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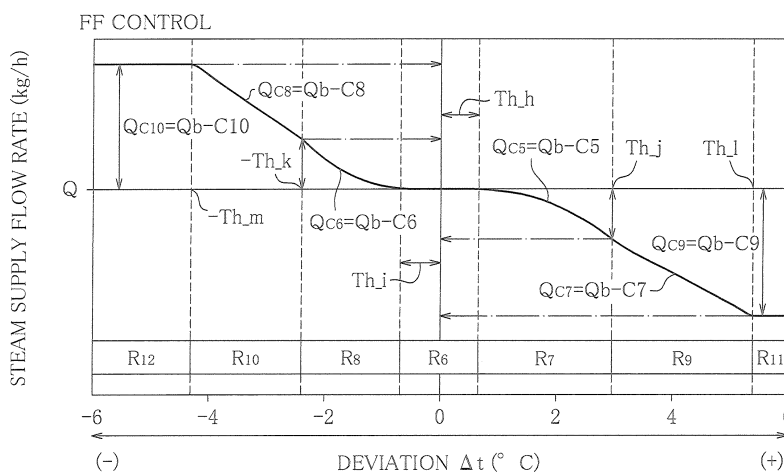
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(54) **METHOD FOR HUMIDIFYING STARTING TOBACCO MATERIAL**

(57) A moisture conditioning method is provided in which tobacco material and steam are supplied to the interior of a rotor to condition the moisture of the tobacco material while the tobacco material passes through the rotor. In the conditioning method, a deviation between the temperature of the tobacco material at the outlet of the rotor and a target temperature is obtained, and cascade control is performed on the supply flow rate of the

steam supplied to the rotor so as to eliminate the deviation. The cascade control includes a main control process having a plurality of control areas for controlling the supply flow rate based on a reference flow rate in the individual control areas, and a sub-control process executed in parallel with the main control process for changing the reference flow rate in accordance with an average value of the deviations within a fixed period.

FIG. 6



Description

Technical Field

5 [0001] The present invention relates to a moisture conditioning method suited for tobacco material such as leaf tobacco.

Background Art

10 [0002] Processing of leaf tobacco as tobacco material includes a moisture conditioning process for increasing the water content of the leaf tobacco. The moisture conditioning process is an important process whereby flexibility is imparted to the leaf tobacco prior to the removal of leafstalks from the leaf tobacco.

15 [0003] A moisture conditioning method in which the above moisture conditioning process is carried out is disclosed, for example, in Patent Document 1 identified below. The moisture conditioning method of Patent Document 1 includes measuring the initial water content, initial temperature and feed rate of leaf tobacco at the inlet of a moisture conditioning machine, as well as the water content and temperature of the conditioned leaf tobacco at the outlet of the moisture conditioning machine, and controlling the amounts of water and steam to be supplied to the leaf tobacco on the basis of the measurement results, to adjust the water content and temperature of the conditioned leaf tobacco to respective target values.

20 Citation List

Patent Literature

25 [0004] Patent Document 1: Japanese Examined Patent Publication No. S63-62185 (JP 1988-62185 B2)

Summary of Invention

Technical Problem

30 [0005] According to the moisture conditioning method disclosed in Patent Document 1, the water content of the conditioned leaf tobacco can be controlled to the target value, but it is necessary that the water content of the leaf tobacco should be measured at each of the inlet and outlet of the moisture conditioning machine. Considering that the purpose of moisture conditioning is to impart flexibility to leaf tobacco, the control of steam amount employed in the moisture conditioning method of Patent Document 1 is more complex than necessary.

35 [0006] An object of the present invention is to provide a moisture conditioning method whereby the water content of tobacco material can be increased with ease to impart required flexibility to the tobacco material.

Solution to Problem

40 [0007] The above object is achieved by a moisture conditioning method for tobacco material according to the present invention. In the moisture conditioning method of the invention, attention is directed to the outlet-side temperature of conditioned tobacco material, or outlet material temperature, and the amount of steam supply is controlled so as to maintain the outlet material temperature at a target temperature.

45 [0008] Specifically, the present invention provides a moisture conditioning method in which tobacco material and steam are supplied to an interior of a rotor to condition moisture of the tobacco material while the tobacco material passes through the interior of the rotor, the moisture conditioning method including:

a process of detecting an outlet material temperature of the tobacco material having just been discharged from an outlet of the rotor while the steam is supplied to the interior of the rotor at a supply flow rate;

50 a process of obtaining a first deviation between a target temperature of the tobacco material at the outlet of the rotor and the outlet material temperature; and

a main control process of controlling the supply flow rate based on a reference flow rate of the steam in accordance with the first deviation,

wherein the main control process includes

55 selecting a control area corresponding to the first deviation, from among a plurality of control areas demarcated according to magnitude and positivity/negativity of the first deviation, and

controlling the supply flow rate of the steam in accordance with a control procedure of the selected control area.

[0009] According to the above moisture conditioning method, during conditioning of the tobacco material, the outlet material temperature of the tobacco material is detected and the flow rate of the steam supplied to the interior of the rotor is controlled on the basis of the reference flow rate so as to make the outlet material temperature equal to the target temperature. Thus, the water content of the tobacco material can be easily increased by adjusting the outlet material temperature of the conditioned tobacco material to the target temperature.

[0010] Specifically, the main control process includes

a neutral area which is selected when the first deviation is between a positive first threshold and a negative second threshold and in which the supply flow rate is maintained at the reference flow rate,

a positive cubic function control area which is selected when the first deviation is greater than the first threshold and is less than or equal to a positive third threshold greater than the first threshold, and in which the supply flow rate is decreased from the reference flow rate in accordance with a corrective flow rate computed according to a cubic function of the first deviation, and

a negative cubic function control area which is selected when the first deviation is greater in magnitude than the negative second threshold and is less than or equal in magnitude to a negative fourth threshold greater in magnitude than the second threshold, and in which the supply flow rate is increased from the reference flow rate in accordance with a corrective flow rate computed according to a cubic function of the first deviation.

[0011] Where the control areas of the main control process include the positive and negative cubic function control areas, the cubic function control areas effectively serve to promptly compensate for an instantaneous change in the outlet material temperature.

[0012] Preferably, the main control process further includes

a positive linear function control area which is selected when the first deviation is greater than the positive third threshold and is less than or equal to a positive fifth threshold greater than the third threshold, and in which the supply flow rate is decreased from the reference flow rate in accordance with a corrective flow rate computed according to a linear function of the first deviation, and

a negative linear function control area which is selected when the first deviation is greater in magnitude than the negative fourth threshold and is less than or equal in magnitude to a negative sixth threshold greater in magnitude than the fourth threshold, and in which the supply flow rate is increased from the reference flow rate in accordance with a corrective flow rate computed according to a linear function of the first deviation.

[0013] Where the main control process further includes the positive and negative linear function control areas as its control areas, the linear function control areas each serve to increase and decrease the supply flow rate in accordance with the corrective flow rate proportional to the first deviation, so that the outlet material temperature can be quickly returned to the target temperature without suddenly changing the supply flow rate.

[0014] Further, the main control process preferably includes

a positive fixed value control area which is selected when the first deviation is greater than the positive fifth threshold and in which the supply flow rate is fixed at a lower-limit flow rate, and

a negative fixed value control area which is selected when the first deviation is greater in magnitude than the negative sixth threshold and in which the supply flow rate is fixed at an upper-limit flow rate.

[0015] The positive and negative fixed value control areas serve to prevent excessive decrease and increase of the supply flow rate.

[0016] Moreover, the moisture conditioning method of the present invention may further include a sub-control process executed in parallel with the main control process. The sub-control process includes a reference flow rate resetting control area repeated on a periodic basis, and the resetting control area includes resetting the reference flow rate in accordance with an average value of the first deviation within a fixed period.

[0017] Such feedback control serves to reduce the adverse influence exerted on the main control process by continuous change of the outlet material temperature, thereby stabilizing the control of the outlet material temperature by the main control process.

[0018] Preferably, the moisture conditioning method of the present invention may further include a start-up control process executed prior to the main control process. The start-up control process includes supplying the steam to the interior of the rotor with the supply flow rate set at a start-up flow rate higher than the reference flow rate.

[0019] The execution of the start-up control process is stopped when the first deviation becomes less than or equal to a seventh threshold, or when a second deviation between the target temperature and a temperature of the steam at the outlet of the rotor becomes less than or equal to an eighth threshold, or when a predetermined start-up period elapses

from start of the start-up control process.

[0020] Moreover, the moisture conditioning method of the present invention may further include a switching control process executed after the start-up control process and before the main control process. The switching control process includes selecting a switching control area corresponding to the first deviation, from among a plurality of switching control areas demarcated according to magnitude and positivity/negativity of the first deviation, and controlling the supply flow rate of the steam in accordance with a control procedure of the selected switching control area.

[0021] The above moisture conditioning method of the present invention is suited for the conditioning of leaf tobacco as the tobacco material.

Advantageous Effects of Invention

[0022] The moisture conditioning method for tobacco material according to the present invention involves only controlling the supply flow rate of the steam on the basis of the first deviation between the outlet material temperature of the tobacco material and the target temperature, and therefore, the outlet material temperature of the tobacco material can be easily adjusted to the target temperature. As a result, the conditioned tobacco material contains a sufficient amount of water.

Brief Description of Drawings

[0023]

FIG. 1 schematically illustrates a moisture conditioning machine for carrying out a moisture conditioning method of the present invention.

FIG. 2 is a functional block diagram illustrating functions of a moisture conditioning controller in FIG. 1.

FIG. 3 is a graph illustrating how an outlet material temperature of tobacco material and an outlet steam temperature change during a start-up control process.

FIG. 4 is a graph illustrating a plurality of control areas included in switching control.

FIG. 5 is a graph illustrating timing for the termination of the switching control.

FIG. 6 is a graph illustrating a plurality of control areas included in FF control.

FIG. 7 is a graph illustrating FB control executed in parallel with the FF control.

FIG. 8 illustrates how a deviation between a target temperature and the outlet material temperature is sampled and an average deviation is calculated for the FB control.

Description of Embodiments

[0024] Prior to the explanation of a moisture conditioning method for tobacco material according to the present invention, a moisture conditioning machine for carrying out the moisture conditioning method will be briefly described below with reference to FIG. 1.

[0025] The moisture conditioning machine is equipped with a cylindrical hollow rotor 10. The rotor 10 has a material inlet 12 for receiving leaf tobacco as tobacco material (hereinafter merely referred to as the material) and a material outlet 14 for discharging the material which has undergone moisture conditioning. The material is a mixture of a plurality of kinds of leaf tobacco, and the mixture is used to manufacture cigarettes of a specified brand.

[0026] The rotor 10 is rotatable in one direction. As the rotor 10 rotates, the material fed into the rotor 10 through the material inlet 12 is transferred within the rotor 10 toward the material outlet 14, and in the process of transfer, the material is conditioned with use of steam, more specifically, water vapor supplied to the interior of the rotor 10. The conditioned material is discharged from the material outlet 14 to a conveyance path and then is conveyed on the conveyance path toward a subsequent processing station (not shown).

[0027] The moisture conditioning machine is further provided with a steam supply path 16 for supplying steam to the rotor 10, and the supply path 16 includes the internal space of the rotor 10 as part thereof. Specifically, the supply path 16 has a steam inlet 18 and a steam outlet 20, both opening into the rotor 10. The steam inlet 18 is located on the same side as the material inlet 12, and the steam outlet 20 is located on the same side as the material outlet 14.

[0028] The supply path 16 has an upstream section extending from a steam supply source, more specifically, a boiler room, to the steam inlet 18 of the rotor 10, and a downstream section extending from the steam outlet 20 of the rotor 10. The upstream section of the supply path 16 has a diaphragm-type steam flow regulator 22 and a steam flowmeter 24 arranged therein, and the downstream section of the supply path 16 is open to the atmosphere at a terminal end thereof.

[0029] The steam flow regulator 22 and the steam flowmeter 24 are electrically connected to an arithmetic unit 26. The arithmetic unit 26 is supplied with a target value Q_0 of the steam flow rate to be supplied to the interior of the rotor 10 and an actual steam flow rate Q_a measured by the steam flowmeter 24, and controls operation of the steam flow

regulator 22 so that the actual steam flow rate Q_a may become equal to the target value Q_o .

[0030] A temperature sensor 28 is arranged at the material outlet 14 and measures an outlet material temperature T_a of the material discharged from the rotor 10. Also, a temperature sensor 30 is arranged in the downstream section of the supply path 16 and measures a discharge temperature T_s of the steam discharged from the rotor 10.

[0031] The outlet material temperature T_a and the discharged steam temperature T_s are supplied as electrical signals to an arithmetic unit 32, which then computes the target value Q_o of the steam flow rate on the basis of the outlet material temperature T_a , the discharged steam temperature T_s and various setting values and supplies the target value Q_o to the arithmetic unit 26. The setting values include values specific to the brand for which the material is used, the capacity of the rotor 10, and so forth.

[0032] As is clear from FIG. 2, the arithmetic unit 32 executes a start-up control process, a switching control process and a cascade control process in cooperation with the arithmetic unit 26. In the following, the control processes will be explained in detail.

Start-up Control Process

[0033] When the aforementioned moisture conditioning machine is put into operation, that is, when the material is fed into the rotor 10, the arithmetic unit 32 sets the target value Q_o of the steam flow rate (supply flow rate at which steam is supplied to the rotor 10) to a start-up flow rate Q_{st} (kg/h) and provides the start-up flow rate Q_{st} to the arithmetic unit 26. The start-up flow rate Q_{st} is an unambiguous value determined on the basis of the setting values mentioned above. Accordingly, during execution of the start-up control process, the actual steam flow rate Q_a is controlled to the start-up flow rate Q_{st} .

[0034] The start-up control process ends when any one of the following three transition conditions 1 to 3 is fulfilled.

[0035] Transition Condition 1: A deviation $\Delta t'$ ($= T_o - T_s$) between a target temperature T_o of the material at the material outlet 14 and the discharged steam temperature T_s is less than or equal to a threshold Th_a .

[0036] Transition Condition 2: A deviation Δt ($= T_o - T_a$) between the target material temperature T_o and the outlet material temperature T_a is less than or equal to a threshold Th_b .

[0037] Transition Condition 3: The time elapsed from the start of the start-up control process reaches $T1$.

[0038] The target temperature T_o is an unambiguous value set in accordance with the brand for which the material is used, and the thresholds Th_a and Th_b are, for example, 2°C and 5°C, respectively.

[0039] As is clear from FIG. 3, the discharged steam temperature T_s normally tends to rise more quickly than the outlet material temperature T_a , and therefore, by employing the transition condition 1 in addition to the transition condition 2, it is possible to quickly terminate the start-up control process. The transition condition 3 serves to prevent the duration of the start-up control process from being undesirably prolonged.

[0040] When any one of the transition conditions 1 to 3 is fulfilled, the arithmetic unit 32 terminates the start-up control process and then executes the switching control process described below.

Switching Control Process

[0041] First, the arithmetic unit 32 changes the target value Q_o of the steam flow rate from the start-up flow rate Q_{st} to a reference flow rate Q_b . The reference flow rate Q_b is smaller than the start-up flow rate Q_{st} and is an unambiguous value determined on the basis of the aforementioned setting values, like the start-up flow rate Q_{st} .

[0042] The arithmetic unit 32 includes a control map for the switching control, such as the one illustrated in FIG. 4. The control map has a plurality of control areas demarcated according to the magnitude and positivity/negativity of the aforementioned deviation Δt . Specifically, the control map has a neutral area R1, positive and negative cubic function control areas R2 and R3 defined on both sides of the neutral area R1, and positive and negative fixed value control areas R4 and R5 defined outside of the respective cubic function control areas R2 and R3.

[0043] When the deviation Δt fulfills the relationship indicated by the following expression, the neutral area R1 is selected.

$$-Th_d \leq \Delta t \leq Th_c$$

[0044] As is clear from FIG. 4, thresholds Th_c and $-Th_d$ are positive and negative small values, respectively, smaller than or equal in magnitude to 1°C. The threshold Th_c may be equal to $|-Th_d|$.

[0045] When the neutral area R1 is selected, the deviation Δt is small, and accordingly, the arithmetic unit 32 maintains the target value Q_o of the steam flow rate at the reference flow rate Q_b . Thus, in the neutral area R1, the actual supply flow rate Q_a is controlled to the reference flow rate Q_b .

[0046] When the deviation Δt fulfills the relationship indicated by the following expression, the positive cubic function control area R2 is selected.

$$Th_c < \Delta t \leq Th_e$$

[0047] A threshold Th_e is a positive value (e.g. 4°C) greater than the threshold Th_c .

[0048] When the cubic function control area R2 is selected, the arithmetic unit 32 computes a positive corrective flow rate C1 according to a cubic function $F1[(a1 \times \Delta t)^3]$ of the deviation Δt . In the formula, $a1$ represents a coefficient. Then, the arithmetic unit 32 changes the target value Qo of the steam flow rate to a supply flow rate $Qc1 (= Qb - C1)$ obtained by having the corrective flow rate C1 reflected in the reference flow rate Qb . Consequently, in the cubic function control area R2, the actual supply flow rate Qa is controlled to the supply flow rate $Qc1$.

[0049] Since the corrective flow rate C1 is calculated on the basis of the cubic function F1 of the deviation Δt , it increases along the cubic curve with increase in the deviation Δt . Thus, where the deviation Δt is small, the supply flow rate $Qc1$ is not so significantly smaller than the reference flow rate Qb , but as the deviation Δt becomes greater and greater, the supply flow rate $Qc1$ becomes much smaller than the reference flow rate Qb . As a result, the outlet material temperature Ta is effectively lowered according to the magnitude of the deviation Δt , toward the target temperature To .

[0050] On the other hand, when the deviation Δt fulfills the relationship indicated by the following expression, the negative cubic function control area R3 is selected.

$$-Th_f \leq \Delta t < -Th_d$$

[0051] A threshold $-Th_f$ is a negative value (e.g. about -3.2°C) greater than the threshold $-Th_d$.

[0052] When the cubic function control area R3 is selected, the arithmetic unit 32 computes a corrective flow rate C2 according to a cubic function $F2[(a2 \times \Delta t)^3]$ of the deviation Δt . In the formula, $a2$ represents a coefficient.

[0053] In this case, the arithmetic unit 32 changes the target value Qo of the steam flow rate to a supply flow rate $Qc2 (= Qb - C2)$ obtained by having the corrective flow rate C2 reflected in the reference flow rate Qb . Since the deviation Δt is in this case a negative value, the corrective flow rate C2 computed according to the cubic function F2 of the deviation Δt also assumes a negative value. In the cubic function control area R3, therefore, the supply flow rate $Qc2$, that is, the actual steam flow rate Qa is effectively increased according to the magnitude of the deviation Δt , with the result that the outlet material temperature Ta quickly rises toward the target temperature To .

[0054] In this manner, the cubic function is not only useful in effectively changing the outlet material temperature Ta toward the target temperature To but also facilitates handling of the positivity/negativity of the deviation Δt in the computation of the corrective flow rates C1 and C2.

[0055] Further, when the deviation Δt fulfills the relationship indicated by the following expression, the fixed value control area R4 is selected.

$$Th_e < \Delta t$$

[0056] In this case, the arithmetic unit 32 computes, as the target value Qo of the steam flow rate, a supply flow rate $Qc3$ according to the equation below.

$$Qc3 = Qb - C3 (= F1[(a1 \times Th_e)^3])$$

[0057] Consequently, in the fixed value control area R4, the actual steam flow rate Qa is controlled to the supply flow rate $Qc3$.

[0058] Since the corrective flow rate C3 is a positive value, the supply flow rate $Qc3$ is fixed at a minimum value, and with the supply flow rate $Qc3$ set in this manner, the outlet material temperature Ta is lowered toward the target temperature To .

[0059] On the other hand, when the deviation Δt fulfills the relationship indicated by the following expression, the negative fixed value control area R5 is selected.

$$\Delta t < -Th_f$$

5 **[0060]** In this case, the arithmetic unit 32 computes, as the target value Q_o of the steam flow rate, a supply flow rate Q_{c4} according to the following equation.

$$10 \quad Q_{c4} = Q_b - C4 \quad (= F2[a2 \times (-Th_f)^3])$$

[0061] Since the corrective flow rate $C4$ is a negative value, the supply flow rate Q_{c4} is fixed at a maximum value. Accordingly, in the fixed value control area $R5$, the actual steam flow rate Q_a is controlled to the supply flow rate Q_{c4} , with the result that the outlet material temperature T_a is quickly raised toward the target temperature T_o .

15 **[0062]** The aforementioned switching control ends when either one of the following transition conditions 4 and 5 is fulfilled.

[0063] Transition Condition 4: The deviation Δt is less than or equal to a threshold Th_g (see FIG. 5).

[0064] Transition Condition 5: The time elapsed from the start of the switching control reaches $T2$.

[0065] The threshold Th_g satisfies the relationship indicated by the following expression.

$$20 \quad Th_g < Th_a$$

[0066] When either the transition condition 3 or 4 is fulfilled, the arithmetic unit 32 terminates the switching control process and then executes the cascade control process described below.

25 Cascade Control Process

[0067] The cascade control process includes a feedforward (FF) control process as a main control process, and a feedback (FB) control process as a sub-control process. In the following, the FF control process and the FB control process will be explained.

30 FF Control Process

35 **[0068]** The arithmetic unit 32 further includes a control map for the FF control process, such as the one illustrated in FIG. 6. The control map has a plurality of control areas demarcated according to the magnitude and positivity/negativity of the deviation Δt . Specifically, the control map has a neutral area $R6$, positive and negative cubic function control areas $R7$ and $R8$ defined on both sides of the neutral area $R6$, positive and negative linear function control areas $R9$ and $R10$ defined outside of the respective cubic function control areas $R7$ and $R8$, and positive and negative fixed value control areas $R11$ and $R12$ defined outside of the respective linear function control areas $R9$ and $R10$.

40 **[0069]** When the deviation Δt fulfills the relationship indicated by the following expression, the neutral area $R6$ is selected.

$$45 \quad -Th_i \leq \Delta t \leq Th_h$$

[0070] As is clear from FIG. 6, thresholds Th_h and $-Th_i$ are positive and negative small values, respectively, smaller than or equal in magnitude to 1°C . The threshold Th_h may be equal to $|-Th_i|$.

50 **[0071]** When the neutral area $R6$ is selected, the deviation Δt is small, and accordingly, the arithmetic unit 32 maintains the target value Q_o of the steam flow rate at the reference flow rate Q_b . That is, in the neutral area $R6$, the actual steam flow rate Q_a is controlled to the reference flow rate Q_b .

[0072] When the deviation Δt fulfills the relationship indicated by the following expression, the positive cubic function control area $R7$ is selected.

$$55 \quad Th_h < \Delta t \leq Th_j$$

[0073] A threshold Th_j is a positive value (e.g. 3°C) greater than the threshold Th_h .

[0074] When the cubic function control area R7 is selected, the arithmetic unit 32 computes a positive corrective flow rate C5 according to a cubic function $F3[a1 \times \Delta t]^3$ of the deviation Δt and changes the target value Qo of the steam flow rate to a supply flow rate $Qc5 (= Qb - C5)$ by having the corrective flow rate C5 reflected in the reference flow rate Qb . Consequently, in the cubic function control area R7, the actual steam flow rate Qa is controlled to the supply flow rate $Qc5$.

[0075] On the other hand, when the deviation Δt fulfills the relationship indicated by the following expression, the negative cubic function control area R8 is selected.

$$-Th_k \leq \Delta t < -Th_i$$

[0076] A threshold $-Th_k$ is a negative value (e.g. about -2.5°C) greater in magnitude than the threshold $-Th_i$.

[0077] When the cubic function control area R8 is selected, the arithmetic unit 32 computes a negative corrective flow rate C6 according to a cubic function $F4[a2 \times \Delta t]^3$ of the deviation Δt and sets, as the target value Qo of the steam flow rate, a supply flow rate $Qc6 (= Qb - C6)$ obtained by having the corrective flow rate C6 reflected in the reference flow rate Qb . In the cubic function control area R8, therefore, the actual steam flow rate Qa is controlled to the supply flow rate $Qc6$.

[0078] As is clear from the above explanation of the switching control, since the corrective flow rates C5 and C6 are calculated according to the respective cubic functions F3 and F4 of the deviation Δt , the supply flow rates $Qc5$ and $Qc6$ are decreased or increased from the reference flow rate Qb according to the magnitude of the deviation Δt . As a result, the outlet material temperature Ta is effectively varied toward the target temperature To .

[0079] Also in this case, handling of the positivity/negativity of the deviation Δt in the computation of the corrective flow rates C5 and C6 is facilitated.

[0080] When the deviation Δt fulfills the relationship indicated by the following expression, the positive linear function control area R9 is selected.

$$Th_j < \Delta t \leq Th_l$$

[0081] A threshold Th_l is a value (e.g. 5.5°C) greater than Th_j .

[0082] When the linear function control area R9 is selected, the arithmetic unit 32 computes a positive corrective flow rate C7 according to a linear function $F5(b1 \times \Delta t)$ of the deviation Δt . In the formula, $b1$ represents a coefficient. Then, the arithmetic unit 32 sets, as the target value Qo of the steam flow rate, a supply flow rate $Qc7 (= Qb - C7)$ obtained by having the corrective flow rate C7 reflected in the reference flow rate Qb . Accordingly, in the linear function control area R9, the actual steam flow rate Qa is controlled to the supply flow rate $Qc7$.

[0083] On the other hand, when the deviation Δt fulfills the relationship indicated by the following expression, the negative linear function control area R10 is selected.

$$-Th_m \leq \Delta t < -Th_k$$

[0084] A threshold $-Th_m$ is a negative value (e.g. -4.3°C) greater in magnitude than $-Th_k$.

[0085] When the linear function control area R10 is selected, the arithmetic unit 32 computes a negative corrective flow rate C8 according to a linear function $F6(b2 \times \Delta t)$ of the deviation Δt . In the formula, $b2$ represents a coefficient. Then, the arithmetic unit 32 sets, as the target value Qo of the steam flow rate, a supply flow rate $Qc8 (= Qb - C8)$ obtained by having the corrective flow rate C8 reflected in the reference flow rate Qb . In the linear function control area R10, therefore, the actual steam flow rate Qa is controlled to the supply flow rate $Qc8$.

[0086] The corrective flow rates C7 and C8 are computed according to the respective linear functions F5 and F6 of the deviation Δt and, therefore, assume values proportional to the magnitude of the deviation Δt . Thus, the supply flow rates $Qc7$ and $Qc8$ are decreased or increased in accordance with the deviation Δt . As a result, the outlet material temperature Ta is quickly varied toward the target temperature To .

[0087] Further, when the deviation Δt fulfills the relationship indicated by the following expression, the positive fixed value control area R11 is selected.

$$Th_l < \Delta t$$

[0088] In this case, the arithmetic unit 32 computes a supply flow rate Qc9 according to the following equation, and sets the computed supply flow rate Qc9 as the target value Qo of the steam flow rate.

$$Qc9 = Qb - C9 (= F5(b1 \times Th_l))$$

[0089] In the equation, a corrective flow rate C9 is a positive value. Accordingly, the supply flow rate Qc9 is fixed at a minimum value, and the outlet material temperature Ta is lowered toward the target temperature To.

[0090] On the other hand, when the deviation Δt fulfills the relationship indicated by the following expression, the negative fixed value control area R12 is selected.

$$\Delta t < -Th_m$$

[0091] In this case, the arithmetic unit 32 computes a supply flow rate Qc10 according to the following equation, and sets the computed supply flow rate Qc10 as the target value Qo of the steam flow rate.

$$Qc10 = Qb - C10 (= F6(b2 \times -Th_m))$$

[0092] In the equation, a corrective flow rate C10 is a negative value, and therefore, the supply flow rate Qc10 is fixed at a maximum value, with the result that the outlet material temperature Ta is raised toward the target temperature To.

[0093] In the aforementioned FF control process, the moisture conditioning for the material is carried out by causing the outlet material temperature Ta to become equal to the target temperature To, and thus the material can easily be made to have a required water content after being conditioned.

[0094] Also, the combination of the cubic function control areas R7 and R8 and the linear function control areas R9 and R10 makes it possible to promptly eliminate instantaneous change of the outlet material temperature Ta and stably maintain the outlet material temperature Ta at the target temperature To.

[0095] Further, since the control areas of the FF control process include the positive and negative fixed value control areas R11 and R12, the flow rate of the steam supplied to the rotor 10 is not excessively increased even if the deviation Δt is large.

[0096] Furthermore, even if the initial water content or feed rate of the material fed to the material inlet 12 of the rotor 10 is changed, such change exerts no influence upon the execution of the FF control process, and the outlet material temperature Ta can be controlled to the target temperature To.

[0097] The FF control process may include a predetermined transitional standby time provided at the transition from the cubic function control area R7 to the linear function control area R9 and at the transition from the cubic function control area R8 to the linear function control area R10.

FB Control Process

[0098] As illustrated in FIG. 7, the FB control process is executed in parallel with the aforementioned FF control process.

[0099] Specifically, the arithmetic unit 32 starts the FB control process after a lapse of a predetermined standby time T3 from the start of the cascade control process.

[0100] After the FB control process is started, the arithmetic unit 32 repeatedly samples the deviation Δt at regular intervals during a predetermined computation period T4, and computes an average deviation Δt_av of the deviations Δt sampled during the computation period T4.

[0101] Let it be assumed that the deviation Δt changes as shown in (a), (b) and (c) of FIG. 8 within the computation period T4. In the case (a) of FIG. 8, the average deviation Δt_av is "0", and in the cases (b) and (c) of FIG. 8, the average deviation Δt_av assumes values +d and -d, respectively.

[0102] When the average deviation Δt_av is obtained in this manner, the arithmetic unit 32 computes a positive or negative corrective flow rate C11 for the reference flow rate Qb on the basis of the average deviation Δt_av , and resets the reference flow rate Qb to a new reference flow rate Qb' with use of the corrective flow rate C11.

[0103] Specifically, the reference flow rate Q_b' is obtained according to the following assignment expression.

$$Q_b' \leftarrow Q_b - C_{11}$$

[0104] The reference flow rate Q_b' becomes effective at the time when the next FB execution period (resetting control area) T5 starts following the end of the computation period T4, and is used in the aforementioned FF control process. The computation of the corrective flow rate C11 in the computation period T4 and the resetting of the reference flow rate Q_b' in the FB execution period T5 are thereafter repeatedly executed.

[0105] As is clear from FIG. 7, by virtue of the FB control process, the reference flow rate Q_b is reset to the reference flow rate Q_b' in response to a continuous slight change of the outlet material temperature T_a . This enables the FF control process to maintain the outlet material temperature T_a at the target temperature T_o with higher accuracy and stability by using the reference flow rate Q_b' . Thus, the combination of the FB control process and the FF control process, namely, the cascade control process enables excellent moisture conditioning of the material based on the outlet material temperature T_a .

[0106] The present invention is not limited to the moisture conditioning method of the above embodiment and may be modified in various ways.

[0107] For example, various temperature values are mentioned in the above explanation of the start-up control process, the switching control process and the cascade control process, but the temperature values are given by way of example only and may be changed as needed.

[0108] Also, when the type of material fed into the rotor 10 is changed from one to another, that is, when the target temperature T_o is changed during the moisture conditioning, the moisture conditioning method of the present invention is started from the switching control process, as indicated by the dashed line in FIG. 2.

[0109] Further, the material to be used is not limited to leaf tobacco, and the moisture conditioning method of the present invention is applicable to a variety of materials.

Reference Signs List

[0110] 10: rotor; 12: material inlet; 14: material outlet; 16: steam supply path; 18: steam inlet; 20: steam outlet; 22: steam flow regulator; 24: steam flowmeter; 26: arithmetic unit; 28: temperature sensor; 30: temperature sensor; 32: arithmetic unit; R6: neutral area; R7, R8: cubic function control area; R9, R10: linear function control area; R11, R12: fixed value control area; T4: computation period; T5: FB execution period

Claims

1. A moisture conditioning method for tobacco material, in which the tobacco material and steam are supplied to an interior of a rotor to condition moisture of the tobacco material while the tobacco material passes through the interior of the rotor, comprising:

a process of detecting an outlet material temperature of the tobacco material having just been discharged from an outlet of the rotor while the steam is supplied to the interior of the rotor at a supply flow rate;

a process of obtaining a first deviation between a target temperature of the tobacco material at the outlet of the rotor and the outlet material temperature; and

a main control process of controlling the supply flow rate based on a reference flow rate of the steam in accordance with the first deviation,

wherein said main control process includes

selecting a control area corresponding to the first deviation, from among a plurality of control areas demarcated according to magnitude and positivity/negativity of the first deviation, and

controlling the supply flow rate of the steam in accordance with a control procedure of the selected control area.

2. The moisture conditioning method according to claim 1, wherein the control areas include

a neutral area which is selected when the first deviation is between a positive first threshold and a negative second threshold and in which the supply flow rate is maintained at the reference flow rate,

a positive cubic function control area which is selected when the first deviation is greater than the first threshold and is less than or equal to a positive third threshold greater than the first threshold, and in which the supply flow rate is decreased from the reference flow rate in accordance with a corrective flow rate computed according to a cubic

function of the first deviation, and

a negative cubic function control area which is selected when the first deviation is greater in magnitude than the negative second threshold and is less than or equal in magnitude to a negative fourth threshold greater in magnitude than the second threshold, and in which the supply flow rate is increased from the reference flow rate in accordance with a corrective flow rate computed according to a cubic function of the first deviation.

3. The moisture conditioning method according to claim 2, wherein the control areas further include a positive linear function control area which is selected when the first deviation is greater than the positive third threshold and is less than or equal to a positive fifth threshold greater than the third threshold, and in which the supply flow rate is decreased from the reference flow rate in accordance with a corrective flow rate computed according to a linear function of the first deviation, and a negative linear function control area which is selected when the first deviation is greater in magnitude than the negative fourth threshold and is less than or equal in magnitude to a negative sixth threshold greater in magnitude than the fourth threshold, and in which the supply flow rate is increased from the reference flow rate in accordance with a corrective flow rate computed according to a linear function of the first deviation.
4. The moisture conditioning method according to claim 1, wherein the control areas further include a positive fixed value control area which is selected when the first deviation is greater than the positive fifth threshold and in which the supply flow rate is fixed at a lower-limit flow rate, and a negative fixed value control area which is selected when the first deviation is greater in magnitude than the negative sixth threshold and in which the supply flow rate is fixed at an upper-limit flow rate.
5. The moisture conditioning method according to claim 1, further comprising a sub-control process executed in parallel with said main control process, wherein said sub-control process includes a reference flow rate resetting control area repeated on a periodic basis, and the resetting control area includes resetting the reference flow rate in accordance with an average value of the first deviation within a fixed period.
6. The moisture conditioning method according to claim 1, further comprising a start-up control process executed prior to said main control process, wherein said start-up control process includes supplying the steam to the interior of the rotor with the supply flow rate set at a start-up flow rate higher than the reference flow rate.
7. The moisture conditioning method according to claim 6, wherein execution of said start-up control process is stopped when the first deviation becomes less than or equal to a seventh threshold, or when a second deviation between the target temperature and a temperature of the steam at the outlet of the rotor becomes less than or equal to an eighth threshold, or when a predetermined start-up period elapses from start of said start-up control process.
8. The moisture conditioning method according to claim 1, further comprising a switching control process executed after said start-up control process and before said main control process, wherein said switching control process includes selecting a switching control area corresponding to the first deviation, from among a plurality of switching control areas demarcated according to magnitude and positivity/negativity of the first deviation, and controlling the supply flow rate of the steam in accordance with a control procedure of the selected switching control area.
9. The moisture conditioning method according to claim 1, wherein the tobacco material is leaf tobacco.

FIG. 1

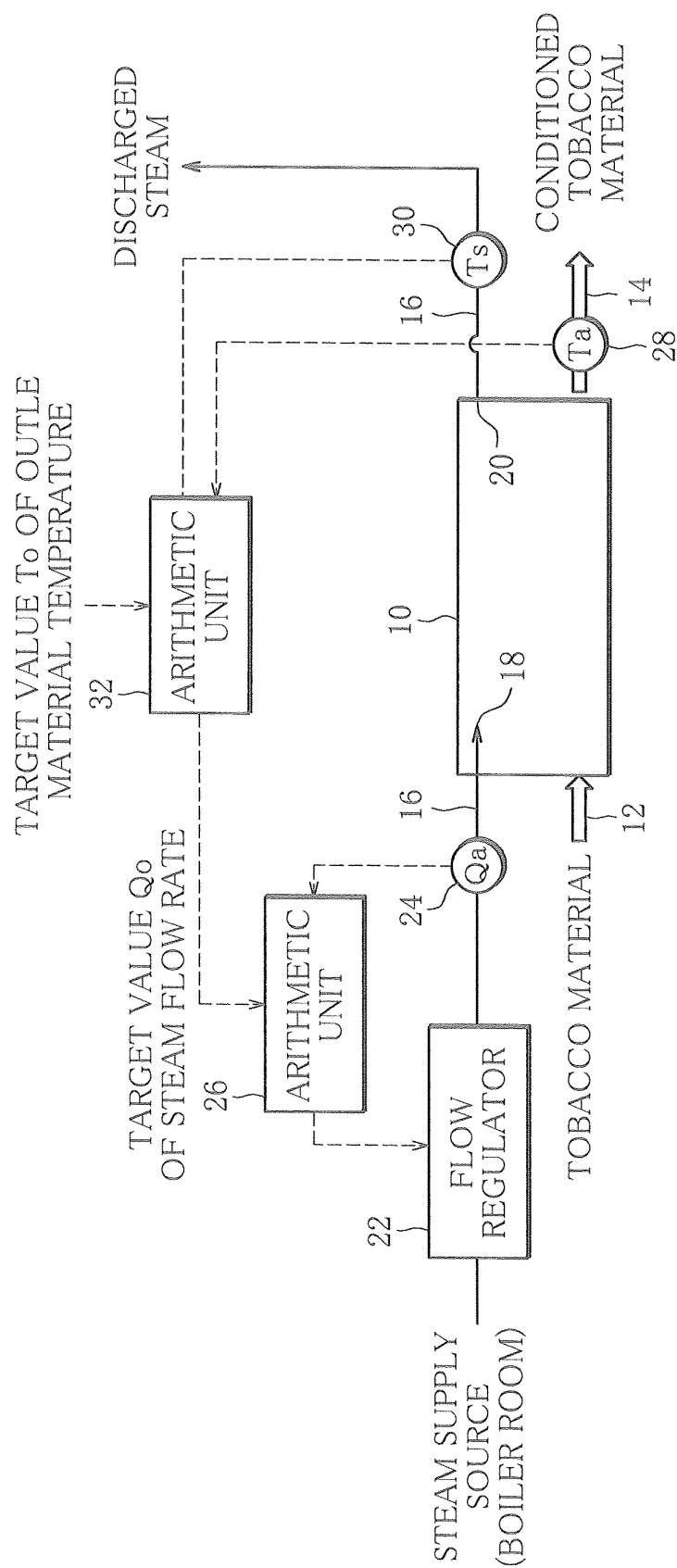


FIG. 2

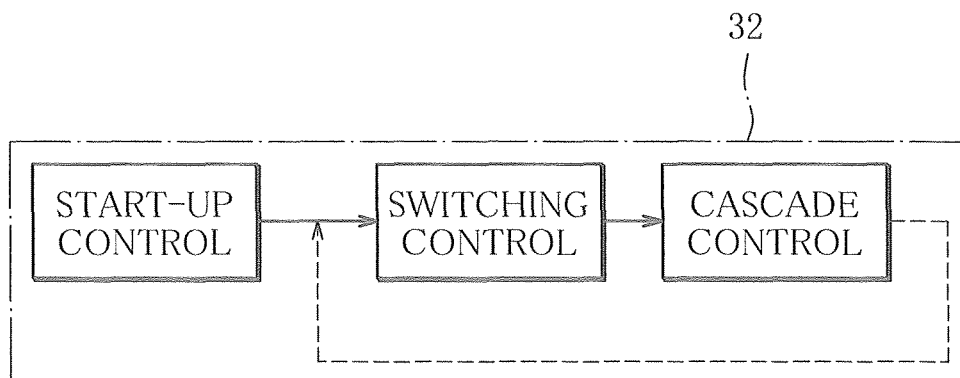


FIG. 3

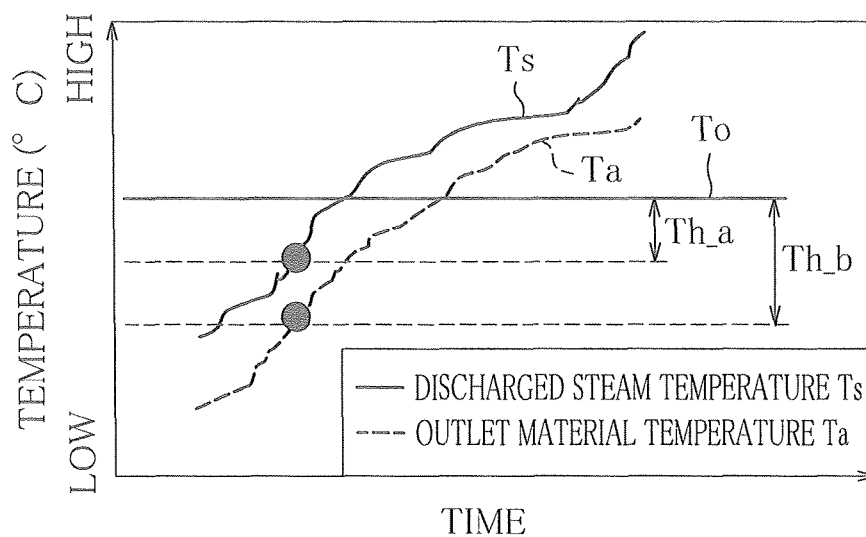


FIG. 4

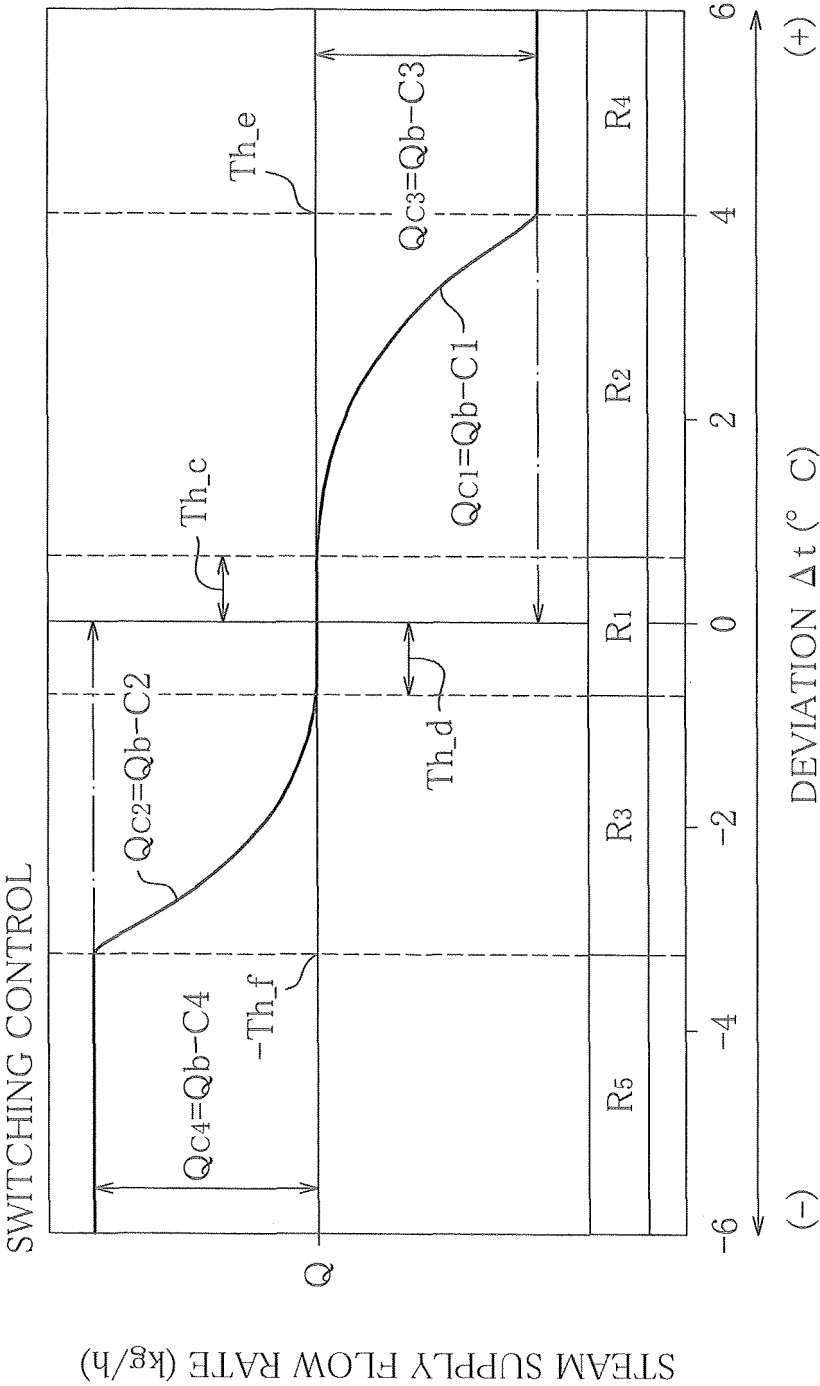


FIG. 5

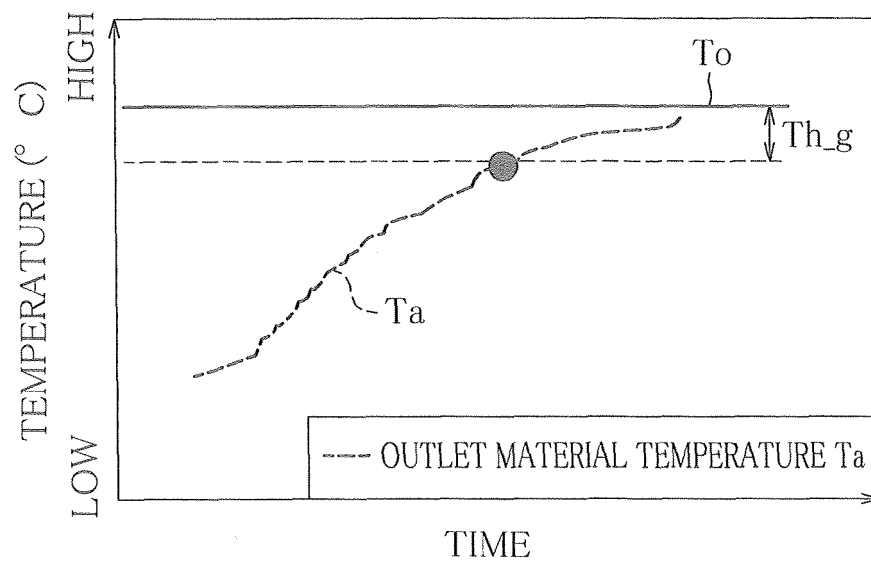


FIG. 6

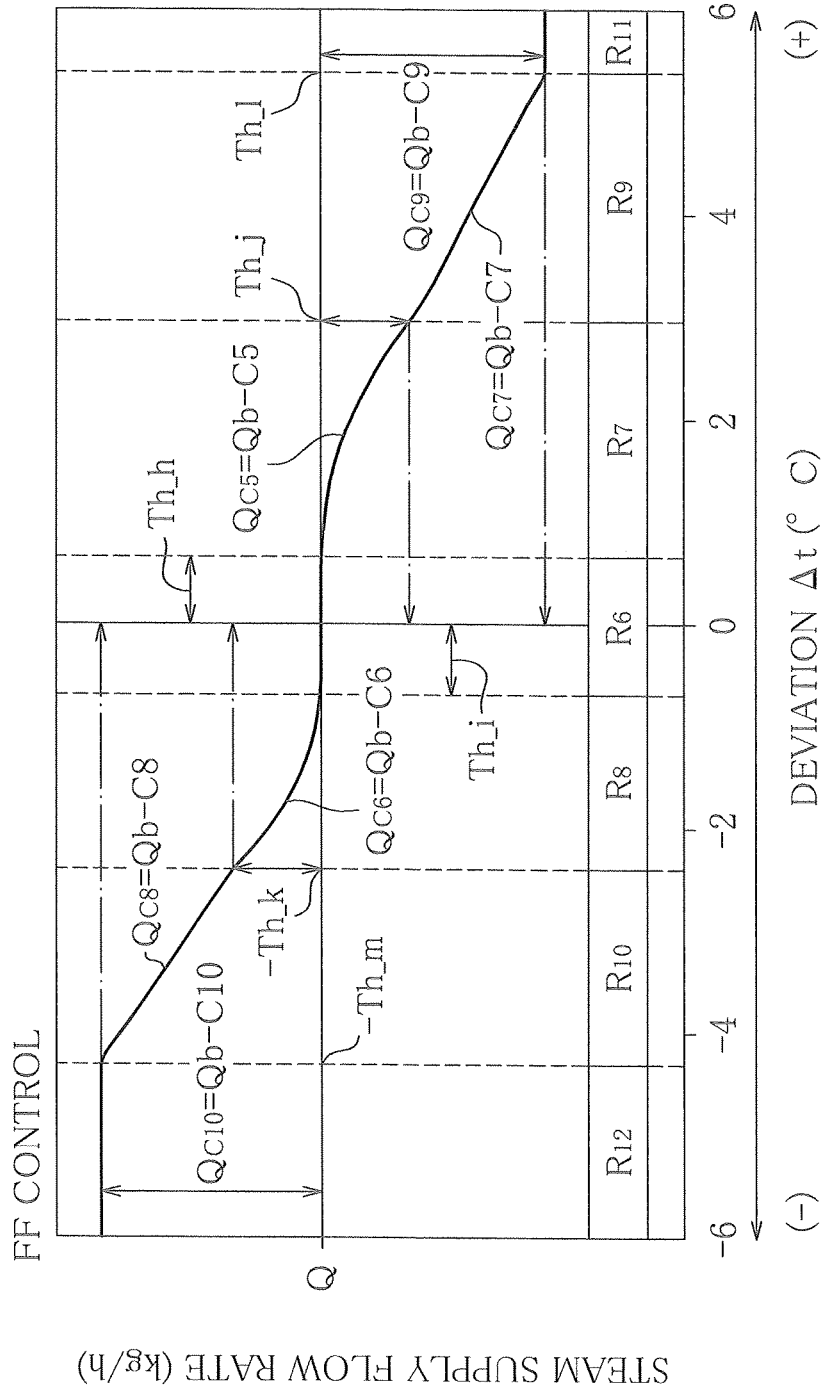


FIG. 7

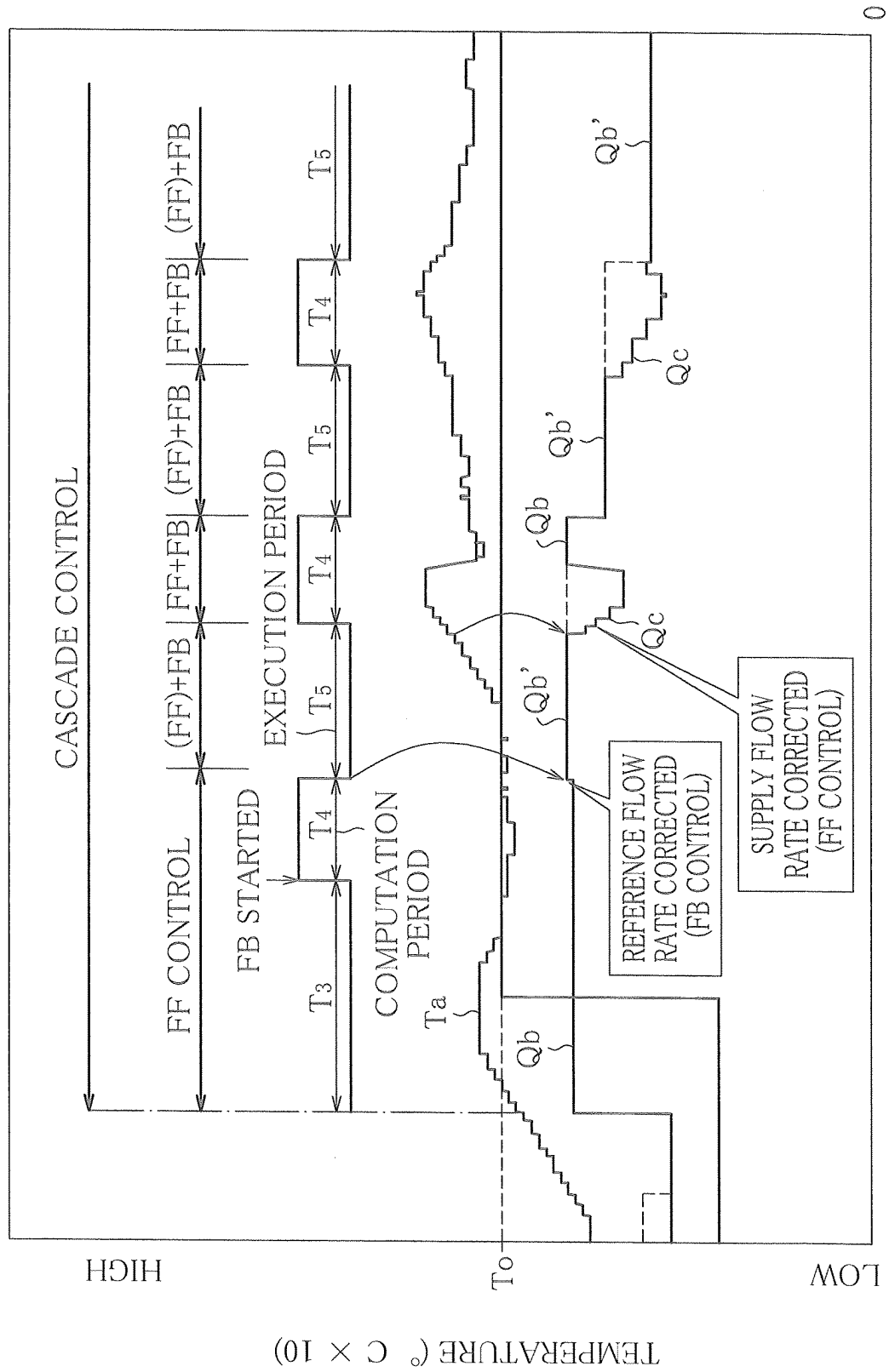
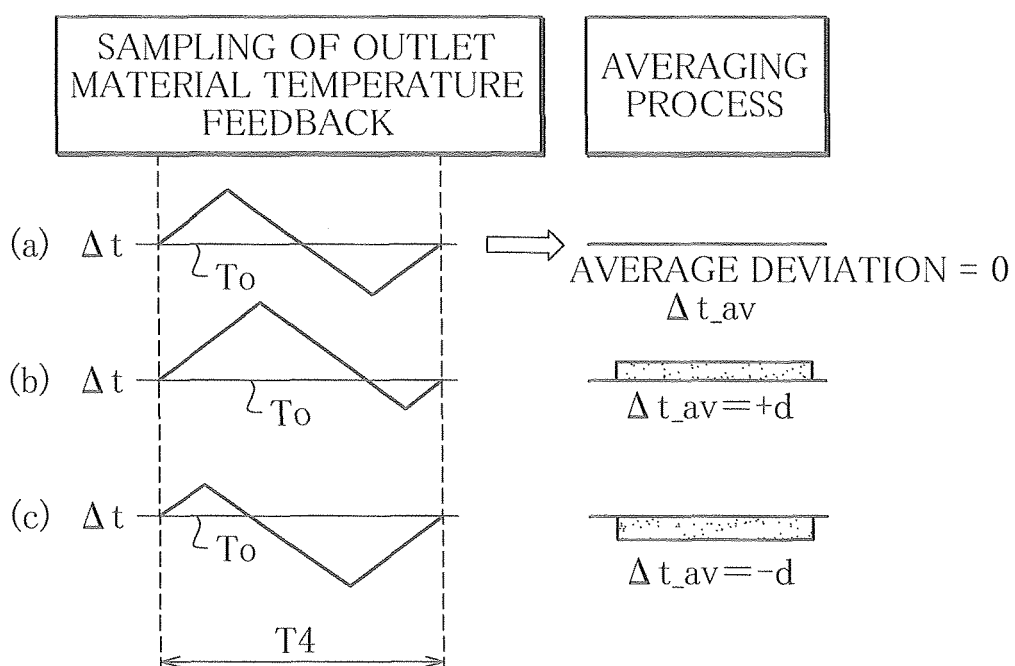


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/056716

A. CLASSIFICATION OF SUBJECT MATTER

A24B3/02 (2006.01) i, A24B3/12 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A24B3/02, A24B3/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 63-062185 B2 (Japan Tobacco Inc.), 01 December 1988 (01.12.1988), entire text; all drawings & JP 60-24171 A & US 4709708 A & EP 135281 A2	1-9
A	JP 62-019149 B2 (Japan Tobacco Inc.), 27 April 1987 (27.04.1987), claim 1; fig. 1 to 3 & JP 61-85182 A	1-9
A	EP 1273240 A2 (GARBUIO S.p.A.), 08 January 2003 (08.01.2003), entire text; all drawings & DE 60203069 D & DE 60203069 T & IT TV20010086 A & IT TV20010086 D0	1-9



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

28 June, 2012 (28.06.12)

Date of mailing of the international search report

10 July, 2012 (10.07.12)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP S6362185 B [0004]
- JP 63062185 B [0004]