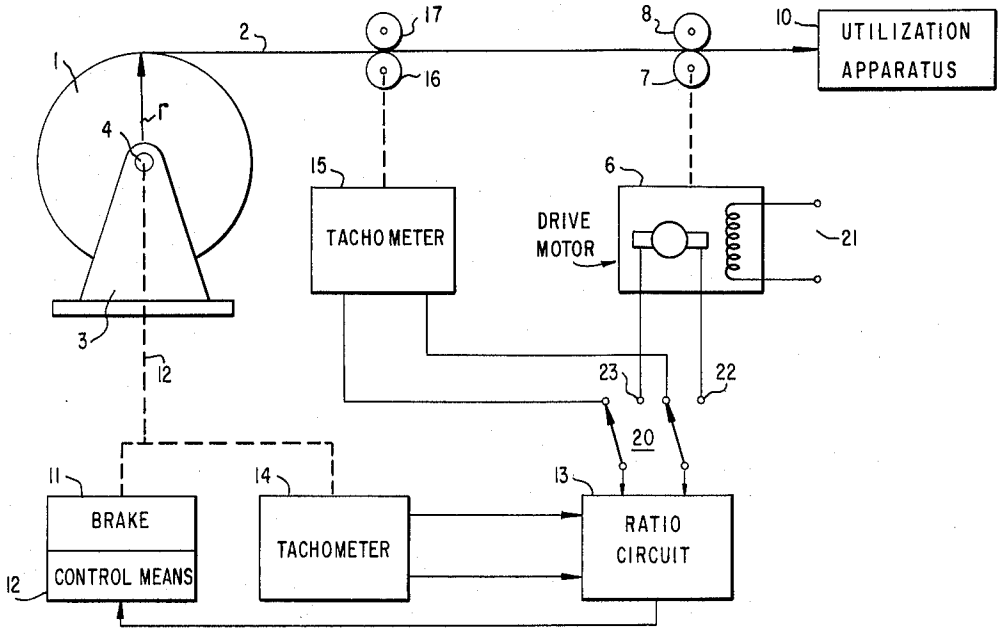
June 21, 1966 J. W. DRENNING 3,257,086

TENSION EQUALIZING CONTROL SYSTEM

Filed Aug. 2, 1963

FIG. 1



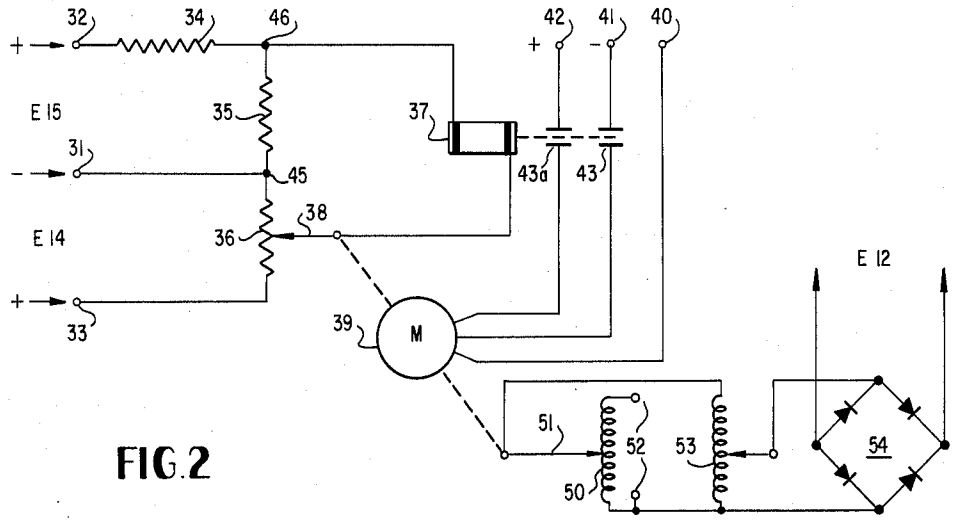


FIG. 2

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TENSION EQUALIZING CONTROL SYSTEM

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The present invention is directed to equalizing tension in a linear material fed from a spiral supply. Linear material, in many processes, is most conveniently stored in a spiral configuration on a shaft or mandrel. In many situations it is highly desirable and often necessary to establish and maintain constant tension on the material as it is drawn from the supply.

Maintained constant tension in such a traveling material fed from a spiral supply may be desirable in textile technology, where threads or yarns may be unwound from spools or bobbins and fed to weaving or knitting machinery, or where flat textile material in rolls is fed out for further processing. Maintaining constant tension in recording tape fed from a feed reel is a prevalent problem in magnetic and other tape recording and reproduction. In processing webs of paper fed from a roll, constant tension maintenance is extremely important.

The problem of maintaining constant tension is even more important where multiple spiral supplies of a linear material are being fed into apparatus for producing a composite product. In the example mentioned above, where multiple threads or yarns are fed to a machine, not only is constant tension highly desirable, but equal tension on the stock drawn from separate supplies is desirable. Equalized tension at constantly maintained values is highly desirable also in processing webs of paper from supply rolls wherever two webs are plied together to form a composite product. In the manufacture of corrugated paperboard, for instance, tension in the feeding webs is controlled when these are joined to the corrugated liner.

In tensioning linear material drawn from a spiral supply, it is usual to mount the supply for concentric rotation and draw the material off at the periphery. As the stock is used, its diameter constantly decreases so that application of uniform tension on the traveling web requires a constantly decreasing brake torque resisting rotation of the spiral supply. Brake control means are therefore required which vary the torque in proportion to the effective radius from which the linear material is being drawn. Determination of this radius has been a serious problem in the art. Mechanical means have been used which ride against the surface of the spiral supply for this purpose, but much inconvenience attends their use, and in many cases, particularly where heavy supply rolls are employed, breakage of the mechanical engagement elements is a frequent occurrence.

It is, accordingly, an object of the present invention to provide a constant tension control system in which linear material may be drawn from a spiral supply at a preselected tension which is maintained independently of the decreasing diameter of the supply.

The invention will be further described in connection with the drawings wherein:

FIGURE 1 shows in diagrammatic arrangement means for feeding linear material from the spiral supply under constant tension embodying the system of the present invention, and

FIGURE 2 shows representative electrical circuitry employed with the system of FIGURE 1.

As shown in FIGURE 1, a spiral supply **1** of a linear material **2** is mounted on trunnion means **3** for rotation about its axis on shaft **4**. The linear material **2** may be flat sheet material, such as paper or textile, or it may

be filamentary linear material, such as textile threads or yarns, or other linear material, such as wire. In providing a spiral supply of filamentary linear material, successive helixes may be arranged in overlapping relationship to form the spiral supply. In this instance, the radius of the spiral supply will remain generally constant as each helix is fed off, the radius decreasing discontinuously as one helix is exhausted and the next is drawn upon.

Draft means is provided for drawing the linear material from the spiral supply **1** comprising a drive motor **6** for rotating a pair of pinch rolls **7** and **8**, between which the material **2** is frictionally engaged. On the rotation of the drive motor **6**, therefore, the material **2** is drawn off the spiral supply **1**. The drive motor **6** is normally energized for rotation at a selected speed which is the primary controlling parameter for the linear speed of the material delivered.

In handling linear material, it is further necessary to provide a control tension against which the draft means operates. The tension developed in the traveling material in its pass from the spiral supply to the draft means is controlled by a brake applying a controllable torque operating to resist the rotation of the supply as the material **2** is drawn from its outer periphery. The brake is shown diagrammatically at **11** in FIGURE 1, and is mechanically connected by coupling **12** to apply the necessary torque to supply **1**. In practice, the supply **1** may be a roll of paper affixed to a shaft **4** to which the braking torque may be applied by brake **11**.

The characteristics of brake **11** are important to the operation of the system, which is of the open loop type and does not measure the tension it establishes. Fading of the brake with continued use is undesirable, but its avoidance with mechanical equipment is possible but expensive. Fading is not a serious problem with an eddy current brake, but at very low or zero r.p.m., little or no restraint is exerted. Particularly with large, heavy rolls of sheet material, it is a practical necessity to have the brake operative when the spiral supply is stationary. Consequently, by far the most preferable type of brake for use with the system of the invention is the magnetic particle brake, which embodies the desired characteristics in quite economic structure.

Representative of the types of brake structures preferably employable in the system of the present invention are those shown in United States Patents 2,685,947, 2,709,507 and 2,840,206. The controlling magnetic field in the magnetic particle brake is generated by a coil which constitutes an electrically responsive control means which determines the braking torque in dependency on the applied voltage. The coil may be energized by a variably selectable D.C. voltage.

In the system of FIGURE 1, the electrically responsive control means for brake **11** is shown at **12** and is energized by control voltage generated by a ratio circuit **13**. Ratio circuit **13** is in turn responsive to a first electrical signal varying proportionally with the speed at which linear material **2** is delivered through the draft means, and a second electrical signal proportional to the speed of rotation of stock supply **1**. These voltages, as combined in the ratio circuit, supply a signal to the brake control means varying with the speed of the linear material as delivered through the draft means divided by the second signal which is proportional to the speed of rotation of the spiral stock supply to control the braking torque and thereby provide constant tension.

In the system of FIGURE 1, a generating tachometer **14** is mechanically connected to measure the rotational speed of stock supply **1**, through coupling **12** connecting the tachometer to shaft means **4** affixed to the supply.

The tachometer output is a D.C. voltage varying linearly with the speed of rotation of spiral supply **1**. Therefore, as the radius of the stock supply decreases with continued delivery, the magnitude of the output signal from tachometer **14** increases proportionally with decrease in radius to provide an output control signal in accordance with the speed of rotation of stock supply **1**.

The other control voltage applied to the ratio circuit **13** may, in the embodiment of FIGURE 1, be generated by a similar tachometer **15** rotationally driven by pinch rolls **16** and **17** engaging the linear material between the stock supply and the draft means. The output of tachometer **15** is, as described in connection with tachometer **14**, a D.C. voltage of a magnitude proportional to the velocity of the linear material.

In some installations, a velocity indicating voltage of the same type is available as an operating voltage in the draft means, and where this is available, the tachometer **15** is unnecessary. In the arrangement of FIGURE 2, switch **20** may be provided to supply the same control voltage to ratio circuit **13** in lieu of the output from the tachometer **15**. In the arrangement of FIGURE 1, drive motor **6** comprises a variable speed direct current motor having a constant voltage field supply **21** and an armature energized by an adjustable D.C. voltage source at terminals **22** and **23**. Since the armature supply source voltage itself constitutes a parameter whose variations vary with the speed of the material passing through the draft means where the tension is equalized by the present system, this voltage itself, or a constant fraction thereof, may be directly supplied to ratio circuit **13** for the purposes aforesaid.

In the system of FIGURE 1 as specifically described above, the control voltages generated in dependency on the speed of the linear material and the rate of revolution of the spiral supply are unipolar D.C. voltages of an amplitude proportional to the quantity indicated. Obviously, other forms of sensing voltage could be employed, such as those obtained by using small alternators to supply uniform amplitude output signals whose frequencies are respectively characteristic of the values to be determined. In such illustrative system, ratio circuit **13** could be similarly energized by the outputs of frequency discriminator circuits responsive to the respective variable frequency alternators.

The ratio circuit of FIGURE 1 is designed to supply the desired output signal to brake **11** as described above. It may comprise any of many suitable networks, an example of which is shown in FIGURE 2 of the drawings.

The ratio circuit of FIGURE 2 operates to develop the necessary brake torque on the spiral supply in response to the control voltages fed to its inputs from tachometers **14** and **15**. The negative leads from these tachometers are connected in common to terminal **31**, while the positive potential from tachometer **15** is supplied at terminal **32**, with the positive potential from tachometer **14** supplied to terminal **33**. Resistor **34** and resistor **35** are connected across tachometer **15**, and a motor driven variable potentiometer **36** is connected across the output from tachometer **14**. Relay **37** is connected between the junction of resistors **34** and **35** and brush **38** of potentiometer **36**.

Motor **39** is connected mechanically to brush **38** and energized by the operation of relay **37** to drive brush **38** of the potentiometer to the position at which the relay **37** has zero voltage across it, or a voltage lying in a restricted range about zero. In this operation, the motor may be energized from a neutral source terminal **40** and either a negative source terminal **41** or a positive source terminal **42**. The motor drives in reverse directions, depending upon the polarity with which it is energized. Relay **37** controls the polarity of this energization in selectively closing contacts **43** or **44** in dependency on the direction of current through the relay coil, provided the same is above the balanced range. Within the balanced range around zero potential across relay **37**, contacts **43** and **44** are both open. The motor circuit is poled to drive brush **38** in the correct direction to decrease toward zero whatever potential is developed across the coil of relay **37**.

In the circuit of FIGURE 2, potentiometer **36** is provided with a linear resistance element so that the resistance between point **45** and brush **38** is a direct function of brush angle. Consequently, the angular position of brush **38** is the analog of the desired control voltage applied to brake **11** of FIGURE 1. In the circuit of FIGURE 2, the actual control voltage applied to the brake is developed from a variable transformer **50** provided with brush **51** mechanically driven from the shaft of motor **37**, and provides an output voltage proportional to the brush angle. Transformer **50** is energized at terminals **52**. The controlled output voltage is adjustable in magnitude by a manually settable autotransformer **53** to adjust the system to the desired tension in material **2**. The control potential is rectified in bridge **54** to deliver an output voltage E**12** to the control means **12** for brake **11**.

As will presently appear, the values of the components of the ratio circuit of FIGURE 2 are selected in accordance with the characteristics of the mechanical system characteristic to provide the desired output signal at E**12**.

Operation of motor **39**, under control of relay **37**, depends on the ratio of voltage E**14**, a function of the rotational speed of the spiral supply, to voltage E**15**, a function of the velocity of the linear material. When the circuit is in equilibrium, the voltage across resistor **35** is equal to the voltage developed in the portion of potentiometer **36** lying between connection **45** and brush **38**. Taking this portion of the resistance **36** as *r***36** and the total resistance of potentiometer **36** as R**36**, the voltage between connection **45** and brush **38** is E**14** [*r*36/*R*36]. The voltage developed across resistor **35** is E**15**

$$[R35/(R34+R35)]$$

Since these two voltages are necessarily equalized and balanced by the circuit, we have the following equation:

$$r36=[E15/E14][R35R36/(R34+R35)]$$

Resistance *r***36** is, however, the controlling parameter determining the magnitude of potential E**12**, as follows: $E12=Kr(r36)$, where K*r* is a constant.

Therefore, the output control voltage is as follows:

$$E12=[E15/E14][KrR35R36/(R34+R35)]$$

It will therefore be seen that the control voltage applied to brake **11** and the consequent torque applied to the spiral supply is proportional to the product of the ratio of the output of speed responsive tachometer **15**, divided by a voltage proportional to the rate of revolution of the spiral supply as generated by tachometer **14**, multiplied by constant factor. This constant factor is determined by the values of resistor and potentiometer elements **34**, **35** and **36**, together with factor K*r*, which represents the mechanical coupling ratios between brush arm **38** and variable transformer brush arm **51** taken in connection with the energization voltage for transformer **50** applied at terminals **52** and the setting of autotransformer **53**. The value of this constant factor is designed in relation to the constants of the mechanical system, as will now appear.

Referring back to FIGURE 1, the delivery velocity of material **2** is conveniently taken as V under a desired tension T. Under these circumstances, the rotational speed of the spiral supply (or r.p.m.) is $N=V/2\pi r$.

The radius *r* represents the radius of the spiral supply to its periphery at the point of delivery of the material into its flight to the draft means.

The tension T is desired to be equalized, and its value is $T=t/r$.

The brake torque *t* is a function of the magnitude of the input control signal to the control means **12** of brake

11, which may be expressed as $t=K12E12$, K12 being a constant. We then have the equation: $E12=(rT)/K12$. Since $r=V/2\pi N$, the following relation exists:

$$E12=[V/N][T/2\pi K12]$$

However, the speed of rotation of the spiral supply is measured by the voltage E14 so that $N=E14K14$. The material velocity V is measured by the output of tachometer 15 which supplies a voltage $E15/K15=V$. As a result of substitutions in the above, it is clear that the desired brake control voltage is as follows:

$$E12=[E15/E14][TK14/2\pi K12K15]$$

In order to obtain this voltage E12 as the desired output of the circuit of FIGURE 2, it is only necessary to establish the pertinent parameters of the latter in accordance with the following equation:

$$[KrR34R36/(R34+R35)]=[TK14/2\pi K12K15]$$

Similar design procedure may be employed for other ratio voltage type circuits. As will be understood from the earlier discussion, instead of using voltage E15 derived from a tachometer 15, an armature supply voltage for the draft means may be substituted therefor from terminals 22 and 23 in FIGURE 1. Such a substitution will merely change the constant K15 to a new one, K'15.

While the system, as described, has emphasized the brake torque adjustment to compensate for varying diameter of the stock supply, it may be noted that constant tension is developed despite linear speed variations in the material under varied energization of draft motor 6. As the linear speed of the material approaches zero, the voltages E15 and E14 from tachometers 15 and 14 maintain the same ratio to hold the tension constant and to leave the spiral supply under rotational constraint when delivery is stopped. Where the voltage E15 is derived from the armature winding of draft motor 6, similar conditions obtain whether the excitation voltage is reduced to zero to stop delivery; or the energization circuit opened to permit the system to coast to a stop. In the latter operation, the back E.M.F. generated in the armature provides the necessary control voltage for ratio circuit 13.

Constant tension control systems constructed according to the principles of the present invention are simple, trouble free and stable in operation. The scope of the instant invention will be understood with reference to the appended claims.

I claim:

1. Apparatus for a tension equalizing control system for feeding linear material from a spiral supply comprising: means for supporting a spiral supply of material for rotation under feed of said material from the supply, circuit means for generating an electric signal varying proportionally with the speed of rotation of said supply; brake means coupled to said supply and having electrically responsive control means, said brake means being operative to constrain said supply from any rotation upon energization of its control means in the absence of feed; circuit means for supplying an electric signal varying proportionally with the linear speed of said material under feed; and ratio circuit means operative responsively only to both said circuit means to supply a control signal to the electrically responsive brake control means to maintain constant material tension by decreasing the brake torque on the supply as material is fed off and including means for maintaining said control signal at its effective valve as and after feed of the material is stopped.

2. A tension equalizing control system for feeding linear material from a spiral supply comprising means for supporting a spiral supply for rotation, means for generating an electric signal varying proportionally with the speed of rotation of said supply; brake means coupled to said supply and having electrically responsive torque control means, said brake means being operative to constrain said supply from any rotation upon energization of its control means in the absence of feed; draft means receiving said linear material from the periphery of said supply operative to feed the material continuously therefrom; means for generating an electric signal varying proportionally with the linear speed of said material as it is fed from the supply to the draft means; and ratio circuit means operative responsively only to both generating means to supply a control signal to the electrically responsive brake control means to maintain constant material tension by decreasing the brake torque on the supply as the material is fed off and including means for maintaining said control signal at its effective value as and after feed of the material is stopped.

3. The system of claim 2 wherein the brake means comprises a magnetic particle brake.

4. A tension equalizing control system for feeding linear material from a spiral supply comprising means for supporting a spiral supply for rotation, means for generating an electric signal varying proportionally with the speed of rotation of said supply; brake means coupled to the supply and having electrically responsive control means, said brake means being operative to constrain said supply from any rotation upon energization of its control means in the absence of feed; draft means receiving said linear material from the periphery of said supply operative to feed the material continuously therefrom; means for generating an electric signal varying proportionally with the linear speed of said material as it is fed from the supply to the draft means; and circuit means operative responsively only to both generating means to supply a control signal proportional to the ratio of the output of the second generating means to the output of the first generating means to the electrically responsive control means to maintain uniform material tension between the spiral supply and the draft means and to supply thereto a continuous effective energizing voltage as and after feed of the material is stopped.

5. A tension equalizing control system for feeding linear material from a spiral supply comprising means for supporting a spiral supply for rotation, means for generating an electric signal varying proportionally with the speed of rotation of said supply; magnetic particle brake means coupled to the supply and having electrically responsive control means, said brake means being operative to constrain said supply from any rotation upon energization of its control means in the absence of feed; draft means receiving said linear material from the periphery of said supply operative to feed the material continuously therefrom; means for generating an electric signal varying proportionally with the linear speed of said material as it is fed from the supply to the draft means; ratio circuit means comprising a pair of connected impedance means separately energized in the same polarity only by the respective generating means; motor means operative responsively only to the difference between a predetermined fraction of the voltage applied to one impedance means and a variable fraction of the voltage applied to the other impedance means to equalize the magnitudes of said fractional voltages; and variable voltage supply means responsive to motor movement operative to energize the electrically responsive control means to control brake torque and to maintain a continuous energizing voltage as and after feed of the material is stopped to constrain said supply from any rotation in the absence of feed.

6. A tension equalizing control system for feeding linear material from a spiral supply comprising means for supporting a spiral supply for rotation, means for generating an electric signal varying proportionally with the speed of rotation of said supply, magnetic particle brake means coupled to the supply and having an electrically responsive control means, said brake means being operative to constrain said supply from any rotation upon energization of its control means in the absence of feed, variable speed draft means receiving said linear material from the periphery of said supply operative to feed the

material continuously therefrom, means for generating an electric signal varying proportionally with the linear speed of said material as it is fed from the supply to the draft means, ratio circuit means comprising a first resistive element connected only with one of said generating means, a second resistive element connected only with the other of said generating means, means connecting ends of said two resistive elements of the same polarity together, a movable brush mounted for slidable engagement along one resistive element, motor means drivably connected with said brush, relay means operative to energize said motor means responsively to the potential difference between the remote end of the other resistive element and said brush to activate said motor means to reduce said potential to a substantially null value, and variable voltage supply means responsive to movement of said motor operative to energize the electrically responsive control means to control brake torque to maintain uniform material tension between the spiral supply and the draft means and to maintain a continuous energizing voltage as and after feed of the material is stopped to constrain said supply from any rotation in the absence of feed.

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