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 [21] Appl. No. **784,335**
 [22] Filed **Dec. 17, 1968**
 [45] Patented **Nov. 9, 1971**
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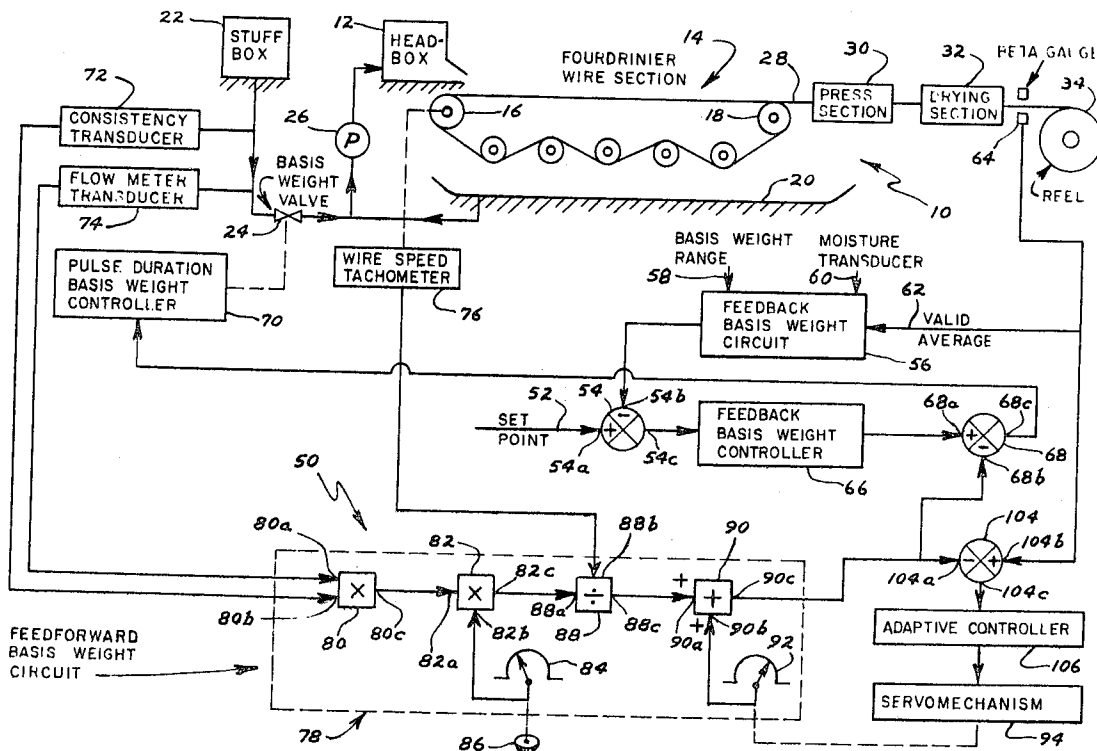
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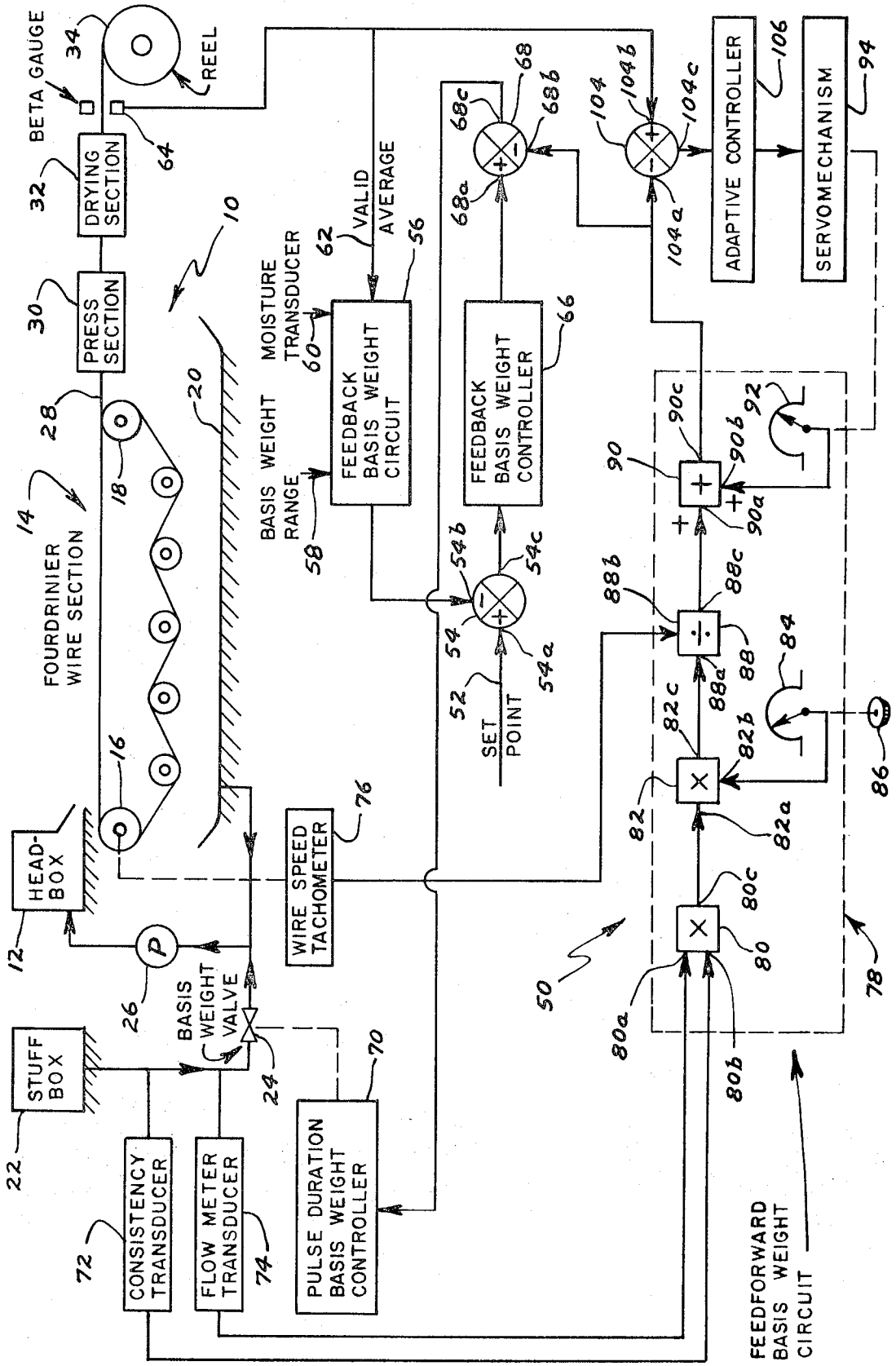
[54] **BASIS WEIGHT CONTROL SYSTEM FOR A PAPERMAKING MACHINE**
5 Claims, 1 Drawing Fig.

[52] U.S. Cl. **162/258,**
 162/198, 162/252, 162/263, 235/151.1
 [51] Int. Cl. **D21f 1/08**
 [50] Field of Search **162/252,**
 258, 259, 198, 336, 263; 235/151.12, 151.34, 151.1

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ABSTRACT: A system for controlling the final basis weight of a paper web by adjusting the amount of heavy fiber stock supplied to a Fourdrinier Machine headbox in response to an adjusted predicted basis weight signal. Such signal is based on comparisons between the actual basis weight of the paper web downstream of the drying section, a desired basis weight signal input, and a predicted basis weight signal derived from the consistency of heavy stock, its rate of flow, and the speed of the paper web forming section. Means are provided for comparing the actual basis weight signal with a desired basis weight signal input to provide a first error signal. A second error signal is generated by comparing the feedforward predicted basis weight with the actual basis weight signal. A new predicted basis weight signal is then produced by adjusting the predicted basis weight signal in response to the second error signal. The basis weight is then controlled by adjusting the heavy stock flow valve in response to a signal representing a comparison between the first error signal and the new predicted basis weight signal, which thus provides an adjusted predicted basis weight signal.





BASIS WEIGHT CONTROL SYSTEM FOR A PAPERMAKING MACHINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to paper making machines and pertains more particularly to an adaptive control system for producing a web of paper having a relatively uniform final basis weight.

2. Description of the Prior Art

Owing to the process delay in a paper making machine, when an incorrect final basis weight is sensed at the dry end of the machine it is too late to make a correction at the wet end of the machine. In other words, by the time that the wet end has been adjusted, there is a time lag occurring before such an adjustment reflects itself in the paper web at the dry end. The manufacture of paper is a complex process and a number of variables enter into any overall adjustment. Hence, where a human operator in the past has made one adjustment this has precipitated the need for another adjustment. However, human operators, even through highly skilled, cannot effect the optimum degree of balance that should be realized in order to produce a good grade of paper in an economical manner. Inasmuch as certain process variables encountered in the making of paper should be corrected for well before they begin to become troublesome, the need has heretofore existed for a control system that reacts quickly to changed conditions that would not normally be noticed by human operators or control systems previously available to the paper making industry.

SUMMARY OF THE INVENTION

The present invention provides a control system that compares the actual basis weight with the predicted basis weight and constantly adapts a parameter used in the computation of the predicted basis weight in accordance with the time integral of any error between the predicted basis weight and the actual basis weight. Stated somewhat differently, the present invention has for an aim the provision of an error signal between the predicted basis weight and the actual basis weight that performs a supervisory function that becomes increasingly more pronounced if the error or difference between the predicted basis weight and the actual basis weight persists for a relatively long period of time.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE exemplifying the invention is a combined block and schematic diagram showing salient sections of a conventional paper making machine with our adaptive control system superimposed thereon.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The paper making machine denoted generally by the reference numeral 10 is of conventional construction. However, it is necessary to present certain sections of such a machine in order to illustrate the different locations where operational data is sensed in the machine.

Therefore, the paper machine 10 includes a headbox 12 which spreads the mixed stock onto a Fourdrinier wire section 14, this being the web forming section of the machine, having a breast roll 16 and a drive roll 18. The whitewater is collected in a wire pit 20. A stuff box 22 contains the heavy fiber stock which is fed through a basis weight valve 24 and then combined with the whitewater from the pit 20. A fan pump 26 elevates the mixed stock into the headbox 12. The web of paper indicated by the reference numeral 28, while still wet, is directed from the web forming section 14 through a press section 30, a drying section 32 and in its dried state onto a reel 34.

Referring now to the system for controlling the basis weight at the reel 34, it will be observed from the drawing that the system has been denoted in its entirety by the reference nu-

meral 50. Depending upon the grade of paper and hence the particular basis weight that is desired at the reel 34 of the machine 10, an appropriate set point is provided at 52. When a different grade of paper is to be produced, a new set point will be used. The particular set point may be entered via the line 52 manually or the proper value taken from a magnetic disc, drum or core storage.

However, in the illustrated situation, the desired set point signal is delivered to a summing circuit or comparator 54 having a pair of input terminals 54a, 54b and an output terminal 54c. The input terminal 54a is connected to the set point line 52, whereas the input terminal 54b is connected to a computer that is identified in the drawing as a feedback basis weight circuit 56. The circuit 56 has a number of input lines. In this regard, one input line 58 feeds into the network forming the circuit 56 information relating to basis weight range, an input 60 introduces data relating to moisture that is obtained from an appropriate transducer (not shown), and a third input line 62 receives operational data sensed from a Beta gauge 64. For the sake of simplicity, it will be assumed that this gauge 64 is of the integrating type and that the signal arriving via the line 62 represents the valid average. Of course, it will be understood that the gauge 64 could forward instantaneous information and the valid average could be computed after a complete scan by the gauge 66 when of the nonintegrating type. All that need be provided is a signal that is delivered to the feedback circuit 56, which when processed along with the other input data, namely, the inputs entered on line 58 and 60, furnishes an appropriate feedback signal that is indicative of the actual basis weight of the web of paper 28 as it is wound on the reel 34 after the drying section 32 has reduced its moisture to only several percent.

The feedback signal provided by the circuit 56 is introduced into the comparator 54 via the input terminal 54b and is then compared with the signal representing the desired set point that is introduced via the input terminal 54a. It is the difference or error signal, when it exists, as determined by the comparator 54 that constitutes a modified or updated set point that is applied by way of the output terminal 54c to a feedback basis weight controller 66. The feedback controller 66 performs an integrating function, the integral signal at the output side thereof being applied to another comparator 68 by means of its first input terminal 68a. The comparator 68 has a second input terminal labeled 68b which will be referred to in more detail hereinafter and this comparator has an output terminal 68c which is connected in the exemplary situation to a pulse duration basis weight controller 70.

The controller 70 is utilized to adjust or position the basis weight valve 24 so as to vary the rate of heavy stock flow to the pump 26 and subsequently to the wire section 14 via the headbox 12. The controller 70 performs an actuating function, specifically, the proper positioning of the basis weight valve 24 so that the heavy stock flow is accurately determined as will be better understood from the ensuing portion of the description.

At this time, attention is called to the need for signals representative of certain operational data that is to be processed by the control system 50. In this regard, a consistency transducer 72 is located so as to measure the consistency of the heavy stock and provide a signal in accordance therewith. More specifically, the transducer 72 measures the consistency of the heavy stock as it is delivered from the stuff box 22. Also, a flowmeter transducer 74 provides a signal in accordance with the rate of flow of the heavy stock. Still further, a wire speed tachometer 76 is connected to the breast roll 16 of the wire section 14 so as to provide a signal indicative of the speed at which the wire or web forming section is actually moving.

Contributing considerably to the realization of a desired control of the basis weight valve 24 is a feed forward basis weight circuit 78 that provides a computed signal representative of the predicted basis weight. The mathematical model for the circuit 78 is as follows:

$$B = K_1 \frac{C \cdot F}{V} + E_0$$

where: B = bone dry basis weight

C = heavy stock consistency measurement

F = heavy stock flow (G.P.M.)

V = Fourdrinier wire speed

K_1 = one proportionality constant

$$E_o = K_2 \int_0^T e_o dt$$

In the above equation:

K_2 = a second proportionality constant

e_o = error signal representing the difference between predicted basis weight and actual basis weight

T = a given time interval for e_o

The values for K_1 and K_2 may be obtained empirically or with a special program which applies a least mean squares fit to the variables appearing above.

With the foregoing in mind, it is believed that the function of the feed forward basis weight circuit 78 will be understood as far as the computations expected of it. In this regard, the signals representative of heavy stock consistency (C in the above equation) and rough stock rate of flow (F in the above equation) are fed to a multiplier 80 having first and second input terminals 80a and 80b and an output terminal 80c. The output terminal 80c is connected directly to a multiplier 82 having an input terminal 82a which is connected to the output terminal 80c and a second input terminal 82b which introduces into the multiplier 82 a signal representative of the constant K_1 , the means for providing this signal being schematically portrayed by a potentiometer 84 that can be appropriately set to the proper value by means of a knob 86. The product signal at the output terminal 82c of the multiplier 82 is forwarded to a divider 88, more specifically its input terminal 88a, whereas its second input terminal 88b is connected to the tachometer 76 so as to cause the product signal from the multiplier 82 to be impressed on the input terminal 90a so as to be divided by the signal (V in said equation) obtained from the tachometer 76. The quotient signal appearing at the output terminal 88c of the divider 88 is then delivered to an adder 90, more specifically its input terminal labeled 90a. The second input terminal 90b of the adder 90 is attached or connected to a potentiometer 92 that is positioned or adjusted through the agency of a servomechanism 94 which performs a function hereinafter described. All that need be appreciated at the moment, though, is that the input at the terminal 90a is increased by an amount supplied at the input terminal 90b as furnished by the potentiometer 92 which is adjusted by the servomechanism 94.

An important feature of the invention is the ability of the system 50 to adapt itself in a manner so as to correct for differences owing to model inaccuracies or limitations between the actual basis weight and the predicted basis weight. For the purpose of sensing any difference between the actual basis weight as determined by the Beta gauge 64 and the predicted basis weight as computed by the circuit 78, there is a summing circuit or comparator 104 having one input terminal 104a connected to the output line from the feed forward basis weight circuit 78. The input terminal 104a is connected to the output terminal 90c of the adder 90. The comparator 104 has its second input terminal 104b connected to the Beta gauge 64. Thus, the same signal forwarded from the Beta gauge 64 is delivered to the input terminal 104b that is fed to the input line 62 of the feedback basis weight circuit 56.

Owing to the comparison role performed by the comparator 104, it will be appreciated that if the predicted basis weight as determined by the circuit 78, the circuit 78 being adaptive by virtue of the fact that it automatically modifies its parameters based on wet end and model determinations, differs from the actual basis weight as determined by the Beta gauge 64, then a difference or error signal e_o will result at the comparator 104. This error signal is delivered from the output terminal 104c of the comparator 104 to an adaptive controller 106 that performs an integrating function. More specifically, the integrator or controller 106 takes the signal from the output terminal 104c of the comparator 104 and integrates the signal on a time

basis. The signal provided by the controller 106 is indicated as E_o in the equation hereinbefore given. If the error signal e_o persists at the output terminal 104c for a relatively long period of time, then the error signal E_o that is used for operating the servomechanism 94 will be correspondingly greater because of the longer time interval, this being T in the earlier presented equation. Of course, if e_o also increases, then E_o will be even larger. On the other hand, if there are only short periods during which the actual basis weight differs from the predicted basis weight, then the influence of the integrator-controller 106 will be rather minimal, the servomechanism 94 under these circumstances acting only in a minor way as far as introducing a corrective signal into the adder 90 through its input terminal 90b and the schematically presented potentiometer 92, the wiper of which is positioned by said servomechanism.

OPERATION

Having described the foregoing components comprising my adaptive control system 50 and having presented to some extent the most important sections of a typical paper making machine 10, it is thought that the advantages to be gained from a practicing of the invention should be readily comprehended. Even so, it will be of some assistance, it is thought, to describe briefly the operation that takes place under certain environmental conditions.

First, it will be recognized that if a process disturbance is occasioned by a change in heavy stock consistency, a change in the rate of flow of heavy stock or in the speed of the Fourdrinier wire section 14, such a disturbance will ultimately affect the actual basis weight of the paper web 28 as it leaves the machine 10 and which basis weight is sensed by the Beta gauge 64. While the feedback circuit 56 is capable of initiating a correction for such disturbances, it will be understood that the correction is made at the wet end through the instrumentality of the basis weight valve 24 and that there will be a delay time or transport lag of sizable magnitude.

The purpose of the feed forward basis weight circuit 78 is to provide a relatively fast correction. This is accomplished by supplying the comparator 68 via its input terminal 68b a feed forward signal that will cause a more rapid change of the basis weight valve 24 to occur than would result with only a feedback loop, doing so by feeding a signal to the pulse duration basis weight controller 70 in accordance with the magnitude of the difference detected between the feedback and feed forward loops which contain therein the circuits 56 and 78, respectively. Thus, the mathematical model provided by the circuit 78 is adaptive by reason of the modification or change to its control parameters, this being done through the potentiometer 92 and adder 90.

By changing the position of the basis weight valve 24, a corrective action is initiated and ultimately the correction will be reflected in what the Beta gauge 64 senses at the dry end of the paper making machine 10. However, if the signal provided by the Beta gauge 64, this signal being representative of the actual basis weight, is not sufficiently and promptly corrected for, there will continue to be a difference between the signal representing the actual basis weight which is applied to the input terminal 104b of the comparator 104 and the predicted basis weight signal appearing at the input terminal 104a. The signal forwarded from the circuit 78 which is impressed on the input terminal 104a is the same as that delivered to the input terminal 68b of the comparator 68. At any rate, if the difference or error persists for any length of time, the difference will be integrated by reason of the adaptive action of the controller 106 and will thereby forward a signal representing the need for a greater change, the servomechanism 94 thereby acting through the agency of the potentiometer 92 to introduce a greater signal to the adder 90 via its input terminal 90b than would be delivered if the potentiometer remained fixed.

Thus, the signals provided by the transducers 72 and 74 plus the signal provided by the wire speed tachometer 76 result in a signal in accordance with these process variables. If there is no signal forwarded from the adaptive controller 106 via the servomechanism 94, then it is only this particular signal that is further processed and compared with the modified or updated set point signal appearing at the input terminal 68a of the comparator 68. On the other hand, when an error signal is determined to exist between the predicted basis weight the actual basis weight, such a signal is used to adjust the predicted basis weight signal to a new value. The predicted basis weight signal now contains a function of the error signal, more specifically, the integral employed to actuate the servomechanism 94 and which actuation results in the adding of a signal component at the adder 90 through the input terminal 90b to the signal delivered to the adder via the input terminal 90a. With a change occurring in the output signal from the circuit 78, which signal is impressed on the input terminal 68b of the comparator, it follows that without a sufficient compensating change in the feedback signal applied to the input terminal 68a, the command signal appearing at the output terminal 68c will be of sizable magnitude and thus will exert a greater influence in the positioning of the basis weight valve 24 than would otherwise occur, doing so through the controller 70. In this way, the entire paper making machine 10 is stabilized more rapidly as to the several process variables that are causing the disturbances.

I claim:

1. A machine for making a continuous web of paper, said machine including a web forming section, a headbox and a basis weight valve for varying the flow of heavy stock to said headbox subsequently delivered to said web forming section via said headbox, a system for controlling the final basis weight of said paper web comprising means providing a signal indicative of the actual final basis weight of the paper web, means for deriving a feedback signal from said actual basis said basis weight valve in signal, means comparing said feedback signal with a desired basis weight signal to provide a first error signal representative of any difference therebetween, means for deriving the predicted basis weight from heavy stock consistency and flow data to provide a signal indicative of predicted basis weight, means providing a second error signal derived from any difference between said actual and predicted basis weight signals, means for adjusting said predicted basis weight signal in response to said second error signal to provide a new predicted basis weight signal, means for comparing said first error signal with said new predicted basis weight signal to provide a corrective command signal, and means for controlling said basis weight valve in response to said command signal.

2. A machine for making a continuous web of paper, said machine including a web forming section, a headbox and a basis weight valve for varying the flow of heavy stock to said headbox subsequently delivered to said web forming section via said headbox, a system for controlling the final basis weight of said paper web comprising means providing a set point indicative of a desired basis weight, means providing a feedback signal indicative of the actual final basis weight, means comparing said desired set point with said feedback signal to provide a modified set point signal representing any difference present between said signals, means providing a

predicted basis weight signal derived from the consistency and the rate of flow of heavy stock through said valve and the speed of said web forming section, means for comparing said predicted basis weight signal with said feedback signal to provide an error signal representing any difference present between said predicted and feedback signals, and means responsive to said error signal for controlling said predicted basis weight signal means to provide an adjusted predicted basis weight signal which is a function of said error signal in addition to being a function of the consistency of heavy stock, its rate of flow and the speed of said web forming section and means for controlling said basis weight valve in response to said adjusted predicted basis weight signal.

3. The machine and control system of Claim 2 in which said error responsive means includes an integrator which provides a control signal representative of said error signal and the time integral thereof.

4. A machine for making a continuous web of paper, said machine including a web forming section, a headbox, a stuff box, a basis weight valve between said stuff box and headbox for varying the flow of heavy stock to said headbox subsequently delivered to said web forming section via said headbox, a system for controlling the final basis weight of said paper web comprising means providing a set point signal indicative of a desired basis weight, means providing a feedback signal indicative of the actual final basis weight, first means comparing said desired set point signal with said feedback signal to provide a modified set point signal representing any difference present between said signals, means providing a signal derived from the consistency of heavy stock flowing through said basis weight valve, means providing a signal derived from the rate of flow of heavy stock through said valve, first means for multiplying said consistency signal and said flow signal together to provide a product signal, second means for multiplying said product signal by a signal representative of a selected constant to provide a second product signal, means providing a signal representative of the web speed, means for dividing a second product signal by said speed signal to provide a quotient signal which is representative of the predicted basis weight, second means for comparing said quotient or predicted basis weight signal with said feedback signal to provide an error signal representing any difference present between said predicted and feedback signals, summing means having a pair of input terminals and an output terminal, one input terminal being connected to said dividing means and its output terminal being connected to said second comparing means, means including a servomechanism connected between said second comparing means and the second input terminal of said summing means to provide an adjusted basis weight signal which is a function said error signal in addition to being a function of the consistency of heavy stock, its rate of flow, and the speed of said web forming section and means for controlling said basis weight valve in response to said adjusted predicted basis weight signal.

5. The machine and control system of claim 4 including a potentiometer connected between said servomechanism and the second input terminal of said summing means, whereby said servomechanism adjusts said potentiometer in accordance with any error signal provided by said comparing means.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,619,360 Dated November 9, 1971

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

Column 5, line 37, delete "said basis"; same line, after "weight"
delete "valve in".

Signed and sealed this 25th day of April 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents