of one of the common class of reversible electric motors characterized by modest power requirements and negligible overrun suitable for control by a servo amplifier. An example of one such suitable motor for this purpose is the Model SM-10 of the Jordan Company, Inc. of Milwaukee, Wisconsin, sold under the trade name of Valvetrol.

Means for regulating the control valve 25 includes the electrical circuit components of FIGS. 3-5, most of which are contained within a control box indicated somewhat diagrammatically at 30 in FIG. 1. The box 30 includes a control panel 31 upon which is mounted the controls by which the system is regulated by an operator. The panel 31 includes a solenoid on-off switch 33 connected as shown in FIG. 2, to control the solenoid valve 23 for controlling the admission of the air from the valve 25 to the brake 20. A function selector switch 35, designated as Hand-Auto, provides for the selection of

either manual or fully automatic tension control. The panel 31 also includes an Increase push button 36 and a Decrease push button 37 by means of which an operator can manually effect an increase or decrease in the air pressure at the brake 20 to vary the tension in the web 12. The buttons 36 and 37 are also operable to establish a break-away tension in the web 12 prior to the starting of the rewinder motor 16 in either position of the Hand-Auto switch 35.

Means on the panel 31 for setting in a desired tension for automatic maintenance includes a Load Set dial 40. The dial 40 may be positioned according to the experience of an operator at given position corresponding to a given tension within the limits which can be maintained by the system, and this tension will be maintained throughout the operation of the slitter rewind 14. The control box 30 includes time delay means for effecting a transfer from the break-away tension as set in by the buttons 36 and 37 to the constant tension as set in by the Load Set dial 40.

Not all of the system components can conveniently be located on or within the control box 30, and in addition to an external 115 volt, 60 cycle power source indicated generally at 42, a motor load signal pick-up means in the form of a current transducer 43 is positioned in the power leads to the rewind motor 16. The current transducer 43 measures the load on the motor 16 as an indication of the tension in the web 12. The transducer 43 may consist of a calibrated shunt for D.C. rewind motors, and a rectifying current transformer in the case of an A.C. motor, to provide a D.C. electric signal proportional to the motor load.

Referring now to the wiring diagrams of FIGS. 3-5, and considering them as a whole, it will be seen that an electric circuit is provided which takes the signal from the current transducer 43 and compares it with a reference signal set in by the Load Set dial 40 to provide an output signal for the control of the air control valve 25. A primary power supply for the system is shown in FIG. 3 as including a power transformer 45 with a primary 46 connected to the 115 volt 60 c.p.s. reference source 42. A high voltage secondary 47 provides a plurality of isolated rectified high voltage sources, indicated as B+1, B+2 and B+3, through one half of a dual triode 50, connected here as a diode, and a common R-C filter-decoupling network 51. The voltages B+1, B+2 and B+3 are employed by the servo amplifier portion of the system shown in the wiring diagram of FIG. 5. The power transformer 45 also includes a low voltage secondary 52 for the purpose of supplying a -5 volts D.C. through a selenium rectifier 53, with a filter capacitor 54 and load resistor 55. The -5 volts D.C. supply is also employed by the circuit components of FIG. 5. A common filament winding 56 supplies 6.3 volts A.C. as required by the components of the circuit.

Referring now to FIG. 4, means for providing a variable reference signal representing a desired tension in the web 12 includes a step-down transformer 60 having a primary connected to the source 42. A pair of diodes 61 are connected to the secondary of the transformer 60 for full wave rectification through a R-C filter network 62. Accurate voltage regulation is maintained by a zener diode 63 connected across the output of the network 62. A Load Set potentiometer 65, connected for mechanical movement with the dial 40, is electrically connected in series with an adjustable rheostat 66 and, in turn, connected in parallel with the diode 63.

The output of the Load Set potentiometer 65 is a low level regulated D.C. signal representing a desired motor 16 load, and this signal is applied past a decoupling capacitor 68 to one leg of a stabilizing circuit consisting of a partial differentiating network 70. A second input to the network 70 comprises the motor load signal from the current transducer 43 which is fed to the network 70 through a shielded lead-in cable 72. The network 70

partially differentiates the input signal from the transducer 43 to supply a voltage having a component proportional to the motor 16 load and another component proportional to the rate of change of the motor load. The network 70 includes a rate adjust potentiometer 75 for adjusting the ratio of the rate signal as compared to the motor load signal, the purpose of which is to provide compensation for various time lags in the system. This signal is then compared to the applied reference voltage from the Load Set potentiometer 65 and the difference therebetween is applied to the armature 80 of a synchronous vibrator 81. The alternately selected contacts 82 and 83 of the vibrator 81 are connected to the opposite ends of the primary of a coupling transformer 85.

The purpose of the synchronous vibrator 81 and the transformer 85 is to provide an A.C. signal having a magnitude proportional to the difference between the partially differentiated motor signal and the reference voltage, and either in phase with the reference supply 42 or 180° out-of-phase therewith, depending upon whether the motor load signal is greater than or less than the reference voltage. The secondary of the transformer 85 is connected to the grid of the first of a pair of series-connected common amplifier stages 86 and 87 each associated with a dual triode tube 88 of FIG. 5. It may be noted that the voltages B+1 and B+2 are used here for the purpose of supplying plate voltage to the sections of the tube 88.

A third amplifier stage includes the second half of the dual triode 50, the grid of which is connected to the preceding stage through a variable gain potentiometer 91. The potentiometer 91 forms the means by which the gain of the servo amplifier of FIG. 5 may be controlled and adjusted to meet the requirements of a given installation.

The system includes delay means by which the pre-selected tension on the dial 40 is held from being applied through the circuit to the brake 20 until the motor 16 is started and the web 12 is brought up to operating speed. This has the effect of delaying the application of automatic control until after the surge of starting current is past. The delay means includes a time delay relay 95 having an armature actuating coil 96 connected for energization through a switch 97. The switch 97 is preferably an integral part of the starting switch for the motor 16 to be closed at the same time that the motor 16 is started.

The relay 95 is adjusted to close a pair of normally open contacts 98 approximately 30 seconds after the closing of the switch 97. The closing of the contacts 98 applies the B+3 voltage to the plate of the tube 50. The relay 95 includes a set of normally closed contacts 100 through which the tension may be adjusted by means of the push buttons 36 and 37 prior to the starting of the motor 16.

The output of the tube 50, comprising the now considerably amplified signal from the transformer 85, is applied equally to each of the control grids of a pair of thyratrons 105 and 106. The grids of the thyratrons are normally biased to cut off by the -5 volts D.C. from the power supply transformer 45. The plates of each of the thyratrons are connected to ground through the secondaries 108 of a pair of identical saturable transformers 110 and 111. The primaries 112 of the transformers 110 and 111 are, in turn, energized from the reference source 42 of 115 volts A.C. through an autotransformer 115. The thyratrons 105 and 106 are therefore respectively energized from the source 42 through the transformers 110 and 111. However, the voltage across the thyatron 105 is 180° out-of-phase with that at the thyatron 106, as indicated by the conventional dots on the transformers 110 and 111 indicating the instantaneous polarity.

It will therefore be seen that any given A.C. signal output from the tube 50, if of sufficient magnitude, will fire only one of the thyratrons depending upon the phase of the signal, that is, depending upon whether an increase or decrease in tension is required. The firing of one of

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the thyratrons 105, 106 saturates its associated transformer 110 or 111, greatly reducing its reactive impedance.

The reversible motor 27 of the valve has one of its inputs 120 connected for energization from the autotransformer 115 through the primary 112 of the transformer 110 and has its other input 121 connected for energization through the primary 112 of the transformer 111. The conduction of the thyratrons, due to the presence of an amplified difference signal, will necessarily be for half cycles only of the power source 42. This however is sufficient to saturate the associated transformer 110 or 111 and the transformer which remains substantially saturated during the non-conducting half cycle, thereby providing for the application of the power from the autotransformer 115 to the appropriate motor 27 input. The purpose of the autotransformer 115 is to overcome the IR drop within the saturable transformers 110 and 111.

The Hand-Auto switch 35 operates in the Auto position to connect the cathodes of the thyratrons 105 and 106 to ground. In the Hand position, the servo amplifier of FIG. 5 is disabled. However, this position applies the power source 42 to the Increase and Decrease push buttons 36 and 37. The push buttons 36 and 37 are connected to apply the source 42 directly to the appropriate motor 27 input 120 or 121 to effect an increase or a decrease of the air supply to the brake 20 as long as the button is depressed. Releasing the button breaks the circuit to the motor 27. The normally closed contacts 100 on the relay 95 also serve to apply the source 42 to the buttons 36 and 37 so that the tension may be regulated prior to starting the motor 16 regardless of the position of the Hand-Auto switch 35.

The operation of this invention is largely self-evident from the foregoing description. It will be seen that the tension may be either increased or decreased by the appropriate operation of the push buttons 36 and 37 prior to the starting of the rewind motor 16, and during the operation of the rewinder 13 by placing the switch 35 in the Hand position. However, the Auto position is normally employed for the purpose of maintaining a given tension in the web 12 according to the setting of the Load Set dial 40. Any variation from the setting as thus specified causes a difference signal to be applied to the thyratrons 105 and 106 to effect corrective action by either increasing or decreasing the air pressure at the brake 20 through the control valve 25. It will therefore be seen that a fully automatic and versatile tension regulating system is provided which eliminates guesswork and affords uniform tension control throughout the entire conversion of a web under circumstances where a control of tension is desired.

While the form of apparatus herein described constitutes a preferred embodiment of the invention, it is to be understood that the invention is not limited to this precise form of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A constant tension regulator for a moving web from an unwind roll onto a motor driven winder roll, comprising a variable brake on said unwind roll for determining the tension in said web, means providing a signal in proportion to the motor load on said winder roll representing the actual tension in said web, means providing a reference signal proportional to a desired motor load representing a desired web tension, means for comparing said motor signal and said reference signal and providing an output signal in response to the difference between the actual and the desired tension, and servo means responsive to said output signal for varying said brake in such a manner as to tend to equalize said motor signal and said reference signal.

2. A continuous closed loop system for regulating the

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tension in a moving web from an unwind roll to a winder roll driven by a motor, comprising controllable drag brake means on said unwind roll, means for measuring the load on said winder motor for providing an electric signal representing said load, means providing a variable standard reference signal representing a desired motor load, continuous signal comparison means for comparing said reference signal with said motor load signal and providing an output signal representative of the difference therebetween, and reversible servo follow-up means responsive to said output signal connected to control said drag means to modify the drag on said unwind roll to equalize said reference signal and said load signal.

3. A constant tension regulator for a moving web from an unwind roll onto a motor driven winder roll, comprising a variable brake on said unwind roll for determining the tension in said web, means providing a signal in proportion to the motor load on said winder roll, a manually variable reference signal generating means providing a reference signal proportional to a desired motor load representing a desired web tension, means for comparing said motor signal and said reference signal and providing an output signal in response to the difference therebetween, and servo means responsive to said output signal for varying said brake in such a manner as to tend to equalize said motor signal and said reference signal.

4. A constant tension regulator for a moving web from an unwind roll onto a motor driven winder roll, comprising a variable brake on said unwind roll for determining the tension in said web, means providing a signal in proportion to the motor load on said winder roll, means providing a reference signal proportional to a desired motor load representing a desired web tension, circuit means for comparing said motor signal and said reference signal and providing a difference signal, differentiating means for providing an output signal having a factor representative of the rate of change of said difference signal, and servo means responsive to said output signal for varying said brake in such a manner as to tend to equalize said motor signal and said reference signal.

5. A constant tension regulator for a moving web of paper from an unwind roll onto a motor driven winder roll, comprising a variable brake on said unwind roll for determining the tension in said web, means providing a signal in proportion to the motor load on said winder roll, a manually controlled reference signal proportional to a desired motor load representing a desired web tension, means for comparing said motor signal and said reference signal and providing an output signal in response to the difference therebetween, servo means responsive to said output signal for varying said brake in such a manner as to tend to equalize said motor signal and said reference signal, and manually operable circuit means connected to said servo means for changing said tension independently of said reference signal.

6. A device for regulating the tension in a moving web of paper from an unwind roll to a winder roll driven by a motor comprising an air brake on said unwind roll, a source of air under pressure, a variable air valve connecting said source and said brake for varying the air pressure applied to said brake from said source, means responsive to the load on said winder motor for supplying an electric signal in proportion to said motor load, means providing a variable reference signal representing a desired tension in said web, circuit means for comparing said reference signal and said motor load signal and providing an output signal proportional to the difference therebetween, means for differentiating said output signal to provide an indication of the rate of change of said load, and reversible servo means connected to operate said variable air valve and responsive to said differentiated signal to cause said air brake to modify said unwind tension to tend to equalize said motor signal and said reference signal.

7. A constant tension regulator system for a moving web from an unwind roll onto a motor driven winder roll, comprising a variable brake on said unwind roll for determining the tension in said web, means providing a signal in proportion to the motor load on said winder roll, means providing a reference signal proportional to a desired motor load representing a desired web tension, circuit means for comparing said motor signal and said reference signal and providing a difference signal, adjustable means for compensating for system delays including a manually variable differentiating means for providing an output signal having an adjustable factor representative of the rate of change of said difference signal, and servo means responsive to said output signal for varying said brake in such a manner as to tend to equalize said motor signal and said reference signal.

8. A constant tension regulator system for controlling the tension in a moving web from an unwind roll onto a motor driven winder roll, comprising variable brake means on said unwind roll for creating tension in said web, controllable valve means connected to control said variable brake means, a control circuit for operating said valve means including means for measuring the load on said winder and providing a signal indicative of the tension in said web, automatic control means connected to receive said signal from said load measuring means for controlling said valve means, manual circuit means separate from said automatic control means for presetting a desired starting tension in said web through said valve means, and transfer means for transferring control from said manual means to said automatic means in response to the starting of said

winder including a delay relay having one set of contacts in said manual circuit means and having a further set of contacts operable upon the closing of said relay to activate said automatic control means.

9. A tension regulating system for controlling the tension in a web of sheet material from an unwind roll onto a winder roll driven by an electric motor, comprising a controllable air brake on such unwind roll for effecting tension in such web, a source of brake operating air under pressure, an air regulating valve connecting said source and said brake for supplying air under regulated pressure to said brake and having a reversible drive motor connected to increase and decrease the air pressure supplied by said valve, means for measuring the load on such winder motor and providing a signal thereof, servo means connected to operate said reversible drive motor and responsive to said signal to vary the tension in said web, manual control means operable through said reversible drive motor to set in a break-away tension independently of said servo means, and automatic switch means connected to transfer the control of said brake from said manual means to said servo means a fixed time subsequent to the starting of the winder motor.

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