Dec. 10, 1968 A. A. PINTO ETAL 3,416,051

WEB TENSION CONTROL SYSTEM

Filed Feb. 4, 1966 2 Sheets-Sheet 1

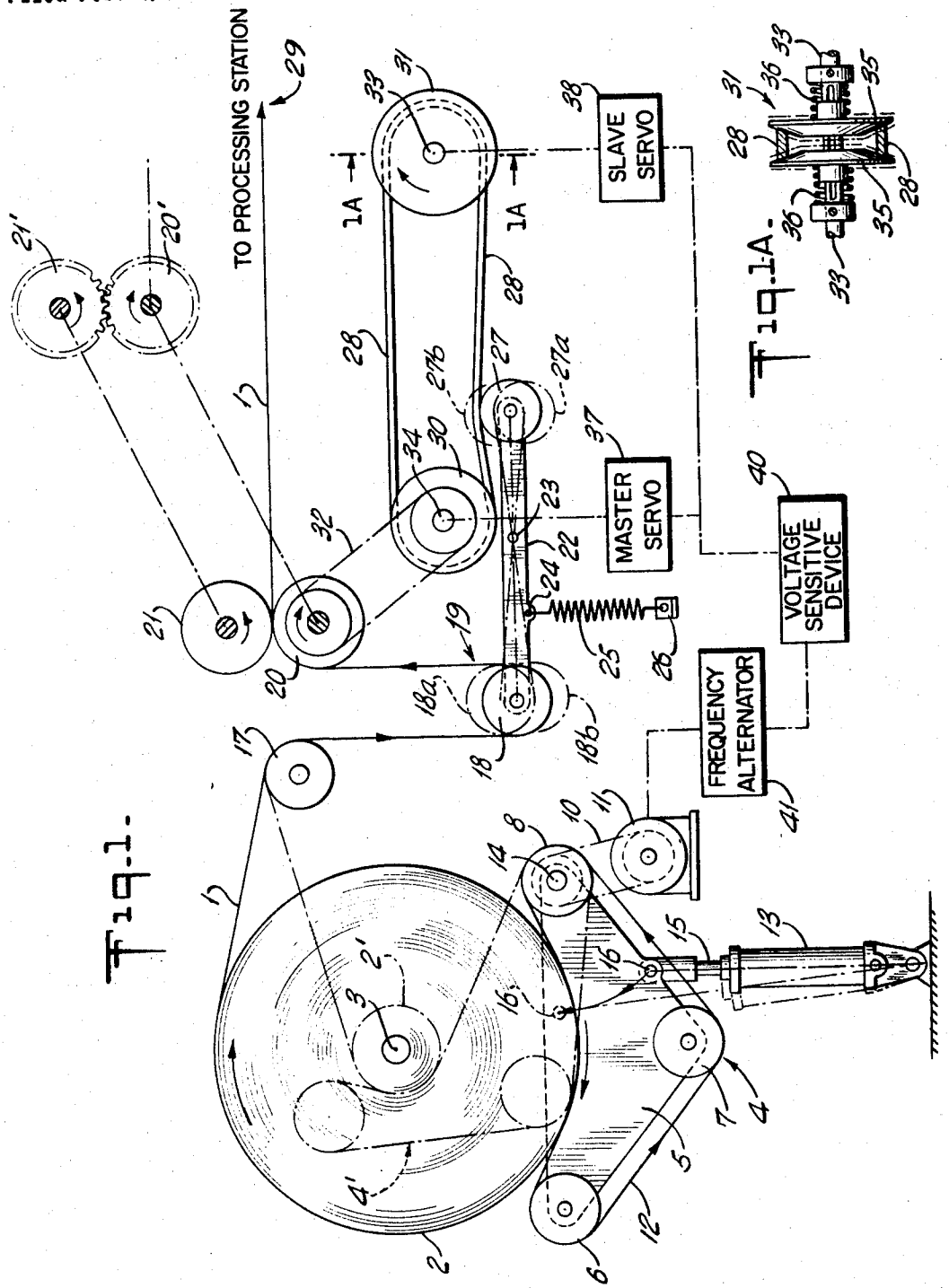


Fig. 1.

Fig. 1A.

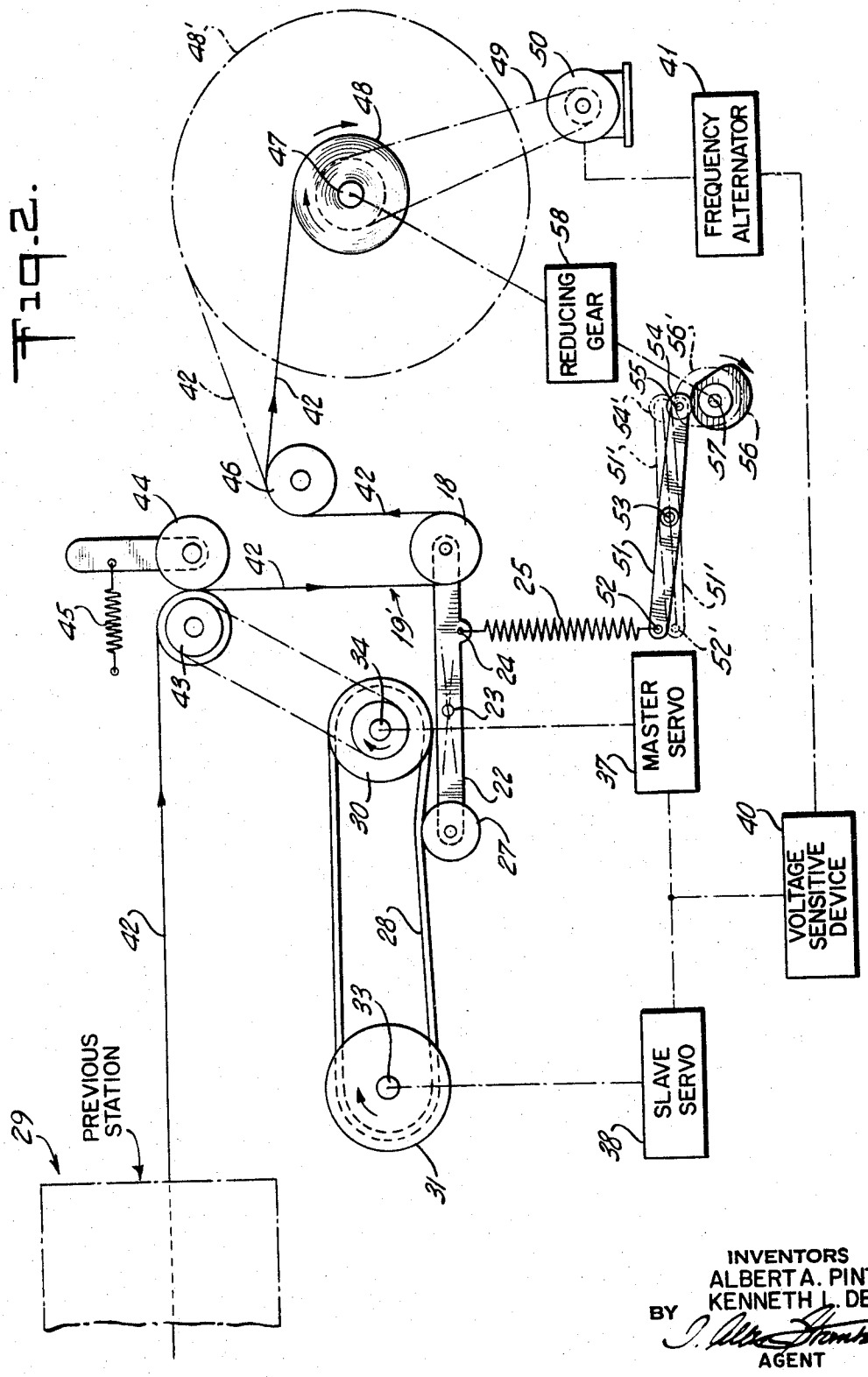
INVENTORS
ALBERT A. PINTO
KENNETH L. DEW
BY
AGENT

Dec. 10, 1968 A. A. PINTO ETAL 3,416,051

WEB TENSION CONTROL SYSTEM

Filed Feb. 4, 1966 2 Sheets-Sheet 2

Fig. 2.



INVENTORS
ALBERT A. PINTO
KENNETH L. DEW
BY J. Alex Stonebraker
AGENT

United States Patent Office 3,416,051 Patented Dec. 10, 1968

3,416,051

WEB TENSION CONTROL SYSTEM

Albert A. Pinto, White Plains, N.Y., and Kenneth L. Dew, Fair Lawn, N.J., assignors to National Biscuit Company, a corporation of New Jersey

Filed Feb. 4, 1966, Ser. No. 537,584
3 Claims. (Cl. 318—6)

ABSTRACT OF THE DISCLOSURE

An apparatus in which a web of material being moved through various steps for coating, lamination, perforation, or other treatment is automatically kept at suitable constant tension to prevent wrinkling, breaking or undue stress by utilizing a servomechanism system or feedback control means. The latter detects the difference between a reference signal and some function of a controlled variable signal to provide an "actuating error signal" which is fed back to a suitable control element which instantly responds to correct the variation in the tension of the moving web without necessitating contact with the material of the web in carrying out the correction.

Many devices have been designed to automatically control tension in a moving web. Most of these are extremely complex and consequently very sensitive to minute inaccuracies in construction. They also require a great amount of maintenance to keep them functioning properly. Then too, most previous devices do not lend themselves to a variety of applications for, in general, they have been designed for a particular operation, thus limiting their versatility. Cost has also been a prohibitive factor in the widespread use of the highly sensitive tension control devices. This present invention, though a highly sensitive tension control device, eliminates many of the above described undesirable features as will be pointed out in further detail.

Therefore, the primary object of the invention is to provide an automatic device for controlling tension in a moving web of material.

A further object of the invention is to provide an automatic tension control device that will respond instantaneously to a deviation in tension of the moving web from a predetermined value.

Another important object of the invention is to provide an automatic tension control device that will not only control tension at the unreeling and reel winding stations but will also be capable of operating between conversion stations in a web system.

A still further object of the invention is to provide an automatic tension control device which is highly sensitive in controlling slight changes in web tension without requiring the use of complex equipment.

Yet another object of the invention is to provide an automatic tension control device in which the desired tension can be varied while the system is in operation.

A further object of the invention is to provide a programmed tension control device which will automatically regulate and vary progressively or otherwise as desired the tightness with which the web material is wound onto a roll.

Other objects and unique features of the invention will be apparent from the following description and claims taken in connection with the accompanying drawings in which:

FIGURE 1 is a diagrammatic representation which includes a schematic wiring diagram of the tension control apparatus embodying the features and principles of the invention in operation with a web supply mechanism;

FIGURE 1–A is a detailed cross sectional view taken along line 1A–1A of the variable pitch pulley shown in FIGURE 1.

FIGURE 2 is a diagrammatic representation including a schematic wiring diagram of the tension control apparatus as used in conjunction with a programmed tension control device in operation with a web windup mechanism.

The following description will make reference to the accompanying drawings which are for the purpose of illustration only and do not limit or define exactly the structural details of the invention.

Referring now to the drawings, there is shown in FIGURE 1 a diagrammatic representation of a strip or web of material **1** in the process of being withdrawn or unwound at a constant linear speed from a storage roll **2**. The storage roll is fixed to spindle **3** and is being driven by a peripheral surface drive mechanism **4** which is well known in the art. Drive mechanism **4** comprises a triangular plate **5** with two guide pulleys **6** and **7** and drive pulley **8**, the pulleys being rotatably mounted at the corners of plate **5**. Passing around all three pulleys is an endless drive belt **12** with the pulleys **6** and **8** positioned so as to provide the belt with a suitable angle of drive wrap applied to the storage roll **2**. As seen in FIGURE 1 triangular plate **5** is pivoted on fixed shaft **14** and is supported by piston shaft **15** which is pivotally connected to plate **5** by a pin **16**. Piston shaft **15** is actuated by air cylinder **13** providing a constant upward force thus lifting the surface drive mechanism **4** into continuous peripheral driving position. Contact between drive belt **12** and storage roll **2** is maintained at a constant predetermined pressure by operation of air cylinder **13** which also forces the drive belt **12** to follow the contour of the storage roll **2** as the diameter of the latter decreases due to the unwinding of the sheet material on the roll. FIG. 1 also shows the surface drive mechanism **4'** operating with a greatly depleted storage roll **2'** (dot and dash outline).

Speed control of drive belt **12** and consequently the rate at which the web material **1** unwinds from the storage roll **2**, is controlled by variable speed motor **11** which is coupled to drive pulley **8** by endless belt **10**. Speed variation of variable speed motor **11** provides the means for controlling the tension in moving web **1**.

VARIABLE SPEED MOTOR CONTROL

As seen in FIGURE 1 the web of sheet material **1** unwinds from storage roll **2** and passes about guide roller **17** and then under a floating roller **18**. From the roller **18** the web **1** passes about a driven roller **20** which pulls the material at a constant rate by means of driven roller **21** which bears against the web of material as it passes around roller **20**. Driven rollers **20** and **21** are rotated synchronously at the same predetermined speed thus supplying the material to a processing station **29** at a constant linear velocity. The rollers are mechanically linked as shown in the dot and dash outline **20'** and **21'**.

With the sheet material **1** being pulled at a constant rate by rollers **20** and **21**, tension variation in the web material will be inevitable between the supply roll **2** and the pull rollers **20** and **21** unless the rotational speed of the supply roll **2** is closely controlled so as to regulate the rate of unwinding of the material from the roll. Thus, tension control in the moving web is being obtained by making the supply roll rotational speed directly proportional to a desired tension in the moving web. This is accomplished by a mechanical sensing system in combination with an electrical feedback correcting system as shown in FIGURE 1. The mechanical sensing system comprises the floating roller **18** fixed to a sensing arm **22** which is rotatably mounted on a pivot point **23**. Fixed

at one end to sensing arm **22**, at connection point **24**, is a tension spring **25** and suspended intermediate of the pivot **23** is a load **26** which provides a predetermined downward moment about pivot point **23** acting on sensing arm **22**. The value of this moment is predetermined to directly oppose the upward moment about pivot point **23** caused by the web of material forming a loop **19** about the floating roller **18**. Under ideal operating conditions the opposing forces will cancel each other and sensing arm **22** (FIGURE 1—solid outline) will remain in a horizontal and relatively stable position. Any desired value of tension in the moving web of material can be obtained by varying the load on tension spring **25**. Such a change in load will vary the opposing upward moment produced by the moving web of material and consequently change the tension in the material. The opposing forces will determine the position of sensing arm **22**, which, as stated previously, is free to move about pivot point **23**. As sensing arm **22** changes position due to variations of the opposing moments resulting from changes of tension in the moving web, it will pivot about point **23**, consequently changing the position of the follower pulley **27** fixed to its opposite end. Follower pulley **27** is in contact with an endless belt **28**, which passes about a fixed pitch pulley **30** and a variable pitch pulley **31**. Fixed pitch pulley **30** is driven from roller **20** at the same rotational speed of the latter by means of drive belt **32**. Thus, the speed of pulley **30** will be directly proportional to the speed of pull rollers **20** and **21**. Consequently belt **28** which passes around pulley **30** will also travel at a speed directly proportional to that of pull rollers **20** and **21**, the speed of which will vary according to the demands of the web receiving equipment or the demand from processing station **29**. As belt **28** passes about variable pitch pulley **31** the pulley is driven at a speed dependent upon the distance of the belt from the center of shaft **33** onto which the pulley **31** is fixed (FIG. 1–A).

As shown in FIGURE 1–A, variations of rotational speed of pulley **31** may be obtained by forceably changing the position of belt **28** relative to shaft **33**. For instance, to obtain a greater rotational speed of pulley **31**, belt **28** is forced inward towards the shaft causing the side plates **35** of pulley **31** to move in opposite directions along shaft **33** which permits belt **28** to change its position and consequently the pitch surface and effective radius of pulley **31**. Thus, with belt **28** changing its position and causing a change in effective radius but still maintaining the same speed, pulley **31** will be driven at a greater rotational speed, the increase of which will be directly proportional to the change of the effective radius. The converse is effected when the belt **28** is forced outwardly, thus increasing the effective radius and pitch surface of pulley **31**. The pulley side plates **35** (FIGURE 1–A) are held in position by compression springs **36** which permit lateral in and out movement of said plates **35** on the shaft **33**.

Coupled directly to shafts **33** and **34** (as shown in FIG. 1) are servomotors **38** and **37** respectively and which consequently generate a constant signal directly proportional to the speed at which they are being driven. Under desired tension conditions of the moving web, the sensing arm **22** will dispose the follower pulley **27** in a neutral position (shown in solid outline) against drive belt **28** so as to place the belt around variable pitch pulley **31** with a pitch surface and effective radius equal to that of fixed pitch pulley **30**. With both pulleys having the same effective radius, variable pitch pulley **31** will be synchronized with pulley **30** which is being driven by the pull rollers **20** and **21**. Thus with both pulleys **30** and **31** rotating at the same speed their respectively linked servomotors **37** and **38** will generate signals precisely identical in value causing a zero differential of electrical potential between the two servomotors. A zero differential will only occur when tension in the moving web is at a predetermined desirable value thus requiring no correction. As soon as a tension variation occurs, floating roller **18** will change position to compensate for an increase **18***a* or decrease **18***b* in the length of the loop **19** formed by the web **1**. This change of position of floating roller **18** not only compensates for a change in tension of the moving web but also initiates corrective procedures to alleviate the cause of the variation in tension. This corrective procedure is commenced instantaneously with the initial change of position of sensing roller **18** for as sensing roller **18** changes position sensing arm **22** and follower pulley **27** will simultaneously change position to **27***a* or **27***b*. This change of position of follower pulley **27** which is directly proportional to the variations of tension in the web will change the position of belt **28** and consequently the effective radius and pitch surface of variable pitch pulley **31**.

The servomotor **38** which is called the "slave servo" generates an E.M.F. which is directly proportional to the actual tension in the moving web.

Servomotor **37** which is called the "master servo" and which is linked and driven by fixed pitch pulley **30**, generates an E.M.F. directly proportional to the varying demands of the processing stations or web receiving equipment. The difference of the two signals generated by the "master" and "slave" servos will be proportional to the difference in actual and desired tension in the moving web and will be measured by the voltage sensitive device **40**. The difference or "error signal" will have a magnitude and a plus or minus direction which will be received by the frequency alternator **41** through the voltage sensitive device **40**. As the frequency alternator **41** converts the generated signal into a corrective frequency it is then applied to the variable speed synchronous motor **11**, subsequently increasing or decreasing the rotational speed of supply roll **2** thus correcting the rate at which the web material **1** is being unwound. In this manner, a change of material unwinding rate will correct the error in tension and return sensing arm **22** back to a "neutral position" with both "master" and "slave" servomotors rotating at precisely the same speed to return the "error signal" to a zero value. This correcting process is not a step function but rather a continuous correcting operation changing with uncontrolled variations of tension from a desired value and meeting the demands for varying rates of web material.

The windup of sheet material from a processing operation as shown in FIGURE 2 will also require tension control in order to maintain proper operating conditions. The processed sheet material **42** is drawn from the processing station **29** by driven pull roller **43** which pulls the material at a constant linear velocity. To maintain the material in contact with the pull roller **43** to provide a constant drawing of material from the processing equipment, pinch roller **44** bears against the web of material as it is drawn by the pull roller. The pinch roller **44** maintains a proper pressure against the pull roller **43** and the web therebetween by means of spring **45**. From the pull roller **43**, the web of material **42** passes under sensing roller **18** and then about guide pulley **46** from which the material is drawn onto driven spindle **47** to form the beginning of a roll of material **48**.

Spindle **47**, as shown in FIG. 2, is driven by sychronous motor **50** by means of drive belt **49**. The rotational speed of the spindle **47** is dependent upon the length of the loop of material **19'** in the moving web of material as sensed by roller **18** and sensing arm **22**, the operation of which is similar to that previously discussed for the system shown in FIG. 1.

The tension in the moving web of material **42** will also determine the tightness of wrap of the web material being wound around spindle **47**. Precise control of web tension is especially important, for example, in winding of plastic film which would require a more tightly wound roll near the spindle with a progressively looser winding towards the outer circumference. This can be effected by utilizing the same tension control system as described

in FIG. 1 with a programmed change of desired tension to be applied through spring **25**. A programmed variation of tension in the moving web of material **42** is obtained by means of a plate cam **56** fixed to shaft **57** which is linked to and driven by shaft **47**. The cam is rotated by suitable driving gears **58** to make one complete revolution for every completely wound roll of material **48'**. As cam **56** rotates, it actuates follower **54** which is in contact with the cam contour. The displacement of follower **54** is in a vertical plane and designed to rock the lever arm **51** from minimum to maximum in one 360° rotation of the cam **56**. The follower **54** is free to rotate on shaft **55** which is fixed to rocker **51**. The rocker **51** which is free to oscillate at its fulcrum **53** provides the means of transmitting the follower displacement to spring **25** which is fixed to the opposite end of rocker **51** at point **52**. As previously discussed for the system in FIG. 1, spring **25** provided the means for setting a desired tension in the moving web of material by suspending the required load from its end. By connecting the end of spring **25** to the rocker arm **51** at point **52** the load is replaced by a varying force equivalent to the follower displacement. This is illustrated in the dot-and-dash outline **51'** of FIG. 2. As cam **56** is rotated during the winding cycle to position **56'**, follower **54** will be gradually displaced to position **54'**. Consequently rocker **51** is pivoted about its fulcrum **53** to position **51'**. Any change in position of rocker **51** will simultaneously displace connection point **52** to position **52'** which will result in a displacement of spring **25** and consequently effect a downward force applied to sensing arm **22** by the spring. This change in the downward force being applied to sensing arm **22** will cause a directly proportional change in tension in the moving web of material **42**. A change in tension as previously stated will directly change the tightness in which the sheet material will be wound into a roll. Thus, any variation of tightness can be obtained by varying the contour of the plate cam **56**. The previous reference to plastic film which would require a more tightly wound roll near the spindle with a progressively looser winding towards the outer circumference can be easily obtained by forming the plate cam **56** so as to impart a maximum rise of follower **54** at the beginning of the winding cycle with a gradual decline thereafter. This will effect a maximum tension in the moving web of material at the beginning of the cycle which will consequently provide a more tightly wound roll of plastic film near the spindle as required. A gradual decrease in tension will then provide a looser winding toward the peripheral surface of the roll.

It will be understood that various changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What we claim as our invention and desire to secure by Letters Patent is:

1. An apparatus for automatically controlling tension in a moving web of sheet material comprising in combination:

(a) means for rotating a roll of said web material, including motor means;

(b) means for providing linear velocity to said material including a pair of rollers engaging the opposite sides of said material;

(c) means for setting a desired value of tension in said moving web of material in direct proportion to the rotational speed of said roll of web material including;

(d) a loop of web material depending between said roll and said linear velocity rollers, a roller floating in said loop, an endless belt, a fixed pitch pulley and a variable pitch pulley about which said endless belt travels, said pulleys rotating at the same speed when the tension in the moving web is at a predetermined desirable value not requiring correction;

(e) a fulcrumed sensing arm means having a following pulley at the opposite end thereof from said floating roller, to the latter of which the other end of said arm is pivoted, said arm yieldably maintaining the roller and pulley in contact respectively with the loop of the web and the endless belt whereby variation in the speed of the material effecting a movement of said loop will vary the speed of operation of said variable pitch pulley;

(f) slave servomotor means associated with said variable pitch pulley for generating an E.M.F. signal directly proportional to the tension in the web as detected by the movement of said floating roller;

(g) master servometer means associated with said fixed pitch pulley for generating an E.M.F. signal directly proportional to the desired tension in the web of material, the difference in the two signals generated by said slave and master servomotor means being proportional to the difference in actual and desired tension in the moving web;

(h) voltage sensitive means in circuit with said slave and master servomotor means for providing an error signal in magnitude and plus or minus direction, and

(i) frequency alternator means for converting said error signal into a corrective frequency for controlling the operation of said motor means whereby a continuous correcting operation, changing with uncontrolled variations of tension from a desired value and meeting the demands for varying rates of web material tension is provided.

2. An apparatus according to claim **1** wherein said means for rotating said web of material includes:

(a) pivoted triangular plate means, guide and drive pulleys mounted at the camers of said plate means and over which pulleys passes a drive belt;

(b) synchronous motor means for driving said belt, and

(c) air cylinder means including a piston shaft pivoted to said plate means and operable through the air cylinder to raise and lower said plate means to maintain the drive belt in contact with the periphery of said roll of material.

3. An apparatus according to claim **1** wherein said sensing arm means includes tension spring load means for providing a predetermined downward movement about the fulcrum of said arm means.

References Cited

UNITED STATES PATENTS

2,984,429	5/1961	Huck	242—75.1
3,148,816	9/1964	Martin et al.	226—95
3,223,906	12/1965	Dinger	318—7
3,283,228	11/1966	Asseo	318—7

ORIS L. RADER, *Primary Examiner.*

B. A. COOPER, *Assistant Examiner.*

U.S. Cl. X.R.

242—75.51