United States Patent [19]

O'Callaghan et al.

[11] **3,910,521**

[45] **Oct. 7, 1975**

[54] **WINDER CONTROL**

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[73] Assignee: **Eaton Corporation,** Cleveland, Ohio

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[52] **U.S. Cl.** **242/75.51;** 318/6

[51] **Int. Cl.²** **B65H 23/20;** B65H 77/00

[58] **Field of Search** 242/75.51, 75.52, 75.44, 242/75.45, 75.47, 186, 187, 188, 191; 318/6, 7

[56] **References Cited**

UNITED STATES PATENTS

2,874,917	2/1959	Pell	242/75.51
3,114,850	12/1963	Hansen	318/6 X
3,348,107	10/1967	Hamby	242/75.51 X
3,372,320	3/1968	Boyum et al.	242/75.51 X
3,548,270	12/1970	Silva	318/6
3,749,331	7/1973	Nedreski	242/75.51
3,749,989	7/1973	Pittner	242/75.44

FOREIGN PATENTS OR APPLICATIONS

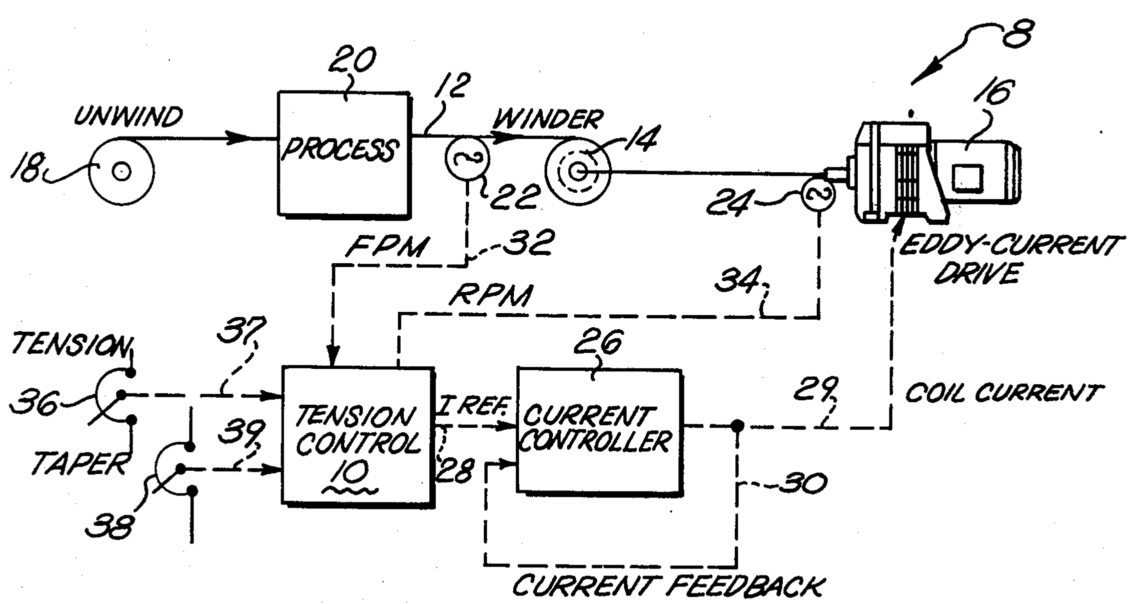
1,175,407	12/1969	United Kingdom	318/6

Primary Examiner—John W. Huckert
Assistant Examiner—John M. Jillions
Attorney, Agent, or Firm—Teagno & Toddy

[57] **ABSTRACT**

A winder control for programming the torque to be applied by a winder to effect winding of material into a roll wherein the tension applied to the material to be wound is dependent upon the instantaneous radius of the roll of wound material, the winder includes first sensing means for sensing the angular velocity of the roll of material and producing a signal indicative thereof, second sensing means for sensing the linear velocity of the material to be wound, and producing a signal indicative thereof, and divider means for generating a signal indicative of the instantaneous radius of the roll of wound material. The radius signal is directed to means for multiplying the instantaneous radius signal by a factor indicative of the desired tension to be applied to the material when the roll of material has a predetermined radius. This establishes a torque signal indicative of the torque the winder must apply to the roll of material to obtain the predetermined tension in the material to be wound at the instantaneous radius calculated by the divider means.

17 Claims, 4 Drawing Figures



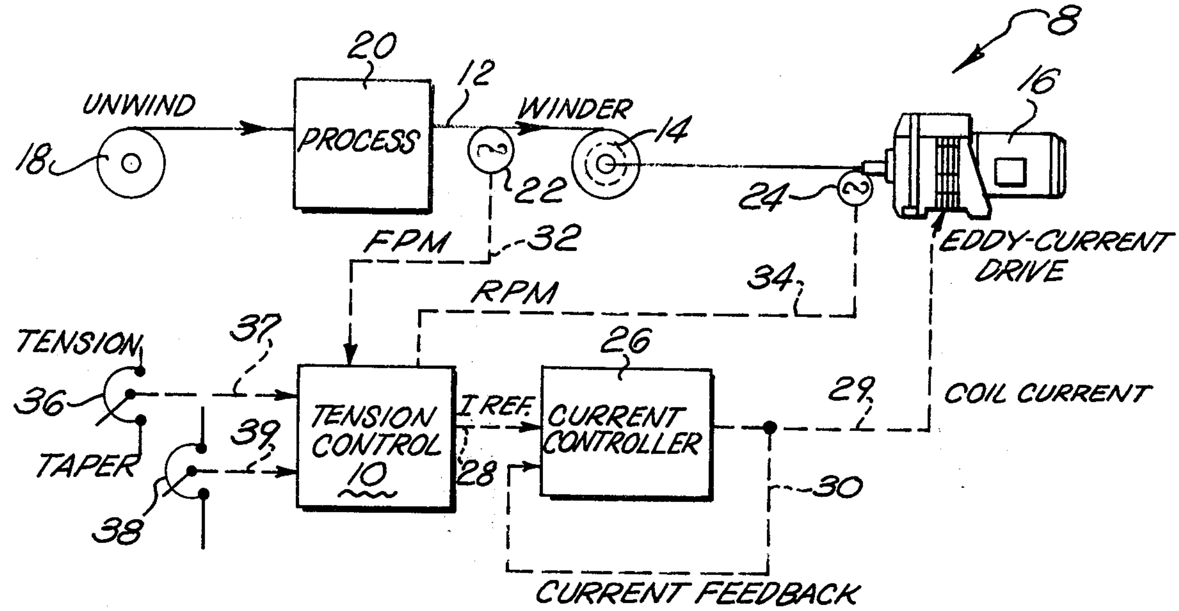

UNWIND
PROCESS
WINDER
EDDY-CURRENT DRIVE
FPM
RPM
TENSION
TAPER
TENSION CONTROL
I REF.
CURRENT CONTROLLER
COIL CURRENT
CURRENT FEEDBACK

FIG. 1

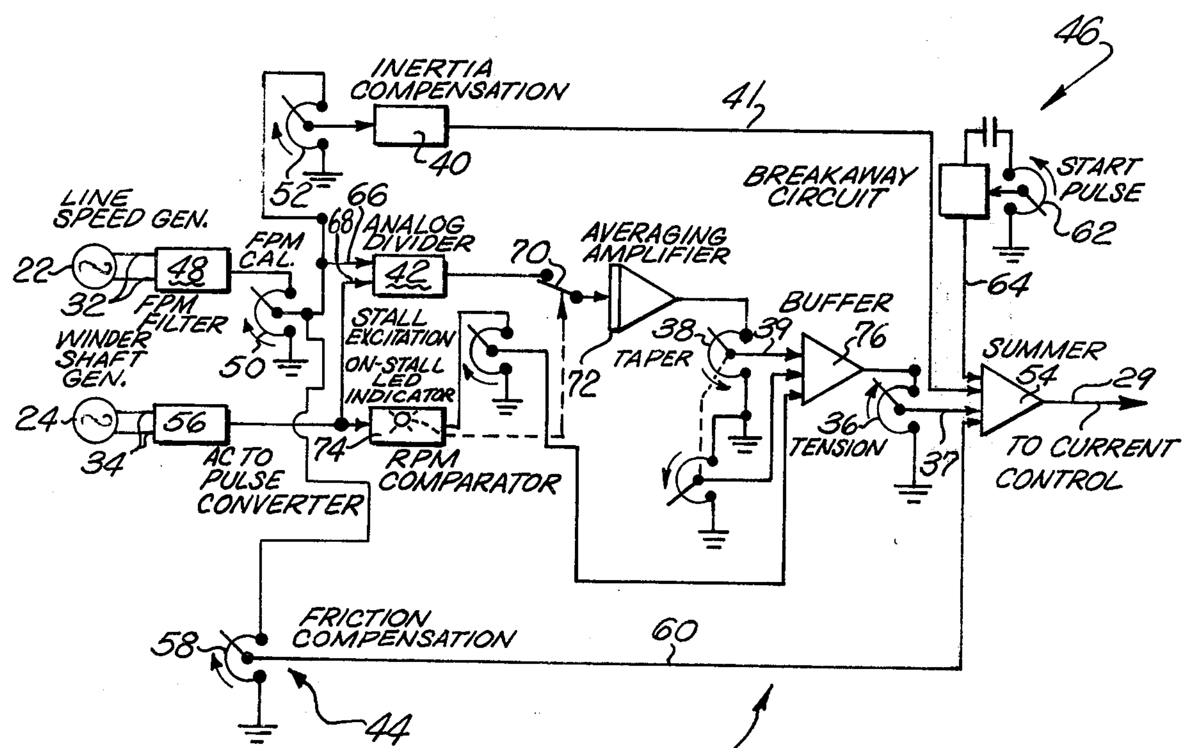

INERTIA COMPENSATION
BREAKAWAY CIRCUIT
START PULSE
LINE SPEED GEN.
FPM CAL.
FPM FILTER
ANALOG DIVIDER
AVERAGING AMPLIFIER
BUFFER
WINDER SHAFT GEN.
STALL EXCITATION
ON-STALL LED INDICATOR
TAPER
SUMMER
TENSION
TO CURRENT CONTROL
AC TO PULSE CONVERTER
RPM COMPARATOR
FRICTION COMPENSATION

FIG. 2

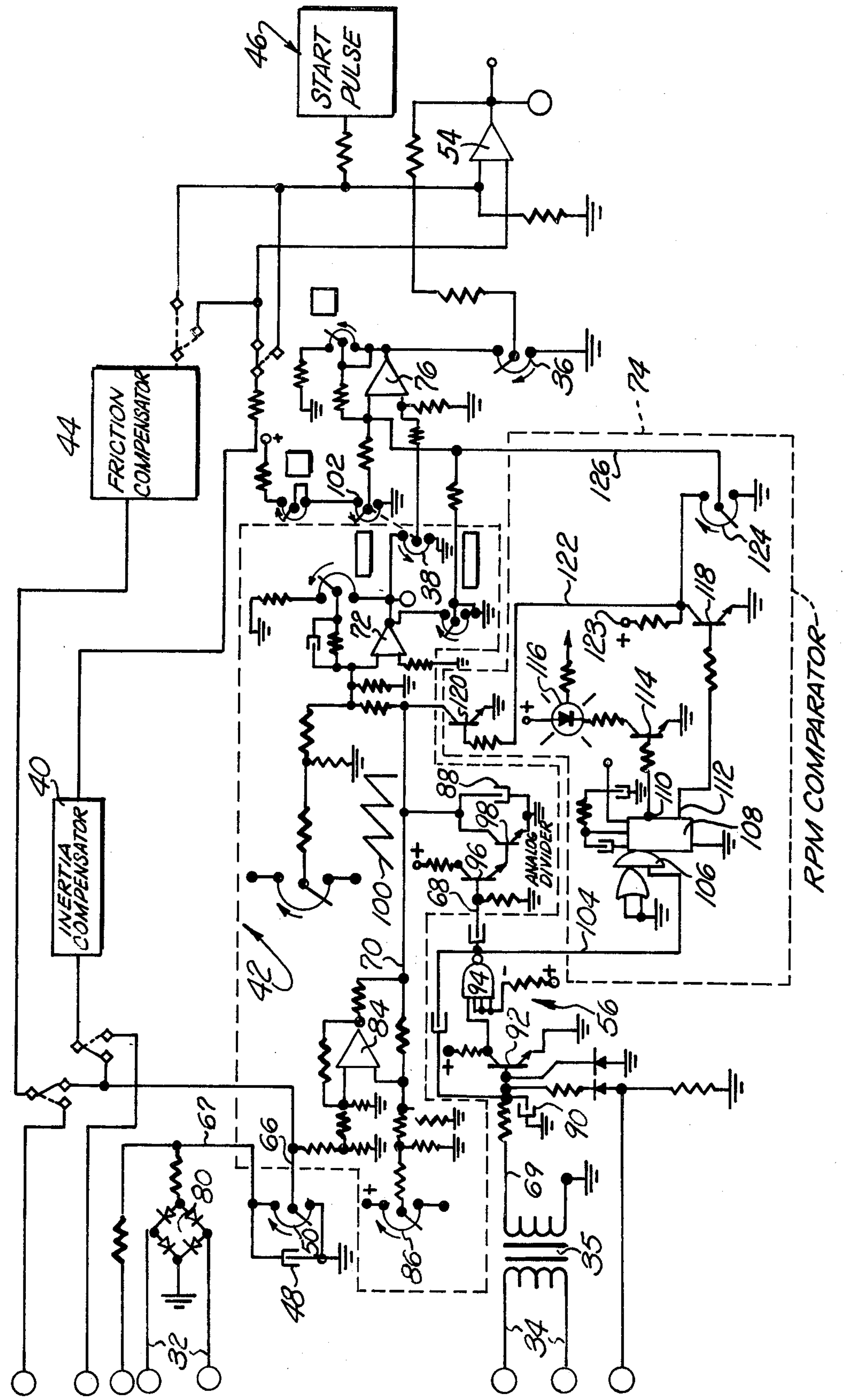

START PULSE
46
54
FRICTION COMPENSATOR
44
INERTIA COMPENSATOR
40
RPM COMPARATOR
ANALOG DIVIDER
74
36
76
102
38
72
126
122
124
118
123
116
114
120
88
98
96
110
112
108
106
104
68
100
42
70
84
94
56
92
90
66
67
80
50
48
86
69
35
34
32

FIG. 3

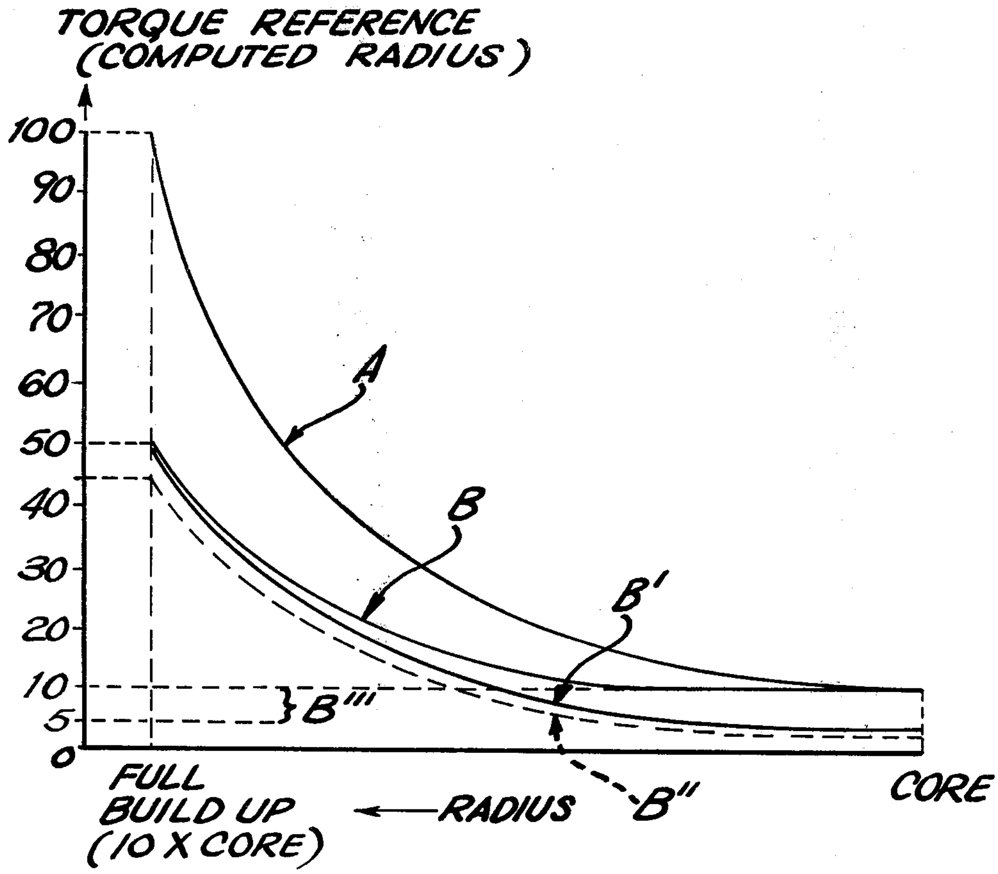

TORQUE REFERENCE
(COMPUTED RADIUS)
100
90
80
70
60
50
40
30
20
10
5
0
A
B
B'
B'''
B''
FULL
BUILD UP
(10 X CORE)
RADIUS
CORE

FIG. 4

WINDER CONTROL

BACKGROUND OF THE INVENTION

The present invention relates to a winder control for controlling the torque generated by a winder for effecting the winding or unwinding of a web or filament of material wherein the tension of the material to be wound is controlled as a function of the instantaneous radius of the wound material.

Known winder controls utilized a drive mechanism to control the tension applied by the winder to the material to be wound. The known controls generally utilized a closed loop system in which a tension feedback signal, indicative of the actual tension applied by the drive, was modified by a radius signal and the modified tension signal directed to a torque or current control to program the control so that the desired taper of tension was maintained. The present invention provides an open loop winder control wherein the instantaneous radius of the wound material is calculated by an analog divider. This instantaneous radius signal is utilized to program a torque or current control to establish the proper taper of tension. A tension feedback signal is not provided as in known winder controls and the instantaneous radius signal acts to progam the torque or current control to maintain the proper taper of tension. In this way, a simpler, more reliable, and less expensive winder control is provided for controlling the torque generated by a drive.

SUMMARY OF THE PRESENT INVENTION

The present invention provides a new and improved winder control for controlling the torque generated by a winder to thereby control the tension on the material to be wound or unwound so that the tension is automatically controlled in response to the radius of the wound material. The winder control includes a first sensing means for generating a signal indicative of the angular velocity of the wound material, a second sensing means for generating a signal indicative of the linear velocity of the wound material and divider means for establishing a signal indicative of the instantaneous radius of the wound material. The signal indicative of the instantaneous radius of the wound material is multiplied by a taper potentiometer which establishes a signal indicative of the taper of tension as a function of the instantaneous radius of the wound material. The taper of tension signal is combined with an inertia compensation signal and a friction compensation signal to establish a signal indicative of the torque to be applied to the roll of material by the winder. The torque signal is directed to a current control which controls the energization of the winder so as to maintain the torque generated by the winder in correspondence with the desired torque at the instantaneous radius. Thus, the winder control functions to control the torque generated by the winder to enable the winder to vary the tension on the material to be wound as a function of the radius of the wound material.

From the above it should be apparent that an object of the present invention is to provide a new and improved winder control for controlling the torque to be applied by a winder to control the tension imparted to material to be wound or unwound so that a predetermined taper of tension, which is a function of the instantaneous radius of the roll of material, is maintained.

DESCRIPTION OF THE DRAWINGS

This and other objects of the present invention will become apparent from the following description of a preferred embodiment of the invention taken in conjunction with the accompanying drawings wherein:

FIG. **1** is a block diagram illustrating the winder or tension control utilized with a current control and an eddy-current drive;

FIG. **2** is a block diagram more fully illustrating the winder or tension control;

FIG. **3** is a schematic diagram of the winder control; and

FIG. **4** is a graph illustrating the torque by a plot of the build up of wound material on the core of the winder plotted against a tension reference.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention provides a winder or tension control system **8** for controlling the tension of material wound on a winder roll **14.** To this end, FIG. **1** schematically illustrates the winder roll **14** which receives material to be wound **12** thereon from an unwind roll **18.** The material to be wound **12** is processed by a processor **20** as it travels from the unwind roll **18** to the winder roll **14.** A drive **16** is provided for driving the winder roll **14.** While the drive may be any one of a plurality of known drives, the drive is shown, for illustrative purposes only, as comprising an eddy current drive **16.** A tension control **10** provides a signal which effects the energization of the eddy current drive **16** to thereby control the torque applied to the winder roll **14.** The torque applied to the winder roll **14** by the drive **16** controls the tension on the material **12** to be wound. The tension is a function of the radius of the wound material on roll **14** and the torque applied by the drive **16.** The particular equation which governs the tension on the material **12** to be wound is as follows;

$$T = RF$$

where T = the torque, applied to the roll R = the radius of the roll and F = the tension on the wound material. Thus, if the torque is maintained constant, the tension will decrease as the radius increases. It should now be apparent that by controlling the torque generated by the drive **16,** the tension on the material to be wound **12** may be controlled when the radius of the wound material is known and accounted for in varying the torque.

The tension control **10** directs a current reference signal along line **28** to a current controller **26.** The output of the current controller **26** is directed along line **29** to control the energization of the eddy current drive **16.** The current controller **26** may be any one of a plurality of known current controllers and may correspond to the current control disclosed in the O'Callaghan U.S. Pat. No. 3,629,633. The current controller **26** includes a current feedback path **30** and energizes the coil of the eddy current drive **16** in a well known manner to control the torque applied to the winder **14.**

A sensing means, preferably a tachometer generator **22** is provided to sense the linear velocity of the material **12** to be wound. The tachometer generator **22** directs a signal indicative of the linear velocity of the material **12** to be wound, along line **32** to the tension control **10.** A second sensing means **24,** which preferably may be a tachometer generator **24,** is associated with the drive **16** and the winder **14** and senses the angular velocity of the winder **14.** The tachometer generator **24** directs a signal along line **34** to the tension control **10.** The signal directed along line **34** is indicative of the angular velocity of the winder **14.** The tension control **10** utilizes the angular velocity signal directed along line **34** and the linear velocity signal directed along line **32** to calculate the instantaneous radius of the wound material **12** on the winder **14.** A pair of potentiometers **36** and **38** direct signals along lines **37** and **39** respectively to the tension control **10.** The signals established on lines **37** and **39** by the potentiometers **36** and **38** are indicative of the desired tension and taper, respectively, of the material **12** to be wound. The signals established on lines **37** and **39** by the potentiometers **36** and **38** respectively, are combined in the tension control **10** with the signal indicative of the instantaneous radius of the material **12** on the winder **14** to establish a signal to be directed along line **28** to the current controller **26.** The signal directed to the current controller **26** is indicative of the instantaneous radius of the roll **14** and the desired tension to be applied to the material to be wound **12.** The current controller **26** acts in a well known manner to control the torque generated by the drive **16** in response to the signal on line **28** to thereby control the tension on the material **12** to be wound. While the tension control **10** has been illustrated in conjunction with a current controller **26** it should be appreciated that a suitable torque control could also be utilized in a well known manner.

The tension control, more fully illustrated in FIG. **2,** includes an inertia compensation circuit **40,** an analog divider circuit **42,** a friction compensation circuit **44** and a starting circuit **46.** The inertia compensation circuit **40** establishes a torque signal proportional to the acceleration of the material **12** to be wound which signal compensates for system inertia during acceleration or deceleration of the winder **14.** The inertia compensation circuit **40** receives a signal from the tachometer **22** which is indicative of line speed. The signal from tachometer **22** is directed through a filter circuit **48** and through a pair of calibration potentiometers **50** and **52** to the inertia compensation circuit **40.** The potentiometers **50** and **52** merely act to scale the line speed signal directed to the inertia compensation circuit **40** for a given drive system. The inertia compensation circuit **40** differentiates the line speed signal directed thereto to establish a torque signal proportional to the acceleration of the winder **14.** The inertia compensation circuit **40** then directs its torque signal along line **41** to an input terminal of a summing amplifier **54.** While the input, in the present embodiment, to the inertia compensation circuit **40** has been illustrated as coming from a tachometer **22,** the input thereto could come from a reference signal which has a magnitude proportional to line speed and which is not taken from the tachometer **22.**

The friction compensation circuit **44** establishes a torque signal which is directed along line **60** to the summing amplifier **54** to compensate for friction in the winder **14.** The tachometer **22** directs a signal which is indicative of the velocity of the material **12** through a calibration potentiometer **50** to the friction compensation circuit **44.** The friction compensation circuit **44** comprises a potentiometer **58** which scales the modified signal from the tachometer generator **22** and directs it along line **60** to an input of the summing amplifier **54.** Thus, the input to the summing amplifier **54** from the friction compensation circuit **44** will have a value which is indicative of the velocity of the material **14,** and which will act to compensate for friction losses which occur in the winder **14.** The friction of such a winder varies in response to the angular speed of the reel and to the weight of material currently wound on the reel, both of which are ordinarily related to the outer radius of the wound material. Air friction losses of the reel also depend upon the outer radius of the material wound on the reel. The setting of potentiometer **58** scales the friction compensation signal for a given drive with which the tension control is utilized. While the friction compensation circuit **44** has been illustrated as receiving its input from the tachometer **22,** the friction compensation circuit **44** could also receive its input from the tachometer **24.** Thus, the input to the friction compensation circuit **44** may be either an input indicative of the linear velocity of the material **12** to be wound of the angular velocity of the wound material **12.** In either instance, the signal directed along line **60** to the summing amplifier **54** will act to compensate for friction losses which occur in the winder system. These friction losses result from friction acting on the winder roll, guide rollers, etc. over which the material to be wound travels.

The start circuit **46** establishes a pulse for breakway torque upon winder start up. The breakaway torque needed for start up is the torque required to overcome static friction when the winder is started. The height of the start pulse is adjustable by a potentiometer **62** and the width of the pulse is maintained constant. The area underneath the pulse is indicative of the energy needed tc overcome the static friction of the system upon start up. The start pulse is directed along line **64** to the summing amplifier **54** upon initial starting of the system and overcomes the static friction of the system to enable the system to start smoothly. It should be appreciated that in many systems where a web of thin material is being moved, such as a web of paper, jerky starting of the system could cause the web of material to break. This problem is accordingly overcome by the starting circuit **46.**

The instantaneous radius of the material **12** on the winder **14** is calculated by the analog divider circuit **42.** The analog divider circuit includes a first input terminal **66** which is connected through the scaling potentiometer **50** to the tachometer generator **22.** The tachometer generator **22** establishes a signal on input terminal **66** which is proportional to the linear velocity of the material to be wound. The analog divider circuit **42** includes a second input terminal **68** which receives a signal thereon from the tachometer generator **24** which is indicative of the angular velocity of the winder **14.** The analog divider **42** operates to divide the linear velocity signal by the angular velocity signal and establishes at its output terminal **70** a signal indicative of the instantaneous radius of the wound material **12** on the winder **14.** To accomplish this the analog divider **42** produces a sawtooth waveform whose average value or area under the sawtooth waveform is proportional to the ratio of the linear velocity voltage signal to the angular velocity frequency signal. As an example, doubling the linear velocity signal doubles the ramp rate of the sawtooth and the sawtooth height. This doubles the sawtooth triangle area and hence the average value of the divider **42** output. Similarly doubling the angular velocity frequency signal halves the sawtooth triangle base thereby halving the triangle area and hence the average value of the output. The signal on the output terminal **70** of the analog divider **42** is directed to an averaging amplifier **72** which averages the signal and directs it through a taper potentiometer **38,** a buffer amplifier **76** and a tension potentiometer **36** to an input terminal of the summing amplifier **54.** The output from the analog divider circuit **42** is a sawtooth wave form which necessitates the use of the averaging amplifier **72** in the system. Thus, the output of the averaging amplifier **72** is essentially a DC signal which is indicative of the instantaneous radius of the roll of material **12** on the winder **14.** This signal is scaled through the taper potentiometer **38** which programs the winder control to establish the degree of taper of tension, i.e., variance in tension, on the material to be wound as the radius changes. The taper of tension, as will be more fully explained hereinbelow, is a function of the instantaneous radius of the material to be wound. The signal from the taper potentiometer **38** is directed through the buffer amplifier **76** and through the tension potentiometer **36** which scales the signal for the given system to the summing amplifier **54.**

An RPM comparator circuit **74** is provided for cutting out the operation of the analog divider **42** at low speeds. This prevents the analog divider from operating in the circuit when the angular velocity signal from the winder shaft generator **24** is very small. At a predetermined low speed, the RPM comparator **74** will cut off the analog divider **42** and apply a constant predetermined potential to the averaging amplifier **72** to prevent the occurrence of erroneous signals from the analog divider **42** at low speeds.

Upon initial energization of the tension control **10** a breakaway pulse will be applied from the start circuit **46** to the input of the summing amplifier **54.** Simultaneously, a constant signal will be applied to the summing amplifier **54** by the stall circuit or RPM comparator **74** due to the fact that the core of the winder **14** is not rotating at a speed high enough to cut out the RPM comparator **74.** As the speed of rotation of the winder roll **14** increases, the RPM comparator circuit **74** will cut out and the analog divider circuit **42** will produce a signal indicative of the instantaneous radius of the roll of material **12** and direct this signal to the summing amplifier **54** along with signals from the friction compensation circuit **44** and the inertia compensation circuit **40.** The signals sent to amplifier **54** will then be summed and directed to the current controller **26.** The signals directed to the current controller will act as a current reference signal to control the energization of the drive **16** to thereby control the tension on the material **12** to be wound.

The operation of the analog divider **42** and the RPM comparator **74** will now be more fully discussed with reference to FIG. **3.** The linear velocity signal from the tachometer generator **22** is directed along lines **32** where it is rectified by a bridge circuit **80** and directed along input line **67** across a filter circuit **48** which, in the present embodiment, comprises a capacitor **48** and through the scaling potentiometer **50** to an input of an operational amplifier **84.** A bias voltage is directed to the other input of the operational amplifier **84** from a biasing potentiometer **86.** The signal applied through the bias potentiometer **86** cancels the offset voltage in the amplifier **84.** The amplifier **84** acts as a current source in that it converts a voltage proportional to the linear speed of the material **12** to a current value to effect charging of a capacitor **88.** The output of the operational amplifier **84** charges the capacitor **88** at a rate which is dependent upon the linear velocity of the material **12** to be wound as sensed by the tachometer generator **22.**

The tachometer generator **24** directs a signal indicative of the angular velocity of the winder **14** along lines **34** and through a transformer **35** to input line **69** of the AC to pulse converter **56.** The signal on input line **69** is filtered by a filter capacitor **90** and is directed to the base of a transistor **92.** The collector of the transistor **92** is connected to an input terminal of a Schmitt trigger **94.** Transistor **92** is switched on every time the sinusoidal wave form on input line **69** is high. Switching on of transistor **92** will effect a high output from the Schmitt trigger **94.** The transistor **92** acts to produce a gain in the system during low winder speeds whenever the output from the tachometer generator **24** is low. Since the input on line **69** is essentially sinusoidal and the transistor **92** switches from a conductive to a nonconductive condition depending upon the polarity of the sinusoidal signal, the output of the Schmitt trigger **94** essentially forms a square wave. The output of the Schmitt trigger **94** is high when the transistor **92** is on and low when the transistor **92** is nonconductive. The output of the Schmitt trigger **94** is fed along line **68** to the base of an amplifying transistor **96.** A high output from Schmitt trigger **94** will cause transistor **96** to momentarily conduct. The emitter of transistor **96** is connected to the base of a transistor **98.** Conduction of transistor **96** will effect conduction of transistor **98.** Transistor **96** and **98** will momentarily conduct at the leading edge of the pulsating output from the Schmitt trigger **94.** The momentary conduction of transistor **98** will control the frequency of wave form **100.**

The capacitor **88** is connected between the collector and emitter of transistor **98** and, as stated hereinbefore, is charged by the output of the scaling amplifier **84.** The charge directed to the capacitor **88** from the amplifier **84** is produced by a current which is proportional to line speed. Capacitor **88** is discharged by the conduction of the transistor **98.** Since the transistor **98** conducts in a cyclical fashion due to the cyclic conduction of the transistor **92,** which conducts at a frequency proportional to the angular velocity of the winder **14,** transistor **98** will cyclically cause the capacitor **88** to discharge at a frequency which is dependent upon the angular velocity of the winder **14.** The charging of the capacitor **88** by the amplifier **84** and the cyclical discharging of the capacitor **88** by the conduction of the transistor **96** will generate a sawtooth wave form, schematically illustrated as wave form **100** on line **70.** The frequency of the sawtooth wave will be controlled by the conduction of the transistor **98** which is proportional to the angular velocity of the winder. The magnitude of the ramp wave form will be proportional to the charge on capacitor **88** which charge is proportional to the linear velocity of the material **12** to be wound. The ramp wave form **100** is directed along line **70** to the input of an averaging amplifier **72.** The output of the averaging amplifier **72** will be a signal having a magnitude proportional to the average value of the ramp wave form **100** and as such will be proportional to the instantaneous radius of the wound material.

The output of the averaging amplifier **72** is directed to the taper potentiometer **38** which sets the percent taper of the tension and directs a signal indicative thereof to the input of the buffer amplifier **76**. Associated with the taper potentiometer **38** is a taper bias potentiometer **102** which is ganged to the taper potentiometer **38**. The taper bias potentiometer **102** applies a constant voltage to the buffer amplifier **76** which provides a taper offset signal dependent upon the build up range of the specific winder system. The taper offset signal is combined with the taper signal from the taper potentiometer **38** at the buffer amplifier **76**. The taper bias potentiometer **102** is ganged to the taper potentiometer **38** so that as the percent of taper is reduced by the taper potentiometer **38** the DC taper offset from the taper bias potentiometer **102** is automatically increased to the proper value. Thus, the percent taper signal, which is a function of the setting of the taper potentiometer **38** and the instantaneous radius of the wound material, is fed to one terminal of the buffer amplifier **76** and the taper offset signal, which is a function of the setting of the taper potentiometer **38**, is fed from the taper bias potentiometer **102** to the other terminal of the buffer amplifier **76**. The two signals are combined in the buffer amplifier **76** and applied through the tension potentiometer **36** to the summing amplifier **54**. The tension potentiometer **36** scales the output of the buffer amplifier **76** for a particular tension desired in a specific system and directs the signal to the summing amplifier **54** which sums the signal with the dynamic compensation signals from the friction compensation circuit **44** and the inertia compensation circuit **40**. The output of the summing amplifier **54** is directed to the current control **26** to effect energization of the drive **16**.

The operation of the system and specifically the taper potentiometer **38** and the taper bias potentiometer **102** will be more fully understood from FIG. 4 which is a plot of the tension reference versus the build up of the material on the core of the winder **14**. The curve A illustrates the condition when a constant tension is maintained from initial winding at the core to full build up of the roll of wound material. The curves of FIG. 4 were plotted utilizing the equation that torque equals tension times radius. In curve A the torque applied by the drive **16** when material is initially being wound on the core and has a radius essentially equal to the radius of the core, will be **10** percent of the maximum torque that the drive **16** may apply. As the radius of the roll builds up, the torque will increase to maintain a constant tension on the material to be wound. At full build up of the roll the torque will be **100** percent of the rated torque of the drive **16** and the tension will remain constant. Scaling the curve A by setting the taper potentiometer at 50 percent produces curve B′. Curve B′ shows the uncorrected taper signal without the taper offset normally established by the taper bias potentiometer **102**. Curve B′ keeps the tension at 50 percent from initial core radius to full buildup of material **12**. In curve B′ the percent of torque at the core radius will be 5 percent and the percent of torque at full material **12** buildup will be 50 percent. To achieve taper the signal plotted on curve B′ is further reduced to 45 percent tension as is shown in curve B″. In curve B″ the percent tension at the initial core radius is 45 percent and remains at 45 percent to full material **12** buildup while the percent torque at the initial core radius is 4.5 percent and varies to 45 percent at full material **12** buildup. Thus, B″ gives us an uncorrected taper signal. To correct the uncorrected taper signal, the taper bias potentiometer **102** is set to apply a constant DC voltage to the buffer amplifier **76** which has a weighted value equal to 5 percent of the desired tension reference curve. Thus, the corrected signal is the sum of the two signals, the constant DC voltage as indicated on curve B‴ and the B″ curve. These two signals when added together form the reference curve B which is the desired reference curve. Since the two signals for taper are taken from the ganged potentiometers **102** and **38**, when the radius signal is reduced via the potentiometer **38** the DC taper offset is automatically increased to the proper value by the bias potentionmeter **102**. Thus, the desired taper signal is directed from the taper offset potentiometers to the buffer amplifier **76** and to the main summing amplifier **54** where it is summed along with the other dynamic compensation signals.

The RPM comparator or stall circuit **74**, as illustrated in FIG. **3**, receives an input along line **104** from the output of the Schmit trigger **94**. The input on line **104** is a square wave, having a frequency indicative of the angular velocity of the winder **14**, which is applied to the terminals of an AND gate **106**. The output of AND gate **106** is connected to the input of a monostable multivibrator **108**. The monostable multivibrator **108** includes a pair of output terminals **110** and **112**. When the monostable multivibrator is set by a positive portion of the square wave input, the output terminal **110** will be low and the output terminal **112** will be high. The monostable multivibrator **108** functions such that when it is set it automatically resets after a predetermined period of time. If the monostable multivibrator **108** is not set again before it resets, the monostable multivibrator will reset automatically and apply a high signal on the output terminal **110** and a low signal on the output terminal **112**. The output terminal **110** is connected to the base of a transistor **114** and when a high pulse is applied to the base of the transistor **114**, the transistor **114** will conduct and cause an indicator light **116** to come on indicating that the unit is at a stall speed. At or below the stall speed the input pulses to the monostable multivibrator **108** are such that the monostable multivibrator **108** will reset itself automatically before being set by the next incoming pulse. The stall speed is the speed at which the angular velocity signal to the analog divider **42** is too small that the divider is not utilized to calculate the instantaneous radius of the material **12** on the winder **14** and the RPM comparator **56** is used to direct a constant reference signal to the buffer amplifier **76** to take the place of the signal from the analog divider **42**.

The output terminal **112** of the monostable multivibrator is connected to the base of a transistor **118**. When the monostable multivibrator is in its normal or set condition, the output on terminal **112** will be high and the transistor **118** will conduct. The collector of the transistor **118** is tied to the base of a transistor **120** via line **122**. Normally when the transistor **118** is conducting and the monostable multivibrator **108** is in its set condition, the conduction of the transistor **118** will prevent the conduction of the transistor **120**. However, when the transistor **118** is rendered nonconductive by the resetting of the monostable multivibrator **108**, a positive potential will be applied along line **122** from a voltage source **123** to the base of the transistor **120** to effect conduction of the transistor **120.** The positive potential applied along line **122** will also be applied to a stall potentiometer **124** which directs a biasing input along line **126** to the input of the amplifier **76.** Conduction of the transistor **120** will prevent the application of the cyclic ramp wave **100** on line **70** to the input of operational amplifier **72.** The conduction of the transistor **120** will pull line **70** down to ground to prevent the divider **42** from operating in the circuit when the RPM signal from tachometer generator **24** indicates that the core of the winder **14** is rotating at a relatively slow speed. This will prevent the divider from operating in the circuit during a stall condition. When the transistor **120** is conductive, the stall potentiometer **124** will apply a potential along line **126** to the amplifier **76** to take the place of the radius signal normally applied to amplifier **76.** The signal applied by the stall potentiometer **124** will be a constant signal which represents a constant artificial radius when the analog divider **42** is not operating due to the angular velocity of the system being too low.

From the foregoing it should be apparent that a new and improved winder control has been provided by the present invention. The winder control includes a tension control which senses the linear velocity of the material to be wound and the angular velocity of the material to be wound and which divides the linear velocity by the angular velocity to determine the instantaneous radius of the wound material. The instantaneous radius signal is fed through taper setting potentiometers which determine the percent of taper of tension of the wound roll and through a tension potentiometer to a main summing amplifier. The main summing amplifier also includes inputs from an inertia compensation circuit which compensates for the inertia of the winder during acceleration and an input from a friction compensation circuit which compensates for the friction of the winder at different speeds thereof. The inertia compensation signal, friction compensation signal and the tension signal which is proportional to the instantaneous radius of the wound material are summed by the summing amplifier and directed to a current control which operates in a well known manner to control the drive of the system. In this manner an inexpensive yet reliable and accurate drive system has been provided for accurately controlling the taper of tension on a roll of wound material.

While the preferred embodiment of the present invention has been illustrated as a control for controlling the tension on material to be wound, it should be readily appreciated that the present invention could also be utilized to control the tension on material being unwound from a roll of material.

What we claim is:

1. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll wherein the predetermined tension is dependent upon the instantaneous radius of the roll of material comprising, first sensing means for sensing the angular velocity of the roll of material and establishing a first signal indicative of the angular velocity of the roll of material, second sensing means for sensing the linear velocity of the material and establishing a second signal indicative of the linear velocity of the material, means including a divider means responsive to said second signal and said first signal for establishing a radius signal indicative of the instantaneous radius of the roll of wound material, summing means for establishing a control signal indicative of the desired tension to be applied to said material, drive means for driving said roll of material, control means responsive to said control signal for energizing said drive means to maintain a predetermined tension on said material which tension is dependent upon the instantaneous radius of the material on the roll, said divider means being responsive to said first and second sensing means to establish a cyclic sawtooth wave form having a frequency dependent upon the angular velocity of the roll of material and a ramp magnitude dependent upon the linear velocity of the material, said means for establishing said cyclic wave form including means responsive to said second sensing means for generating a current signal having a magnitude dependent upon the linear velocity of the material, energy storage means responsive to said current signal for storing energy having a magnitude which is dependent upon the magnitude of said current signal and switching means for periodically discharging said energy storage means to establish said cyclic wave form, and said switching means acting to periodically discharge said energy storage means at a frequency which is dependent upon the angular velocity of the roll of material.

2. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll as defined in claim **1** further including averaging means for establishing said radius signal which has a magnitude indicative of the average value of said cyclic wave form and taper and taper-bias potentiometers ganged together for setting the taper and taper-bias of the material being transferred, said taper potentionmeter modifying said radius signal indicative of the average value of said cyclic wave form and said taper-bias potentiometer establishing a constant biasing signal having a value indicative of the setting of said taper potentiometer and directing said biasing signal to said summing means.

3. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll wherein the torque to be applied by the winder is dependent upon the instantaneous radius of the wound material on the roll and the desired tension to be applied to the material being transferred which varies with the radius of the wound material, said control comprising first sensing means for establishing an angular velocity signal indicative of the angular velocity of the wound material, second sensing means for establishing a linear velocity signal indicative of the linear velocity of the material being transferred, means including divider means responsive to said linear velocity signal and said angular velocity signal for establishing a radius signal indicative of the instantaneous radius of the wound material, inertia compensation means for establishing an inertia compensation signal dependent upon acceleration of the winder for compensating for inertia of the winder during acceleration, friction compensation means responsive to the linear velocity of the material being transferred for establishing a friction compensation signal indicative of the friction acting on the winder at a given velocity, summing means for summing said radius signal indicative of the instantaneous radius of the wound material, said friction compensation signal and said inertia compensation signal establishing a control signal indicative of the torque to be applied by the winder to the material being transferred to maintain a predetermined tension on the material being transferred which is dependent on the instantaneous radius of the wound material, and comparator means responsive to the angular velocity of said roll of wound material for rendering said divider means inoperative to generate said radius signal when the angular velocity of the roll of material is below a predetermined minimum value, said comparator means generating a constant radius reference signal when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means.

4. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll wherein the predetermined tension is dependent upon the instantaneous radius of the roll of material comprising, first sensing means for sensing the angular velocity of the roll of material and establishing a first signal indicative of the angular velocity of the roll of material, second sensing means for sensing the linear velocity of the material and establishing a second signal indicative of the linear velocity of the material, dynamic compensation means for establishing a dynamic compensating signal, means including a divider means for establishing a radius signal indicative of the instantaneous radius of the roll of wound material, summing means for summing said instantaneous radius signal and said dynamic compensation signal and establishing a control signal indicative of the desired tension to be applied to said material, drive means for driving said roll of material, control means responsive to said control signal for energizing said drive means to maintain a predetermined tension on said material which tension is dependent upon the instantaneous radius of the material on the roll and comparator means responsive to said first sensing means to render said divider means inoperative at a predetermined angular velocity of said roll of material, and wherein said comparator means responsive to the angular velocity of said roll of wound material generates a constant radius reference signal when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means, divider means includes means responsive to said first and second sensing means for establishing a cyclic wave form having a frequency dependent upon the angular velocity of the roll of material and a magnitude dependent upon the linear velocity of the material, and wherein said means for establishing said cyclic wave form includes means responsive to said second sensing means for generating a current signal having a magnitude dependent upon the linear velocity of the material, energy storage means responsive to said current signal for storing energy having a magnitude which is dependent upon the magnitude of said current signal and switching means for periodically discharging said energy storage means to establish said cyclic wave form, said switching means acting to periodically discharge said energy storage means at a frequency which is dependent upon the angular velocity of the roll of material.

5. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll as defined in claim **4** wherein said comparator means includes means responsive to said first sensing means for establishing a control signal when the angular velocity of the winder roll is below a predetermined level, cut out means responsive to said control signal for preventing said radius signal from being directed to said summing means when the angular velocity of the winder roll is below a predetermined level and means for directing said constant radius reference signal generated by said comparator means to said summing means when said cut out means is energized and said radius signal is prevented from being directed to said summing means.

6. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll as defined in claim **5** wherein said dynamic compensation means includes a friction compensation means for compensating for friction in the winder and inertia compensation means for compensating for the inertia of the winder and the material being transferred, said friction compensation means including means responsive to said second signal for establishing a friction compensation signal dependent upon the linear velocity of the material being transferred and operative to direct said friction compensation to said summing means, said inertia compensation means including means responsive to said second signal for establishing an inertia compensation signal dependent upon the linear velocity of the material being transferred and operative to direct said inertia compensation signal to said summing means.

7. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll wherein the torque to be applied by the winder is dependent upon the instantaneous radius of the wound material on the roll and the desired tension to be applied to the material being transferred which varies with the radius of the wound material, said control comprising first sensing means for establishing an angular velocity signal indicative of the angular velocity of the wound material, second sensing means for establishing a linear velocity signal indicative of the linear velocity of the material being transferred, means including divider means responsive to said linear velocity signal and said angular velocity signal for establishing a radius signal indicative of the instantaneous radius of the wound material, inertia compensation means for establishing an inertia compensation signal dependent upon acceleration of the winder for compensating for inertia of the winder during acceleration, friction compensation means responsive to the velocity of the material being transferred for establishing a friction compensation signal indicative of the friction acting on the winder at a given velocity, summing means for summing said radius signal indicative of the instantaneous radius of the wound material, said friction compensation signal and said inertia compensation signal establishing a control signal indicative of the torque to be applied by the winder to the material being transferred to maintain a predetermined tension on the material being transferred which is dependent on the instantaneous radius of the wound material, and comparator means responsive to the angular velocity of said roll of wound material for rendering said divider means inoperative to generate said radius signal when the angular velocity of the roll of material is below a predetermined minimum value, said comparator means generating a constant radius reference signal when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means, and wherein said divider means includes means responsive to said first and second sensing means for establishing a cyclic wave form having a frequency dependent upon the angular velocity of the roll of material and a magnitude dependent upon the linear velocity of the material, and wherein said means for establishing said cyclic wave form includes means responsive to said second sensing means for generating a current signal having a magnitude dependent upon the linear velocity of the material, energy storage means responsive to said current signal for storing energy having a magnitude which is dependent upon the magnitude of said current signal and switching means for periodically discharging said energy storage means to establish said cyclic wave form, said switching means acting to periodically discharge said energy storage means at a frequency which is dependent upon the angular velocity of the roll of material.

8. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll as defined in claim **7** further including averaging means for establishing said radius signal which has a magnitude indicative of the average value of said cyclic wave form and taper and taper-bias potentiometers ganged together for setting the taper and taper-bias of the material being transferred, said taper potentionmeter modifying said radius signal indicative of the average value of said cyclic wave form and said taper-bias potentionmeter establishing a constant biasing signal having a value indicative of the setting of said taper potentiometer and directing said biasing signal to said summing means.

9. An open-loop control for maintaining the tension on a filament of material which is being transferred between a source of material and a roll in correspondence with a predetermined tension which is dependent upon the instantaneous radius of the roll of material comprising drive means for driving the roll of material, a tension control means for establishing a reference signal indicative of the instantaneous radius of the roll of material and the desired tension to be applied to the filament at the instantaneous radius, a control circuit responsive to the reference signal of said tension control means and being connected to said drive means for energizing said drive means to maintain the predetermined tension on said filmanet of material, first sensing means for sensing the angular velocity of the roll of material and establishing an angular velocity signal indicative thereof and second sensing means for sensing the linear velocity of the filament of material for establishing a linear velocity signal indicative thereof, said tension control means being responsive to said angular velocity signal and said linear velocity signal and including means having a divider circuit for establishing a radius signal indicative of the instantaneous radius of the roll of material and means for modifying said radius signal to establish said reference signal which is indicative of the instantaneous radius of the roll of material and the desired tension to be applied to the filament at the instantaneous radius, and comparator means responsive to the angular velocity of said roll of wound material for rendering said divider means inoperative to generate said radius signal when the angular velocity of the roll of material is below a predetermined minimum value, said comparator means generating a constant radius reference signal when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means, and wherein said divider means includes means responsive to said first sensing means for establishing a cyclic wave form having a frequency dependent upon the angular velocity of the roll of material and a magnitude dependent upon the linear velocity of the material, and wherein said means for establishing said cyclic wave form includes means responsive to said second sensing means for generating a current signal having a magnitude dependent upon the linear velocity of the material, energy storage means responsive to said current signal for storing energy having a magnitude which is dependent upon the magnitude of said current signal and switching means for periodically discharging said energy storage means to establish said cyclic wave form, said switching means acting to periodically discharge said energy storage means at a frequency which is dependent upon the angular velocity of the roll of material.

10. A control for maintaining the tension in a filament of material which is being transferred between a source of material and a roll in correspondence with a predetermined tension as defined in claim **9** wherein said comparator means includes means responsive to said first sensing means for establishing a control signal when the angular velocity of the winder roll is below a predetermined level, cut out means responsive to said control signal for preventing the establishment of said radius signal when the angular velocity of the winder roll is below a predetermined level and means for establishing said constant radius reference signal when said cut out means is energized.

11. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll wherein the predetermined tension is dependent upon the instantaneous radius of the roll of material comprising, first sensing means for sensing the angular velocity of the roll of material and establishing a periodic first signal indicative of the angular velocity of the roll of material, second sensing means for sensing the linear velocity of the material and establishing a second signal indicative of the linear velocity of the material, dynamic compensation means for establishing a dynamic compensating signal, means including a divider means for establishing a radius signal indicative of the instantaneous radius of the roll of wound material, summing means for summing said instantaneous radius signal and said dynamic compensation signal and establishing a control signal indicative of the desired tension to be applied to said material, drive means for driving said roll of material, control means responsive to said control signal for energizing said drive means to maintain a predetermined tension on said material which tension is dependent upon the instantaneous radius of the material on the roll and comparator means responsive to said first sensing means to render said divider means inoperative at a predetermined angular velocity of said roll of material, and wherein said comparator means responsive to the angular velocity of said roll of wound material generates a constant radius reference sngial when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means, and wherein said comparator means includes means responsive to said first sensing means for establishing a control signal when the angular velocity of the winder roll is below a predetermined level, cut out means responsive to said control signal for preventing said instantaneous radius signal from being directed to said summing means when the angular velocity of the winder roll is below a predetermined level, and means for directing said constant radius reference signal generated by said comparator means to said summing means when said cut out means is energized and said instantaneous radius signal is prevented from being directed to said summing means, wherein said means responsive to said first sensing means for establishing said control signal includes monostable multivibrator means for establishing a reference period for comparison with the period of said periodic first signal, said reference period corresponding to the angular velocity of said winder roll at said predetermined level, and further includes circuit means for producing said control signal when said period of said periodic first signal is below said reference period.

12. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll wherein the torque to be applied by the winder is dependent upon the instantaneous radius of the wound material on the roll and the desired tension to be applied to the material being transferred which varies with the radius of the wound material, said control comprising first sensing means for establishing a periodic angular velocity signal indicative of the angular velocity of the wound material, second sensing means for establishing a linear velocity signal indicative of the linear velocity of the material being transferred, means including divider means responsive to said linear velocity signal and said angular velocity signal for establishing a radius signal indicative of the instantaneous radius of the wound material, inertia compensation means for establishing an inertia compensation signal dependent upon acceleration of the winder for compensating for inertia of the winder during acceleration, friction compensation means responsive to the linear velocity of the material being transferred for establishing a friction compensation signal indicative of the friction acting on the winder at a given velocity, summing means for summing said radius signal indicative of the instantaneous radius of the wound material, said friction compensation signal and said inertia compensation signal establishing a control signal indicative of the torque to be applied by the winder to the material being transferred to maintain a predetermined tension on the material being transferred which is dependent on the instantaneous radius of the wound material, and comparator means responsive to the angular velocity of said roll of wound material for rendering said divider means inoperative to generate said radius signal when the angular velocity of the roll of material is below a predetermined minimum value, said comparator means generating a constant radius reference signal when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means, and wherein said comparator means includes means responsive to said first sensing means for establishing a control signal when the angular velocity of the winder roll is below a predetermined level, cut out means responsive to said control signal for preventing said radius signal from being directed to said summing means when the angular velocity of the winder roll is below a predetermined level and means for establishing said constant radius reference signal and directing said constant radius reference signal to said summing means when said cut out means is energized and said radius signal is prevented from being directed to said summing means, and wherein said means responsive to said first sensing means for establishing said control signal includes monostable multivibrator means for establishing a reference period for comparison with the period of said periodic angular velocity signal, said reference period corresponding to the angular velocity of said winder roll at said predetermined level, and further includes circuit means for producing said control signal when said period of said periodic angular velocity signal is below said reference period.

13. An open-loop control for maintaining the tension on a filament of material which is being transferred between a source of material and a roll in correspondence with a predetermined tension which is dependent upon the instantaneous radius of the roll of material comprising drive means for driving the roll of material, a tension control means for establishing a reference signal indicative of the instantaneous radius of the roll of material and the desired tension to be applied to the filament at the instantaneous radius, a control circuit responsive to the reference signal of said tension control means and being connected to said drive means for energizing said drive means to maintain the predetermined tension on said filament of material, first sensing means for sensing the angular velocity of the roll of material and establishing a periodic angular velocity signal indicative thereof and second sensing means for sensing the linear velocity of the filament of material for establishing a linear velocity signal indicative thereof, said tension control means being responsive to said angular velocity signal and said linear velocity signal and including means having a divider circuit for establishing a radius signal indicative of the instantaneous radius of the roll of material and means for modifying said radius signal to establish said reference signal which is indicative of the instantaneous radius of the roll of material and the desired tension to be applied to the filament at the instantaneous radius and comparator means responsive to the angular velocity of said roll of wound material for rendering said divider means inoperative to generate said radius signal when the angular velocity of the roll of material is below a predetermined minimum value, said comparator means generating a constant radius reference signal when said divider means is rendered inoperative, said comparator means directing said constant reference radius signal to said summing means, and wherein said comparator means includes means responsive to said first sensing means for establishing a control signal when the angular velocity of the winder roll is below a predetermined level, cut out means responsive to said control signal for preventing the establishment of said radius signal when the angular velocity of the winder roll is below a predetermined level and means for establishing said constant radius reference signal when said cut out means is energized, and wherein said means responsive to said first sensing means for establishing said control signal includes monostable multivibrator means for establishing a reference period for comparison with the period of said periodic angular velocity signal, said reference period corresponding to the angular velocity of said winder roll at said predetermined level, and further includes circuit means for producing said control signal when said period of said periodic angular velocity signal is below said reference period.

14. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll wherein the torque to be applied by the winder is dependent upon the instantaneous radius of the wound material on the roll and the desired tension to be applied to the material being transferred which varies with the radius of the wound material, said control comprising first sensing means for establishing an angular velocity signal indicative of the angular velocity of the wound material, second sensing means for establishing a linear velocity signal indicative of the linear velocity of the material being transferred, means including divider means for establishing a radius signal indicative of the instantaneous radius of the wound material, inertia compensation means for establishing an inertia compensation signal dependent upon acceleration of the winder for compensating for inertia of the winder during acceleration, friction compensation means responsive to the linear velocity of the material being transferred for establishing a friction compensation signal indicative of the friction acting on the winder at a given velocity, summing means for summing said radius signal indicative of the instantaneous radius of the wound material, said friction compensation signal and said inertia compensation signal establishing a control signal indicative of the torque to be applied by the winder to the material being transferred to maintain a predetermined tension on the material being transferred which is dependent on the instantaneous radius of the wound material, and wherein said divider means includes means responsive to said first and second sensing means for establishing a cyclic wave form having a frequency dependent upon the angular velocity of the roll of material and a magnitude dependent upon the linear velocity of the material, and wherein said means for establishing said cyclic wave form includes means responsive to said second sensing means for generating a current signal having a magnitude dependent upon the linear velocity of the material, energy storage means responsive to said current signal for storing energy having a magnitude which is dependent upon the magnitude of said current signal and switching means for periodically discharging said energy storage means to establish said cyclic wave form, said switching means acting to periodically discharge said energy storage means at a frequency which is dependent upon the angular velocity of the roll of material.

15. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll as defined in claim **14** further including averaging means for establishing said radius signal which has a magnitude indicative of the average value of said cyclic wave form and taper and taper-bias potentiometers ganged together for setting the taper and taper-bias of the material being transferred, said taper potentiometer modifying said radius signal indicative of the average value of said cyclic wave form and said taper-bias potentiometer establishing a constant biasing signal having a value indicative of the setting of said taper potentiometer and directing said biasing signal to said summing means.

16. A control for maintaining a predetermined tension on material being transferred between a source of material and a roll wherein the predetermined tension is dependent upon the instantaneous radius of the roll of material comprising, first sensing means for sensing the angular velocity of the roll of material and establishing a first signal indicative of the angular velocity of the roll of material, second sensing means for sensing the linear velocity of the material and establishing a second signal indicative of the linear velocity of the material, dynamic compensation means for establishing a dynamic compensation signal, means including a divider means for establishing a radius signal indicative of the instantaneous radius of the roll of wound material, summing means for summing said instantaneous radius signal and said dynamic compensation signal and establishing a control signal indicative of the desired tension to be applied to said material, drive means for driving said roll of material, control means responsive to said control signal for energizing said drive means to maintain a predetermined tension on said material which tension is dependent upon the instantaneous radius of the material on the roll and comparator means responsive to said first sensing means to render said divider means inoperative at a predetermined angular velocity of said roll of material, and wherein said dynamic compensation means includes friction compensation means for compensating for friction in the winder, said friction compensation means including means responsive to said second signal for establishing a friction compensation signal dependent upon the linear velocity of the material being transferred and operative to direct said friction compensation signal to said summing means.

17. A winder control for generating a signal indicative of the instantaneous torque to be applied by a winder to maintain a predetermined tension on material being transferred between a source of material and a roll wherein the torque to be applied by the winder is dependent upon the instantaneous radius of the wound material on the roll and the desired tension to be applied to the material being transferred which varies with the radius of the wound material, said control comprising first sensing means for establishing an angular velocity signal indicative of the angular velocity of the wound material, second sensing means for establishing a linear velocity signal indicative of the linear velocity of the material being transferred, including divider means for establishing a radius signal indicative of the instantaneous radius of the wound material, inertia compensation means for establishing an inertia compensation signal dependent upon acceleration of the winder for compensating for inertia of the winder during acceleration, friction compensation means responsive to the linear velocity of the material being transferred for establishing a friction compensation signal indicative of the friction acting on the winder at a given velocity, summing means for summing said radius signal indicative of the instantaneous radius of the wound material, said friction compensation signal and said inertia compensation signal establishing a control signal indicative of the torque to be applied by the winder to the material being transferred to maintain a predetermined tension on the material being transferred which is dependent on the instantaneous radius of the wound material.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,910,521

DATED : 10/7/75

INVENTOR(S) : G. F. O'Callaghan; J.M.Haurykiewicz

It is certified that error appears in the above–identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 13, line 29: Correct spelling of "potentiometer".

line 31,32: Correct spelling of "potentiometer".

line 49: Correct spelling of "filament".

Col. 14, line 64: Correct spelling of "signal".

Col. 18, line 49: Insert "means" after "transferred".

Signed and Sealed this

sixteenth **Day of** *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT AND TRADEMARK OFFICE

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