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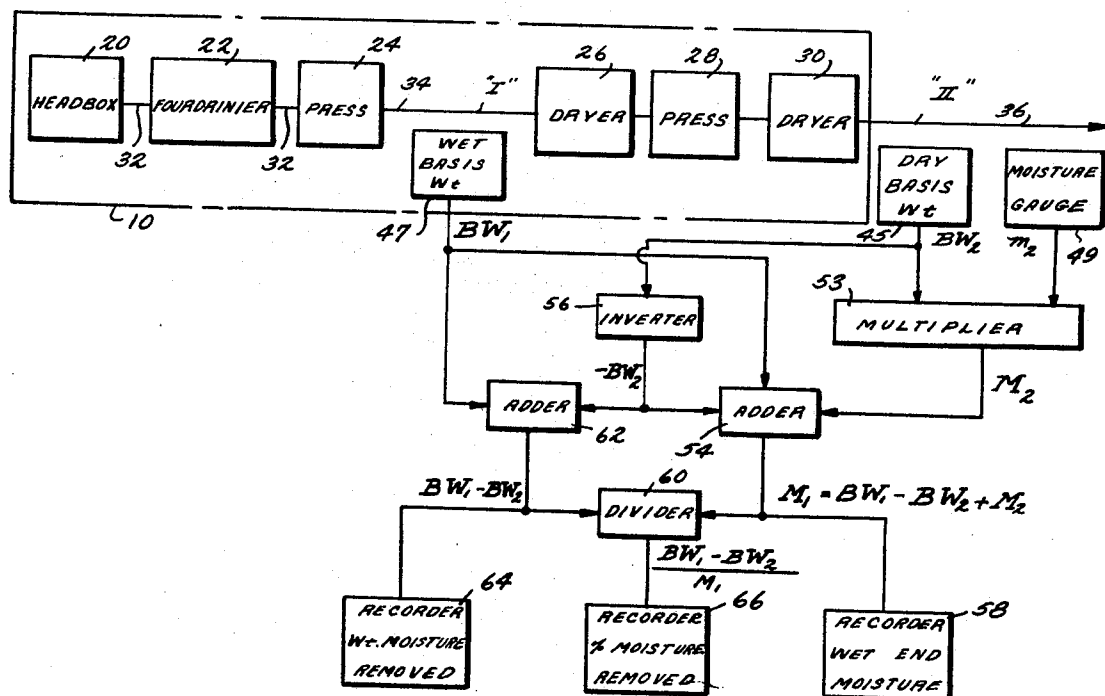
3,260,642 1966 Canter, Jr. 162/252
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III and C. Henry Peterson

[54] **APPARATUS FOR DETERMINING PERCENT OF WET-END MOISTURE REMOVED**
12 Claims, 3 Drawing Figs.

[52] U.S. Cl. 235/151.35,
73/73; 162/252
[51] Int. Cl. G01n 23/16,
G01n 33/34
[50] Field of Search. 235/151.35;
250/83.3; 73/73

[56] **References Cited**
UNITED STATES PATENTS
3,073,153 1963 Petitjean 73/73

ABSTRACT: To determine the percentage of moisture removed from a traveling material between first and second points along its direction of travel, the difference in basis weight at those two points is divided by the wet-end moisture weight per unit area. The wet-end moisture weight per unit area is obtained by multiplying the dry-end basis weight by the dry-end percent moisture with the product being then added to the difference of the basis weights. In another embodiment, the wet-end moisture weight is obtained by use of two operational amplifiers, one of which operates as a multiplier providing an output proportional to the difference in the dry-end moisture weight and the dry-end basis weight. This output is then added to the wet-end basis weight to obtain the wet-end moisture weight, which is then divided into the difference of the basis weights as above.



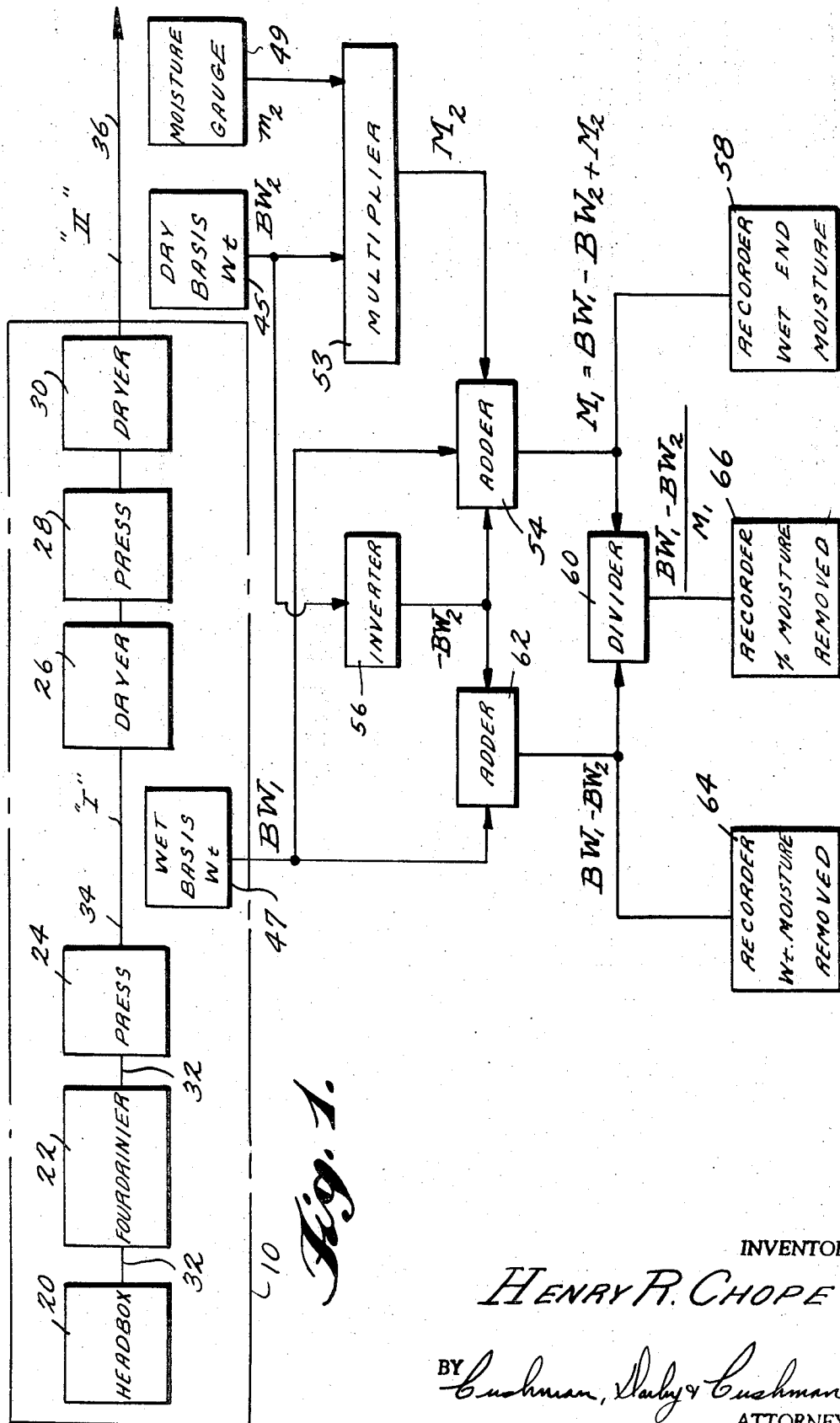


Fig. 2.

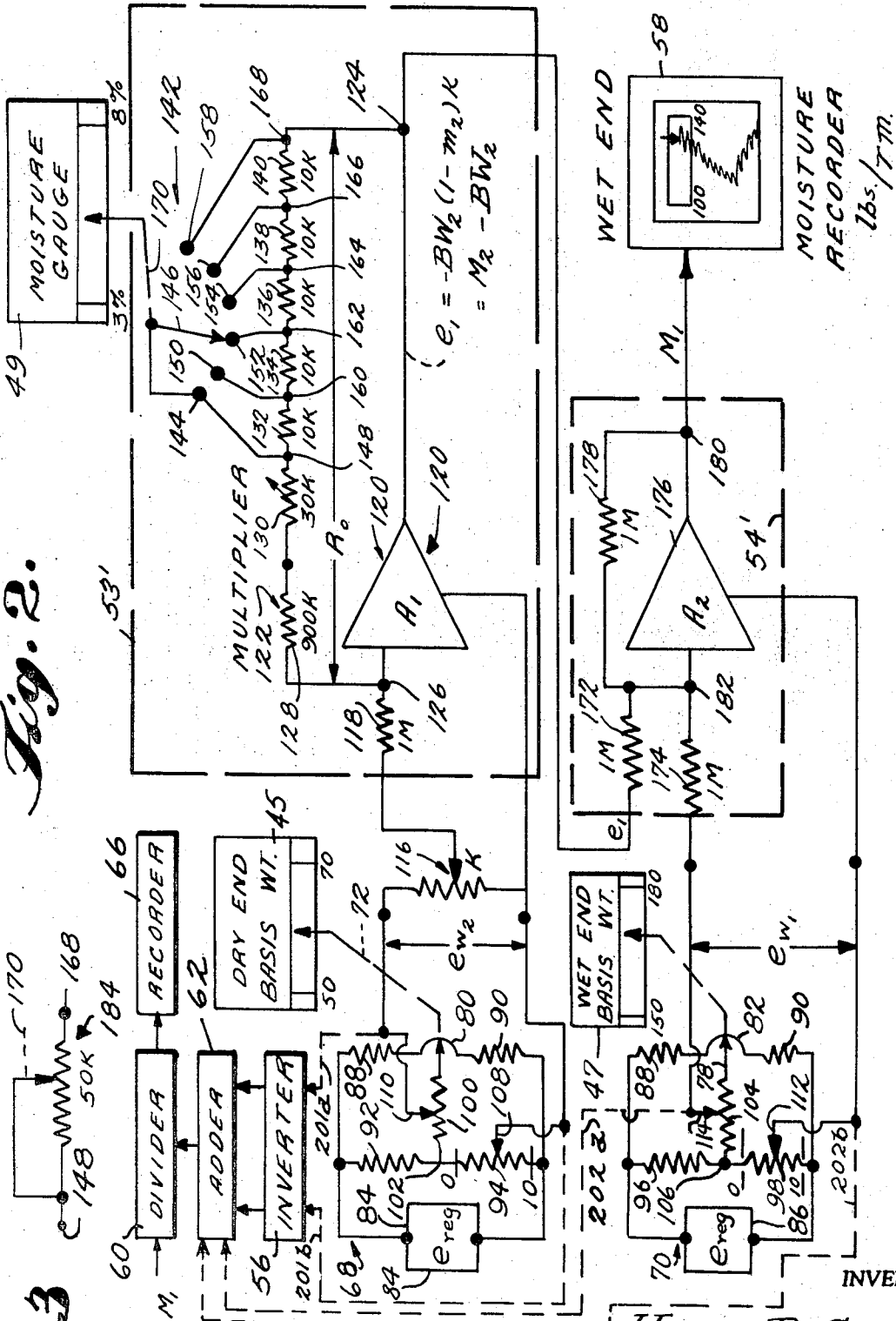
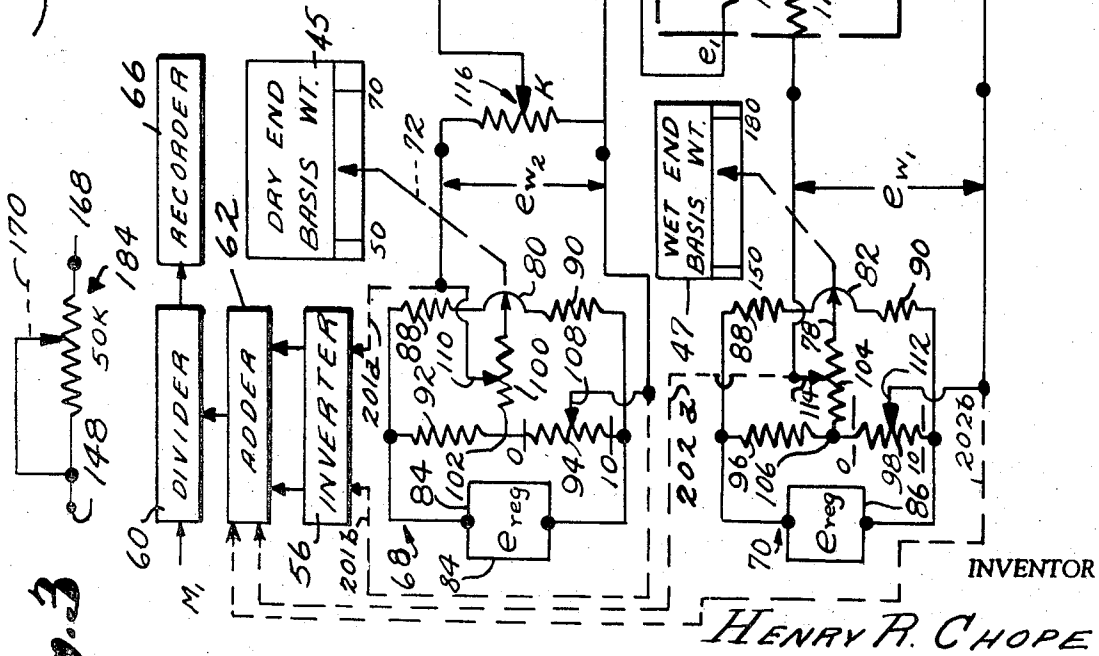


Fig. 3



BY *Cushman, Darby & Cushman*
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APPARATUS FOR DETERMINING PERCENT OF WET-END MOISTURE REMOVED

The present invention relates to apparatus for determining the percent moisture removed from a traveling material such as a web of paper being made, between first and second points between which the material is subjected to a moisture removal operation.

In the Fourdrinier paper-making process, as well as other methods of manufacturing paper and various other materials which are subjected to a moisture removal process during their manufacture, it is desirable and often necessary to determine the percentage of moisture removed by the process on the basis of the wet-end moisture. For the purpose of definition, the term "wet end," as used herein refers to any point of the paper-making or like process at which the amount of moisture is too high to be directly measured with sufficient accuracy by conventional apparatus. More specifically, and with respect to the Fourdrinier paper-making process, the "wet end," refers to that portion of the process at a point downstream from the Fourdrinier section and upstream from the point where the paper is passed through the dryer sections. In general, the "dry end" refers to that portion of the paper-making process when the paper has been dried, i.e., water removed to some low level although the paper is not completely without moisture, as the term might imply, but where the moisture is measurable by conventional apparatus.

In the Fourdrinier paper-making process, it has been found that in the area of the presses which follow the Fourdrinier section, the fiber-bonding process, which is an all-important phenomenon, begins and that its extent is strongly affected by the moisture percent in the sheet at that point. It has further been found that due to the high amount of moisture present in the paper in the vicinity of the press section, and up to the driers, the amount of moisture weight cannot be directly and accurately measured by known apparatus. Accordingly, that moisture weight and the percent of that moisture weight which is removed downstream must be determined indirectly.

In the prior art, a variety of different measurements have been made with regard to the moisture in a paper web. For example, Canter U.S. Pat. No. 3,260,642, assigned to the assignee of the present application, determines the wet-end moisture content; U.S. Pat. No. 3,073,153, relates to moisture content determination; German Pat. No. 836,436 of 1952 determines the amount of moisture removed. The copending, commonly owned applications, Ser. No. 673,446, filed Oct. 6, 1967, and Ser. No. 654,479, filed Jul. 19, 1967, relate to wet-end moisture content determination. However, in none of the prior art, is any consideration given to the determination of the percent of wet-end moisture removed between first and second points in a paper-making or other process wherein a traveling web traverses those points and has moisture removed therebetween.

Accordingly, it is the primary object of this invention to provide apparatus for making such a measurement.

It is another object of this invention to incorporate in such apparatus equipment for dividing the difference of the basis weights at the wet and dry ends by the weight of wet-end moisture, to arrive at the percentage moisture removed between those two points.

It is a further object of this invention to obtain the wet-end moisture weight by the various ways disclosed below.

Further objects and advantages of this invention will become apparent to those of ordinary skill in the art upon reading the following detailed disclosure in conjunction with the drawings, wherein:

FIG. 1 is a block diagram of one embodiment of the present invention as used in a Fourdrinier paper-making process;

FIG. 2 is a partial circuit diagram of FIG. 1 with modifications; and

FIG. 3 shows a variation for the feedback path in the multiplier of FIG. 2.

Enclosed within dotted line 20 in FIG. 1 there is schematically illustrated the various elements employed in a conven-

tional Fourdrinier paper-making process, including headbox 20, a Fourdrinier wire section 22, press section 24, dryer section 26, another press section 28, and a final dryer section 30. Paper stock supplied to headbox 20 is formed by the Fourdrinier section 22 into a mat schematically illustrated at 32. In other types of paper-making machines, other means may be employed to form the mat 32. Water which clings to the mat 32 is extracted at the press section 24. The damp sheet 34 issuing from the press section 24 is subsequently dried in steam dryer 26. It may be sized, and again pressed, in press section 28 and again dried in dryer 30. The sheet 36, leaving the dryer section 30, is the finally prepared paper which may be subsequently passed through other processing steps such as sizing, coating, calendering, and the like.

Due to the nature of the paper making process, the critical amount of moisture present at point "I" of sheet 34 is quite high and cannot be directly measured with sufficient accuracy and reliability by known techniques. However, the final moisture present at the dry end, i.e., at point "II" of sheet 36, is quite low, in the neighborhood of 4 to 8 percent, and can be directly measured with high accuracy by known techniques, and then used to indirectly determine the amount of moisture at the wet end.

The apparatus for determining the moisture weight per unit area of the web at point "I" includes a dry-end basis weight gauge 45, which is preferably a cross-sheet scanning beta ray gauge of well-known construction, and wet-end basis weight gauge 47 which is also preferably a cross-sheet scanning beta ray gauge. Both of these gauges contain well-known internal circuitry (not shown) to render the output signal thereof proportional to the weight or mass per unit area of the traveling web which includes both the weight of the moisture and the fiber or pulp. Other gauges can be used to generate signals indicative of the mass per unit area.

At the dry end (II), which could also be located at the output of dryer 26, there is further provided a moisture gauge 49 of well-known construction, which develops an output signal m_2 which is indicative of the moisture content, such as the percent moisture present in the traveling web at the dry end. The dry-end basis weight gauge, the wet-end basis weight gauge, and the moisture gauge are preferably interconnected in a well-known manner in order to permit the synchronous scanning of the sheet by each of the gauges.

The output BW_2 of the dry-end basis weight gauge 45 and the output m_2 of the moisture gauge 49 are connected to a multiplier circuit 53, which develops an output signal M_2 which represents the product of the percent moisture and the dry-end basis weight, and consequently is proportional to the moisture weight per unit area. This M_2 signal is applied to adder 54, in conjunction with the wet-end basis weight signal BW_1 and the dry-end basis weight signal BW_2 after its inversion by inverter 56. Adder 54 provides an output signal M_1 , which is the difference of the basis weight signals plus the dry-end moisture weight per unit area. This M_1 signal is applied to recorder 58, which therefore gives an indication of the weight of the wet-end moisture, i.e., the weight of the moisture at point "I."

The M_1 signal from adder 54 is also applied to divider 60 as the denominator quantity. The numerator quantity, which is the difference between the basis weight signals, is obtained from adder 62, which receives its inputs from the wet-end basis weight gauge 47 and inverter 56. The basis weight difference signal from adder 62 is applied not only to divider 60, but also to recorder 64, which indicates the weight of the moisture removed between points "I" and "II."

Divider 60 divides the difference between the basis weights at points "I" and "II" by the wet-end moisture weight and applies its output to recorder 66, which therefore indicates the percent of the wet-end moisture that has been removed between points "I" and "II."

In general, the adders, inverters, dividers and multiplier in FIG. 1 form arithmetic processing means in which variations are possible to obtain the percent moisture removed signal

desired. For example, instead of applying to adder 54 the wet-end basis weight signal BW_1 and the inverted dry-end basis weight signal $-BW_2$, the output of adder 62 could be applied to adder 54 as well as to divider 60, since adder 62 takes the difference of the two signals. This would reduce adder 54 to a two input adder circuit. Another arrangement for reducing adder 54 to a two input circuit is shown in FIG. 2, in which further modifications are also illustrated.

In FIG. 2, the dry-end and the wet-end basis weight signal from gauges 45 and 47 are applied to respective bridges 68 and 70 via respective mechanical couplings 72 and 74 to the sliders 76 and 78 of the slide wires 80 and 82, all in conventional fashion. Each of the bridges 68 and 70 has its own regulated voltage source 84 and 86, across which are placed the repeat slide wires 80 and 82 along with their series-connected equal-valued end resistors 88 and 90. Also connected across the regulated voltage supplies are another set of equal-valued resistors 92 and 94 for bridge 68 and 96 and 98 for bridge 70. The upper slider 76 is connected by resistor 100 to the junction 102 between resistors 92 and 94, while the lower slider 78 is connected by resistor 104 to junction 106 between resistors 96 and 98. Resistors 94 and 100 in the upper bridge 68 are part of respective potentiometers which have taps 108 and 110, between which is the voltage e_{W2} , which corresponds to the dry-end basis weight signal. In like manner, the wet-end basis weight voltage e_{W1} is obtained from the lower bridge 70 between taps 112 and 114 of potentiometers 98 and 104 respectively.

Across the output of the upper bridge 68 is a potentiometer 116, which may be used to scale the upper voltage, if necessary, so that the two bridge output signals will have the same proportionality to the measured basis weight. However, potentiometer 116 may not be necessary as the following example. Assume that the dry-end basis weight may vary over the operative range from 50 to 70 pounds per ream for example, and the wet-end basis weight may vary over the range from 150 to 180 pounds per ream. Considering point 102 in upper bridge 68 as a zero voltage reference point, the slide-wire voltage at slider 76 may vary from +1.2 volts to -1.2 volts as the dry-end basis weight reading is varied from 50 to 70 pounds per ream. The slider 110 may be adjusted so that the attenuated voltage derived therefrom will vary from exactly +1.0 volts to -1.0 volts, with zero output at the 60-pound center point of the range. The slider 108 will be adjusted so that the voltage derived therefrom is exactly 6.0 volts. The bridge output voltage e_{W2} will then be equal to the algebraic difference of these two so-adjusted voltages, that is 5.0 volts for a 50-pound basis weight reading, 6.0 volts when the bridge is balanced at the 60-pound (center scale) reading and 7.0 volts for a 70-pound reading.

Similarly, in the lower bridge 70, with respect to point 106 the voltage at slider 78 may vary from +1.8 volts to -1.8 volts, and the adjusted attenuated voltage from slider 114 will vary from +1.5 volts to -1.5 volts as the wet-end basis weight reading varies from 150 to 180 pounds per ream. Slider 112 will be adjusted to provide 16.5 volts. The bridge output voltage e_{W1} will then be 15.0 volts for a 150-pound basis weight reading, 16.5 volts when the bridge is balanced at the 165-pound center scale reading, and 18.0 volts for a 180-pound reading.

The bridge output voltages are thus both scaled to 1 volt per 10 pounds per ream. The repeat slide-wires 80 and 82 and attenuating potentiometers 100 and 104 provide scaled voltages indicative of the operating variations, within the respective calibration ranges, of the dry- and wet-end basis weight measurements. Potentiometers 94 and 98 constitute biasing means for providing pedestal voltages indicative of the respective basis weight values at selected reference points, preferably the center scale values, on the two different ranges, whereby the bridge outputs will be nonzero throughout the respective ranges.

To effect multiplication, the dry-end basis weight voltage is applied across the input of multiplier 53', enclosed by dotted lines, to the input of operational amplifier 120, having an

input resistor 118. Operational amplifier 120 includes a resistive feedback path 122 from amplifier output terminal 124 to its input terminal 126. The resistive feedback path 122 includes a resistor 128 of 900K ohms for example if resistor 118 is 1 megohm, a variable trim resistor 130 of 30K ohms for example, plus five 10K-ohms resistors 132, 134, 136, 138 and 140. These five resistors 132-140 comprise a variable resistor by virtue of the rotary stepping switch 142 which has its left-hand switch contact 144 and also its arm 146 connected to junction 148, with the successive switch terminals 150, 152, 154, 156 and 158 being respectively connected to these successive resistive increments at junctions 160, 162, 164, 166 and 168 respectively. It is therefore apparent that when switch arm 146 is on contact terminal 144, the resistive feedback path contains all of its resistance, i.e., 970K ohms. Multiplication is effected in this particular embodiment by varying the feedback resistance in successive increments of 10K ohms for example, in correspondence to incremental changes of moisture variation at the dry end. Accordingly, the output of moisture gauge 49 is mechanically coupled as indicated at 170 to step the switch arm 146 in accordance with the percent moisture indicated by the gauge. For example if moisture gauge 49 reads 3 percent, switch arm 146 would be on contact terminal 144, meaning that all of the feedback resistance of 970K ohms would be in the circuit, for a moisture gauge reading of 4 percent, switch arm 146 would be on contact terminal 150, for a feedback resistance of 960K ohms, etc., until the moisture gauge read 8 percent, in which case the switch arm 146 would be on contact terminal 158, causing the feedback resistance to be 920K ohms. In effect, the total feedback resistance is varied by the moisture gauge in accordance with the value of the quantity $(1-m_2)$, and accordingly the multiplication effected by operation amplifier 120 causes its output voltage e_l at point 124 to be proportional to $-BW_2(1-m_2)$ which equals M_2-BW_2 .

That voltage e_l is then added to the wet-end basis weight voltage which is derived from the lower bridge 70, i.e., voltage e_{W1} , by adder 54'. This adder is of the operational amplifier type and includes two input resistors 172 and 174 for conveying the input signals to amplifier 176. The feedback resistor 178 from the amplifier output terminal 182, is preferably of the same resistance as resistors 172 and 174, for example 1 megohm. The output voltage at terminal 180 represents the wet moisture weight, which is indicated in recorder 58.

As a modification of FIG. 2, instead of the stepping switch 142 and the incremental resistors 132-140, a repeat slide-wire or potentiometer 184 as shown in FIG. 3 may be connected between feedback terminals 148 and 168 to be controlled by the moisture gauge 49 in a continuous manner.

From the foregoing description of FIGS. 2 and 3, it is apparent the multiplication effected therein is different from that suggested by FIG. 1. In FIG. 1, the multiplier provides just the M_2 signal which represents the dry-end moisture weight, whereas the FIG. 2 multiplier provides an output signal which is proportional not just to the M_2 signal but to the quantity M_2-BW_2 . Accordingly, adder 54' in FIG. 2 needs only two inputs since the $-BW_2$ input signal required for adder 54 in FIG. 1 is already incorporated in the input signal applied to resistor 172 in adder 54' of FIG. 2.

While this means that an inverter of the dry-end basis weight signal is not necessary for the adder 54', an inverted dry-end basis signal is needed for adder 62 of FIG. 1. Accordingly, in FIG. 2, the dry-end basis weight signal as it appears across potentiometer 116 at its output, or at its input if further scaling of the signal is not necessary, is applied as shown by dotted lines 201a and 201b to an inverter 56 as in FIG. 1 and the resulting $-BW_2$ signal applied to adder 62 in conjunction with the wet-end basis weight signal BW_1 as shown by dotted lines 202a and 202b from the lower bridge 72 and the resulting difference of the basis weight signals is divided in divider 60 by the wet-end moisture weight signal M_1 which appears at the output terminal 180 of adder 54' in FIG. 2. Thus, the percent of wet-end moisture removed is indicated

by recorder 66 as obtained by using the detailed circuit shown in FIG. 2 or FIG. 3.

While FIG. 2 suggests the use of repeat slide-wire bridges 68 and 70 to obtain the dry-end and wet-end basis weight signals, it is feasible to obtain these signals in other ways. In this regard reference may be made to my U.S. Pat. No. 2,790,945 in which FIG. 2 shows an overall circuit which may be employed for either of the basis weight gauges. It will be noted that the bridge in that FIG. 2 of U.S. Pat. No. 2,790,945 is similar to the repeat slide-wire potentiometer bridges 68 and 70 in FIG. 2 of the present application.

Thus, there has been described above several embodiments for carrying out my invention, and still other embodiments and advantages of this invention will become apparent to those of ordinary skill in the art upon reading the foregoing description. It is to be understood, however, that this invention is not limited by that description, but by the appended claims.

I claim:

1. In an apparatus wherein a traveling material is subjected to a moisture removal operation in passing from a first point to a second point, the improvement comprising:

- means for generating a first signal indicative of the basis weight of said material passing said first point;
- means for generating a second signal indicative of the basis weight of said material passing said second point;
- means for generating a third signal indicative of the moisture in the said material passing said second point; and
- arithmetic processing means operative on said first, second and third signals for producing an output signal representing the moisture removed between said two points as a percentage of the moisture at said first point.

2. Apparatus as in claim 1 including means responsive to said output signal for indicating the aforesaid moisture percentage at the first point.

3. Apparatus as in claim 1 wherein each of said first and second basis weight signal generating means includes:

- a respective basis weight gauge operating in a given range and a respective repeat slide-wire potentiometer having a slider connected to the gauge for movement proportional to the operating variation of the gauge within said range to effect a zero potentiometer output at a given point in said range;
- respective biasing means connected to said potentiometer for causing a nonzero output from said potentiometer throughout said range; and
- said biasing means being respectively set in accordance with the respective ranges of the basis weight gauges.

4. Apparatus as in claim 1 wherein said arithmetic processing means operates in accordance with the formula

$$\frac{BW_1 - BW_2}{BW_1 - BW_2 + M_2}$$

wherein BW_1 and BW_2 and M_2 respectively represent said first and second signals, said third signal is indicative of the percent moisture, and M_2 represents the multiplication of said second and third signals.

5. Apparatus as in claim 4 wherein said arithmetic processing means includes adder and multiplying means for developing the numerator and denominator quantities of said formula and division means for dividing those quantities to obtain said output signal.

6. Apparatus as claim 5 including means for multiplying said

second and third signals to obtain an M_2 signal, means for inverting said second signal to form a $-BW_2$ signal and wherein said adder means includes two adders one of which adds the said first signal and the $-BW_2$ signal to form said numerator quantity, the other adds those signals and said M_2 to form said denominator quantity.

7. Apparatus as in claim 6 including recording means responsive to said output signal and being connected to both of said adders for indicating the aforesaid moisture removed percentage at said first point, the unit weight of water removed between said points and the unit weight of moisture removed at said first point.

8. Apparatus as in claim 1 wherein said third signal is indicative of the percent moisture, and said arithmetic processing means includes:

- multiplying means responsive to said second and third signals for developing a fourth signal proportional to the quantity $-BW_2 (1 - m_2)$ wherein BW_2 and m_2 respectively represent said second and third signals;
- adder means responsive to said first and fourth signals to obtain a signal M_1 representing the amount of moisture at said first point;
- means for taking the difference of said first and second signals to obtain a basis weight difference signal; and
- means for dividing said difference signal by said M_1 signal to obtain said percentage moisture output signal.

9. Apparatus as in claim 8 wherein said multiplying means includes an operational amplifier having an input which receives said second signal and having feedback resistance means, and means for varying said resistance means in resistance at least approximately in accordance with the percent moisture variation of the material passing said second point to effect said multiplying.

10. In combination with apparatus wherein a traveling material is subjected to a moisture removal operation in passing from a first point to a second point:

- a basis weight gauge at each of said points;
- means responsive to said gauges for producing first and second variation signals indicative of the basis weight variations within the respective gauge calibration ranges;
- means for adding first and second biasing signals respectively to each of said first and second variational signals to produce first and second basis weight signals;
- an operational amplifier having an input receiving one of said basis weight signals;
- a moisture gauge at said second point;
- feedback means in said amplifier responsive to said moisture gauge for causing said amplifier to produce an amplifier output signal which varies jointly with the moisture content of said material and said one basis weight signal; and
- means responsive to said amplifier output signal and to the other of said basis weight signals for producing a resultant signal indicative of the moisture content of said material passing said first point.

11. Apparatus as in claim 10, further comprising:

- means for producing a signal indicative of the difference between said first and second basis weight signals; and
- means responsive to said difference signal and to said resultant signal for producing a signal indicative of the percent moisture removed from said material between said first and second points.

12. Apparatus as in claim 10 wherein said basis weight gauges at said first and second points have different calibration ranges, and wherein said added first and second biasing signals have mutually different values.