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McCall

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[54] **METHOD AND APPARATUS FOR IMPROVING THE UNIFORMITY OF THE BASIC WEIGHT OF A FABRIC**

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[51] **Int. Cl.** **D06c 3/00**

[58] **Field of Search** ..... 26/57 A, 60; 235/151.1; 162/6; 34/52

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[57] **ABSTRACT**

A method and apparatus is disclosed for regulating the basis weight on the exit side of fabric heat set apparatus to improve the uniformity of the basis weight of the fabric in a mill roll or other selected fabric length. A measured exit fabric basis weight is averaged across the width of the fabric and the average final basis weight is compared with a selected target basis weight to produce a measured final basis weight error signal. The latter signal may be fed into an "on time" proportioning auto control which produces an on-time control signal proportioned to the measured final basis weight error signal and adjusts a motor operated potentiometer to vary a calculated percent moisture signal from an initially manually set estimated magnitude of the percent moisture in the fabric on the entrance side of the heat set apparatus. The percent moisture signal along with signals representing measured entrance basis weight, measured entrance fabric width, measured entrance speed, measured exit speed, and standard fabric width are fed as inputs into a calculated final basis weight computer, which computes a calculated or predicted final basis weight. The calculated basis weight is averaged in a profile averaging computer and compared with the selected target basis weight to produce a calculated basis weight error signal. The latter error signal is fed into a speed proportioning auto control which produces a speed on-time control signal proportional to the calculated final basis weight error signal. A speed motor operated potentiometer is adjusted in response to the speed on-time control signal to vary a overfeed speed control signal from an initially manually set signal. The overfeed speed control signal adjusts the speed of the fabric overfeed means which feeds fabric onto a tenter frame at the entrance end of a heat set oven at a speed greater than the speed of the tenter. By adjusting the speed of the overfeed means in accordance with the calculated basis weight error signal shrinkage of the fabric is regulated in order to improve the uniformity of the fabric final basis weight.

7 Claims, 2 Drawing Figures

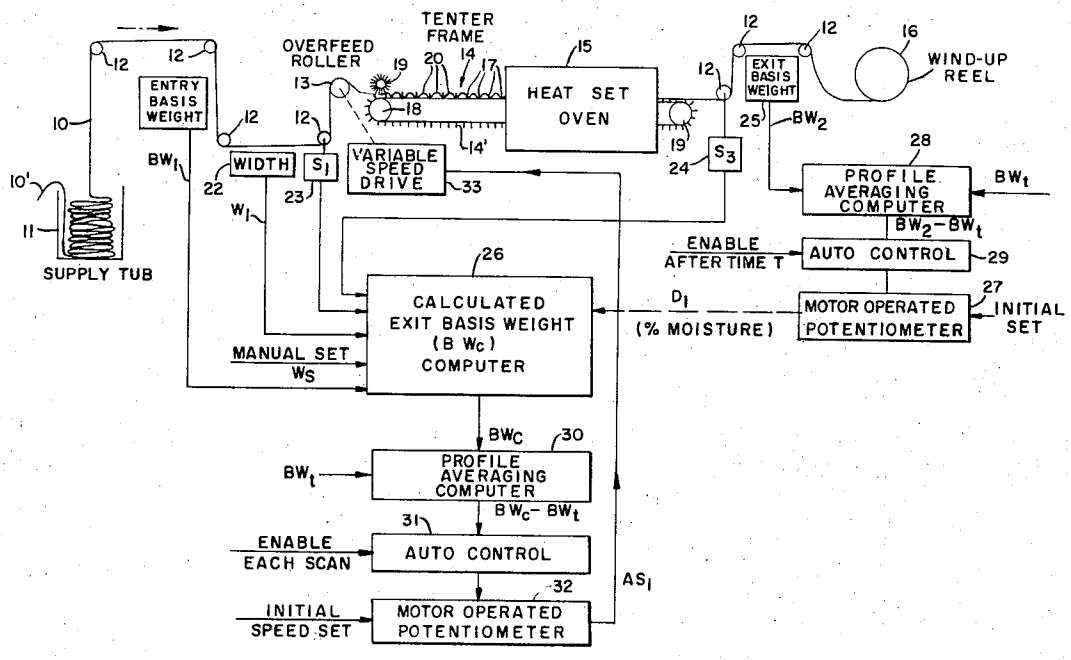


FIG. 1.

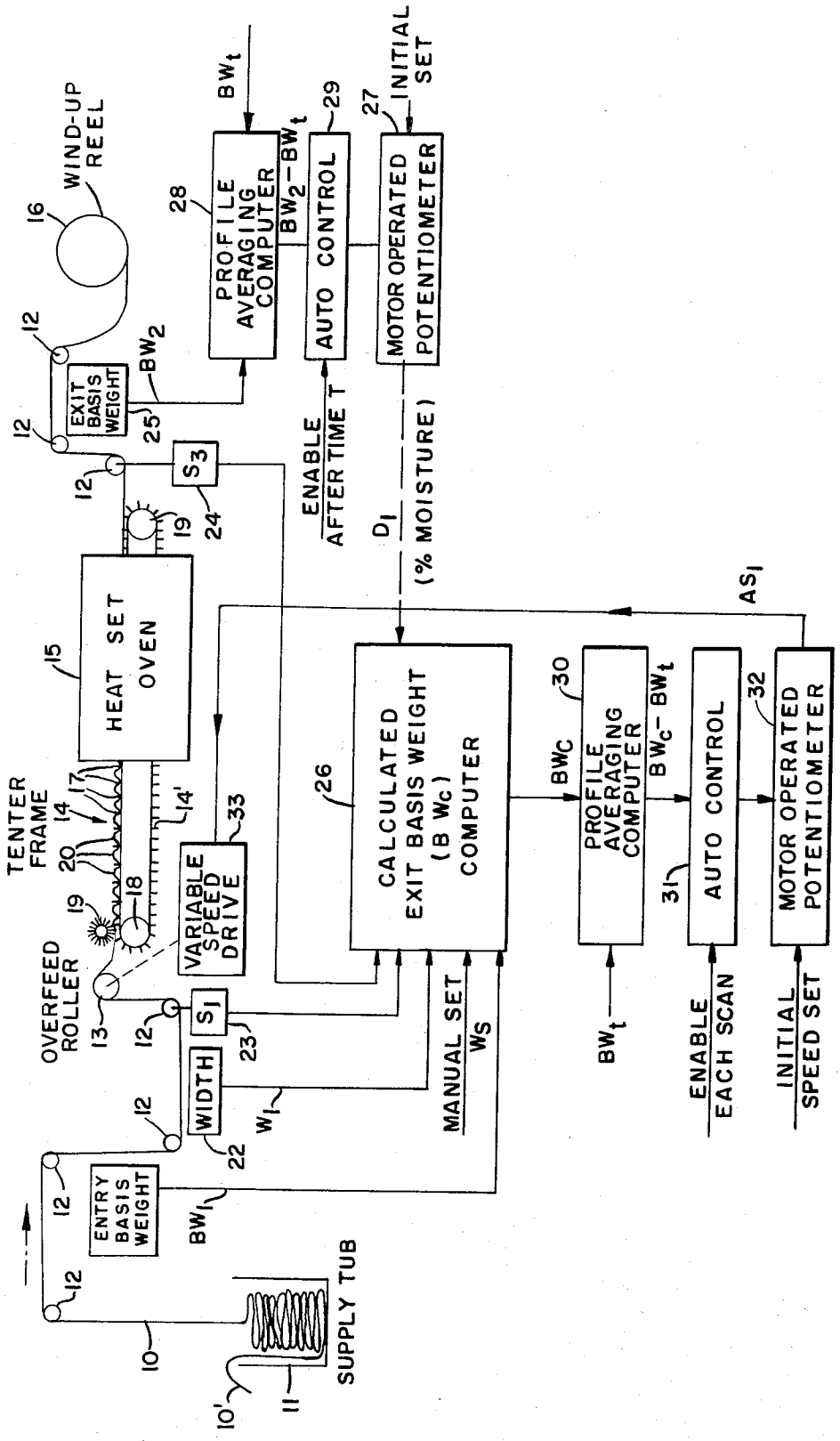
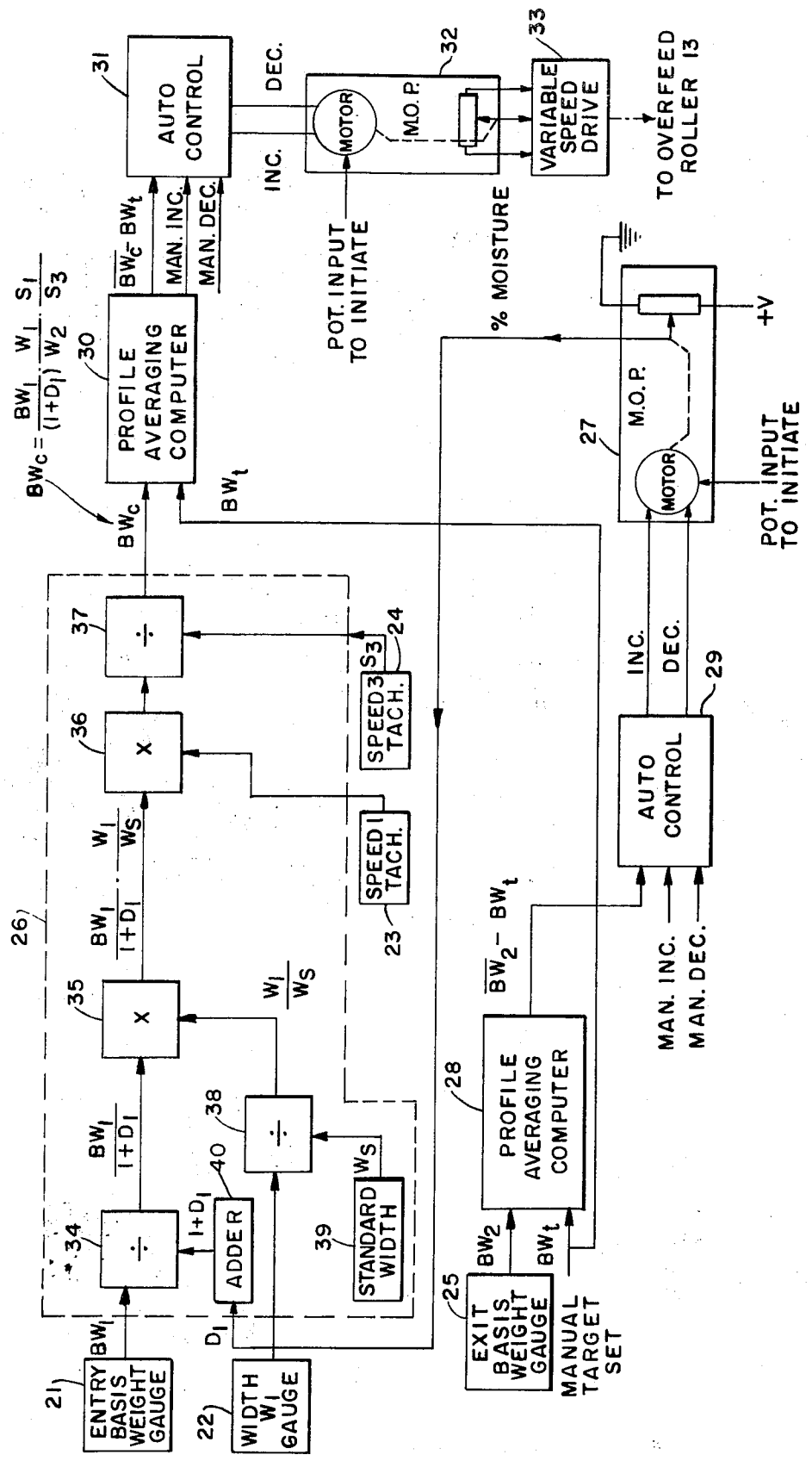

WIND-UP REEL
16
12
EXIT BASIS WEIGHT
25
BW_2
PROFILE AVERAGING COMPUTER
28
BW_t
$BW_2 - BW_t$
AUTO CONTROL
29
MOTOR OPERATED POTENTIOMETER
27
INITIAL SET
ENABLE AFTER TIME T
D_I
(% MOISTURE)
AS_I
S3
24
19
HEAT SET OVEN
15
TENTER FRAME
14
17
20
18
14'
33
VARIABLE SPEED DRIVE
OVERFEED ROLLER
13
S1
23
WIDTH
22
W_I
ENTRY BASIS WEIGHT
BW_I
SUPPLY TUB
10
10'
11
CALCULATED EXIT BASIS WEIGHT (B W_C) COMPUTER
26
MANUAL SET
W_S
BW_C
30
PROFILE AVERAGING COMPUTER
$BW_C - BW_t$
31
AUTO CONTROL
32
MOTOR OPERATED POTENTIOMETER
BW_t
ENABLE EACH SCAN
INITIAL SPEED SET

FIG. 2.


AUTO CONTROL
DEC.
INC.
MOTOR
M.O.P.
VARIABLE SPEED DRIVE
TO OVERFEED ROLLER 13
POT. INPUT TO INITIATE
% MOISTURE
+V
MAN. INC.
MAN. DEC.
PROFILE AVERAGING COMPUTER
ENTRY BASIS WEIGHT GAUGE
WIDTH W1 GAUGE
EXIT BASIS WEIGHT GAUGE
MANUAL TARGET SET
ADDER
STANDARD WIDTH
SPEED1 TACH.
SPEED3 TACH.

METHOD AND APPARATUS FOR IMPROVING THE UNIFORMITY OF THE BASIC WEIGHT OF A FABRIC

The invention relates to a method and apparatus for improving the uniformity of the basis weight of a travelling web of textile fabric at the exit side of fabric heat setting apparatus.

Fabric containing synthetic resin fibers, such as the double knit polyester fabrics, are subjected to a heat set process for the purpose of setting the fabric so that it will retain its "weave." A typical heat set apparatus will include a source of fabric supply from a prior fabric treating station, generally where the fabric is wet with a liquid treating media for cleaning, sizing, or other purpose, overfeed means for feeding the fabric onto a tenter frame which carries the fabric through a heat set oven and regulates the stretch and/or shrinkage of the fabric in one or more directions, and a fabric take up means on the exit side of the heat set oven where the fabric is wound into a large roll known as a mill roll.

Design and economic factors enter to make it highly desirable to obtain a mill roll in which the fabric throughout its entire length and breadth is substantially of a uniform basis weight. Factors which affect the final basis weight of fabric on the exit side of a heat set oven are the basis weight of the fabric entering the heat set apparatus, which in turn is affected by the moisture content of the fabric, the amount of lateral and longitudinal shrinkage, and/or stretch within the heat set oven, and the moisture content of the fabric at the exit side of the oven. Most of the factors effecting final basis weight can be measured and controlled to some degree of accuracy, but the measurement and control of all the factors affecting basis weight requires expensive monitoring and control equipment. Since the cost of the monitoring and control equipment is increased with the number of factors affecting final basis weight that are measured and controlled, it is highly desirable from an economic standpoint to keep the monitoring and control equipment to a minimum while obtaining a product of optimum basis weight uniformity which will satisfy the needs of marketplace.

One known method which has been proposed for controlling a fabric heat set apparatus includes measuring the fabric basis weight and moisture content ahead of the oven, before the overfeed. From these measurements the dry fiber weight may be calculated. The dry fiber weight is compared with the desired final target weight. Any difference would result in a control signal being applied to the overfeed means to increase or decrease the final fabric weight to the target weight. The final fabric weight after the oven would be measured and displayed as an indication to the operator of how well the process was being controlled to the target.

It is a primary object of this invention to monitor and control the final basis weight of a fabric at the output side of heat set apparatus in order to obtain improved uniformity of final basis weight while keeping the cost of the basis weight monitoring and control equipment to a minimum compatible to obtaining the desired uniformity of final basis weight. In conformity with the aforesaid primary objective of this invention, the monitoring and control equipment of this invention omits apparatus for directly measuring the moisture content of the fabric either at the entrance or exit end of the heat set apparatus.

It is an object of this invention to measure the final fabric basis weight (weight per unit area) and control the final basis weight relative to a target basis weight by making adjustments to the speed of the overfeed means feeding fabric onto the tenter frame that carries the fabric through the heat set oven. For the purpose of this invention it will be assumed that certain conditions of the heat set apparatus are substantially met. For one, the heat set oven is of such design that it will dry the fabric substantially completely, secondly the tenter frame is adjusted to produce a fabric at the exit side of the heat set oven which has a selected standard width, and thirdly by controlling the speed of the overfeed means laying the fabric onto the tenter frame the longitudinal shrinkage of the fabric can be regulated, and thus by regulating longitudinal shrinkage of the fabric, the final fabric basis weight can be controlled within acceptable limits relative to a selected target.

Factors affecting the difficulty of final fabric basis weight measurement and control are: a long transportation lag through the heat set oven (transport lag can be one-half of the length of the product being run), a high moisture content in the fabric before the oven (typically thirty percent), width change in the fabric at the entrance end which affects weight per unit area, and fabric shrinkage while going through the heat set oven.

The method of this invention includes measuring the fabric entrance weight, fabric width, and fabric speed at the entrance side of the heat set oven before the overfeed means, measuring the fabric final basis weight and speed at the exit side of the heat set oven, comparing the final basis weight with a selected target basis weight and obtaining an error signal which is used to increase or decrease the magnitude of an initially estimated percent moisture signal in proportion to error signal, feeding the percent moisture signal together with known and measured parameters into a computer and solving the following equation for calculated final basis weight:

$$BW_c = (BW_1/1 + D_1) \cdot (W_1 W_s) \cdot (S_1/S_3) \cdot$$

where

BW_c is calculated final basis weight,
BW_1 is measured entrance basis weight,
S_1 is speed of fabric before overfeed means,
S_3 is speed of fabric after oven,
W_1 is width of fabric near BW_1 gauge,
W_s is standard width of fabric after oven, and
D_1 is estimated or computer percent moisture of fabric at entrance (expressed as a decimal),

comparing the calculated basis weight BW_c with the target basis weight and producing a difference calculated final basis weight error signal, and applying the difference calculated final basis weight error signal to increase or decrease the speed of the overfeed means in proportion to the error signal.

The method of this invention thus provides the following important features:

1. Feedforward control with closed loop feedback as to the controlled variable. The measurement of entrance basis weight is before the point of control actuation, but the actuator (overfeed means) speed feeds back into the system calculation to give feedback on what was done;
2. Indirect readout of percent moisture which is applied to the system computation of calculated final

basis weight and which may be presented on a motor operated potentiometer dial or other display means;

3. Calculation of a predicted final fabric basis weight which is compared with a target basis weight to produce an error signal for varying the speed of fabric overfeed means in order to regulate fabric shrinkage and thus to regulate final fabric basis weight; and
4. A further closed loop feedback, supplying the actual exit basis weight as measured by the exit basis weight gauge, as a check on the calculated final basis weight. The measured final basis weight is also compared with the target basis weight, and any error is used to adjust the estimated moisture entry in the computer, so that an overfeed control action may be made which will ultimately conform the actual exit basis weight to the target basis weight.

Importantly, this control method gives closed loop feedforward control from the first fabric basis weight gauge so that control actions can be done each scan without waiting for the transportation through the oven. An assumption made here is that the unknown variable affecting final basis weight is predominantly moisture in the fabric at the entrance basis weight gauge and that the feedback from an auto controller responsive to the difference between a measured final basis weight and a target basis weight can be used to fine tune the control system of this invention to the proper value so the initial calculations are true. If this is true, changing fabric weights can be easily done by the operator simply changing a target setting to the new weight. If the moisture pickup is the same as the old fabric, he will be on target; if not, the exit basis weight gauge will have to adjust the moisture motor operated potentiometer to make the "calibration" correct. If the moisture pickup changes significantly from fabric to fabric and is not predictable, then the moisture can be measured. However, moisture measurement is a difficult and costly measurement which should be avoided where possible.

The apparatus of the invention includes appropriate gauges of known type for measuring the fabric entrance basis weight, entrance speed, entrance width, exit speed and fabric exit basis weight, a variable speed drive for the fabric overfeed means, a speed motor operated potentiometer for generating an overfeed speed control signal and having means for initially manually setting the overfeed speed, a speed auto control of known type for producing an on-time control signal for adjusting the speed motor operated potentiometer in direction and in proportion to a calculated final basis weight error signal, means for averaging the measured final basis weight across the width of the fabric and comparing the average final basis weight with a target basis weight to produce a measured basis weight error signal, a percent moisture auto control responsive to the measured basis weight error signal to produce an on-time control signal which is proportional to the measured basis weight error signal, a percent moisture motor operated potentiometer for generating a percent moisture signal in response to the on-time control signal from the percent moisture auto control and which includes means for initially manually setting an estimated percent moisture signal, a computer for calculating a predicted final basis weight according to the aforesaid calculated basis weight equation, using measured entry basis weight, entry width, entry speed, final speed, and calculated percent moisture as variable inputs, and having means for setting in a standard fabric exit width, a profile averaging computer for averaging the calculated final basis weight across the width of the fabric and for comparing the calculated final basis weight with the target basis weight and generating a calculated basis weight error signal which is applied to the speed auto control to control the speed motor operated potentiometer. The entrance and exit basis weight gauges are preferably across-fabric scanning gauges. The auto control for the speed motor operated potentiometer is preferably enabled each scan of the entrance basis weight gauge and the auto control for the percent moisture potentiometer is enabled after sufficient time has elapsed to allow for the lag time between the moment when the overfeed means is adjusted and the moment when material at the overfeed means at moment of adjustment reaches the exit basis weight gauge. The latter enabling control can be in response to a selected number of scans or number of feet of process material passing the final basis weight gauge.

The term basis weight as used herein is in accordance with the common usage of the term in the textile industry and is the weight per unit area of textile fabric including any moisture present in the fabric.

With the foregoing objects and features in view and such other objects and features which may become apparent as the specification proceeds, the invention will be understood from the following description taken in conjunction with the accompanying drawings, wherein like character or reference designate like parts and wherein:

FIG. **1** is a diagram schematically illustrating a preferred embodiment of the present invention, in combination with a textile fabric heat setting facility.

FIG. **2** is a block diagram of the measuring, computer, and control circuits employed in the system of FIG. **1.**

With reference now to the drawings and specifically to FIG. **1,** the invention is diagrammatically illustrated in combination with typical apparatus for heat setting fabrics which contain synthetic resin fibers, as for example double knit polyester fabrics. The typical heat setting apparatus includes a material supply **11,** a series of guide rollers **12,** a driven overfeed roller **13,** a tenter frame **14,** a heat set oven **15,** and fabric wind up means **16.** The material supply illustrated in FIG. **1** is a tub in which a batch of fabric **10** is folded with the trailing end **10'** of the fabric draped over the edge of the tub so that it may be sewn onto the lead edge of another batch of fabric in another tub by a sewing machine (not shown) typically provided at the site. The fabric **10** supplied in the tubs **11** is usually wet having been taken from a liquid bath in which the fabric was treated for cleaning, sizing, or for other purposes and may typically contain in the order of thirty percent moisture. The different tubs of fabric are previously sorted so that the basis weight of each batch of fabric connected together at the entry end of the heat setting machine does not vary extremely from a selected basis weight. Normally the wind up reel **16** will receive the content of a number of batches of fabric supplied at the input end. Since it is desired that the basis weight of the material on the windup reel be substantially uniform, the need for sorting the batches of fabric at the entry end according to weight arises in order that the heat setting apparatus

will not require extreme adjustment with each different batch of fabric. Fabric from the tub **10** is fed over a series of guide rollers **12** at the entry end of the heat set apparatus by a driven overfeed roller **13** and is laid onto a tenter frame **14** which carries the fabric through the heat set oven **15** at a somewhat slower speed S_2 than the speed S_1 of the overfeed roller **13.** The tenter frame **14** may be selected from various tenter frames which are well known in the art. A typical tenter frame will include a pair of laterally spaced endless belts, or chains **14'** (only one shown) carrying pins **17** for gripping opposite edges of the fabric. The belts **14'** extend through the oven **15** and are supported at opposite ends of their loops by pairs of sprockets **18** and **19** (only one sprocket of each pair is shown). Provision is made for adjusting the lateral spacing between the belts **14'** in order to stretch and hold the fabric web to a desired and uniform width at the exit end of the heat set oven **15.** In the present invention the tenter frame is adjusted for fabric of a desired width to be delivered to any given wind up roll and will normally not be readjusted while fabric is being applied to any one wind up roll. In order to accommodate and control longitudinal shrinkage within the heat set oven **15** the fabric web **10** is overfed onto the tenter frame by an overfeed roller **13,** the speed of which is controlled in accordance with the present invention. A rotary brush **19** at the entry end of the tenter **14** forces the lateral edges of the fabric web **10** onto the tenter pins **17** so that the fabric is wrinkled, or waved, as indicated at **20** between pins as a result of excess fabric. The amount of overfeed is regulated in accordance with the present invention to control the amount of longitudinal shrinkage in order to obtain a uniform basis weight of the fabric at the exit end of the heat set oven. The heat set oven **15** provides a controlled high temperature environment for heat setting and drying the fabric **10** so that the fabric leaving the oven is assumed to have approximately zero percent moisture and the required heat set characteristics. The heat set process effects the elastic memory of knit polyester fibers or other synthetic resinous fibers in a manner well known in the art. The length of the oven **15** which is necessary to provide the proper heat set characteristics and drying of the fabric **10** is normally long so that there is a long time delay before measurements made at the exit end of the oven, and used to adjust the overfeed roller speed, will be reflected in the measurements at the exit end of the oven.

It is emphasized that this invention is adaptable for use with the heat set equipment to be found in various textile plants which may vary in one or more particulars from plant to plant, the typical heat set apparatus shown in FIG. **1** being given by way of example only. While a batch type supply is illustrated it is to be understood that a continuous web supply from a previous fabric fabricating, or other process, step may be provided.

The monitoring equipment of the invention includes an entry basis weight gauge **21** for measuring the basis weight, BW_1, of the fabric being fed from the supply tub **11,** an entry width gauge **22** for measuring the edge to edge width W_1, an entry speed gauge **23** for measuring the speed S_1 of the fabric being fed by the overfeed roller **13,** an exit speed gauge **24** for measuring the speed S_3 of the fabric at the exit end of the heat set oven, and an exit basis weight gauge **25** for measuring the basis weight, BW_2, of the fabric at the exit end of the heat set oven. The basis weight gauges **21** and **25** are preferably a cross-sheet scanning beta ray gauge of well known construction. They contain well-known internal circuitry (not shown) to render the output signal thereof proportional to the weight or mass per unit area of the travelling web which includes the weight of the moisture and the fabric fiber. Other gauges can be used to generate signals indicative of the weight per unit area.

The width gauge **22** may be any one of several well known width gauges for producing an electrical signal proportional to the width of the web **10.** One such gauge includes a pair of edge sensors (not shown), such as photoelectric cells, mounted on a double threaded lead screw for detecting the opposite edges of the fabric. A servo system is provided for rotating the lead screw to keep the photoelectric cells in position for developing a web edge position signal and a slave potentiometer is driven with the lead screw to give an indication of the distance between the two opposite edge detectors. One such gauge is illustrated in FIG. **1** of U.S. Pat. No. 3,341,888, W. A. Bridge et al., Sept. 19, 1967.

The speed gauges **23** and **24** are preferably tachometers of the well known voltage generating type which are operatively connected to selected guide rollers **12** and are driven by the fabric moving thereover. The speed gauges **23** and **24** produce an output voltage which is proportional to the fabric speed at the points of measurement.

The signals BW_1, W_1, W_1, S_2 and BW_2 are fed as input signals into a computer **26** which solves for an estimated or calculated final weight at the exit end of the heat set oven according to the equation:

$$BW_c = [BW_1/(1 + D_1)] \cdot (W_1/W_s) \cdot (S_1/S_3)$$

where

BW_c = Calculated final fabric weight
BW_1 = Basis Weight of fabric at entry end
W_1 = Width of fabric at entry end
W_s = Selected Standard width at exit end
S_1 = Speed of fabric as fed by overfeed roller
S_3 = Speed of fabric at exit end of heat set oven
D_1 = Calculated percent moisture in fabric at entry end

The standard width W_s is the width of the fabric at the exit end of the heat set oven as it comes off the tenter frame **14** and is therefore normally constant once the tenter frame has been adjusted for the desired final width of the fabric. W_s is manually set into the computer by a potentiometer adjustment. The percent moisture input D_1 is derived from a motor operated potentiometer **27.** Initially D_1 is an estimated value of the percent moisture in the fabric at the supply end of the heat set apparatus, but after the heat set apparatus begins operating, D_1 becomes a calculated value obtained by taking the difference between a target basis weight BW_t and the measured exit basis weight BW_2. The difference between BW_2 and BW_t is assumed to result from an error in the estimated or calculated value of D_1 and therefore the speed of the overfeed roller S_1 is adjusted to bring BW_2 closer to BW_t.

It is to be understood that the amount of longitudinal shrinkage of fabric **10** may be decreased from a predetermined maximum at some high rate of overfeed by the overfeed roller **13,** by decreasing the speed of the

overfeed roller so that less excess fabric **10** is accumulated between the pins **17** on the tenter frame at the lower speeds. Since the fabric tends to become heavier as the fabric shrinks longitudinally, the basis weight BW_2 at the exit end increases with increased fabric shrinkage and decreases as the shrinkage becomes less. Thus the exit basis weight BW_2 may be increased or decreased by increasing or decreasing the speed S_1 of the overfeed roller **13** within limits. The only value in the equation given above for calculated final fabric basis weight which is not either measured or known is the percent moisture D_1. Therefore when the measured exit basis weight BW_2 differs from the target basis weight BW_t, it is assumed that the percent moisture input D_1 is in error; that is, D_1 does not correspond with the actual percent moisture in the fabric on the supply side. The difference between the measured exit basis weight BW_2 and the target basis weight BW_t is obtained from a profile averaging computer **28** of a type known in the art. The profile averaging computer (PAC) **28** obtains a running or current average value $\overline{BW_2}$ of the exit basis weight BW_2 of the fabric web **10** along the width thereof. Instantaneous values of BW_2 are fed into the PAC **28** from the scanning exit basis weight gauge **25,** the integral of this parameter with respect to time is calculated and the integral is divided by the elapsed time to obtain the desired running average $\overline{BW_2}$. One profile averaging computer suitable for use with the invention is illustrated and described in U.S. Pat. No. 3,566,092, granted to Michael P. Grant and Henry T. Jaggers, on Feb. 23, 1971, assigned to the same assignee as the present invention. A comparing circuit (not shown) is provided in the PAC **28** for obtaining a signal which is equal to the difference between the average exit basis weight $\overline{BW_2}$ and the target basis weight BW_t. This difference signal $\overline{BW_2}-BW_t$ is fed into the auto control **29** which is a reset type controller of known type, incorporating means proportioning each corrective adjustment to the magnitude of the error signal and providing means for suspending control action after each adjustment until after a predetermined length as determined which will allow the material subject to the corrective action of this invention to reach the measuring gauge **25.**

One suitable auto control **29** of a reset proportional controller type is illustrated and described in conjunction with FIG. **2** of U.S. Pat. No. 2,895,888 granted to Donald E. Varner on July 21, 1959, assigned to the assignee of the present invention. The auto control **29** will provide either an increase or decrease signal to a motor operated potentiometer **27** depending on whether the difference $\overline{BW_2}-BW_t$ is positive or negative. The auto control signal whether positive or negative will be on for a time proportional to the difference between $\overline{BW_2}$ and BW_t, and will be off for a time approximately equal to the time T required for material to travel from the overfeed roller **13** to the exit basis weight gauge **25.** The off time can be determined by an automatically resetting odometer engaging the fabric **10** and providing a signal indicating the passage of a predetermined length of the traveling material, or the off time may be determined by an automatically resetting counter which counts the number of scans made by the scanning gauge **25** and provides a signal after a predetermined number of scans.

The motor operated potentiometer **27,** includes control means whereby it may be initially manually adjusted to provide an initial percent moisture D_1 output which is estimated by an operator. After the initial manual setting is made the auto control **29** takes over and adjusts the motor operated potentiometer automatically to produce a corrected percent moisture output signal. The percent moisture output signal D_1 is fed to the calculated final basis weight computer **26** which solves the previously given equation for calculated basis weight BW_c.

The output signal BW_c from the computer **26** is fed to a profile averaging computer (PAC) **30** which is similar to the profile averaging computer **28.** The PAC **30** obtains a running or current average value $\overline{BW_c}$ of the calculated basis weight across the width of the fabric **10** for each scan of the entry basis weight gauge **21.** The average calculated final basis weight $\overline{BW_c}$ is compared with the target basis weight BW_t which is manually set into the PAC **30** by making a potentiometer adjustment. A comparing circuit (not shown) is provided in the PAC **30** which produces an output signal which is equal to the difference between the calculated average final basis weight $\overline{BW_c}$ and the target basis weight BW_t. This difference signal $\overline{BW_c}-BW_t$ is fed into an auto control **31** similar to the auto control **29** which proportions a corrective adjustment to the magnitude of the error signal and suspends control action after each adjustment for a predetermined time. The auto control **31** is enabled each scan of the entry basis weight gauge **21** and produces either an increase or decrease signal output to a motor operated potentiometer **32** depending on whether the difference $\overline{BW_c}-BW_t$ is positive or negative. The auto control signal, whether positive or negative, will be on for a portion of the time between each successive scan of the entry basis weight gauge **21** which is proportional to the difference between $\overline{BW_c}$ and BW_t.

The motor operated potentiometer **32** is like the M.O.P. **27** and includes means for manually making an initial potentiometer setting for establishing a predetermined initial speed of the overfeed roller **13.** Its output is applied to a variable speed drive **33** which varies the speed of the overfeed roller **13** in accordance with the error signal from the auto control **31** once the system has become operative.

FIG. **2** illustrates the components of the monitoring and control system of this invention separated from the components of a typical fabric heat set apparatus and shows the components of the calculated final basis weight computer shown within the block **26** indicated by dash lines. The computer **26** includes an adder circuit **40** which adds one plus the percent moisture signal D_1 derived from the M.O.P. **27,** a divider circuit **34,** which divides BW_1 by $1 + D_1$, a second divider circuit **38** which divides the measured width signal W_1 by a standard width signal W_s obtained from a manually set standard width potentiometer **39,** a multiplier circuit **35** which multiplies $BW_1/1 + D_1$ by W_1/W_s, a second multiplier circuit **36** which multiplies $(BW_1/1 + D_1)\cdot(W_1/W_s)$ by the speed signal S_1 derived from the supply feed tachometer **23,** and a third divider circuit **37** which divides $(BW_1/1 + D_1)\cdot(W_1/W_s)\cdot S_1$ by the speed signal S_3 taken from the exit speed tachometer **24.** The adder, divider and multiplier circuits within the calculated final weight computer **26** are selected from well known circuits for performing the indicated function, therefore further description thereof is deemed unnecessary.

While no attempt has been made to illustrate the visual signal displays provided in the apparatus of this invention, it will be understood that means for visually displaying and/or recording the various measured parameters, targets, constants, and calculated values may be provided as desired. The profile averaging computers **28,** and **30** used with this invention each have a strip chart recorder provided with an indicator pen and pointer mechanism which register the average exit basis weight $\overline{BW_2}$ and the average calculated basis weight $\overline{BW_c}$ respectively. The profile averaging computer recorders also include a target indicator assembly comprising a target pointer which may be positioned relative to a scale by means of a mechanically coupled target setting knob. The target adjustment is used by the operator to set a desired target basis weight BW_t. Whenever the indicating pointer is not in alignment with the target pointer an error signal is transmitted to the auto control associated with the respective profile averaging computers **28** and **30.** Means preferably will be provided in the profile averaging computers for selecting various scales and edge of scale settings in a known manner for use with the strip chart recorder. One strip chart recorder of the type discussed herein is illustrated and described in U.S. Pat. No. 2,895,888 previously referred to.

The motor operated potentiometer **27** and **32** each have an indicator scale and pointer (not shown) associated therewith for indicating the potentiometer setting, whether manually set by a control knob, or automatically set by the motor operatively connected to the potentiometer arm. The M.O.P. **27** is calibrated in units of percent moisture, and the M.O.P. **32** is calibrated in units of speed. An operator by observing the M.O.P. **27** is thereby able to observe the calculated value of percent moisture being fed to the computer **26.**

While analogue measurements have been described, it will be understood that digital measurements, computations and display by means well known in the art may be substituted within the spirit and scope of this invention. Further, conversions from analogue to digital, and from digital to analogue can be made as desired in order to facilitate optimum efficiency and economy compatible with the standards required for the invention.

While in the foregoing there has been described and shown a preferred embodiment of the invention, various modifications and equivalents may be resorted to within the spirit and scope of the invention as claimed.

What is claimed is:

1. A method of improving the uniformity of the basis weight of a travelling web of textile fabric at the exit side of fabric heat setting apparatus which includes a source of wet fabric supply, means for heat setting the fabric, tentering means for obtaining a uniform standard width of the fabric at the exit side of said heat setting means and for regulating the longitudinal shrinkage of the fabric by said heat setting means, overfeed means for moving said fabric web from the source of supply onto said tentering means, means for winding up said fabric web after it has passed through said heat setting means and means, for varying the speed of said overfeed means, comprising the steps of generating a signal BW_1 indicative of the measured basis weight of the fabric on the entry side of said heat setting means, generating a signal W_1 indicative of the measured width of the fabric on the entry side of said heat setting means, generating a signal S_i indicative of the measured speed of the web on the supply side of said tentering means, generating a signal S_3 indicative of the measured speed of the web on the exit side of said heat setting means, generating a signal BW_2 indicative of the measured basis weight of said fabric on the exit side of said heat setting means, generating a signal BW_t indicative of a predetermined target basis weight for the web on the exit side of the heat setting means, comparing the signal BW_2 with the signal BW_t and producing an error signal BW_2–BW_t which corresponds with the deviation of the signal BW_2 from BW_t, initially setting a signal D_1 indicative of an estimated percent moisture content of the web on the entry side of the heat setting means, and thereafter automatically increasing the signal D_1 to indicate an increased percentage moisture when BW_2 is greater than the BW_t and decreasing the signal D_1 to indicate a decreased percentage moisture when BW_2 is less than BW_t in proportion to the magnitude of deviation of BW_2 from BW_t, generating a signal BW_c indicative of a calculated exit basis weight according to the formula:

$$BW_c = [BW_1/(1 + D_1)] \cdot (W_1/W_s) \cdot (S_1/S_3)$$

wherein BW_c, BW_1, W_1, S_1, S_3 and D_1 respectively represent previous indicated signals and W_s represents a preset signal indicative of a selected standard width for said fabric at the exit side of the heat setting means, comparing the signal BW_c with the signal BW_t and generating an error signal BW_c–BW_t which corresponds with the deviation of BW_c from BW_t and increasing the speed of the overfeed means when the signal BW_c is less than the signal BW_t and decreasing the speed of the overfeed means when the signal BW_c is greater than the signal BW_t.

2. A system for improving the uniformity of the basis weight of a travelling web of knit fabric on the exit side of fabric heat setting apparatus which apparatus includes a web fabric supply source, means for heat setting the fabric, tentering means for obtaining a uniform standard width of the fabric at the exit side of said heat setting means and for regulating the longitudinal shrinkage of the fabric by said heat setting means, overfeed means for moving said fabric web from the source of supply onto said tentering means, means for winding up said fabric web after it has passed through said heat setting means, and variable speed drive means for said overfeed means, comprising means for generating a signal BW_1 indicative of the measured basis weight of the fabric on the entry side of said heat setting means, means for generating a signal W_1 indicative of the measured width of the fabric on the entry side of said heat setting means, means for generating a signal S_1 indicative of the measured speed of the web on the supply side of said tentering means, means for generating a signal S_3 indicative of the measured speed of the web on the exit side of said heat setting means, means for generating a signal BW_2 indicative of the measured basis weight of said fabric on the exit side of said heat setting means, means for generating a signal BW_t indicative of a predetermined target basis weight for the web on the exit side of the heat setting means, means for comparing the signal BW_2 with the signal BW_t and producing an error signal BW_2–BW_t which corresponds with the deviation of the signal BW_2 from BW_t, variable means for generating a signal D_1 representing percent mois-

ture content of the web on the entry side of the heat setting means including means for manually setting said moisture signal generating means to an initial signal magnitude means responsive to the error signal BW_c–BW_t for automatically increasing the signal D_1 to indicate an increased percent moisture when BW_2 is greater than the BW_t and for decreasing the signal D_1 to indicate a decreased percentage moisture when BW_2 is less than BW_t in proportion to the magnitude of deviation of BW_2 from BW_t, computer means for generating a signal BW_c indicative of a calculated exit basis weight according to the formula:

$$BW_c = [BW_1/(1 + D_1)] \cdot (W_1/W_s) \cdot (S_1/S_3)$$

wherein BW_c, BW_1, W_1, S_1, S_3 and D_1 respectively represent signals previously defined and W_s represents a preset signal indicative of a selected standard width for said fabric at the exit side of the heat setting means, means for comparing the signal BW_c with the signal BW_t and for generating an error signal BW_c–BW_t which corresponds with the deviation of BW_c from BW_t, means for generating a speed control signal which controls the speed of said variable speed drive including means for manually setting an initial speed control signal, auto control means for varying the speed control signal generating means to increase the speed of said variable speed drive means when the signal BW_c is less than the signal BW_t and for varying the speed control signal generating means to decrease the speed of said variable speed drive means when the signal BW_c is greater than the signal BW_t in proportion to the magnitude of the deviation of BW_c from BW_t .

3. The system set forth in claim **2** wherein the means for generating the signals BW_1 and BW_2 are cross web scanning basis weight gauges and the signals BW_1 and BW_2 are instantaneous signals corresponding with the positions of the gauges with respect to the web.

4. The system set forth in claim **3** wherein said basis weight gauges are beta ray gauges.

5. The system set forth in claim **3** wherein said means for comparing the signal BW_2 with the signal BW_t is a profile averaging computer which produces an average value of BW_2 over a predetermined time period and includes a comparing circuit by which the average value of signal BW_2 is compared with the signal BW_t, and wherein said means for comparing BW_c with BW_t is likewise a profile averaging computer which produces an average value of BW_c over a predetermined time period and includes a comparing circuit by which the average value of signal BW_c is compared with the signal BW_t.

6. The system set forth in claim **5** wherein said means for generating said moisture signal D_1 and speed control signal generating means are motor operated potentiometers.

7. A machine for heat setting a travelling web of textile fabric, said machine including means providing a heated environment through which the textile web travels for heat setting the fabric, said heat setting means having an entry side and an exit side, tentering means extending through said heat setting means for carrying the web through said heat setting means, obtaining a uniform standard fabric width at the exit side of the heat setting means, and for regulating longitudinal shrinkage of the fabric, overfeed means on the entry side of said heat setting means for moving the fabric web from a source of supply onto the tentering means at a speed greater than the speed of said tentering means, means for winding the fabric web after it has passed through said heat setting means, means for varying the speed of said overfeed means, a system for controlling the final basis weight of said textile web comprising means providing a target signal indicative of a desired final basis weight on the exit side of said heat setting means, means providing a feedback signal indicative of the actual final basis weight, means comparing said desired final basis weight target signal with said feedback signal to provide a first error signal representing any difference between said signals, means providing a signal representing the percent moisture in the fabric on the entry side of said heat setting means, means responsive to said first error signal for automatically varying said percent moisture signal in proportion to the magnitude of said first error signal, means providing a predicted final basis weight signal derived from the basis weight of the fabric coming from supply, the speed of said fabric coming from supply, the width of the fabric coming from supply, the speed of the fabric on the exit side of the heat setting means, the standard exit width of said fabric, and said percent moisture signal, means for comparing said predicted basis weight signal with said target signal to provide a second error signal representing any difference between said predicted and target signals, and means responsive to said second error signal to provide a control signal to vary the speed of said overfeed speed varying means in order to control the amount of fabric overfeed onto said tentering means and thus to control the amount of fabric shrinkage which effects the final basis weight of the fabric.

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