Feb. 23, 1971 M. A. KEYES IV, ETAL 3,564,724

MOISTURE CONTROL SYSTEM WITH CURL COMPENSATION

Filed Dec. 18, 1968 2 Sheets-Sheet 1

FIG. 1

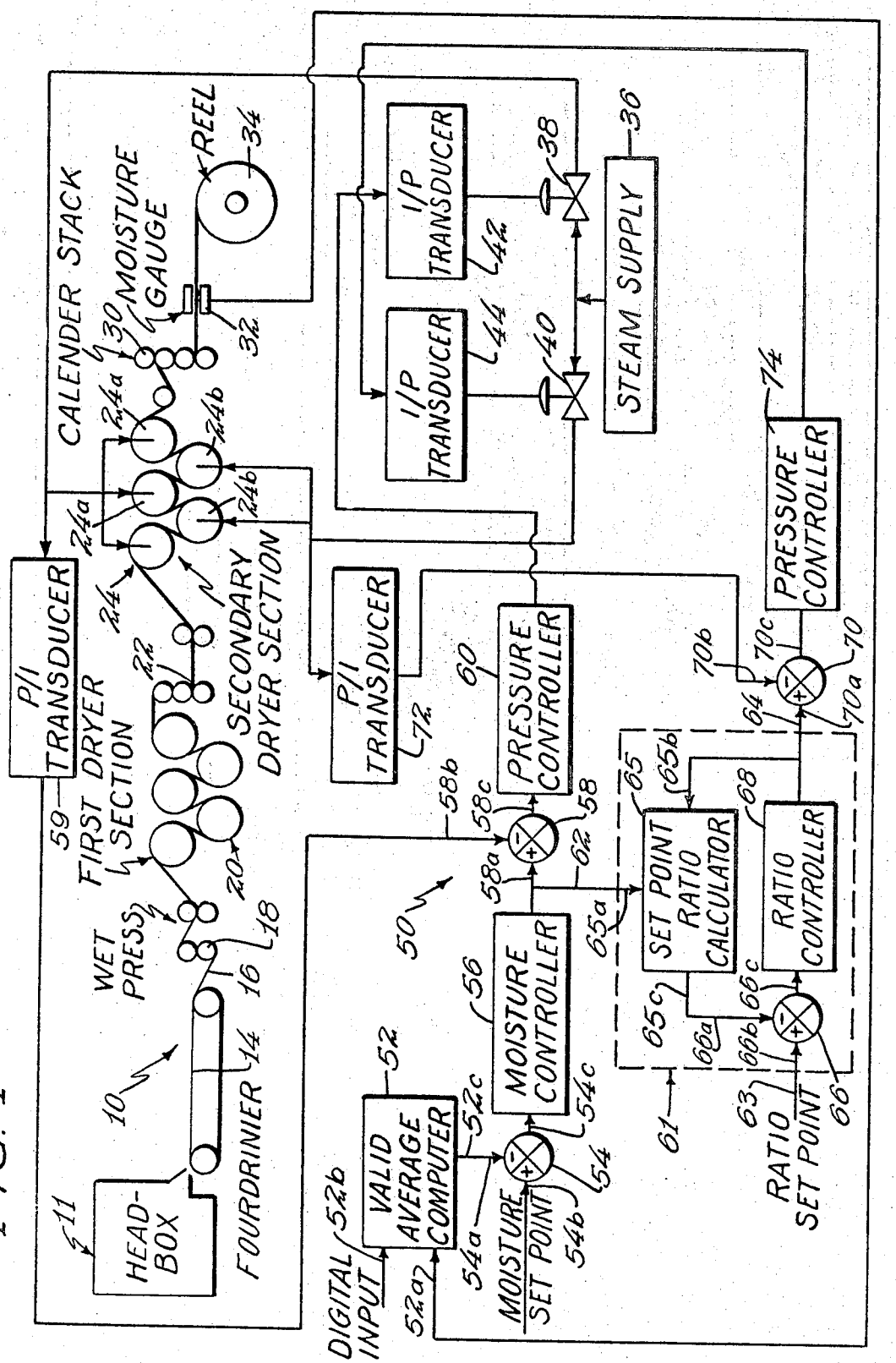


FIG. 2

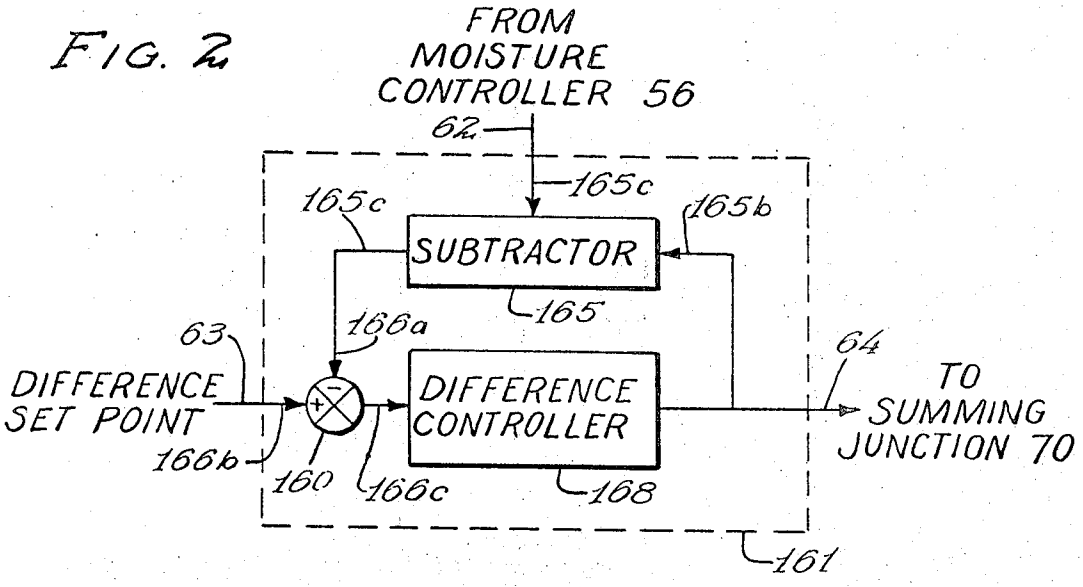


FIG. 3

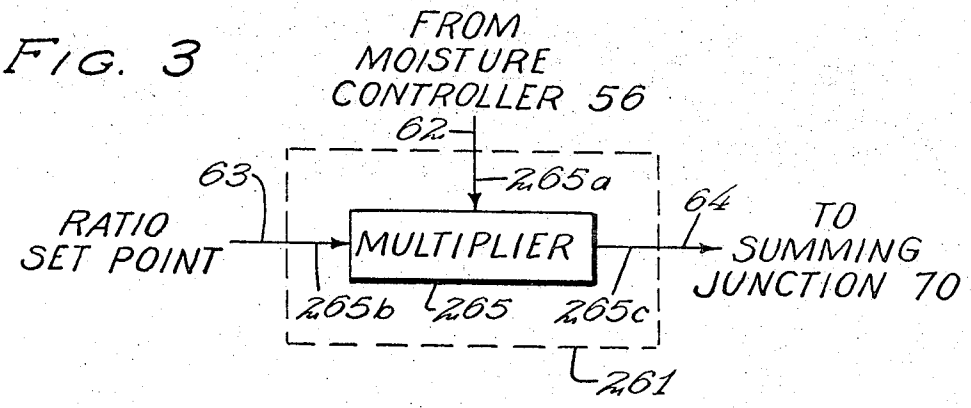
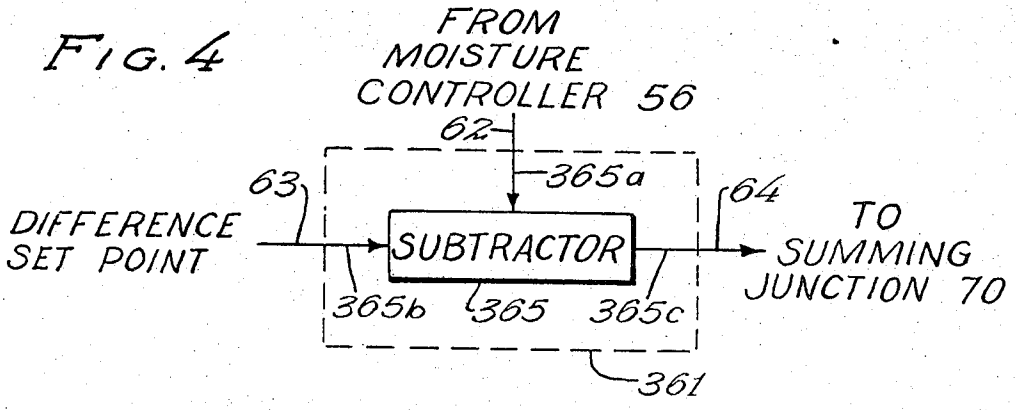


FIG. 4



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3,564,724

MOISTURE CONTROL SYSTEM WITH CURL COMPENSATION

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U.S. Cl. 34—48 13 Claims

ABSTRACT OF THE DISCLOSURE

Upper and lower drying sections, each comprising a plurality of steam-heated drying rolls, are employed in the drying of the paper web as it passes therebetween. A first control loop is associated with the upper section and a second control loop is associated with the lower section. These dryer loops determine the respective amounts of steam delivered to the two sections. A moisture control loop outputs a set point to the first dryer loop and a second set point is provided for the second dryer loop, the second set point being modified so that the rate of steam flow to the second dryer section is maintained in a preferred relationship to the rate supplied by the first dryer section so that the curl of the web is minimized.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates generally to paper making, and pertains more particularly to a control system for minimizing the amount of curl in the sheet by adjustment at a location just ahead of the reel on which the web is being wound.

(2) Description of the prior art

It is generally known that curl or web curvature is caused by several factors. Orientation of the fibers throughout the web and internal stresses within the web are two factors. An important third factor, however, is the unequal distribution of moisture within the web itself. For example, if the web is drier adjacent its top surface than its bottom surface, there is a shinkage at the top that causes the web to curl upwardly. Compensation for curling, whether up or down, is necessary on paper grades, such as tab card stock, and any other situation where uniform sheet characteristics are critical.

In some prior art instances, the curl has been ignored and the paper has been of inferior quality. However, where the use of the paper demands that curl be corrected for, it has proved exceedingly difficult to introduce a compensation that will assure uniformity in the final product. The manner of correction in the past has been largely left up to the judgment of the individual operator and his personal previous experience. In some instances, the operator has made a correction at one drying stage that proves excessive by the time the paper web reaches the reel end.

SUMMARY OF THE INVENTION

One object of the invention is to provide a system for accurate compensation of the amount of curl. In this regard, it is an aim of the invention to make the needed compensation in a systematic manner so that uniformity is assured. More specifically, the present invention envisages the supplying of steam to upper and lower dryer sections at different flow rates so that one section contributes more heat than the other when the tendency to curl requires differing drying rates. In two embodiments, a ratio of the pressures that determine the drying rates is

utilized and in two additional embodiments, the difference between the pressures is resorted to. The set points representing the ratios of pressures and the difference pressures, respectively, is obtained by initially observing the data and selecting the set points so that optimum results will occur. When the necessary amount of correction has been realized, it is then known that the correct ratio or correct difference as far as set points are concerned have been entered by the operator and from that time on the ratio or difference will be automatically maintained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a typical paper making machine with the curl compensation obtained by means of a ratio loop in association with other control loops;

FIG. 2 depicts a modification of the invention, a difference control loop being substituted for the ratio control loop of FIG. 1;

FIG. 3 is another modification of the invention in which a multiplier circuit is substituted for the ratio control loop of FIG. 1, and

FIG. 4 is a fragmentary view illustrating still another modification that the invention may assume, the instant embodiment making use of subtraction rather than a ratio.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A conventional paper making machine has been indicated generally by the reference numeral **10**. The machine **10** comprises the usual headbox **11** which distributes the pulp stock onto a Fourdrinier wire **14**. The web **16** thus formed is directed through a wet press section **18** into a first dryer section **20**. From the first dryer section **20** the web **16** proceeds to a size press **22** where an appropriate sizing additive is applied when such an agent is required. From the size press **22** the web **16** continues to a secondary dryer section **24** which includes what are sometimes referred to as upper and lower tiers but which will herein be referred to as upper and lower dryer sections, these actually being subsections of the dryer section **24**. The upper section has been labeled **24***a* and is composed of any preferred number of steam-heated drying rolls, whereas the lower section has been designated by the numeral **24***b*. These tiers or sections **24***a* and **24***b* are important to a practicing of the present invention as will soon become clear.

When calendering is desired, a calender stack **30** is employed. Thereafter, a moisture gauge **32** senses the amount of moisture contained in the web **16** as the web is wound onto a take-up reel **34**. The moisture gauge **32** may be of the scanning variety. Actually, the particular type of gauge is unimportant to an understanding of the invention.

A source or supply of steam for the various drying sections has been indicated by the reference numeral **36**. A valve **38** is connected to the source of supply **36** and varies the amount or rate of flow of steam passing to the upper section **24***a*. A valve **40** supplies steam to the lower section **24***b*. A current-to-pressure transducer **42** positions the valve **38** as a means to regulate the amount of steam delivered to the upper section **24***a*, whereas a similar transducer **44** positions the valve **40** as a means to regulate the amount of steam fed to the lower drying section **24***b*.

The system for controlling the transducers **42** and **44** has been generally designated by the reference numeral **50**. As explained above, the moisture gauge **32** may be of the scanning type. Thus, the gauge **32** may be considered as traversing the web **16** and in this way obviates the probability of a control predicated on a very atypical point of the web **16**. However, the system will operate on

a single point as long as the single point is representative of the average moisture. However, assuming that a representative single point cannot be reliably obtained, a valid average computer **52** has been depicted having a first input line **52***a* connected to the moisture gauge **32** and a second input line **52***b* which receives a digital control signal only when the gauge **32** has completed a scan from front to back or vice versa.

The output line leading from the valid average computer has been labeled **52***c* and is connected to an input terminal **54***a* of a summing junction or comparator **54**. Hence, the terminal **54***a* introduces one input, this being the computed valid average moisture signal, into the summing junction **54**. Of course, if a good moisture profile exists, the valid average need not be calculated and a single point would be sufficiently representative of the moisture content of the web **16** so as to serve as the input to the summing junction **54**.

The summing junction **54** has another input terminal **54***b* which carries the moisture set point which is representative of a desired moisture level that should exist in the web **16** just prior to the winding of the web onto the reel **34**. The summing junction **54** has an output terminal **54***c* and any difference between the signal applied via the input terminal **54***a* and the moisture set point applied via the terminal **54***b* will appear as an error signal at the output terminal **54***c*.

The output signal from the terminal **54***c* is fed to a moisture controller **56**. The moisture controller then outputs a set point or a signal which functions as one of the inputs to a summing junction or comparator **58**, being impressed upon one input terminal **58***a* belonging to this particular summing junction. Actually, it is the signal from the moisture controller **56** that constitutes a set point for a control loop for the upper drying section **24***a*. The set point derived from the moisture controller **56** is compared with a measured pressure signal coming from a pressure-to-current transducer labeled **59** which receives a pressure signal indicative of the actual steam pressure existing at the upper dryer section **24***a*.

Any difference between the incoming signals applied to the terminals **58***a*, **58***b* is outputed as an error signal on the terminal **58***c* which is connected directly to a pressure controller **60**. Thus, the pressure controller **60** operates on the error transmitted from the summing junction **58** and this error, which is a time function, determines to what extent the valve **38** should be repositioned, doing so through the current-to-pressure transducer **42**. In other words, the valve **38** is adjusted so as to vary the rate of steam flow to the upper dryer section **24***a* in accordance with the value of the error signal that is delivered to the pressure controller **60**.

Mainly to enable a ready comparison of FIG. 1 with FIGS. 2–4 the moisture controller **56**, which outputs a signal used in the control of the upper dryer loop just described, is connected to circuitry generally denoted by the reference numeral **61** by a line **62** that extends thereto from the moisture controller **56**. In the specific situation being described, the circuitry **61** constitutes a calculation ratio loop. To further facilitate a comparison with FIGS. 2–4 it will be observed that a line **63** is utilized leading into the circuitry **61** and a line **64** extending therefrom. The above-mentioned line **62** leads to an input terminal **65***a* belonging to a set point ratio calculator **65**. It is the function of the set point ratio calculator **65** to produce a signal indicative of the ratio of two sets points, one set point being the set point provided by the moisture controller **56** and the other set point being the set point utilized in a control loop for the lower dryer section **24***b*. It is via an input terminal **65***b* leading into the set point ratio calculator **65** that enables a comparison to be made of this particular set point with the set point applied to terminal **65***a*. The calculator **65** has an output terminal **65***c*.

The division performed by the calculator **65** results in the forwarding of a signal via the output terminal **65***c* which represents the ratio of the two set points applied to the input terminals **65***a* and **65***b*. The output terminal **65***c* is connected to an input terminal **66***a* belonging to a summing junction or comparator **66**, the summing junction **66** having a second input terminal **66***b* which is connected to the previously mentioned line **63**. In the present instance, it is the line **63** that carries a ratio set point which is a signal indicative of a desired ratio that should be maintained between the set points applied to the terminals **65***a* and **65***b*. Any difference between the signals impressed on the terminal **66***a* and **66***b* appears as an error signal on the output terminal **66***c*. In this way, a ratio controller **68** receives a signal that represents the difference between the inputs on the terminals **66***a* and **66***b*. The ratio controller **68** then provides a set point having a desired relationship with the set point derived from the moisture controller **56** which last-mentioned set point is utilized in a control loop for the lower dryer section **24***b*.

Included in the control loop for the lower dryer section **24***b* is a summing junction or comparator circuit **70** having a pair of input terminals **70***a*, **70***b* and an output terminal **70***c*. Whereas the input terminal **70***a* is connected to the ratio controller **68**, the input terminal **70***b* is connected to a pressure-to-current transducer **72** that forwards an electrical signal indicative of the actual steam pressure existing at the lower dryer section **24***b*. It is the difference between the inputs applied to the terminals **70***a* and **70***b* that is differenced at the summing junction **70** to produce an error signal at the output terminal **70***c* which is fed to a pressure controller **74**. Through the agency of the pressure controller **74** and the current-to-pressure transducer **44** the valve **40** is positioned to whatever extent is necessary to adjust the steam flow to the dryer section **24***b*.

Although the operation that occurs has been presented as the written description has progressed, nonetheless it will be of benefit, it is believed, to recapitulate briefly as to what transpires. Hence, a moisture control loop is provided by means of the moisture gauge **32**, the computer **52**, the summing junction **54** and the moisture controller **56**. Two pressure control loops are provided, as hereinbefore alluded to. The first one which controls the upper dryer section **24***a* includes the transducer **59**, the summing junction **58**, the pressure controller **60** and the transducer **42** for adjusting the valve **38**. The other pressure control loop includes the transducer **72**, the summing junction **70**, the pressure controller **74** and the transducer **44** for adjusting the valve **40**. Set points are provided for each of these pressure control loops. The set point for the upper loop is derived directly from the moisture controller **56**. On the other hand, the set point for the lower dryer section is dependent on the upper loop set point as influenced by the ratio set point that is determined by observing the resulting curl condition of the web **16** as it is wound onto the reel **34**. If the initial value of the ratio set point that is adopted proves inadequate, another value is chosen. Once the ratio set point is properly determined, though, then the system **50** continues to produce a paper web **16** having a minimum degree of curl. Thus, the valve **40** will control the rate of steam flow to the lower section **24***b* in a predetermined relationship with the rate of steam flow to the upper dryer section **24***a* as determined by the position of the valve **38**. In this way, one side of the web **16** can be dried at a different rate having preferred relationship with the other side, thereby producing a web having optimum curl characteristics imparted thereto.

Referring now to FIG. 2, it will be appreciated that the block **161** replaces the block labeled **61** in FIG. 1. In this embodiment, a differencing of the set points for the two pressure control loops is obtained. Thus, instead of a ratio control loop as set forth in FIG. 1, FIG. 2 deals with a difference control loop. Hence, the previously mentioned line **62** leads to a first input terminal **165***a* belonging to a differencing means or subtractor **165** which

has a second input **165***b*. Thus, the subtractor **165** produces an output on the terminal **165***c* which represents the difference between the two dryer pressure set points.

Included in the block **161** is a summing junction or comparator **166** having a first input terminal **166***a* connected to the output terminal **165***c* and a second input terminal **166***b* connected to the line **63**. It is via the line **63** in the present instance that a difference set point is applied to the input terminal **166***b* and this is differenced with the actual difference signal arriving via the input terminal **166***a* to provide an error signal representative of any disparity. The error signal is fed from the terminal **166***c* to a difference controller **168**.

Hence, the set point provided by the difference controller **168** is fed back by means of the terminal **165***b* and is subtracted from the value of the set point impressed upon the input terminal **165***c* which set point is derived from the moisture controller **56**. Otherwise, the operation is the same as that provided by the system depicted in FIG. 1 labeled **50**, the circuitry shown in block **161** being substituted for the circuitry of block **61** in FIG. 1.

Turning now to a brief description of FIG. 3, it will be perceived that this figure embodies a simplification of FIG. 1 as far as block **61** is concerned To orient the reader, a block labeled **261** is presented. However, the block **261** contains only a multiplier **265** having an input terminal **265***a* and an input terminal **265***b* plus an output terminal **265***c*. The same set point provided by the moisture controller **56** arrives via the line **62** and is inputed at the terminal **265***a*. The same ratio set point utilized in FIG. 1 is applied to the input terminal **265***a*. The two set points are multiplied together to provide the second pressure set point for the lower control loop which includes the dryer section **24***b*. The operation is otherwise the same as that of the system shown in its entirety in FIG. 1.

The remaining modification is presented in FIG. 4. This arrangement may be considered as a simplification of FIG. 2. In this instance the replacement for the block **61** of FIG. 1 has been labeled **361**. As with FIG. 2, the present modification operates on a difference between the set points rather than a ratio thereof. It will be discerned that the subtractor labeled **365** has an input terminal **365***a* and an input terminal **365***b*. It is the input terminal **365***a* that is connected to the line **62** which is in turn connected to the output sides of the moisture controller **56**. Hence, the same set point utilized in FIGS. 1–3 is employed in the present situation. The set point representative of a desired difference between set point values is the same as that utilized in FIG. 2, the set point being applied via the line **63** and thus introduced to the subtractor **365** through the agency of its second input terminal **365***b*. The difference between the two inputed set points appears as an output on the terminal **365***c* which serves as the set point for the control loop associated with the lower dryer section **24***b*. In this instance, not only is a subtraction operation being performed in contradistinction to the ratioing of two set points, but it is done without feedback as resorted to in FIG. 2. Otherwise, the functioning of the modification succinctly presented in FIG. 4 is the same as the other situations herein described.

What is claimed is:

1. In apparatus for making a continuous web of paper comprising a first dryer section for directing heat against one side of said web, a second dryer section for directing heat against the other side of said web, first means for controlling the heat supplied to said first dryer section in accordance with the moisture contained in said web after said web has passed between said dryer sections, and second means responsive to said first control means for controlling said second dryer section in a preferred relationship to said first dryer section to reduce the curl of said web, said first control means including a comparator for comparing a signal representative of the actual moisture content of said web after said web has passed between said dryer sections with a set point representative of a desired moisture content of said web to provide an error signal which is a measure of any difference therebetween, said first means controlling heat supplied to said first dryer section in accordance with the value of said error signal and said second means being responsive to said error signal for controlling said second dryer section as a function of the value of said error signal.

2. The apparatus of claim **1** in which said error signal provides a set point for said first dryer section and said second means provides a set point for said second dryer section, the relative values of said last-mentioned set points determining said preferred relationship.

3. The apparatus of claim **2** in which said second means includes a ratio control loop having said first dryer section set point as one input and a ratio set point as a second input, said ratio loop causing adjustment of the value of said set point for said second dryer section to control said second dryer section in said predetermined relationship to said first dryer section.

4. The apparatus of claim **2** in which said second means includes a difference control loop having said first dryer set point as one input and a difference set point as a second input, said difference loop causing adjustment of the value of said set point for said second dryer section to control said second dryer section in said predetermined relationship to said first dryer section.

5. The apparatus of claim **2** in which said second means includes a ratio calculator having said first dryer section set point as one input and a ratio set point as a second input, said ratio calculator causing adjustment of the value of said set point for said second dryer section to control said second dryer section in said predetermined relationship to said first dryer section.

6. The apparatus of claim **2** in which said second means includes a difference calculator having said first dryer set point as one input and a difference set point as a second input, said difference calculator causing adjustment for said second dryer section to control said second dryer section in said predetermined relationship to said first dryer section.

7. In apparatus for making a continuous web of paper comprising a first steam-heated dryer section for directing heat against one side of said web, a second steam-heated dryer section for directing heat against the other side of said web, a first dryer control loop for adjusting the rate of steam flow to said first dryer section, a second dryer control loop for adjusting the rate of steam flow to said second dryer section, said first loop including means for comparing a signal representative of the steam pressure existing at said first dryer section with a first set point representative of the amount of moisture change required in said web after passing between said dryer sections to provide a first error signal, a first valve for supplying steam to said first dryer section, means responsive to said first error signal for positioning said first valve to adjust the rate of steam flow to said first dryer section in accordance with the value of said first error signal, said second loop including means for comparing a signal representative of the steam pressure existing at said second dryer section with a second set point to provide a second error signal, a second valve for supplying steam to said second dryer section, means responsive to said second error signal for positioning said second valve to adjust the rate of steam flow to said second dryer section, and means responsive to said first set point for changing the value of said second set point in a desired relationship as influenced by the value of said first error signal.

8. The apparatus of claim **7** in which said last-mentioned means includes a set point ratio calculator for providing a ratio signal representative of the ratio of said first set point to said second set point and a comparator for com-

paring said ratio signal with a ratio set point representative of a desired ratio to provide a third error signal, said second set point being determined by the value of said third error signal.

9. The apparatus of claim 7 in which said last-mentioned means includes a set point difference calculator for providing a difference signal representative of the difference between said first and second set points and a comparator for comparing said difference signal with a set point representative of a desired difference between said first and second set points to provide a third error signal representative of any difference therebetween, said third error signal determining the value of said second set point.

10. The apparatus of claim 7 in which said last-mentioned means subtracts a third set point from said first set point, said third set point being representative of a desired difference between said first and second set points, the difference between said first and third set points determining the value of said second set point.

11. The apparatus of claim 7 in which said last-mentioned means multiplies said first set point by a third set point, said third set point being representative of a desired ratio between said first and second set points, to provide a product signal which product signal determines the value of said second set point.

12. In apparatus for making a continuous web of paper having first and second vertically arranged steam-heated dryer sections between which the web passes, a moisture control system for effecting curl compensation comprising a first dryer loop for controlling the flow of steam to said first section, a second dryer loop for controlling the flow of steam to said second section, a moisture loop for providing a first set point signal for controlling said first dryer loop in accordance with the difference between a signal representative of the actual moisture content of said web after passing between said rolls and a second set point signal representative of a desired moisture content of said web, and a ratio loop for dividing said first set point signal into a third set point signal for the second dryer loop and comparing the resulting signal with a fourth set point signal representative of the amount of needed curl compensation.

13. In apparatus for making a continuous web of paper having upper and lower dryer sections between which the web passes, a first valve for supplying steam to said upper section and a second valve for supplying steam to said lower section, a moisture control system for effecting curl compensation comprising means for providing a signal representative of the actual moisture content of said web after passing between said sections, first comparator means for comparing said actual moisture signal with a desired moisture signal to provide a first error signal, means for providing a signal representative of the steam pressure at said upper section, second comparator means for comparing said first error signal with said pressure signal to provide a second error signal, means responsive to said second error signal for adjusting the position of said first valve so as to reduce the value of said first and second error signals, means providing a ratio signal representative of the ratio between said first error signal and a desired curl signal to provide a third error signal, means for providing a signal representative of steam pressure at said lower section, third comparator means for comparing said third error signal with said last-mentioned pressure signal to provide a fourth error signal, and means responsive to said fourth error signal for adjusting the position of said second valve so as to reduce the value of said third and fourth error signals.

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