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(54) TEMPERATURE CONTROL FOR ROTARY DRIERS

(71) We, AMF INCORPORATED, a corporation organised and existing under the laws of the State of New Jersey, United States of America, of 777 Westchester Avenue, White Plains, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to the temperature control of rotary driers for determining the moisture content of tobacco or other lamina materials with a high surface area to thickness ratio.

Rotary driers of the type to be controlled by the present invention, for example, are described in British patents 1,209,929, 1,345,373 and 1,390,396. Such driers have a primary and often and only source of heat which is the cylinder walls and paddles. The secondary source of heat, if utilized, is the air flow through the drier which is limited to a maximum at which it starts to convey tobacco. Therefore, in actual practice, the amount of heat that is available from the air flow is less than the heat available from the cylinder walls and paddles.

From a control point of view, adjustment of the air temperature or the secondary heat source provides a rapid but narrow adjustment of drying capacity, and adjustment of cylinder temperature or the primary heat source is a slower but wider range of adjustment. The latter is slower because of the thermal capacity of the cylinder and paddles.

In current tobacco drying practice the heated air is contra flow (against the tobacco flow) and is reduced to a minimum to improve the filling power of the tobacco. Under these conditions heated air produces a negligible amount of drying heat and so is not normally used for moisture control. A tobacco cooler may form an integral part of the drying process. For although the heat for drying is provided by the drier, a part of this heat is only realized as moisture removal during the evaporative cooling which takes place in the cooler.

The dwell time (retention time of material in the drier) for tobacco can be much lower than for most materials dried in rotary driers due to the high surface area to thickness ratio, but is is still of the order of 2 to 5 minutes. From a feedback control point of view, this is dead time and results in a weak or slow control response. So, it is customary to avoid this dead time by basing the control system on feed-forward control with feedback being used only for corrective trimming.

For feed-forward control, the input variables are measured and a predicted cylinder temperature is computed. For example, in the processing of tobacco leaf, the lamina and stem are separated and processed separately. The cut stem is normally added-back to the cut lamina at the input to the drier so that there are four input variables to be measured and computed to predict the cylinder temperature. These variables are the flow rate and moisture content of the cut lamina, and the flow rate and moisture content of the cut stem.

In computing the desired cylinder temperature, the characteristics of the drier also must be taken into account. Tobacco with its large surface area to thickness ratio can dry in seconds, and in a rotary drier it is not the diffusion of moisture from the interior of the leaf to the surface which limits the drying rate but the transfer of heat from the cylinder to the tobacco. The removal of moisture in a given drier application is thus proportional to the temperature difference between the cylinder and the tobacco and the surface area of the bulk of the tobacco per pound exposed to the heat.

The above is broadly correct for moisture contents above 15% to 20%. Below this, diffusion of moisture is more significant and the tobacco rises in temperature in order to raise the vapor pressure sufficiently to maintain evaporation.

It is commonly assumed for control purposes that for a given cylinder temperature the water removal is independent of the tobacco flow rate through the cylinder or, in terms of % moisture removal, is inversely proportional to flow, i.e. (M%) is proportional to flow (F) to the power of -1 ($M\% \alpha F^{-1}$). This is true provided the paddles are fully loaded (or overloaded) so that the bulk surface area of the tobacco in contact with the cylinder does not increase with flow and hence the water removal remains constant for changes of flow.

However, if the paddles are not fully loaded the surface area of the bulk tobacco in the drier is proportional to the square root of the flow, or double the flow will double the cylinder contents which will have 40% more bulk surface in contact with the cylinder and paddles. So, for a fixed cylinder temperature the water removal will be increased by 1.4 × or in terms of % moisture removal reduced .71 c, i.e. ($M \alpha F^{-1/2}$).

If the paddles are underloaded, a 'clumping' effect can take place in which the cylinder contents do not spread uniformly over the paddles but rather form clumps which do not sub-divide with gaps between. Under these conditions the surface area in contact with cylinder and paddles and hence moisture removal is proportional to flow, or in terms of % moisture removal is independent of flow, i.e. ($M\% \alpha F^{0}$). This latter effect is more pronounced with materials which tend to mat such as cut lamina.

Accordingly, we find that the cylinder temperature (T) required is a constant plus a value proportional to the % moisture to be removed (M-S), the flow (F) to the power (K) depending on the paddle loading and an application factor (Q) which is dependent on the drier size and working conditions and the nature of the tobacco being dried: i.e. ($T = (M-S) \times F^{K} \times Q + C$), where (C) is the cylinder temperature at which the linear equation intersects the zero moisture line ($M-S=O$), and (S) is the set point or desired final moisture content of the tobacco. The temperature constant (C) is dependant on the temperature of the tobacco leaving the drier which is held constant for a given application by adjusting the air flow through the drier. Control of the temperature of the tobacco leaving the drier is an important aspect of drier control as the tobacco exit temperature reflects the temperature of the tobacco within the drier which is a measure of the filling value gain in the drier.

The constant (C) is determined experimentally according to the particular application and tobacco exit temperature. In practice, the change in (C) is substantially equal to the change in tobacco exit temperature while (Q) is substantially constant to changes in tobacco exit temperature.

According to the invention we provide a cylinder temperature control apparatus for rotary driers of the kind having a cylinder slightly inclined to the horizontal and heating means therefor by which the cylinder temperature (T) is variable, comprising converter means for receiving a rate of flow signal (F) and raising it to a power (K) adjustable from 0.1 to 1.0 according to the rate of flow, the output of said converter means serving to control said cylinder temperature, said converter means operating so that T equals a constant plus a value proportional to FK.

In accordance with another aspect of the invention we provide a method of controlling the temperature of the cylinder of a rotary drier of the kind having the cylinder slightly inclined to the horizontal, comprising a signal (F) representing the rate of flow of material into the drier, raising said rate of flow signal to a power (K) adjustable from 0.1 to 1.0, according to the rate of flow, to produce a modified signal (F^{K}) and controlling said heating means in accordance with said modified signal; so that the cylinder temperature (T) equals a constant plus a value proportional to F^{K}.

Further, according to the invention we provide a cylinder temperature control apparatus for rotary driers of the kind described, comprising converter means for receiving a rate of flow signal (F) and raising it to a power (K) adjustable from 0.1 to 1.0, according to the rate of flow, means for summing an input moisture control signal (M) and a desired output moisture signal (S) to provide an output signal (M-S), means for multiplying the output signal ($F^{K,}$) from said converter means by the output signal (M-S) from said summing means, amplifier means for receiving the output signal (F^{K} (M-S)) from said multiplying means for applying a gain (Q) representing the application factor, and further means for summing the output signal (QF^{K} (M-S) from said amplifier means with a bias signal (C) appropriate to the drier to the controlled, said further summing means producing an output signal (T) representing the required cylinder temperature to control said heating means, said temperature control apparatus thereby operating in accordance with the formula $T = Q\,F^{K}\,(M-S+C)$.

The application factor (Q) as mentioned herein including the appended claiming clauses means an adjustment factor which is selected and made by observing the output moisture content and adjusting the factor manually to give the desired output moisture content.

In practice there are changes in the nature of the tobacco which require slight changes in the application factor (Q) to be made to give the correct final moisture content. At present the correct final moisture content is achieved by using a feedback control which corrects the feed-forward cylinder temperature prediction by adding or subtracting a correction according to the deviation of the final moisture content.

The correction signal is a 1, 2 or 3 term control signal and because of the dead time the control settings must be weak or slow. A disadvantage of the known method of correction is that if there is a substantial error in the feed-forward application factor setting, it takes several minutes at every start up before the correction is completed.

A self-adaptive control system may be provided in which the application factor (Q) is corrected if there is a deviation of the final moisture content, so that errors in the application factor setting are automatically removed.

This may be achieved by using the 1, 2 or 3 term control signals from the feedback controller to adjust the application factor via a servo motor. Provision is made to lock the application factor setting when there is no final moisture measurement and for a set period after it is first established, and also to lock it when there is no input measurement, i.e. the final moisture measurement is about to die away.

The foregoing and other objects and advantages will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustration purposes only and are not to be construed as defining the limits of the invention.

Figure 1 is a block diagram of a control apparatus by which the moisture content of tobacco delivered to the drier in a signal stream is controlled in accordance with the present invention.

Figure 2 is a block diagram of a modified control apparatus by which the moisture content of tobacco delivered to the drier in separate streams of cut lamina and cut rolled stem is controlled in accordance with the present invention.

In the arrangement shown in Figure 1 the flow rate of tobacco delivered to the drier is measured in known manner by a weigher flow rate detector 10 which provides a flow rate signal (F) which is fed to the input of a nonlinear generator 12 and to the first input of a log-antilog device 11. The generator 12 provides, in response to the signal (F), an output signal (K), as heretofore described, which is fed to a second input of the log-antilog device 11 which produces an output signal (F^K). Simultaneously, the moisture in the tobacco flow is sensed in a known manner by a moisture meter device which produces a signal (M) representative of the moisture of the tobacco.

A summing network 14 is connected to receive the signal (M) from the moisture meter device 13 and a signal (S) from a final moisture value set point selecting device 15 to provide an output signal (M-S). The outputs (F^K) from the log-antilog device 11 and (M-S) from the summer 14 are fed to a multiplier network 16 which provides an output signal (F^K (M-S)) fed to an amplifier 17 having a gain (Q) representing the application factor which is related to the heat transfer characteristics of the tobacco, the air flow in the drier and the drier size. The output signal (QF^K (M-S)) from the amplifier 17 is summed with a constant voltage bias (C) in a summer 18, the output (T) of which is used for the temperature control of the cylinder temperature set point control device 19.

As a variation, the bias signal (C) may comprise a constant bias adjustment signal B and a variable signal E proportional to the exit temperature. The two signals may be summed in a summing amplifier 40 which then provides the resultant signal (C) to the summer 18.

The circuit shown in Figure 2 comprises a summer 20 for summing the output signals (F_L and F_S) from a cut lamina flow rate detector 21 and a cut rolled stem flow rate detector 22. As in the previous example the flow rate signal (F) from the summer 20 is processed in a log-antilog device 23 which is controlled by a signal (K) produced by a non-linear generator 24 which also receives the flow rate signal (F). In both examples the signal generated by the non-linear generator or characteriser 24 is capable of varying between $K = 0.1$ and $K = 1.0$ (preferably between $K = 0.4$ and $K = 1.0$).

The moisture content figures (M_L and M_S) of the cut lamina and cut rolled stem produced by the moisture meters 25 and 26 are sequentially processed in a summer 27, a multiplier 28 which receives the output signal (F_S/F) from the divider 31, and a summer 31 which has an output ($M_L + F_S/.F\ (M_S - M_L) = M$).

The output (M) of the summer 30 is summed with a signal (S) from an output moisture set point device 32 in a further summer 33. The signal (M-S) from the summer 33 is multiplied by the signal (F^K) from the log-antilog device 23 in a multiplier 34. As in the previous example, an application factor (Q) and a bias signal (C) are applied to the signal from the multiplier 34 by means of an amplifier 35 and a summer 36. The cylinder set point control device 37 receives the signal (T) from the summer 36. In this example also, the signal C may be derived at the output of a summing amplifier 38 receiving a constant bias adjustment signal B and a variable signal E proportional to the exit temperature.

The temperature of the rotary drier required for particular drying rate is calculated from the total input moisture, obtained in this example from the mean moisture content of the cut lamina and cut rolled stem feed paths to the input end of the drier, and from the flow rate (F) obtained from the flow rates (F_S and F_L) in said feed paths.

The separate measurements of cut lamina and cut stem input moisture content (M_L and M_S) are made in known manner, e.g. by two of the applicants' continuous moisture meters (AMF Legg - Hydromet). A third (not shown) measures the output moisture content of the lamina after the cooler (also not shown). These are known electric conductance type meters each with three pairs of trailing resistance sensors mounted over the tobacco stream on a band or vibrating conveyor and a sumberged temperature sensor which corrects the reading for tobacco temperature. Each unit has a multi-turn potentiometer with a digital indicator for blend corrections and a signal simulator switch for rapid checking of the resistance, and temperature compensation circuits. Alternatively, infra-red or dielectric devices may be used.

The flow rates (F_L and F_S) of the streams of tobacco are measured continuously by means of the applicants' apparatus commercially known as the AMF LEGG Pivoted Belt Weigher. These may be either fixed or variable speed weighers. The fixed speed weigher is used for flow rate measurement. The variable speed weigher is used in conjuction with a metering tube for flow rate measurement and control.

The electrical signals measuring the moisture and flow rate of the cut rolled stem and cut lamina (M_S, M_L, F_S, F_L) are fed to the drier control apparatus. These signals are smoothed to eliminate short term variations and used to calculate the total moisture content (M) of the tobacco at the input to the drier.

As seen from Figure 2, the total moisture content is obtained from the signals (M_S, M_L, F_S and F_L) by the summer 20 for adding (F_L) to (F_S), the divider 31 for produing ($\frac{F_S}{F}$), the summer 27 for producing ($M_S - M_L$), the multiplier 28 for producing ($\frac{F_S}{F}(M_S - M_L)$) and the summer 30 for adding (M_L) to ($\frac{F_S}{F}(M_S - M_L)$). The summer 20 for ($F_L + F_S$) is a summing amplifier and a Fairchild Type 741 integrated circuit may be used. The multiplier 28 may be pulse width modulated device.

Accordingly, the total moisture content

$$\left(M = M_L + \left(\frac{F_S}{F_S + F_L}\right)(M_S - M_L)\right)$$

where

(M_L) = % moisture of cut lamina
(M_S) = % moisture of cut rolled stem
(F_S) = Flow rate of cut lamina
(F_L) = Flow rate of cut rolled stem.

The signal representing the total tobacco flow rate (F) obtained by summing the flow rates ($F_S + F_L$) of the cut rolled stem and cut lamina is fed into the special log-antilog circuit 23, e.g Intersil Type 8048-8049. The output of this circuit 23 is (F^K), where (K) is the flow factor and covers the range 0.1 to 1.0.

The predicted cylinder temperature is computed by the equation:

($T = Q\ (M-S)\ F^K + C$). The application factor (Q) is related to the heat transfer characteristics of the tobacco, the air flow in the drier and drier size.

The value of (K) can either be adjusted manually from experiments or automatically as in the examples of Figure 1 and Figure 2 by relating to the drier paddle loading.

The automatic adjustment is effected by the non-linear generator (12 or 24) which is connected between the signal representing total flow rate (F) and the control input to the log-antilog circuit. Provided that the non-linear generator can produce a characteristic compensating that of the drier, the K factor will automatically adjust in accordance with the drier loading and the desired temperature will be achieved for all loading values.

The output signal (T) is used to set the desired temperature on an automatic feedback or closed loop process controller. The output of this controller drives a valve which modulates the heat input to the drier, the latter being gas or oil fired or water or steam heated.

To compensate for any long term changes in the characteristics of the tobacco or drier which may result in the final moisture content being off target a correction is made to the cylinder temperature. This is achieved by comparing the measured moisture content against the desired moisture, the deviation being fed to an automatic controller. The output of the controller is combined with the feed forward signal to give a desired cylinder temperature.

It may be desirable to have the adjustment of the application factor (Q) done automatically in a servo-control loop. The manual adjustment of the application factor (Q) positions the servo motor which has a dual ganged potentiometer. The first potentiometer is a feedback position indicator controlling the position of the servo system. The second potentiometer is for setting the application factor (Q).

The output from the servo position potentiometer is used to set the output signal from the moisture controller in the feed-forward mode. When tobacco is present at the output of the cooler and after a delay the moisture controller will be activated. If there is any deviation between the set moisture and output and final moisture content the controller signal will change and alter the position of the servo motor thereby adjusting the application factor so as to make the final moisture content equal the set moisture.

At the end of the operation the application factor will have been updated to a value based on the complete operation. This value will be stored and may be different from the manually set position. A manual override on the application factor is provided so that adjustment can be made of the position to account for various blends.

The deviation signal from the moisture controller may also be used to set the temperature of the air in the drier and the humidity of the air in the cooler. The air temperature is set at a mean level which allow the temperature to be varied. The humidity of the air in the cooler/air lift is set at a mean value which allows the moisture loss between the 'hot' tobacco at the exit of the drier and the cool tobacco to be controlled.

The air temperature and cooler/air lift humidity may be controlled using conventional 1, 2 or 3 term feedback or closed loop process controllers.

Although several embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes may be made in the design and arrangement of the parts without departing from the spirit and scope of the invention as the same will now be understood by those skilled in the art.

WHAT WE CLAIM IS:-

1. A cylinder temperature control apparatus for a rotary drier of the king having a cylinder slightly inclined to the horizontal and heating means therefor by which the cylinder temperature (T) is variable, comprising converter means for receiving a rate of flow signal (F) and raising it to a power (K) adjustable from 0.1 to 1.0 according to the rate of flow, to control said cylinder temperature, said converter means operating so that T equals a constant plus a value proportional to F^K

2. A cylinder temperature control apparatus for rotary driers having a cylinder slightly inclined to the horizontal and heating means therefor, comprising converter means for receiving a rate of flow signal (F) and raising it to a power (K) adjustable from 0.1 to 1.0, according to the rate of flow, means for summing an initial moisture content signal (M) and a desired final moisture signal (S) to provide an output signal (M-S), means for multiplying the output signal (F^K) from said converter means by the output signal (M-S) from said summing means, amplifier means for receiving the output signal from said multiplying means for applying a gain (Q) representing the application factor (as hereinbefore defined), and further means for summing the output signal from said amplifier means with a bias constant (C) appropriate to the drier to be controlled, said further summing means producing an output signal (T), representing the required cylinder temperature, to control said heating means, said temperature control apparatus thereby operating in accordance with the formula $T = QF^K (M-S) + C$.

3. A cylinder temperature control apparatus for rotary driers of the kind having the cylinder slightly inclined to the horizontal and heating means therefore and serving to dry tobacco in the form of cut lamina and cut rolled stem, comprising a first summing means for summing two flow rate signals (F_L and F_S) representing respectively the flow rate of the cut lamina and the flow rate of the cut rolled stem to produce a combined flow rate signal (F), converter means for receiving said combined rate of flow signal (F) and raising it to a power (K) adjustable from 0.1 to 1.0 according to the rate of flow, a second summing means which receives a cut lamina initial moisture signal (M_L) and a cut rolled stem initial moisture signal (M_S) to produce an output signal (M_S-M_L) representing the difference between said moisture signals a divider which receives the cut rooled stem flow rate signal (F_S) and the combined flow rate signal (F) to produce an output signal ($\frac{F_S}{F}$) representing the cut rolled stem flow rate signal divided by the combined flow rate signal, a first multiplier for receiving the output signal ($\frac{F_S}{F}$) of the divider and the output signal (M_SM_L) of the second summing means to produce a signal ($\frac{F_S}{F}(M_S-M_L)$) representing the product of said divider output signal ($\frac{F_S}{F}$) and said second summing means output signal ($M_S - M_L$), a third summing means for receiving the cut lamina moisture signal (M_L) and the output signal ($\frac{F_S}{F}(M_S - M_L)$) of the first multiplier and for producing the sum (M) of the cut lamina moisture signal and the output signal of the first multiplier, meand for producing a signal (S) representing the desired final moisture content of the tobacco, a fourth summing means for summing the output signal (M) of the third summing means with the final moisture signal (S) to provide an output signal (M-S), a second multiplier for multiplying the output signal (F^K) from said converter means by the output signal (M-S) from said fourth summing means, an amplifier means for receiving the output signal from said second multiplier for applying a gain (Q) representing the application factor (as hereinbefore defined), and a fifth summing means for summing the output signal from said second amplifier means with a bias constant (C) appropriate to the drier to be controlled, said fifth summing means producing an output signal (T), representing the required cylinder

temperature, to control said heating means, said cylinder temperature control apparatus thereby operating in accordance with the formula $T = Q F^K (M-S) + C$ where $M = M_L + \frac{F_S}{F} (M_S - M_L)$ and $F = F_L + F_S$.

4. A temperature control apparatus as claimed in claim 2 or 3 wherein said converter means for raising the rate of flow signal to a power K has means for automatically varying the value of K according the flow rate comprising a non-linear generator having its input connected to the means for producing the signal (F) representing rate of flow and a log-antilog device having a first input for receiving said flow signal (F) and a second input for receiving the output signal (K) from the non-linear generator.

5. A temperature control apparatus in accordance with claim 4, wherein said bias signal (C) is derived at the output of a summer having a first input for receiving a constant bias adjustment signal and a second input for receiving a variable signal proportional to the exit temperature.

6. A method of controlling the temperature of the cylinder of a rotary drier of the kind having a cylinder slightly inclined to the horizontal, comprising producing a signal (F) representing the rate of flow of material into the drier, raising said rate of flow signal to a power (K) adjustable from 0.1 to 1.0, according to the rate of flow, to produce a modified signal (F^K) and controlling said heating means in accordance with said modified signal, so that the cylinder temperature (T) equals a constant plus a value proportional to F^K

7. A method of controlling the temperature of the cylinder of a rotary drier of the kind having the cylinder slightly inclined to the horizontal, comprising producing a signal (F) representing the rate of flow of material into the drier, raising said rate of flow signal to a power (K) variable from 0.1 to 1.0, producing a signal (M) representing the initial moisture content of the material fed to the drier, producing a signal (S) representing the desired final moisture content of the material, summing the input moisture content signal (M) and the desired final moisture signal (S) to produce an output signal (M-S) providing a product of the signal (F^K) having the power applied thereto and the summed signal (M-S) amplifying said product by an application factor (as hereinbefore defined) (Q) and summing the amplified signal with a bias constant (C) appropriate to the drier to be controlled to produce an output signal (T), representing the required cylinder temperature, for controlling said heating means, so that the cylinder temperature T varies in accordance with the formula $T = Q F^K (M-S) + C$.

8. A method of controlling the temperature (T) of the cylinder of a rotary drier of the king having the cylinder slightly inclined to the horizontal and serving to dry tobacco in the form of cut lamina and cut rolled stem comprising producing a first signal (F_L) representing the flow rate of the cut lamina, producing a second signal (F_S) representing the flow rate of the cut rolled stem, summing the two flow rate signals ($F_L + F_S$) to produce a combined flow rate signal (F), applying to said combined rate of flow signal (F) power (K) variable from 0.1 to 1.0, producing a first moisture signal (M_L), representing the initial moisture content of the cut lamina, producing a second moisture signal (M_S) representing the initial moisture content of the cut rolled stem, summing said first moisture signal (M_L) and said second moisture signal (M_S) to produce a final moisture signal (M_S-M_L) representing the difference between said moisture signals, effecting a division of said first flow rate signal (F_S) by said combined flow rate (F) to give a resultant signal ($\frac{F_S}{F}$) providing a product of the resultant signal ($\frac{F_S}{F}$) and the combined final moisture signal (M_S-M_L) summing said product with said second moisture signal (M_S), adding said resultant signal to a signal (S) representing the desired final moisture content of the tobacco, a signal resulting from this summing step being multiplied by a flow signal (F^K) to which a power (K) has been applied amplifying the product, said multiplying the step by an application factor (as hereinbefore defined) (Q) and summing the resulting amplified signal with a bias constant (c) appropriate to the drier to be controlled to produce an output signal (T), representing the required cylinder temperature, to control the cylinder temperature in accordance with the formula

$T = Q F^K (M-S) + C$ where $M = M_L + \frac{F_S}{F} (M_S-M_L)$, $F = F_L + F_S$.

9. A method in accordance with claim 8 wherein the power (K) is applied to said flow signal (F) automatically by means of a non-linear generator having its input connected to receive the flow signal (F) and its output connected to a log-antilog device having a first input for receiving said flow signal (F) and a second input for receiving the output signal (K) from the nonlinear generator.

10. A method in accordance with claim 9, wherein the bias signal comprises a constant bias adjustment signal and a variable signal proportional to the exit temperature.

11. A temperature control apparatus, substantially as described herein with reference to and as illustrated by the accompanying drawing.

12. An apparatus as claimed in claim 1, substantially as hereinbefore described.

13. A method as claimed in claim 6, substantially as hereinbefore described.

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1561303 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

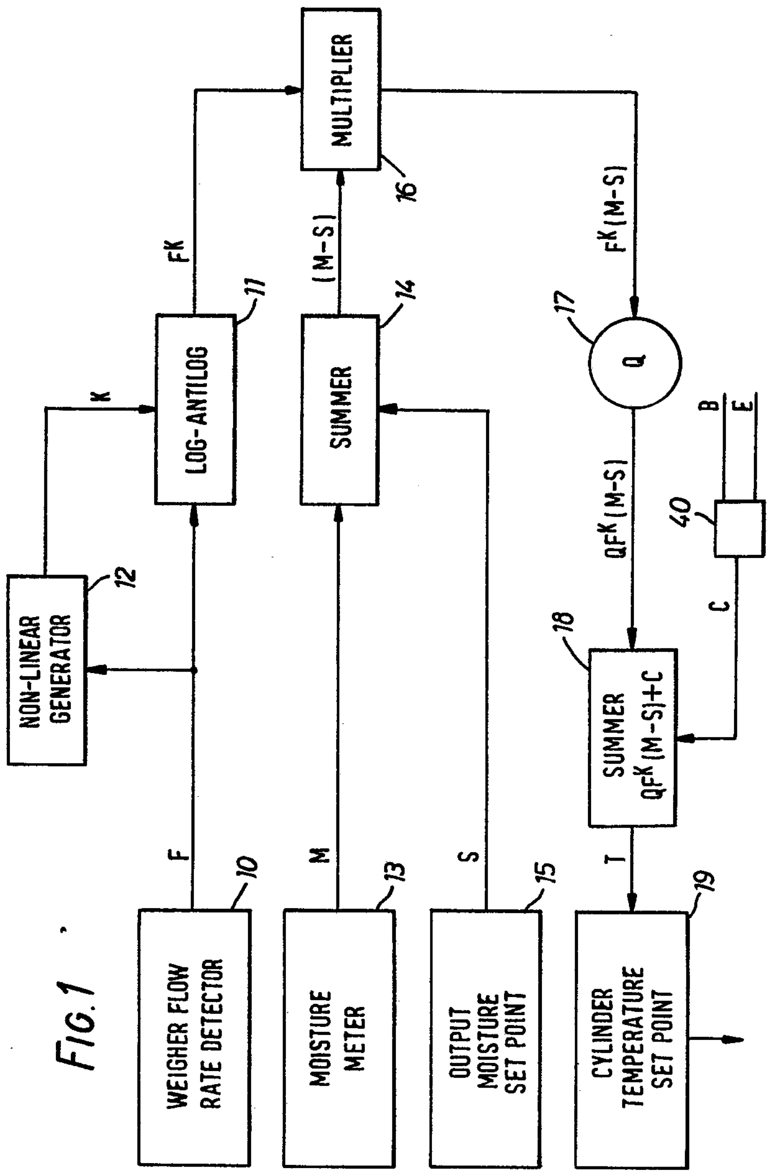
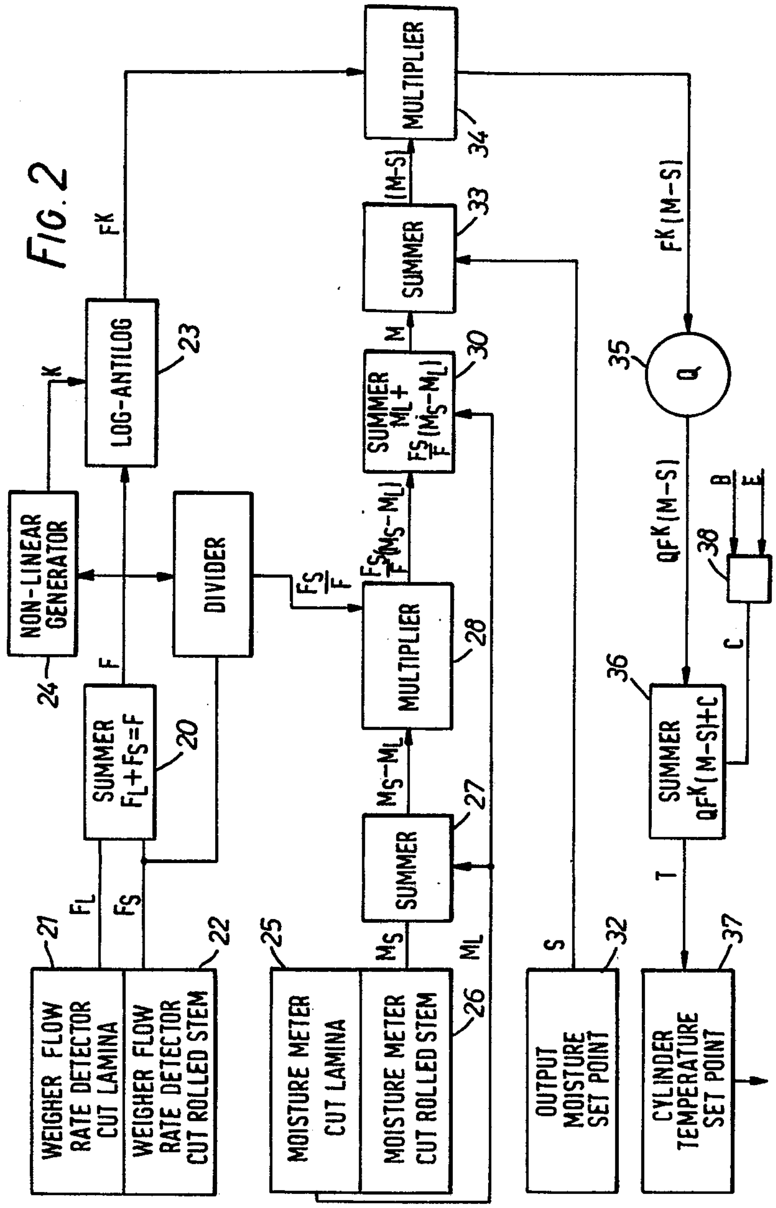


FIG.1

FIG. 2


WEIGHER FLOW RATE DETECTOR CUT LAMINA
WEIGHER FLOW RATE DETECTOR CUT ROLLED STEM
SUMMER $F_L+F_S=F$
NON-LINEAR GENERATOR
LOG-ANTILOG
DIVIDER
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MOISTURE METER CUT ROLLED STEM
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