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(54) **AEROSOL GENERATING DEVICE,
CONTROL METHOD AND STORAGE
MEDIUM**

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(57) **ABSTRACT**

An aerosol generating device includes a power supply that supplies electric power to a heating unit, and a control unit that controls the supply of electric power in accordance with a control sequence consisting of sections including a first section and a second section. The control sequence designates a first time length for the first section and a second time length for the second section. The control unit terminates the first section when the temperature of the heating unit has reached a predetermined temperature and, in a case of terminating the first section earlier than a first time point, continues the second section over a total time of a residual time until the first time point and the second time length.

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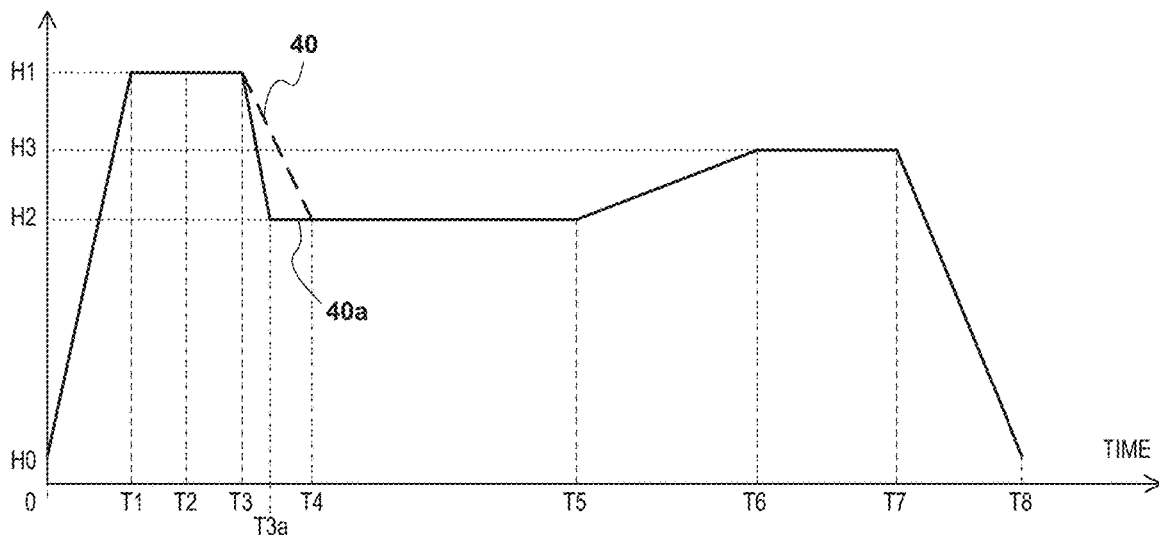
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(63) Continuation of application No. PCT/JP2022/
006894, filed on Feb. 21, 2022.

(30) **Foreign Application Priority Data**

Apr. 28, 2021 (JP) 2021-076017

TEMPERATURE



← S4

ADD

FIG. 1

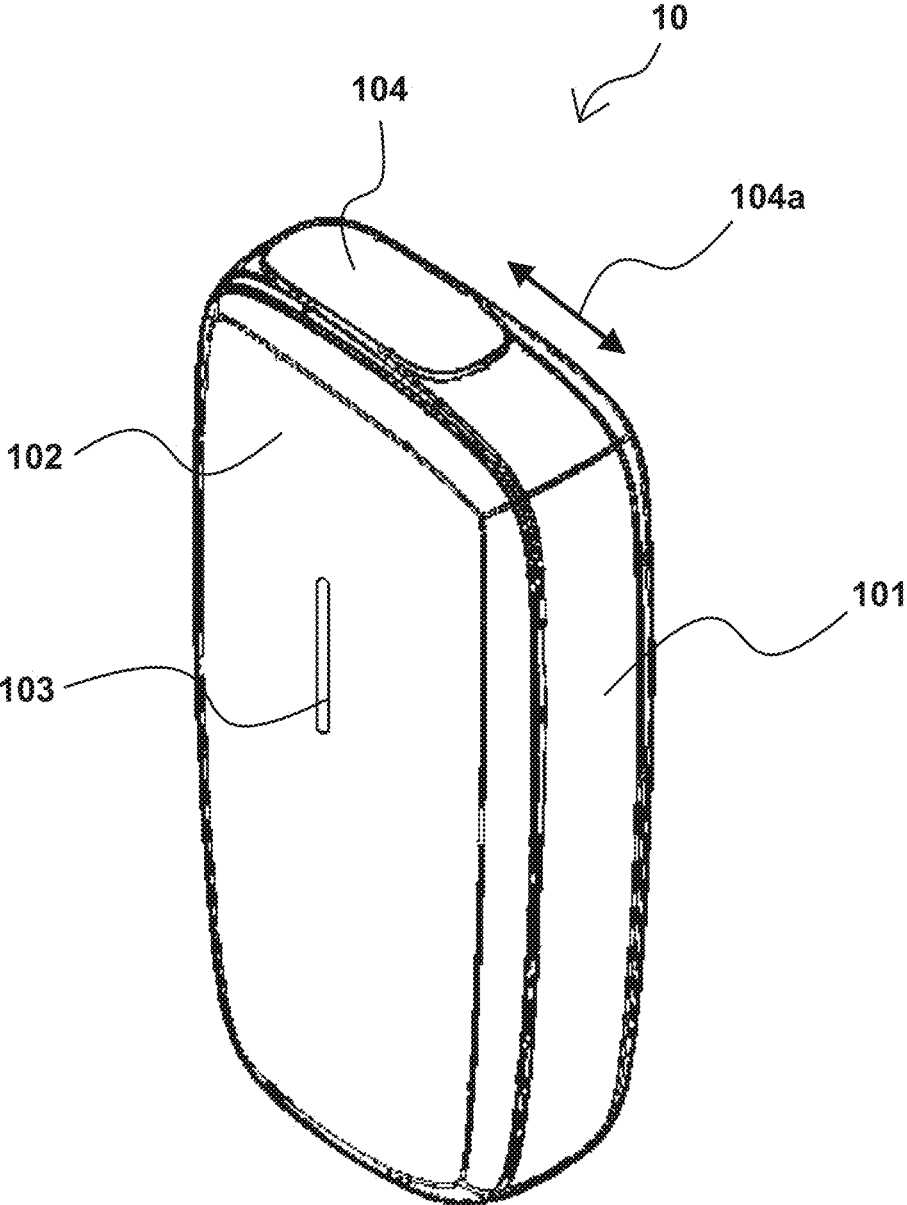


FIG. 2

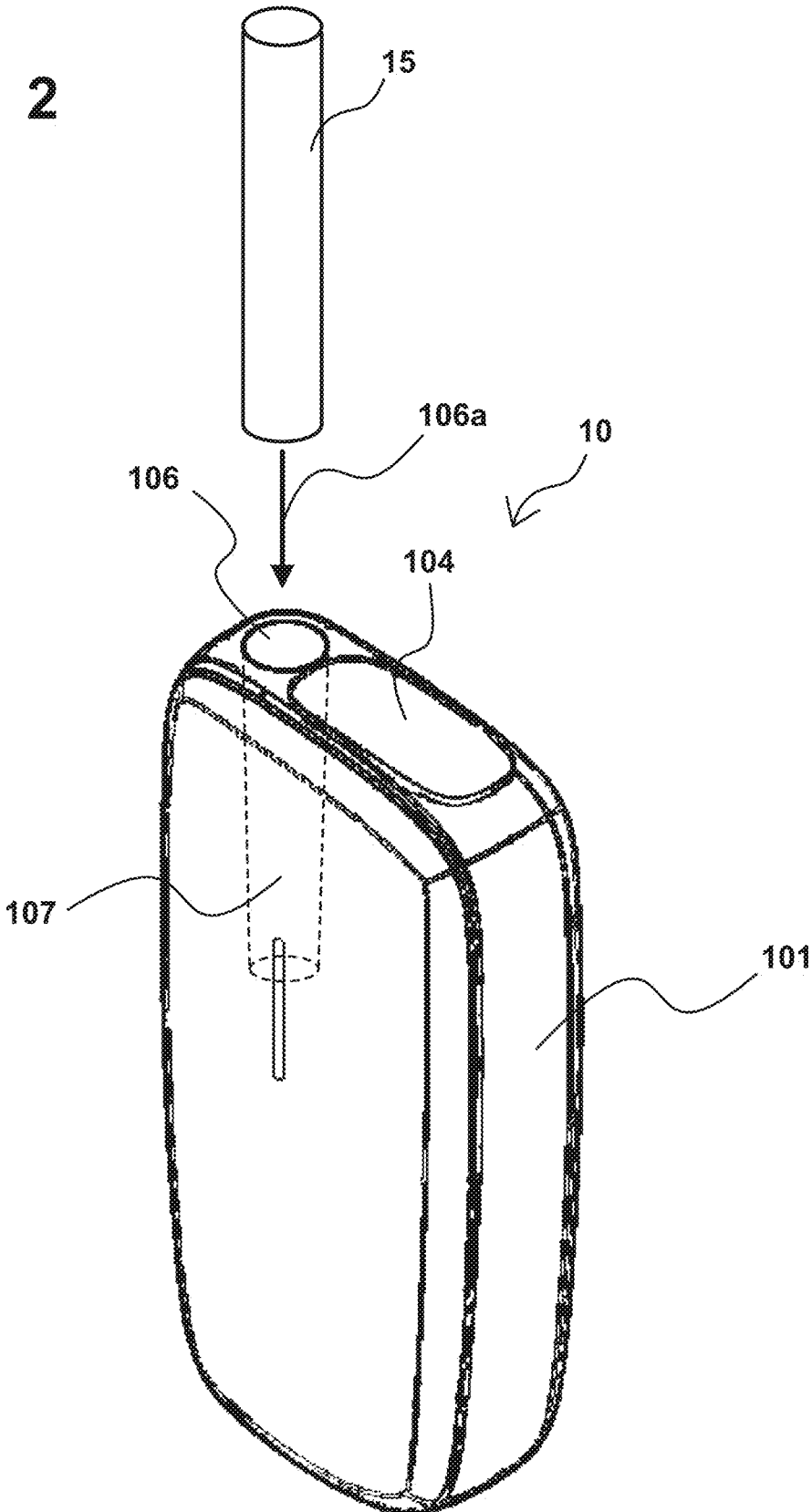
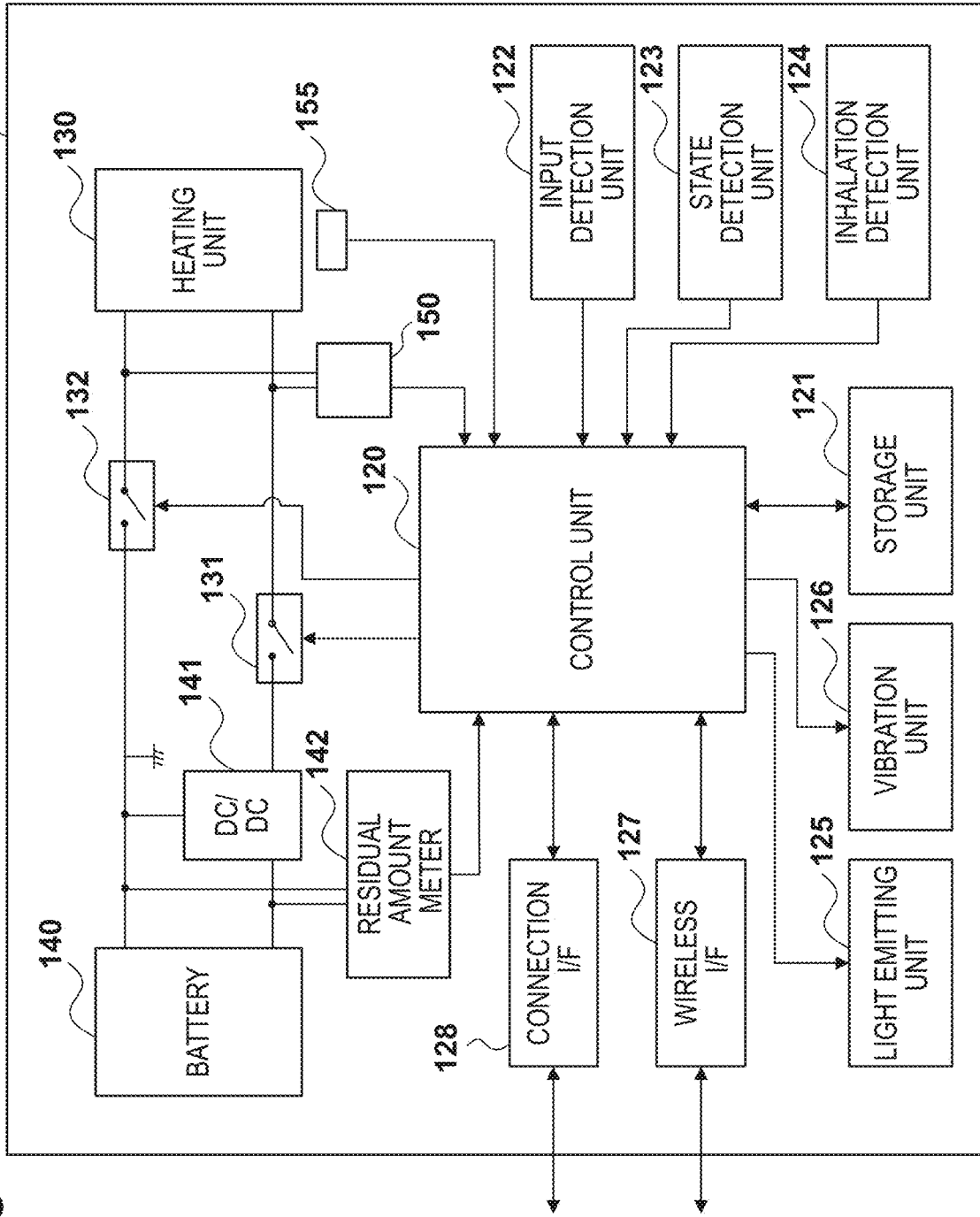


FIG. 3



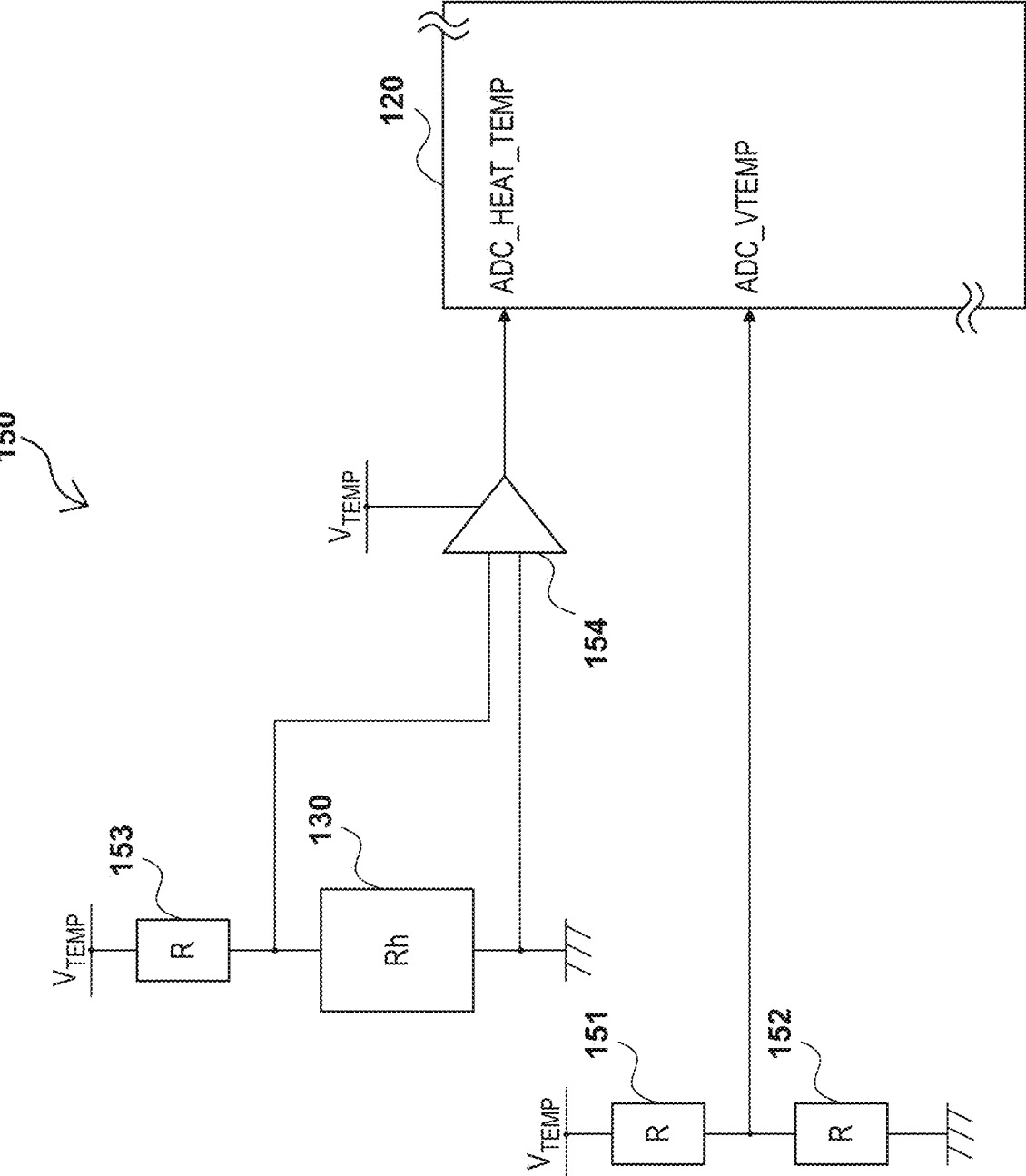


FIG. 4

FIG. 5

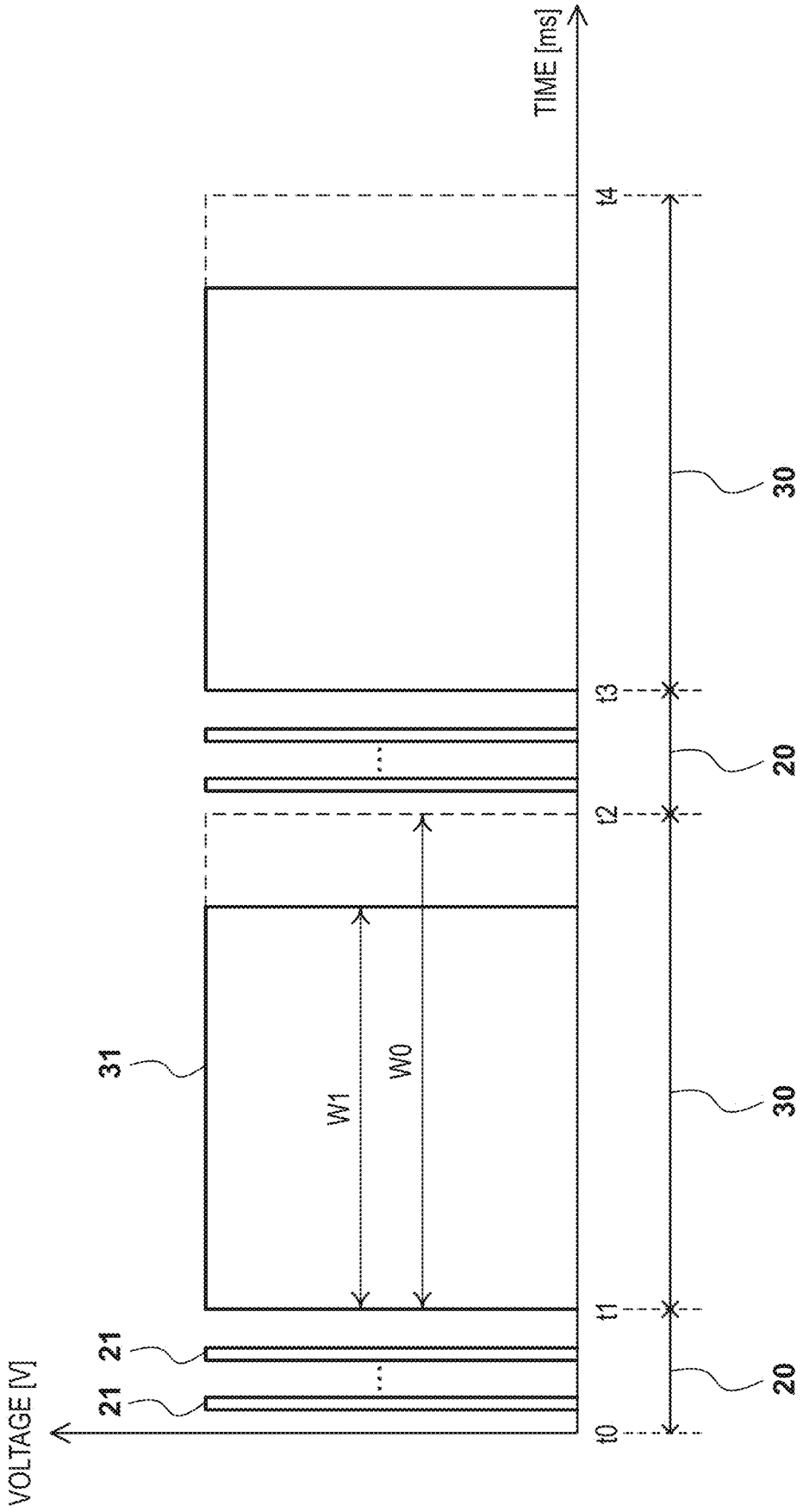
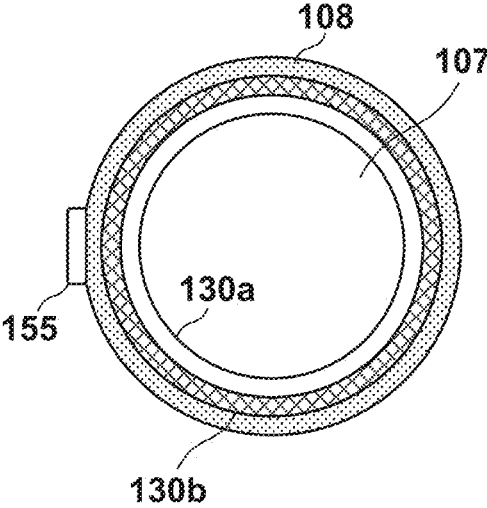


FIG. 6



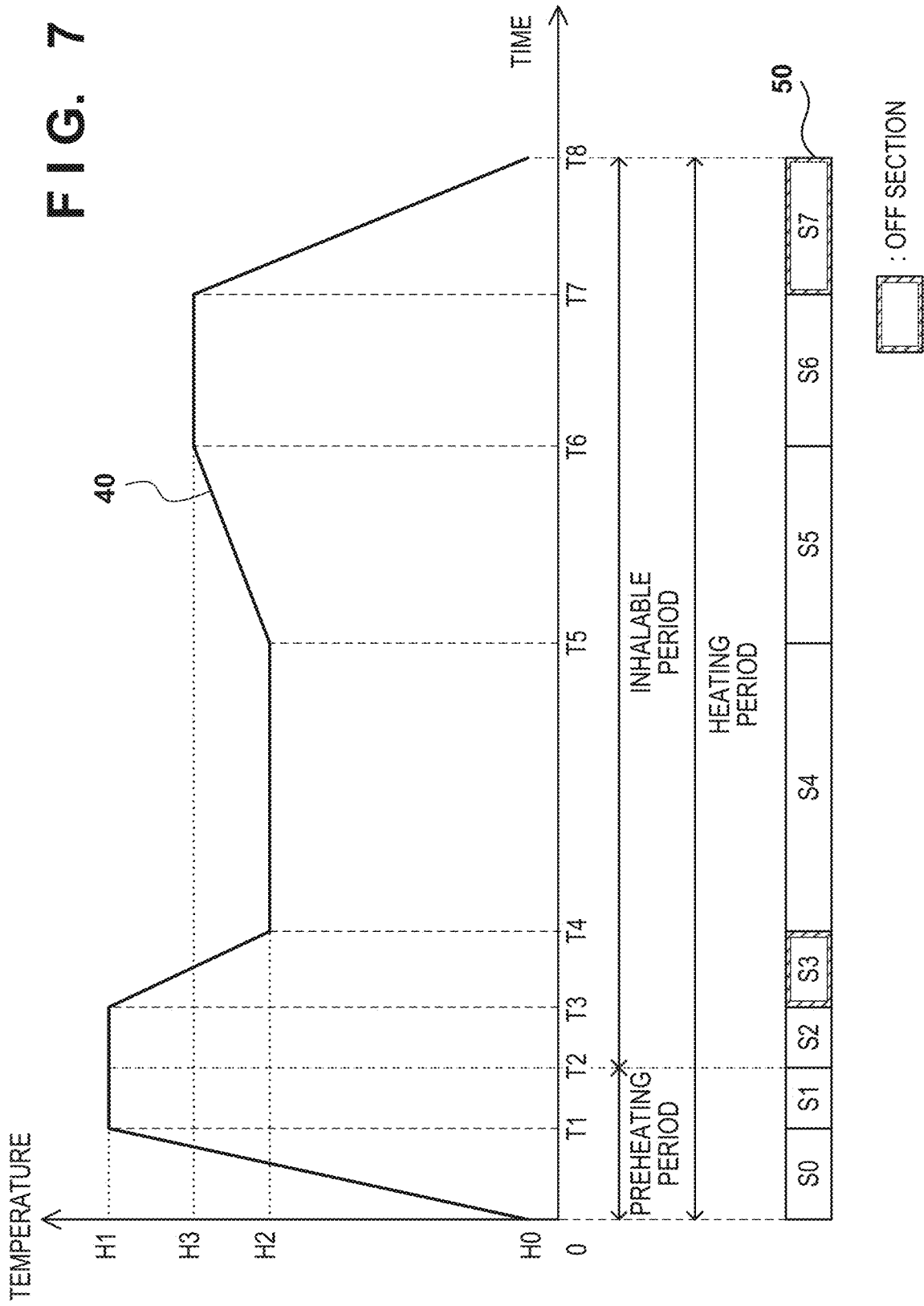


FIG. 8

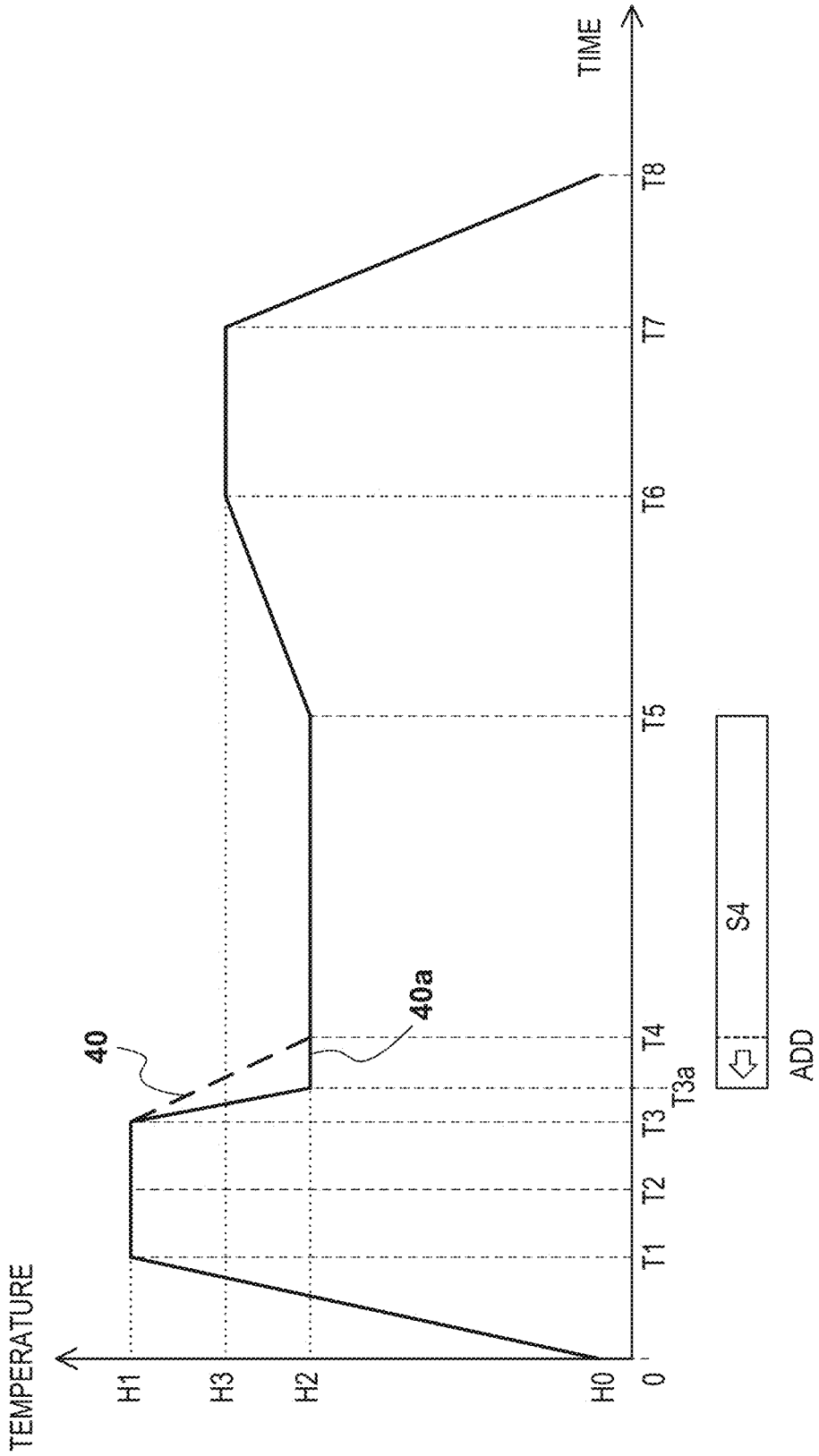


FIG. 9

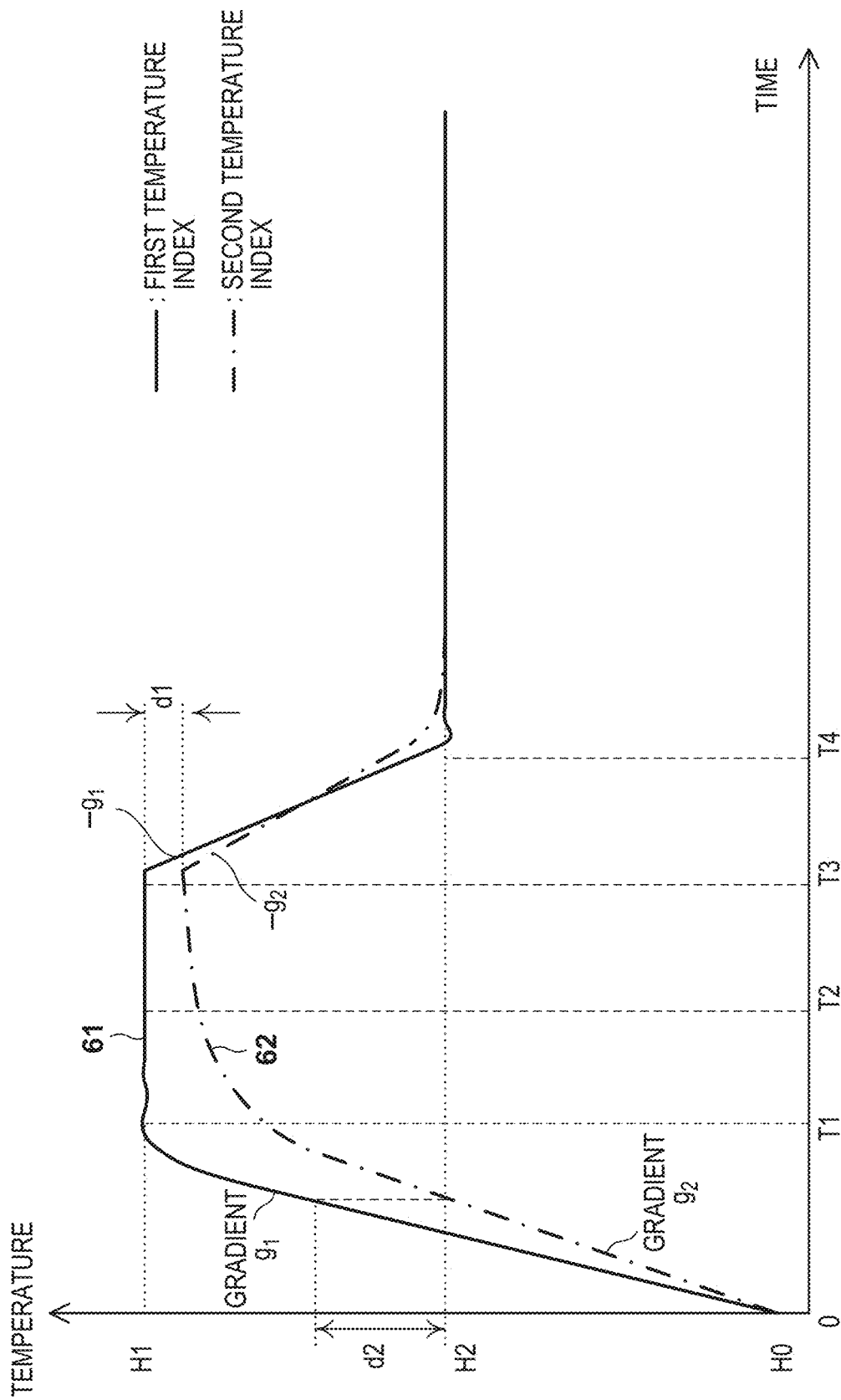


FIG. 10

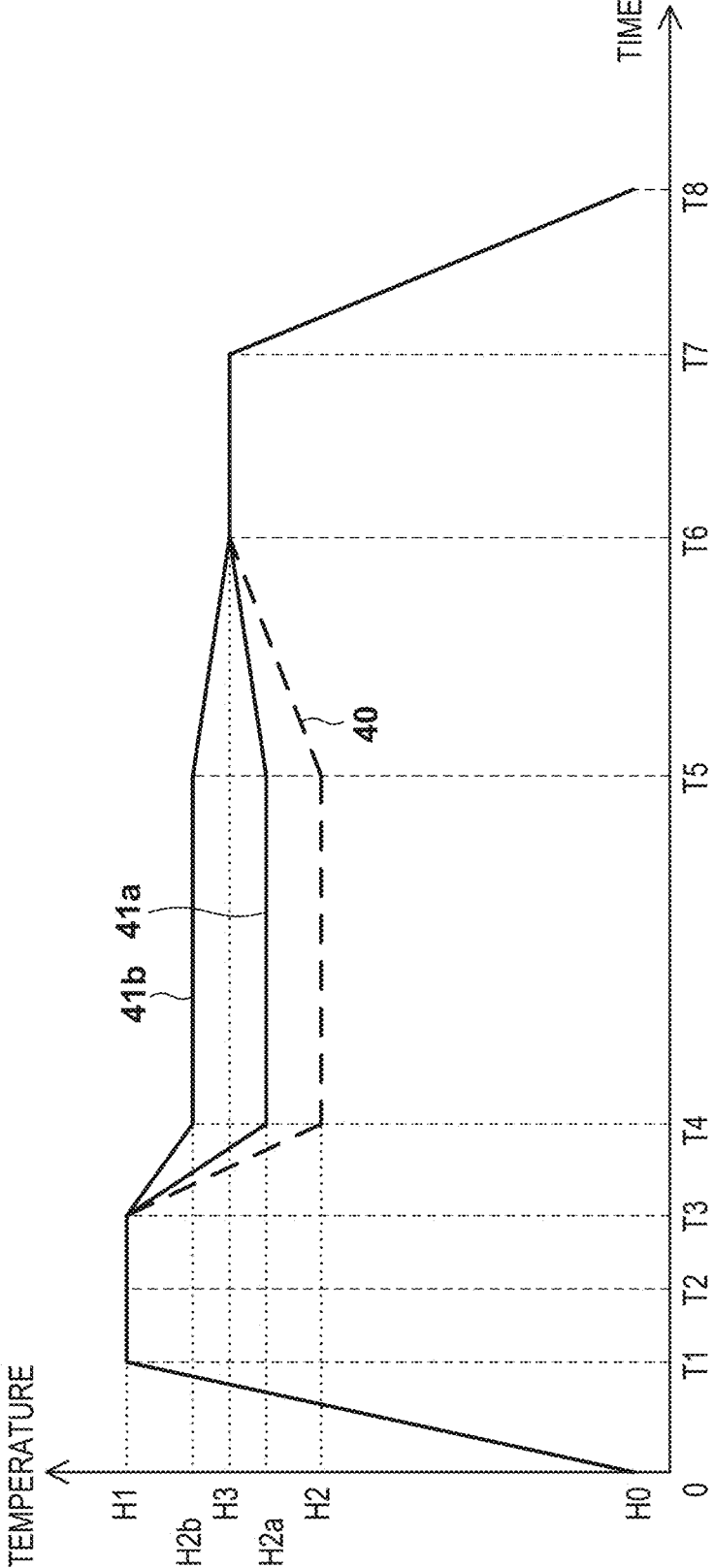


FIG. 11

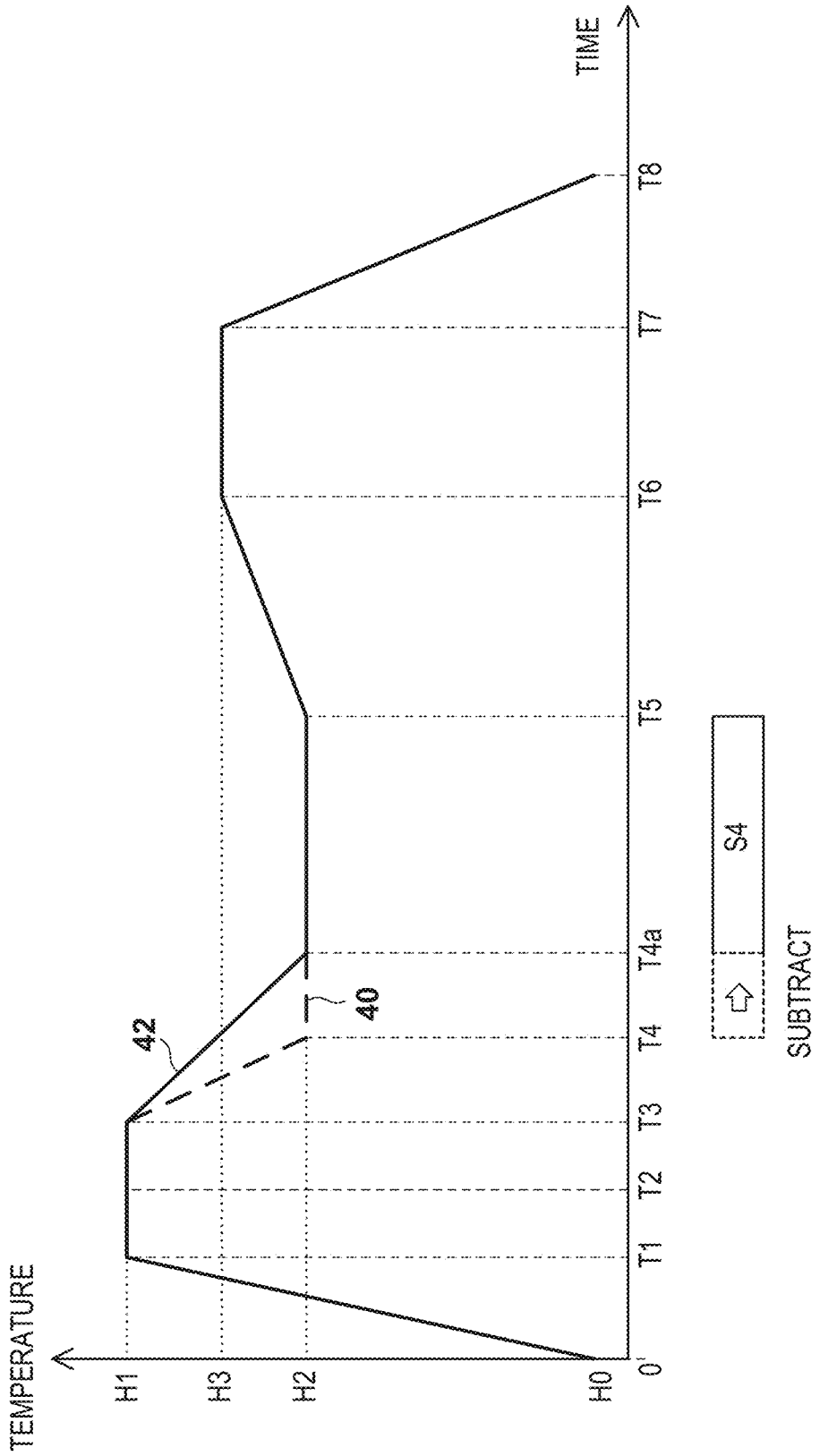


FIG. 12

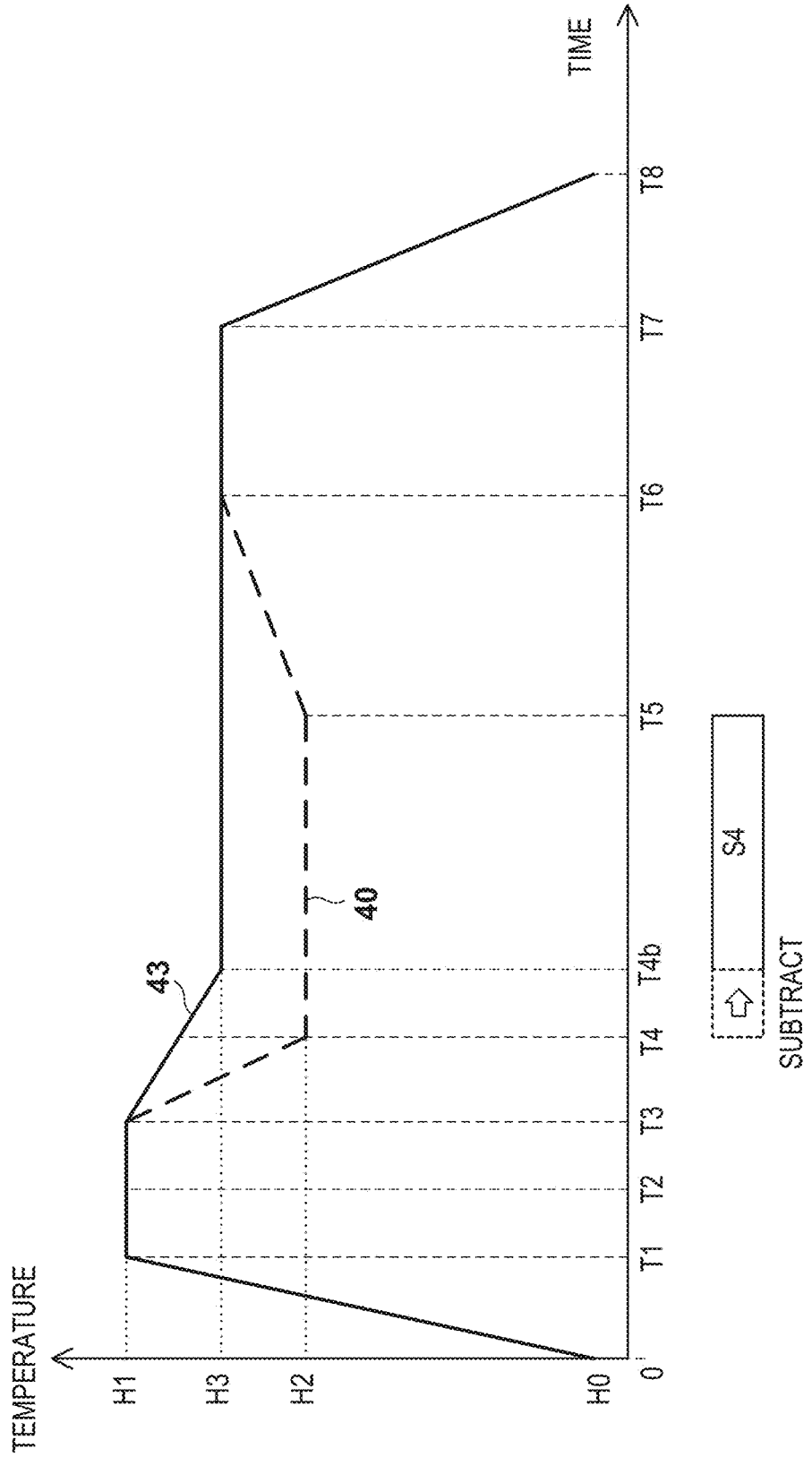


FIG. 13

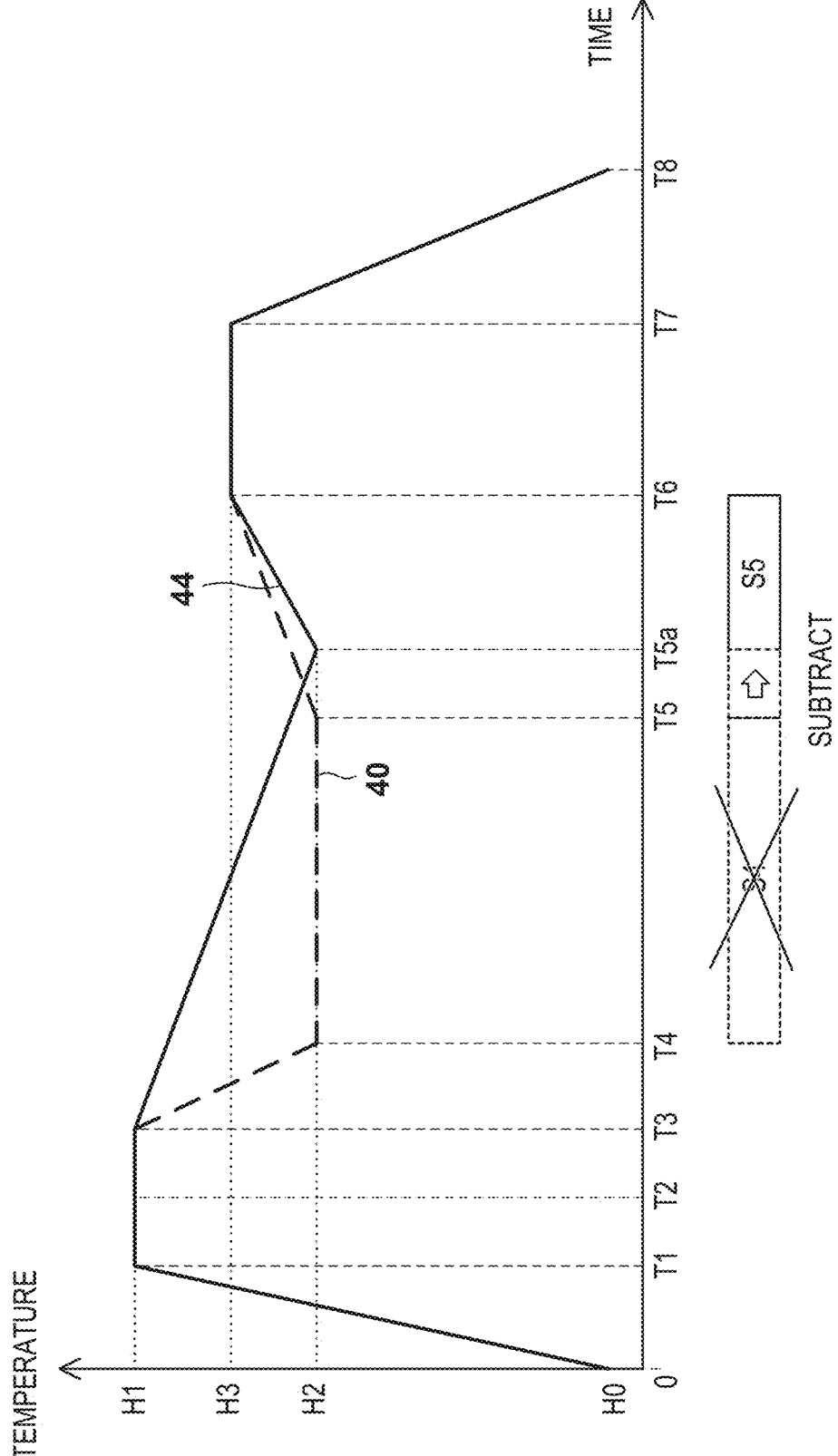


FIG. 14

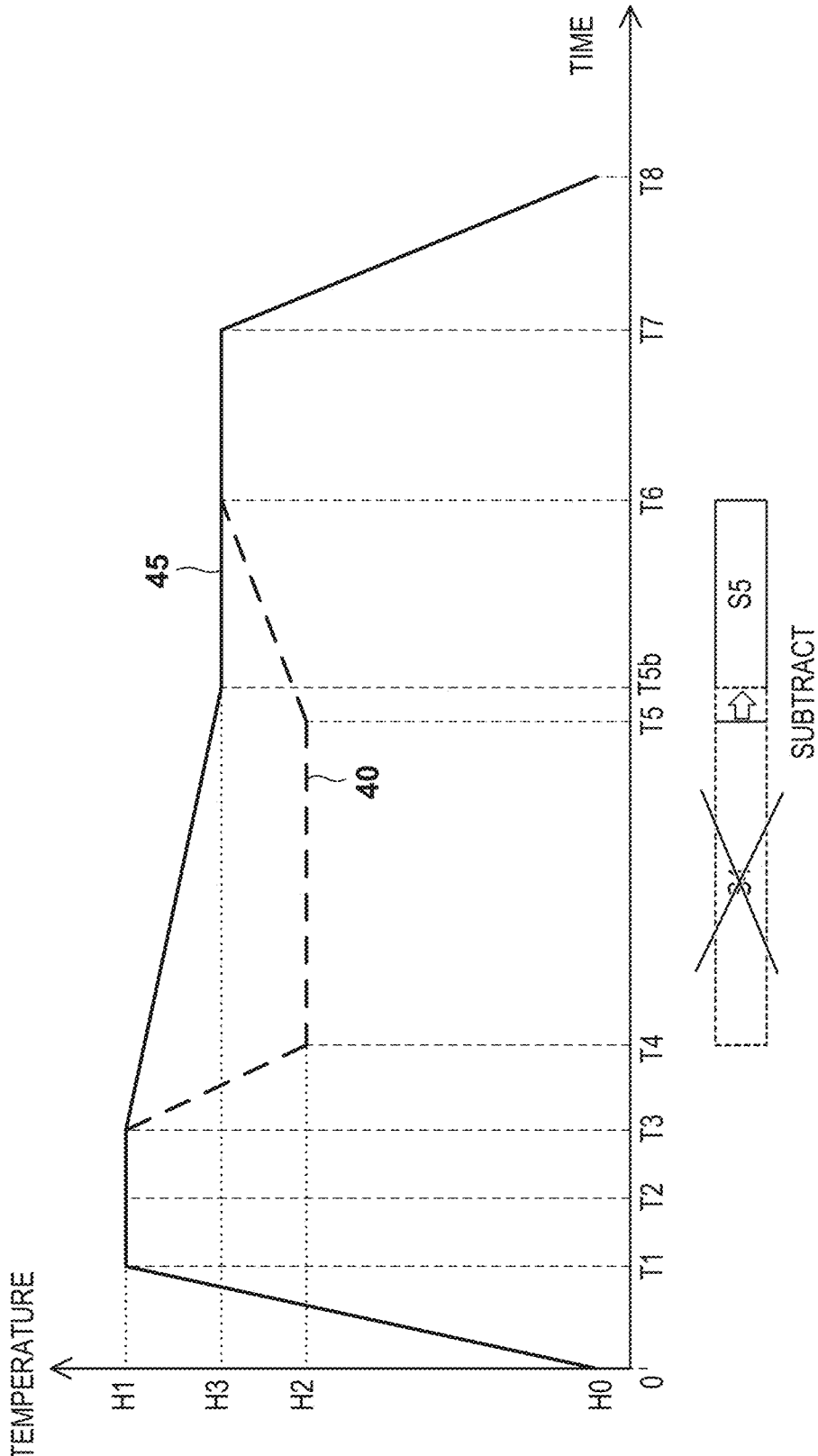


FIG. 15

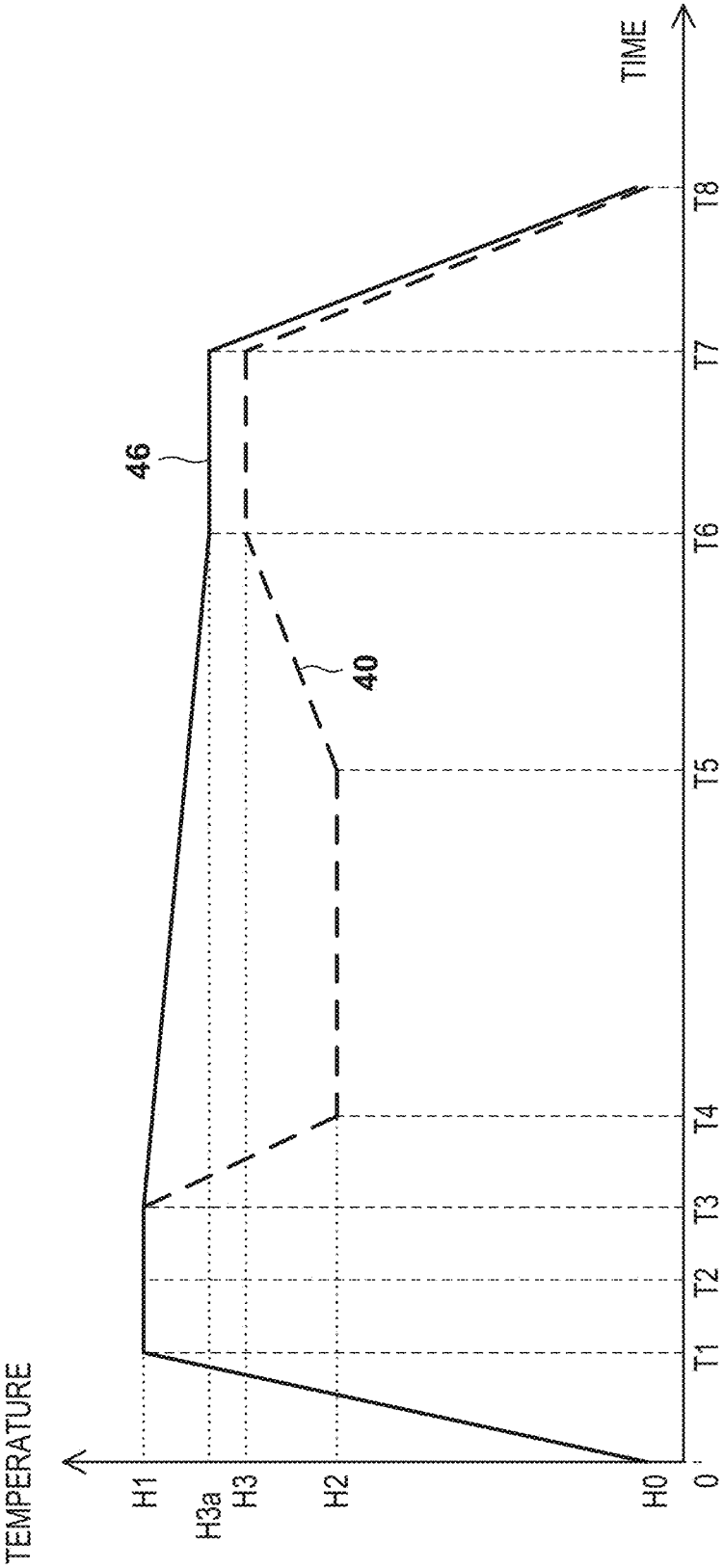


FIG. 16

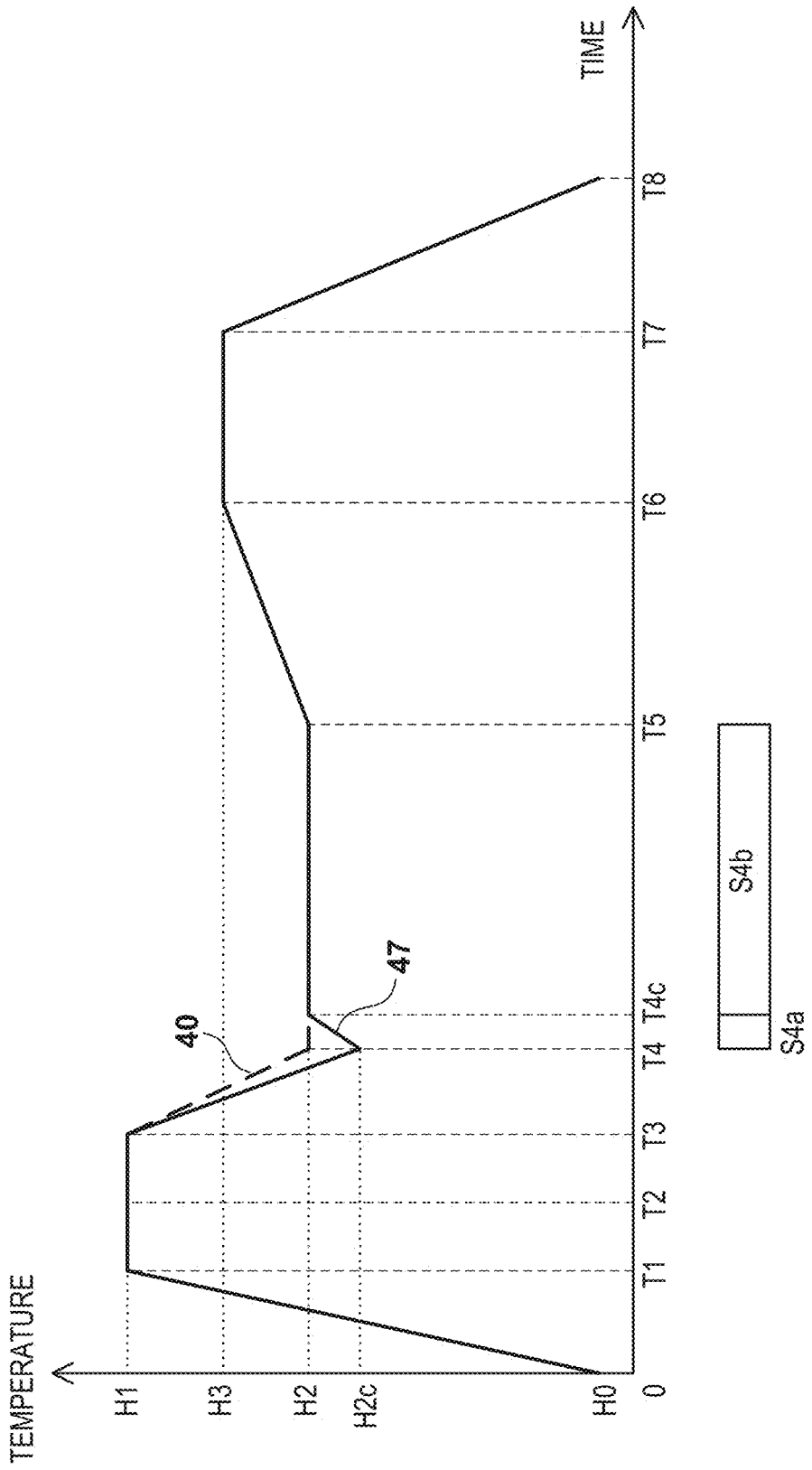


FIG. 17A

51



52	SECTION NUMBER	...	S_n	S_{n+1}	S_{n+2}	...
53	CONTROL METHOD	...	1 (PID:CONSTANT)	0 (OFF)	2 (PID:LINEAR INTERPOLATION)	...
54	TARGET TEMPERATURE[°C]	...	H_n	H_{n+1}	H_{n+2}	...
55	TARGET TEMPERATURE RESISTANCE VALUE[Ω]	...	R_n	R_{n+1}	R_{n+2}	...
56	GAINS	...	K_{p1}, K_{i1}, K_{d1}	—	K_{p2}, K_{i2}, K_{d2}	...
57	TIME LENGTH	...	L_n	L_{n+1}	L_{n+2}	...
58	TERMINATION CONDITION	...	C_n	C_{n+1}	C_{n+2}	...

FIG. 17B

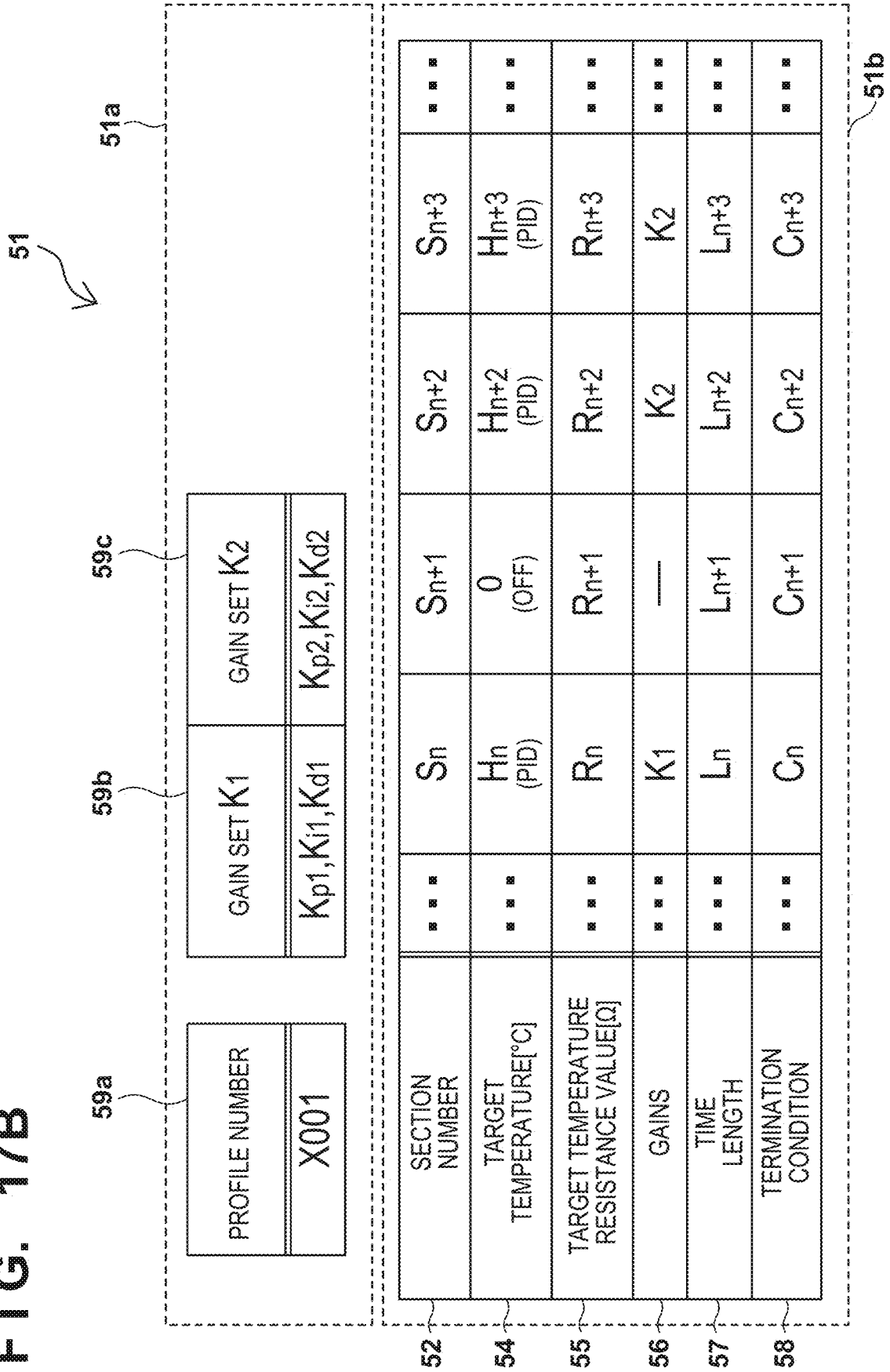


FIG. 18

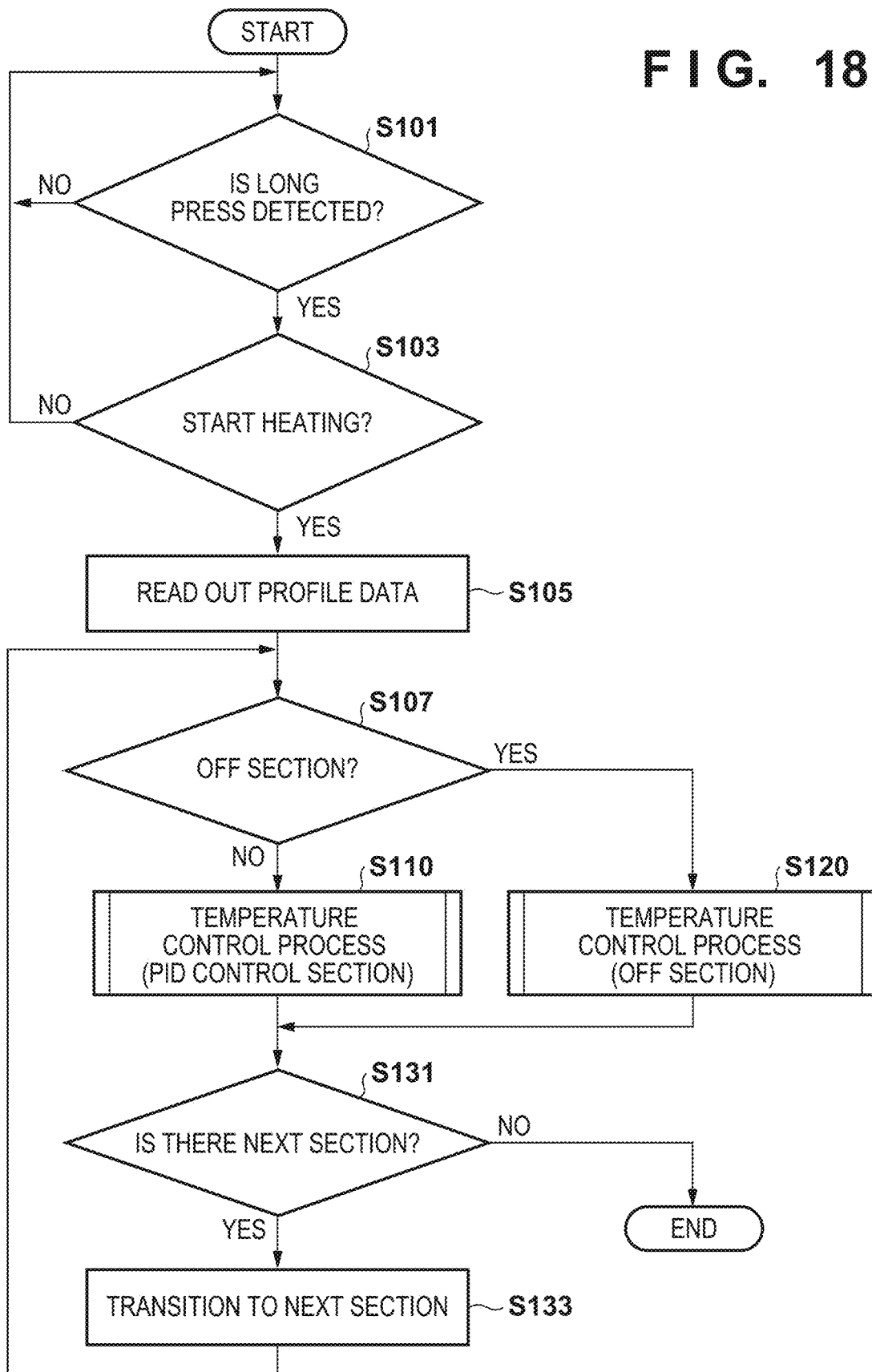


FIG. 19

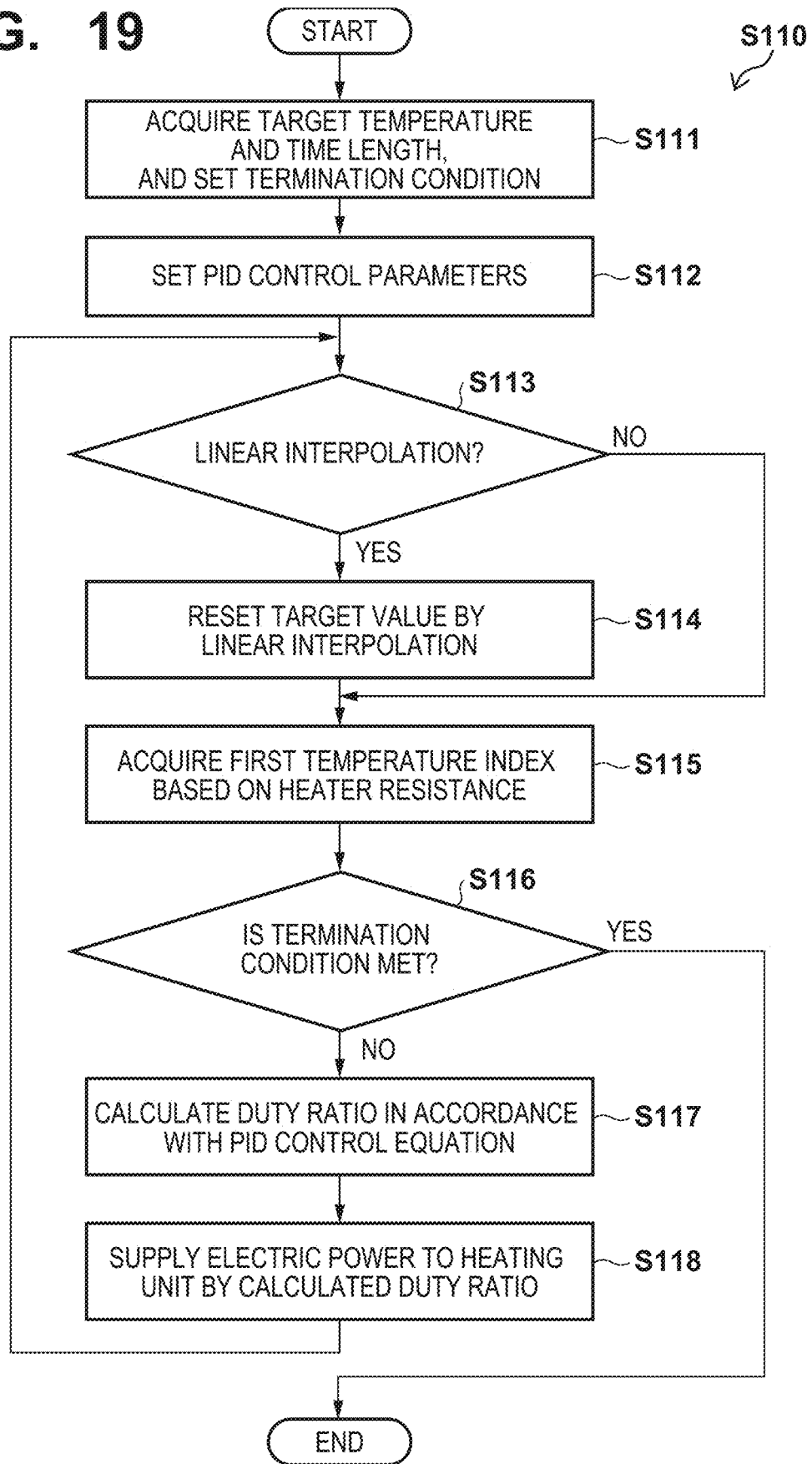


FIG. 20A

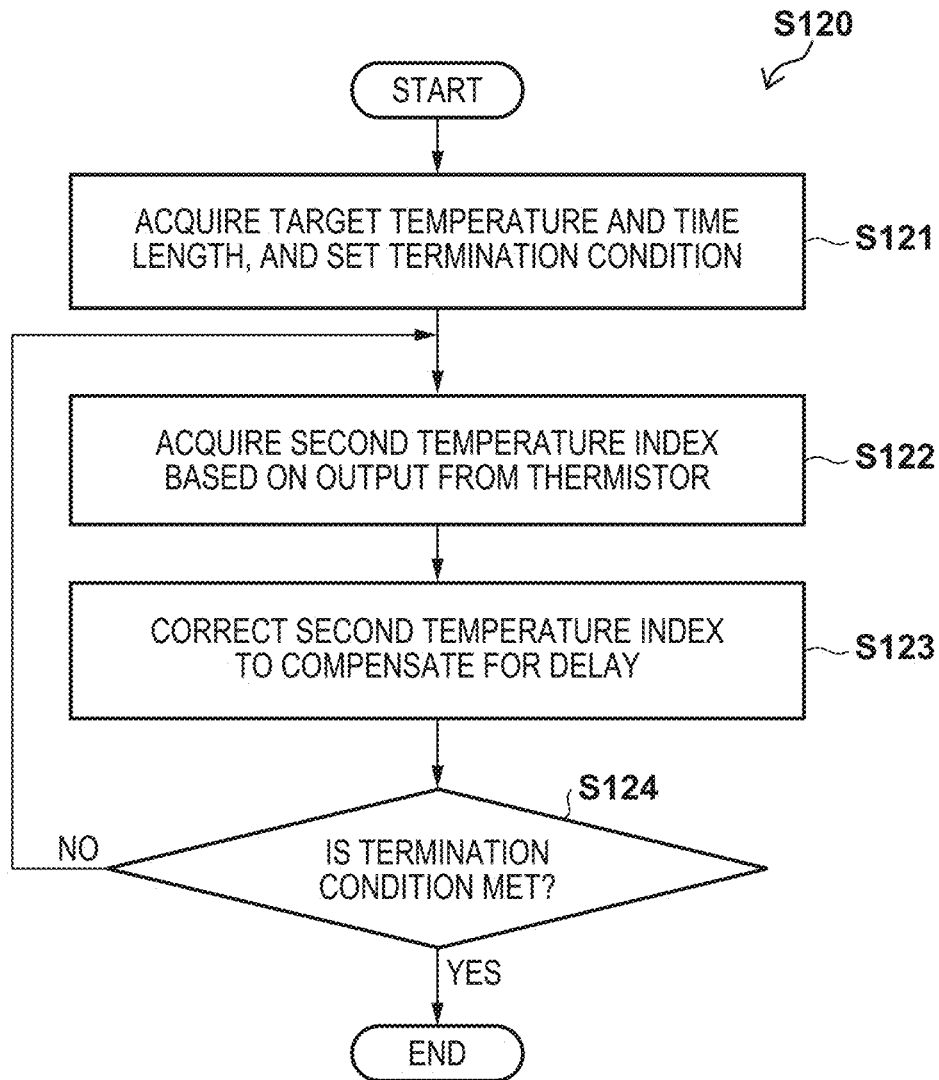


FIG. 20B

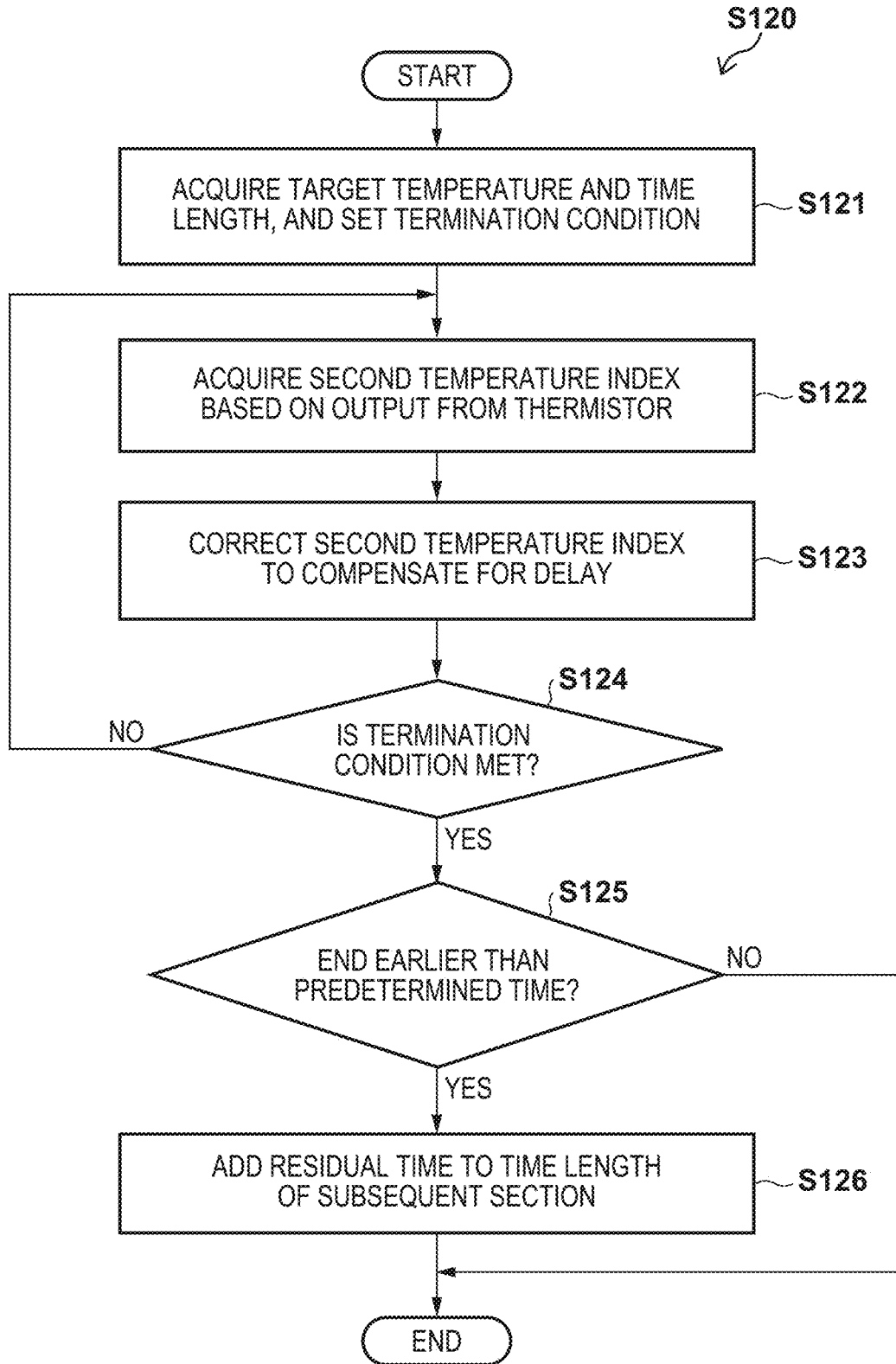


FIG. 20C

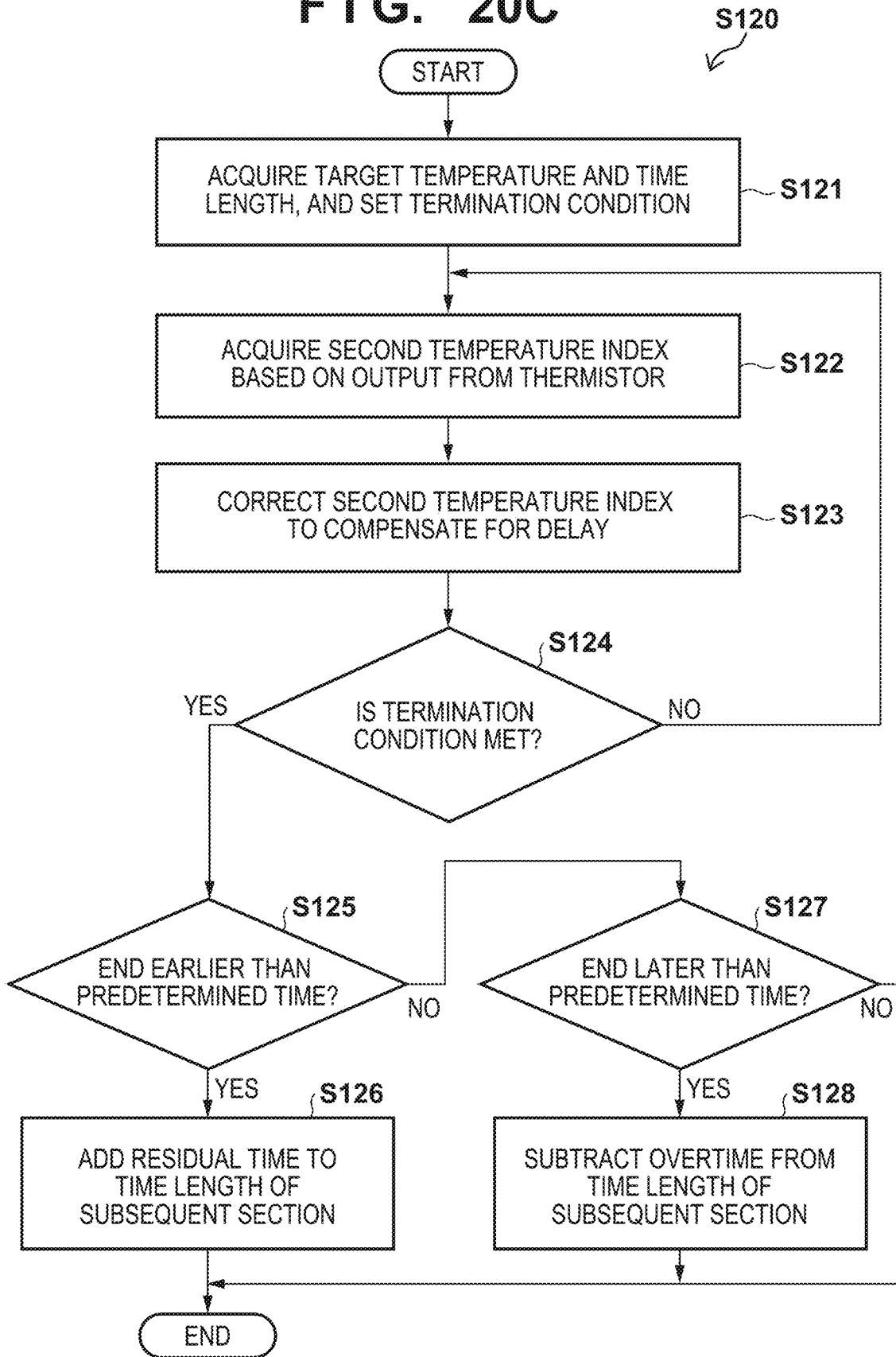


FIG. 21

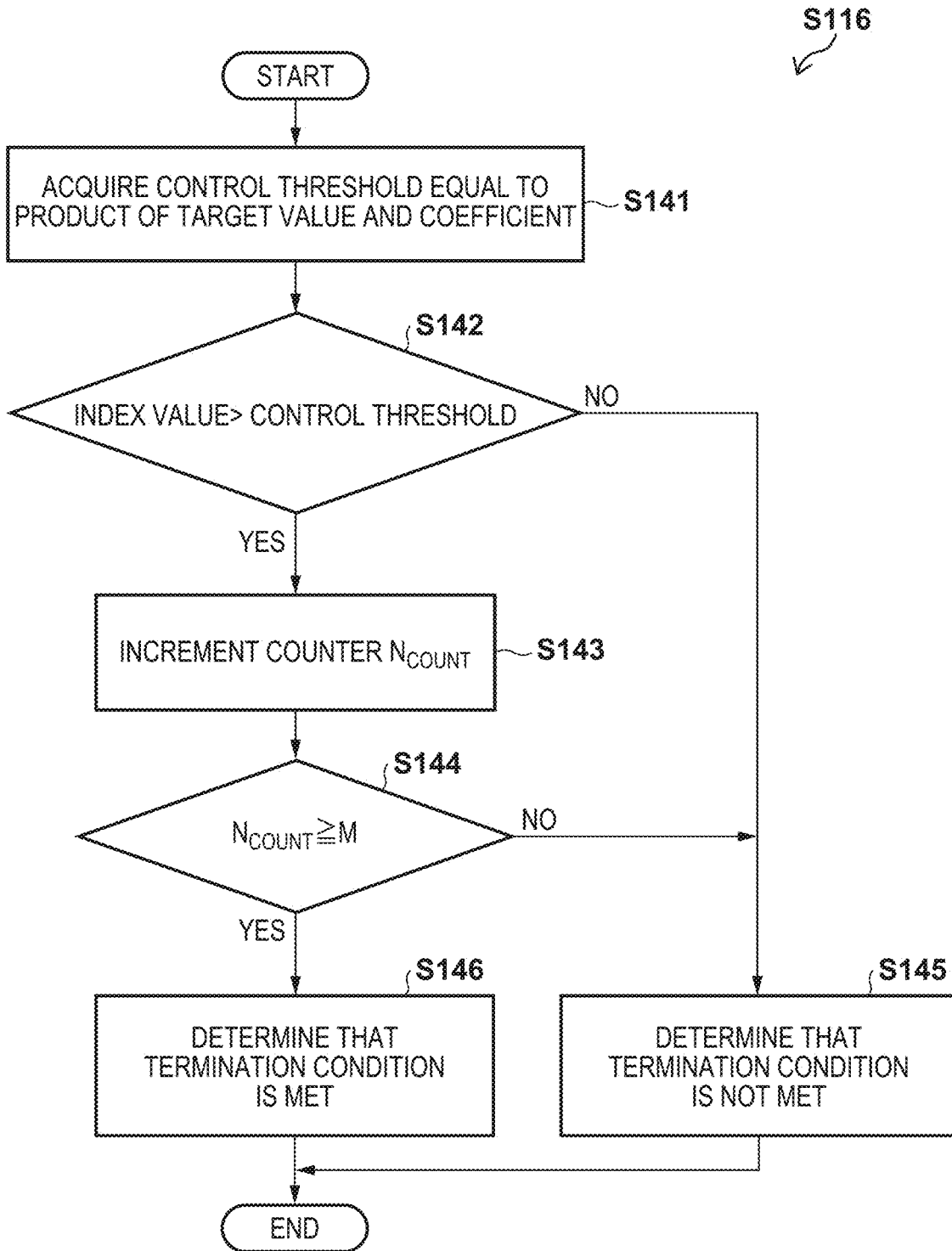


FIG. 22

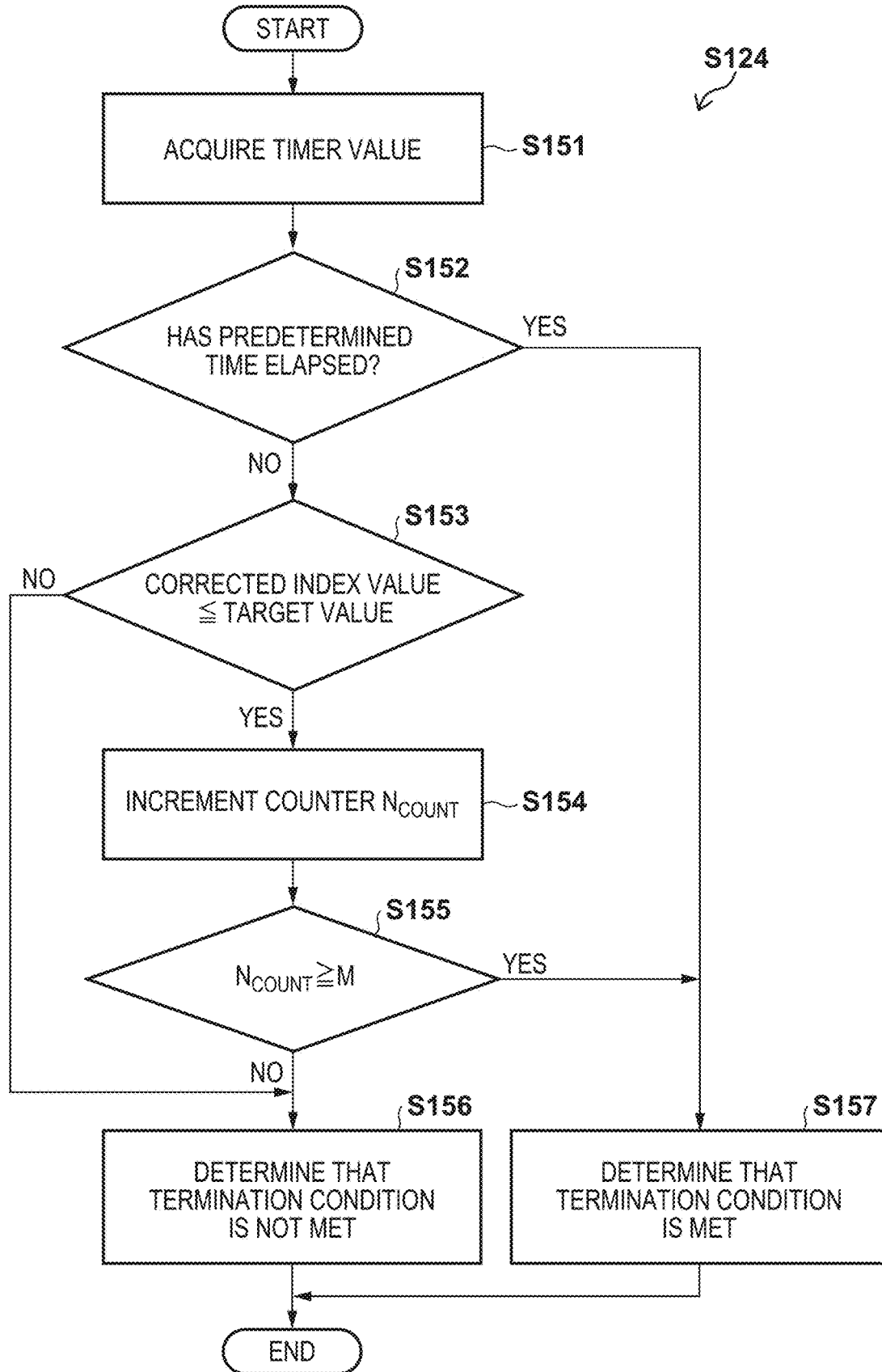
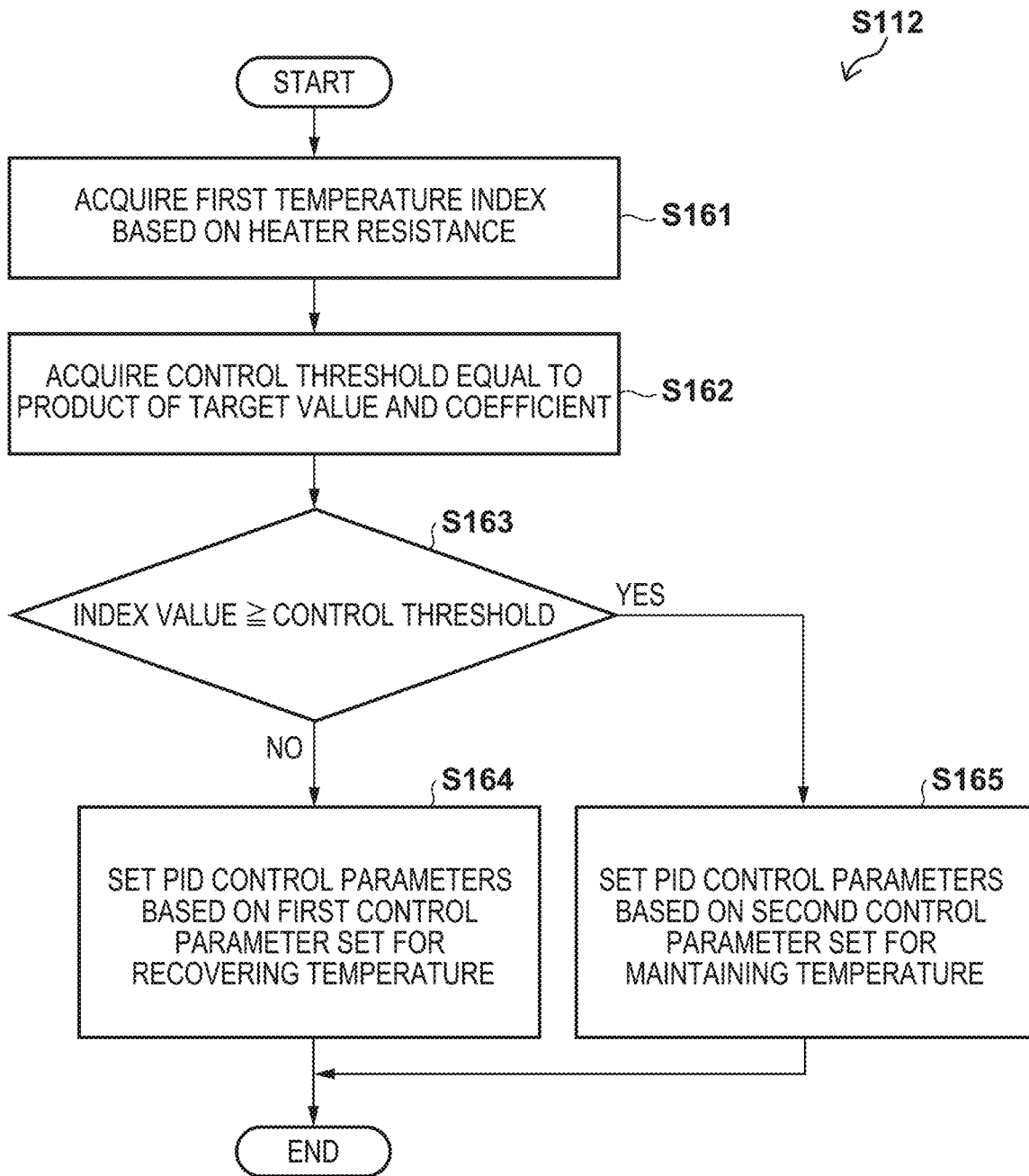


FIG. 23



**AEROSOL GENERATING DEVICE,
CONTROL METHOD AND STORAGE
MEDIUM**

CROSS-REFERENCE TO RELATED
APPLICATIONS

[0001] The present application claims priorities to International Patent Application No. PCT/JP2022/006894 filed on Feb. 21, 2022 and Japanese Patent Application No. 2021-076017 filed on Apr. 28, 2021, both of which are incorporated herein by references.

BACKGROUND OF THE INVENTION

Technical Field

[0002] This disclosure relates to an aerosol generating device, a control method and a storage medium.

Related Art

[0003] An electric heating type aerosol generating device that generates aerosol by heating an aerosol source and delivers the generated aerosol to a user is known. For example, an electronic cigarette is a kind of the above-described aerosol generating device. The electronic cigarette imparts a flavor component to generated aerosol to let the user inhale the aerosol.

SUMMARY

[0004] According to an aspect, there is provided an aerosol generating device that includes: a heating unit configured to generate aerosol by heating an aerosol source; a power supply configured to supply electric power to the heating unit; and a control unit configured to control the supply of electric power from the power supply to the heating unit in accordance with a control sequence that consists of a plurality of sections including: a first section for changing a temperature of the heating unit from a first temperature toward a second temperature, and a second section, which follows the first section, for maintaining the temperature of the heating unit, wherein the control sequence designates a first time length for the first section and a second time length for the second section, the control unit is configured to terminate the first section when the temperature of the heating unit has reached the second temperature, and the control unit is configured to, in a case of terminating the first section earlier than a first time point at which the first time length elapses from the start of the first section, continue the second section over a total time of a residual time until the first time point and the second time length.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 is a perspective view showing the outer appearance of an aerosol generating device according to an embodiment;

[0006] FIG. 2 is an explanatory diagram for explaining the insertion of a tobacco stick into the aerosol generating device shown in FIG. 1;

[0007] FIG. 3 is a block diagram showing an example of a general circuit configuration of the aerosol generating device shown in FIG. 1;

[0008] FIG. 4 is a block diagram showing an example of the configuration of a measurement circuit to be used to measure the temperature of a heating unit;

[0009] FIG. 5 is an explanatory diagram for explaining a measurement period and a PWM control period during a heating period;

[0010] FIG. 6 is an explanatory diagram for explaining an example of the positional relationship between the heating unit and a thermistor;

[0011] FIG. 7 is an explanatory diagram for explaining a temperature profile and a heating profile according to an embodiment;

[0012] FIG. 8 is an explanatory diagram showing an example of a temperature profile in a case where a residual time is added to the time length of a subsequent section because the end of a temperature fall section is earlier than a predetermined time;

[0013] FIG. 9 is an explanatory diagram for explaining the relationship between a first temperature index and a second temperature index;

[0014] FIG. 10 is an explanatory diagram showing two examples of the temperature profile in a case where a target temperature of the subsequent section is reset to the temperature at the terminating point in time of the temperature fall section;

[0015] FIG. 11 is an explanatory diagram showing an example of the temperature profile in a case where the subsequent section is shortened because the end of the temperature fall section is later than a predetermined time in the first modification;

[0016] FIG. 12 is an explanatory diagram showing an example of the temperature profile in a case where the subsequent section is shortened because the end of the temperature fall section is later than a predetermined time in the second modification;

[0017] FIG. 13 is an explanatory diagram showing an example of the temperature profile in a case where the subsequent section is skipped and the next subsequent section is shortened because the end of the temperature fall section is much later than a predetermined time in the first modification;

[0018] FIG. 14 is an explanatory diagram showing an example of the temperature profile in a case where the subsequent section is skipped and the next subsequent section is shortened because the end of the temperature fall section is much later than a predetermined time in the second modification;

[0019] FIG. 15 is an explanatory diagram showing an example of the temperature profile in a case where the target temperature of a temperature-maintaining section before termination is reset to the temperature at a reference point in time;

[0020] FIG. 16 is an explanatory diagram showing an example of the temperature profile including a recovery section according to the third modification;

[0021] FIG. 17A is an explanatory diagram showing the first example of the configuration of profile data describing the heating profile;

[0022] FIG. 17B is an explanatory diagram showing the second example of the configuration of the profile data describing the heating profile;

[0023] FIG. 18 is a flowchart showing an example of the overall flow of an aerosol generation process according to an embodiment;

[0024] FIG. 19 is a flowchart showing an example of a flow of a temperature control process for a PID control section shown in FIG. 18;

[0025] FIG. 20A is a flowchart showing the first example of a flow of a temperature control process for an OFF section shown in FIG. 18;

[0026] FIG. 20B is a flowchart showing the second example of a flow of the temperature control process for the OFF section shown in FIG. 18;

[0027] FIG. 20C is a flowchart showing the third example of a flow of the temperature control process for the OFF section shown in FIG. 18;

[0028] FIG. 21 is a flowchart showing an example of a flow of an end determination process for a preheating temperature rise section;

[0029] FIG. 22 is a flowchart showing an example of a flow of an end determination process for a temperature fall section; and

[0030] FIG. 23 is a flowchart showing an example of a flow of a control parameter selection process after the end of the temperature fall section.

DESCRIPTION OF THE EMBODIMENTS

[0031] Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention, and limitation is not made an invention that requires a combination of all features described in the embodiments. Two or more of the multiple features described in the embodiments may be combined as appropriate. Furthermore, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

[0032] <<1. Configuration Example of Device>>

[0033] In this specification, an example in which the technology according to the present disclosure is applied to a non-combustion-type device that generates aerosol by atomizing an aerosol source by heating it without combustion will mainly be explained. A device like this is also called a reduced-risk product (RRP) or is simply called an electronic cigarette. However, technology according to the present disclosure is not limited to this example and can be applied to an aerosol generating device of any kind such as a combustion-type device or a medical nebulizer.

[0034] <<1-1. Outer Appearance>>

[0035] FIG. 1 is a perspective view showing the outer appearance of an aerosol generating device 10 according to an embodiment. FIG. 2 is an explanatory diagram for explaining the insertion of a tobacco stick into the aerosol generating device 10 shown in FIG. 1. Referring to FIG. 1, the aerosol generating device 10 includes a main body 101, a front panel 102, a display window 103, and a slider 104.

[0036] The main body 101 is a housing internally supporting one or more circuit boards of the aerosol generating device 10. In this embodiment, the main body 101 has a substantially cuboidal rounded shape elongated in the vertical direction of the drawing. The size of the main body 101 can be a size which the user can grasp with one hand. The front panel 102 is a flexible panel member covering the front surface of the main body 101. The front panel 102 can be detachable from the main body 101. The front panel 102 also functions as an input unit for accepting a user input. For example, when the user pushes the center of the front panel 102, a button (not shown) disposed between the main body

101 and the front panel 102 is pressed, so a user input can be detected. The display window 103 is a band-like window extending along the longitudinal direction in substantially the center of the front panel 102. The display window 103 transmits light generated by one or more light emitting diodes (LEDs) arranged between the main body 101 and the front panel 102 to the outside.

[0037] The slider 104 is a cover member slidably disposed along a direction 104a on the upper surface of the main body 101. As shown in FIG. 2, when the slider 104 is slid to the near side of the drawing (that is, when the slider 104 is opened), an opening 106 in the upper surface of the main body 101 is exposed. When inhaling aerosol by using the aerosol generating device 10, the user inserts a tobacco stick 15 into a tubular insertion hole 107 along a direction 106a from the opening 106 exposed by opening the slider 104. A section perpendicular to the axial direction of the insertion hole 107 can be, for example, circular, elliptical, or polygonal, and the sectional area of the section gradually reduces toward the bottom surface. Accordingly, the inner surface of the insertion hole 107 pushes the outer surface of the tobacco stick 15 inserted into the insertion hole 107, thereby preventing a fall of the tobacco stick 15 by the frictional force. This also increases the efficiency of heat transfer from a heating unit 130 (to be described later) to the tobacco stick 15. When the user finishes inhaling aerosol, he or she pulls out the tobacco stick 15 from the insertion hole 107, and closes the slider 104.

[0038] The tobacco stick 15 is a tobacco article holding a filler inside a cylindrical rolling paper. The filler of the tobacco stick 15 can be, for example, a mixture of an aerosol generating substrate and shredded tobacco. As the aerosol generating substrate, it is possible to use a substrate containing an aerosol source of any kind, such as glycerin, propylene glycol, triacetin, 1,3-butanediol, or a mixture thereof. The shredded tobacco is a so-called flavor source. The material of the shredded tobacco can be, for example, a lamina or a backbone. Note that a flavor source not originating from tobacco may also be used instead of the shredded tobacco.

[0039] <<1-2. Circuit Configuration>>

[0040] FIG. 3 is a block diagram showing an example of a general circuit configuration of the aerosol generating device 10. Referring to FIG. 3, the aerosol generating device 10 includes a control unit 120, a storage unit 121, an input detection unit 122, a state detection unit 123, an inhalation detection unit 124, a light emitting unit 125, a vibration unit 126, a communication interface (I/F) 127, a connection I/F 128, a heating unit 130, a first switch 131, a second switch 132, a battery 140, a booster circuit 141, a residual amount meter 142, a measurement circuit 150, and a thermistor 155.

[0041] The control unit 120 can be a processor such as a central processing unit (CPU) or a microcontroller. The control unit 120 controls all functions of the aerosol generating device 10 by executing computer programs (also called software or firmware) stored in the storage unit 121. The storage unit 121 can be a semiconductor memory or the like. The storage unit 121 stores one or more computer programs, and various data (for example, profile data 51 describing a heating profile 50) to be used for heating control (to be described later).

[0042] The input detection unit 122 is a detection circuit for detecting a user input. For example, the input detection unit 122 detects pushing of the front panel 102 (that is,

pressing of a button) by the user, and outputs an input signal indicating the detected state to the control unit 120. Note that the aerosol generating device 10 can include an input device of any kind such as a button, a switch, or a touch-sensitive screen, instead of (or in addition to) the front panel 102. The state detection unit 123 is a detection circuit for detecting an open/closed state of the slider 104. The state detection unit 123 outputs a state detection signal indicating whether the slider 104 is open or closed to the control unit 120. The inhalation detection unit 124 is a detection circuit for detecting inhalation (puff) of the tobacco stick 15 by the user. As an example, the inhalation detection unit 124 can include a thermistor (not shown) disposed near the opening 106. In this case, the inhalation detection unit 124 can detect inhalation by the user based on a change in resistance value of the thermistor resulting from a temperature change caused by the inhalation. As another example, the inhalation detection unit 124 can include a pressure sensor (not shown) disposed on the bottom of the insertion hole 107. In this case, the inhalation detection unit 124 can detect inhalation based on a reduction in atmospheric pressure resulting from an air current caused by the inhalation. The inhalation detection unit 124 outputs, for example, an inhalation detection signal indicating whether inhalation is performed, to the control unit 120.

[0043] The light emitting unit 125 includes one or more LEDs, and a driver for driving the LEDs. The light emitting unit 125 turns on each LED in accordance with an instruction signal input from the control unit 120. The vibration unit 126 includes a vibrator (e.g., an eccentric motor) and a driver for driving the vibrator. The vibration unit 126 vibrates the vibrator in accordance with an instruction signal input from the control unit 120. The control unit 120 can use one or both of the light emitting unit 125 and the vibration unit 126 by any pattern, in order to notify the user of a certain status (for example, the progress of a session) of the aerosol generating device 10. For example, the light emission patterns of the light emitting unit 125 can be distinguished by elements such as the light emission state (always on/blinking/off), the blinking period, and the light color of each LED. The vibration patterns of the vibration unit 126 can be distinguished by elements such as the vibration state (vibration/stop) and the vibration strength of the vibrator.

[0044] The wireless I/F 127 is a communication interface by which the aerosol generating device 10 wirelessly communicates with another device (for example, a personal computer (PC) or a smartphone owned by the user). The wireless I/F 127 can be an interface complying with a wireless communication protocol such as Bluetooth®, near field communication (NFC), or a wireless local area network (LAN). The connection I/F 128 is a wired interface having a terminal for connecting the aerosol generating device 10 to another device. The connection I/F 128 can be a universal serial bus (USB) interface or the like. The connection I/F 128 can also be used to charge the battery 140 from an external power supply (via a feeder line (not shown)).

[0045] The heating unit 130 is a resistive heat generating part that generates aerosol by heating an aerosol source included in an aerosol generating substrate of the tobacco stick 15. As a resistive heat generating material of the heating unit 130, it is possible to use a mixture of one of more of copper, a nickel alloy, a chromium alloy, stainless steel, and platinum rhodium. One terminal of the heating unit 130 is connected to the positive electrode of the battery

140 via the first switch 131 and the booster circuit 141, and the other terminal of the heating unit 130 is connected to the negative electrode of the battery 140 via the second switch 132. The first switch 131 is a switching element disposed in a feeder line between the heating unit 130 and the booster circuit 141. The second switch 132 is a switching element disposed in a ground line between the heating unit 130 and the battery 140. The first switch 131 and the second switch 132 can be, for example, field effect transistors (FETs).

[0046] The battery 140 is a power supply for supplying electric power to the heating unit 130 and other constituent elements of the aerosol generating device 10. FIG. 3 does not show feeder lines from the battery 140 to the constituent elements except the heating unit 130. The battery 140 can be, for example, a lithium-ion battery. The booster circuit (DC/DC converter) 141 is a voltage conversion circuit for amplifying the voltage of the battery 140 in order to feed the heating unit 130. The residual amount meter 142 is an IC chip for monitoring the residual power amount and other statuses of the battery 140. The residual amount meter 142 can periodically measure the status values of the battery 140, such as the state of charge (SOC), the state of health (SOH), the relative SOC (RSOC), and the power supply voltage, and can output the measurement results to the control unit 120.

[0047] When a user input requesting the start of heating is detected, the control unit 120 starts to cause electric power to be supplied from the battery 140 to the heating unit 130. This user input can be, for example, long press of a button to be detected by the input detection unit 122. The control unit 120 can cause electric power to be supplied from the battery 140 to the heating unit 130 at a voltage amplified by the booster circuit 141 by outputting control signals to the first switch 131 and the second switch 132 to turn on the two switches. In a case where the first switch 131 and the second switch 132 are FETs, the control signals to be output from the control unit 120 to the two switches are control pulses to be applied to the gates of these switches. In temperature control to be described below, the control unit 120 adjusts the duty ratio of these control pulses by pulse width modulation (PWM). Note that the control unit 120 can also use pulse frequency modulation (PFM) instead of PWM.

[0048] <1-3. Measurement of Heater Temperature>

[0049] In this embodiment, the control unit 120 controls the supply of electric power from the battery 140 to the heating unit 130 so as to implement a desired temperature profile for providing a good user experience throughout the whole heating period including a preheating period and an inhalable period. This control can mainly be feedback control using a temperature index having a correlation with the temperature of the heating unit 130 as a controlled variable, and the duty ratio of PWM as a manipulated variable. Assume that PID control is adopted as this feedback control. In this embodiment, the aerosol generating device 10 has two types of measurement units for measuring the temperature index of the heating unit 130. The measurement circuit 150 shown in FIG. 3 is one of the two types of measurement units, and measures a first temperature index based on the electrical resistance value of the heating unit 130. The other measurement unit is the thermistor 155 to be explained later.

[0050] FIG. 4 is a block diagram showing an example of the configuration of the measurement circuit 150 shown in FIG. 3. Referring to FIG. 4, the measurement circuit 150 includes divider resistors 151, 152, and 153, and an operational amplifier 154. One terminal of the divider resistor 151

is connected to a power supply voltage VTEMP, and the other terminal is connected to one terminal of the divider resistor 152. The other terminal of the divider resistor 152 is grounded. The contact between the divider resistor 151 and the divider resistor 152 is connected to a terminal ADC_VTEMP of the control unit 120. An input to the terminal ADC_VTEMP indicates a reference value for resistance value measurement. One terminal of the divider resistor 153 is connected to the power supply voltage VTEMP, and the other terminal is connected to the feeder line of the heating unit 130. The contact between the divider resistor 153 and the feeder line of the heating unit 130 is connected to a first input terminal of the operational amplifier 154. A second input terminal of the operational amplifier 154 is grounded. An output terminal of the operational amplifier 154 is connected to a terminal ADC_HEAT_TEMP of the control unit 120. An input to the terminal ADC_HEAT_TEMP indicates a value that changes due to an electrical resistance value Rh depending on the temperature of the heating unit 130. The control unit 120 can calculate the electrical resistance value Rh of the heating unit 130 based on the ratio of the value input to the terminal ADC_HEAT_TEMP to the value (reference value) input to the terminal ADC_VTEMP.

[0051] The electrical resistance value of the heating unit 130 has, for example, the characteristic that the value monotonously increases as the temperature rises (that is, the value has a correlation to the temperature). In this embodiment, therefore, the control unit 120 uses the electrical resistance value of the heating unit 130, which is calculated by using the measurement circuit 150, as a temperature index (first temperature index) as the controlled variable of PID control. Note that the control unit 120 may, of course, further convert the calculated electrical resistance value into a temperature by using a resistance-temperature coefficient, and use the derived measured temperature as the controlled variable of PID control.

[0052] <1-4. Temperature Control>

[0053] In this embodiment as described above, temperature control of the heating unit 130 is mainly performed by the method of deciding the duty ratio of PWM of electric power to be supplied to the heating unit 130. Letting R_{TGT} [Ω] be the target value (the resistance value corresponding to the target temperature) of PID control, and $R(n)$ [Ω] be the value (measured resistance value) of the first temperature index in a current control cycle n (n is an integer), a duty ratio $D(n)$ of the control cycle n can be derived in accordance with, for example, equation (1) below:

$$D(n) = \frac{\{K_p \times (R_{TGT} - R(n)) + K_i \times \sum_0^n (R_{TGT} - R(k)) - K_d \times (R(n) - R(n-1))\}}{1000} \quad (1)$$

[0054] In equation (1), K_p , K_i , and K_d respectively represent a proportional gain, an integral gain, and a differential gain. Note that in the second term on the right side as an integral term, saturation control can be applied to a cumulative value of a deviation of the index value with respect to the target value. In this case, if the cumulative value is larger than a predetermined upper limit value, the cumulative value is substituted by the upper limit value; and if the cumulative value is smaller than a predetermined lower limit value, the cumulative value is substituted by the lower limit value.

[0055] To enable feedback control during the heating period in this embodiment, the control unit 120 sets a part of repetitive control cycles as a measurement period for measuring the first temperature index, and sets the remainder of the control cycles as a PWM control period for performing

PWM control. FIG. 5 is an explanatory diagram for explaining the measurement period and the PWM control period during the heating period. In FIG. 5, the abscissa represents the time, and the ordinate represents the voltage to be applied to the heating unit 130. One control cycle during the heating period includes a measurement period 20 at the beginning and a PWM control period 30 as the remainder. In this example shown in FIG. 5, a period from t_0 to t_1 is the measurement period 20 of one control cycle, and a period from t_1 to t_2 is the PWM control period 30 of the same control cycle. Likewise, a period from t_2 to t_3 is the measurement period 20 of the next one control cycle, and a period from t_3 to t_4 is the PWM control period 30 of the same control cycle. The length of one control cycle is equivalent to the periodicity of measurement of the first temperature index, and can be, for example, tens of milliseconds.

[0056] In the control cycle n, the control unit 120 applies a very short pulse 21 (for example, the pulse width is 2 ms) to the heating unit 130 a plurality of times (for example, 8 times) during the measurement period 20, and obtains the average value of resistance values calculated a plurality of times by using the measurement circuit 150 during one measurement period 20 as the measured value $R(n)$ of the first temperature index. By using the measured value $R(n)$, the control unit 120 calculates the duty ratio $D(n)$ of PWM in the control cycle n in accordance with the above-described control equation. Then, in the PWM control period 30, the control unit 120 applies a pulse 31 having a pulse width $W1$ equivalent to the product of a length $W0$ of this period and the duty ratio $D(n)$ to the heating unit 130 (that is, outputs control pulses having the same pulse width $W1$ to the first switch 131 and the second switch 132). The temperature of the heating unit 130 is so controlled as to approach the target value by repeating the feedback control as described above.

[0057] <1-5. Introduction of Auxiliary Thermistor>

[0058] The above-described control cycle can be kept repeated by periodically setting the measurement period 20 throughout the whole heating period. However, the method of applying pulses to the heating unit 130 during the measurement period 20 raises the temperature of the heating unit 130 and consumes the residual battery amount, although the pulse width is short. Meanwhile, a desired temperature profile of the heating unit 130 may include a period in which the temperature of the heating unit 130, which is once raised to a high value, is decreased to a lower value. During this period, it is advantageous to apply no pulses to the heating unit 130 at all in order to efficiently lower the temperature of the heating unit 130. However, if no pulses are applied to the heating unit 130 at all, the first temperature index cannot be measured by using the measurement circuit 150. As generally shown in FIG. 3, therefore, the aerosol generating device 10 according to this embodiment further includes the thermistor 155. The thermistor 155 is disposed near the heating unit 130, and outputs a value depending on the temperature of the heating unit 130 to the control unit 120. In a section in which the temperature of the heating unit 130 is decreased, the control unit 120 determines a timing at which this section is terminated, by using the second temperature index based on the output value from the thermistor 155 (for example, by comparing the index value with the target value). On the other hand, in other sections, the control unit 120 controls the supply of electric power from

the battery 140 to the heating unit 130 by using the first temperature index based on the electrical resistance value of the heating unit 130, as described above. The periodicity of measurement of the second temperature index can be, for example, tens of milliseconds to hundreds of milliseconds.

[0059] FIG. 6 shows an example of the positional relationship between the heating unit 130 and the thermistor 155, when viewed in the direction 106a shown in FIG. 2 (the axial direction of the insertion hole 107). In this example shown in FIG. 6, a cylindrical member 130a is a member defining the space of the insertion hole 107 for receiving the tobacco stick 15. The cylindrical member 130a is formed by using a material having a high thermal conductivity, such as stainless steel (SUS) or aluminum. A film heater 130b is so wound as to surround the outer circumferential surface of the cylindrical member 130a. The film heater 130b is formed by a pair of films having a high heat resistance and high insulation properties, and a resistive heat generating material sandwiched between these films. The heating unit 130 is formed by the cylindrical member 130a and the film heater 130b described above, and a Joule heat generated by an electric current flowing through the film heater 130b heats the tobacco stick 15 inserted into the insertion hole 107 via the cylindrical member 130a. In addition, a heat insulating member 108 is so wound as to surround the outer circumferential surface of the film heater 130b. The heat insulating member 108 is formed by glass wool or the like, and protects the constituent elements of the aerosol generating device 10 from the heat of the heating unit 130. The thermistor 155 is disposed outside the heat insulating member 108. The surface of the film heater 130b is normally smooth, so positioning often becomes difficult if the thermistor 155 is disposed on the outer circumferential surface of the film heater 130b. However, when the thermistor 155 is disposed on the outer circumferential surface of the heat insulating member 108 formed by glass wool, it becomes easy to position the thermistor 155, and a control circuit connected to the thermistor 155 is well protected. However, the positional relationship in which the heat insulating member 108 is disposed between the heating unit 130 and the thermistor 155 causes the second temperature index based on the output value from the thermistor 155 to follow the temperature change of the heating unit 130 with a certain delay.

[0060] <1-6. Temperature Profile and Heating Profile>

[0061] The control unit 120 executes temperature control of the heating unit 130 in accordance with the heating profile as a control sequence defining temporal changes in control conditions for implementing a desired temperature profile. In this embodiment, the heating profile includes a plurality of sections temporally dividing the heating period, and designates specifications of temperature control of each section by a target value and other control parameters.

[0062] FIG. 7 is an explanatory diagram for explaining the temperature profile and the heating profile adoptable in this embodiment. In FIG. 7, the abscissa represents the elapsed time from the start of power supply to the heating unit 130, and the ordinate represents the temperature of the heating unit 130. A thick line represents a temperature profile 40 as an example. The temperature profile 40 includes a preheating period (T0 to T2) at the beginning, and an inhalable period (T2 to T8) following the preheating period. As an example, the whole length of the inhalable period can be about five minutes, and the user can perform inhalation more than 10 times during the inhalable period.

[0063] The preheating period includes a temperature rise section (T0 to T1) in which the temperature of the heating unit 130 is rapidly raised from an environmental temperature H0 to a first temperature H1, and a maintaining section (T1 to T2) in which the temperature of the heating unit 130 is maintained at the first temperature H1. By thus rapidly heating the heating unit 130 to the first temperature H1 at the beginning, it is possible to sufficiently spread heat to the whole aerosol generating substrate of the tobacco stick 15 in an early stage, and start providing the user with high-quality aerosol more rapidly.

[0064] The inhalable period includes a maintaining section (T2 to T3) in which the temperature of the heating unit 130 is maintained at the first temperature H1, a temperature fall section (T3 to T4) in which the temperature of the heating unit 130 is lowered to a second temperature H2, and a maintaining section (T4 to T5) in which the temperature of the heating unit 130 is maintained at the second temperature H2. Since the temperature of the heating unit 130, which is once raised to the first temperature H1, is lowered to the second temperature H2 as described above, it is possible to stably provide the user with inhalation with a good tobacco flavor for a longer time. The inhalable period further includes a temperature rise section (T5 to T6) in which the temperature of the heating unit 130 is gradually raised from the second temperature H2 to a third temperature H3, a maintaining section (T6 to T7) in which the temperature of the heating unit 130 is maintained at the third temperature H3, and a temperature fall section (T7 to T8) in which the temperature of the heating unit 130 is lowered to the environmental temperature H0. Since the temperature of the heating unit 130 is again raised in the second half of the inhalable period as described above, it is possible to suppress a decrease in tobacco flavor in a situation in which the amount of the aerosol source included in the tobacco stick 15 decreases, and provide the user with a highly satisfactory experience to the end of the inhalable period.

[0065] For example, the first temperature H1, the second temperature H2, and the third temperature H3 can be 295° C., 230° C., and 260° C., respectively. However, it is also possible to design a different temperature profile in accordance with, for example, a design guideline of a manufacturer, user preference, or characteristics of each type of a tobacco article.

[0066] The heating profile 50 includes eight sections S0 to S7 bounded by T1 to T7. As will be explained later, however, the transition timing between two sections does not necessarily match one of the points in time T1 to T7 shown in the drawing, but follows a termination condition designated for each section. The heating profile 50 defines one or more control parameters, which are enumerated below for each of the sections S0 to S7:

- [0067] "Section type"
- [0068] "Target temperature"
- [0069] "Target temperature resistance value"
- [0070] "PID control type"
- [0071] "Gains"
- [0072] "Time length"
- [0073] "Termination condition"

[0074] "Section type" is a parameter for designating whether the corresponding section is a PID control section or an OFF section. The PID control section is a section in which PID control is performed based on the first temperature index calculated by the control unit 120 by using the

measurement circuit **150**. The OFF section is a section in which the control unit **120** stops power supply to the heating unit **130** without performing PID control.

[0075] “Target temperature” is a parameter for designating the temperature of the heating unit **130**, which should be reached at the end of the corresponding section. “Target temperature resistance value” is a parameter for designating a value obtained by converting the value of “target temperature” into a resistance value. For example, a target temperature H_{TGT} [° C.] can be converted into the target temperature resistance value R_{TGT} [Ω] in accordance with equation (2) below:

$$R_{TGT} = (P_{TGT} - P_{ENV}) \cdot \alpha \cdot R_{ENV} + R_{ENV} \quad (2)$$

[0076] In equation (2), H_{ENV} represents a reference environmental temperature, α represents the temperature-resistance coefficient of the resistive heat generating material of the heating unit **130**, and R_{ENV} represents an electrical resistance value at the reference environmental temperature. The values of H_{ENV} , α , and R_{ENV} are measured or derived by an evaluation test in advance and prestored in the storage unit **121**.

[0077] “PID control type” is a parameter for designating whether to constantly maintain the target value at the value of “target temperature resistance value” throughout the PID control section, or linearly change the target value by linear interpolation. If “PID control type” is “constant”, the control unit **120** performs feedback control while keeping the target value of temperature control constant in the corresponding section. If “PID control type” is “linear interpolation”, the control unit **120** performs feedback control while changing the target value of temperature control step by step in the corresponding section. The control target value in “linear interpolation” can be set at a specific start value (for example, a currently-measured value or a target value of an immediately preceding section) at the beginning of the section, and increased or decreased practically linearly (in practice, step by step for each control cycle) so that the value becomes “target temperature resistance value” at the end of the section. “PID control type” and “section type” can also be regarded as parameters for designating a control method to be applied to temperature control in each section.

[0078] “Gains” is a set of parameters for designating the values of the proportional gain K_p , the integral gain and the differential gain K_d for the PID control section. Note that when a gain value different from a gain value designated in a preceding section is designated in a certain PID control section, the cumulative deviation of the integral term (the second term on the right side of equation (1)) of feedback control may be reset.

[0079] “Time length” is a parameter for designating a predefined temporal length for each section. “Termination condition” is a parameter for designating a condition for terminating temperature control in each section (that is, a condition for transitioning temperature control to the next section). For example, “termination condition” can be one of C1, C2, and C3 below:

[0080] C1: Elapse of time designated by “time length”

[0081] C2: Arrival of a temperature index at a resistance value designated by “target temperature resistance value”

[0082] C3: Either one of C1 and C2, which is earlier
The control unit **120** can have an internal timer in order to determine the termination conditions C1 and C3.

[0083] In this embodiment, when determining the conditions C2 and C3 in the temperature rise section, the control unit **120** can regard that the temperature index has arrived at the target value in a case in which the temperature index becomes larger than a control threshold $R_{TGT}' (= \beta \cdot R_{TGT})$ equal to the product of the target value R_{TGT} and a coefficient β (β is a positive number slightly smaller than 1. For example, $\beta=0.9975$) representing an allowable deviation. By thus using the arrival at a certain ratio of the target value, instead of the target value itself, as the termination condition of a section, temperature control can appropriately be advanced to the next section even in a situation in which the residual deviation from the target value is not completely zero. The control unit **120** can also count the number (N_{COUNT}) of measurement periods **20** in which the temperature index exceeds the target value R_{TGT} or the control threshold R_{TGT}' , and regard that the temperature index has reached the target value if the counter N_{COUNT} becomes equal to a determination threshold M (M is an integer larger than 1. For example, M=3). By thus using the condition that the temperature index has reached the threshold value a plurality of times as the termination condition of the section, it is possible to reduce the possibility that temperature control advances to the next section at a very early timing as a result of erroneous determination caused by an error of resistance value measurement. This is useful to implement robust condition determination in a situation in which the measurement circuit **150** may undergo an influence of noise (for example, an instantaneous current value variation).

[0084] In the next clause, a more specific configuration example of the heating profile **50** will be explained in order for individual sections.

[0085] <<2. Configuration Example of Heating Profile>>

[0086] <2-1. Initial Temperature Rise (S0)>

[0087] The section S0 is a section at the beginning of the heating profile **50**. “Section type” of the section S0 is “PID control section”, and “Target temperature” is the first temperature H1. “Target temperature resistance value” is a resistance value (to be referred to as R1 hereinafter) corresponding to the first temperature H1. “PID control type” of the section S0 can be “constant”, and the time required to raise the temperature can be shortened as much as possible by setting the proportional gain K_p of “Gains” at a value higher than those of other sections. “Termination condition” of the section S0 is the condition C2, more specifically, the arrival of the first temperature index at the resistance value R1.

[0088] The control unit **120** may further divide the section S0 into a first-half section and a second-half section, and, in the first-half section, can supply electric power from the battery **140** to the heating unit **130** at a maximum settable duty ratio regardless of the gain value and the temperature index value. This can efficiently shorten the preheating period, and rapidly start delivery of aerosol to the user.

[0089] <2-2. Temperature-Maintaining During Preheating (S1)>

[0090] “Section type” of the section S1 is “PID control section”, and “Target temperature” is the first temperature H1. “Target temperature resistance value” is the resistance value R1 corresponding to the first temperature H1. “PID control type” of the section S1 can be “constant”. “Gains” of the section S1 can be set at a value that stabilizes the temperature of the heating unit **130** near the first temperature H1 (for example, a proportional gain having a value smaller

than that of the proportional gain designated for the section S0 may be set for the section S1), unlike the case of the section S0 in which the temperature is rapidly raised. “Time length” of the section S1 can be set at a value within the range of, for example, a few seconds. “Termination condition” of the section S1 is the condition C1, more specifically, the elapse of time indicated by “Time length”. The control unit 120 sets the timer at the start of the section S1, and notifies the user of the end of the preheating period if the control unit 120 determines that the time indicated by “Time length” has elapsed. This notification can be performed by one or both of light emission of the light emitting unit 125 by a predetermined light emission pattern and the vibration of the vibration unit 126 by a predetermined vibration pattern. Upon sensing this notification, the user recognizes that preparations of inhalation are complete and inhalation can be started.

[0091] <2-3. Session Start (S2)>

[0092] “Session type” of the section S2 is “PID control section”, and “target temperature” is the first temperature H1. “Target temperature resistance value” is the resistance value R1 corresponding to the first temperature H1. “PID control type” of the section S2 can be “constant”. “Gains” of the section S2 can be the same as that of the section S1. “Time length” of the section S2 can be set at a value within the range of, for example, a few seconds to about ten seconds. “Termination condition” of the section S2 is the condition C1, more specifically, the elapse of time indicated by “Time length”. If the control unit 120 determines that the time indicated by “Time length” has elapsed, the control unit 120 terminates the section S2 and cause temperature control to transition to the section S3.

[0093] The user normally starts inhaling aerosol generated by the aerosol generating device 10 from the section S2. The control unit 120 can measure one or more of: the number of times of inhalation, the frequency of inhalation, the inhalation time of each inhalation, and the cumulative inhalation time, based on an inhalation detection signal input from the inhalation detection unit 124, and can store the measurement results in the storage unit 121. This measurement can also be performed continuously from the section S3 as well.

[0094] <2-4. Temperature Fall (S3)>

[0095] “Section type” of the section S3 is “OFF section”, and “Target temperature” is the second temperature H2. “Target temperature resistance value” is a resistance value (to be referred to as R2 hereinafter) corresponding to the second temperature H2. That is, in the section S3, the control unit 120 stops causing electric power to be supplied from the battery 140 to the heating unit 130 so that the temperature of the heating unit 130 falls to the second temperature H2 lower than the first temperature H1. Since the section S3 is an OFF section, “PID control type” and “Gains” are not set. “Time length” of the section S3 can be set at a value within the range of, for example, tens of seconds. “Termination condition” of the section S3 is the condition C3. More specifically, the control unit 120 terminates the section S3 when it is determined from the second temperature index based on the output value from the thermistor 155 that the temperature of the heating unit 130 has reached the second temperature H2. However, even before the temperature of the heating unit 130 reaches the second temperature H2, the control unit 120 terminates the section S3 when the time indicated by “Time length” has elapsed from the start of the section S3. In other words, the control unit 120 terminates

the section S3 based on an earlier one of the arrival of the second temperature index at the target value and the elapse of the predetermined time from the start of the section, and causes temperature control to transition to the section S4.

[0096] Note that when the section S3 is terminated by the arrival of the second temperature index at the target value earlier than a time (for example, T4 shown in FIG. 7) at which the time indicated by “Time length” elapses from the start of the section S3, the total time of the session shortens if the time length of the succeeding section does not change. An early termination of the session frustrates the user or brings the inconvenience that the aerosol source included in the aerosol generating substrate is not sufficiently used up. Therefore, when terminating the section S3 earlier than a time point at which the time indicated by “Time length” of the section S3 elapses, the control unit 120 adds the residual time before that time point to “Time length” designated for the succeeding section (for example, the section S4). FIG. 8 shows a temperature profile 40a of a case where the remaining time is added to the time length of the subsequent section S4 because the termination of the section S3 is earlier than the predetermined time, in comparison with the temperature profile 40 shown in FIG. 7. In the temperature profile 40a, the temperature of the heating unit 130 reaches the second temperature H2 at T3a before T4. As a consequence, the residual time (T4-T3a) is added to the time length of the section S4. In an OFF section such as the section S3, the fall rate of the temperature of the heating unit 130 changes depending on the environmental conditions. Accordingly, the use of the method of compensating for the time length of a session as described above is useful to effectively consume the aerosol source and improve the satisfaction of the user.

[0097] <2-5. Correction of Second Temperature Index>

[0098] As described above, the second temperature index based on the output value from the thermistor 155 follows the change in temperature of the heating unit 130 with a certain delay. Therefore, if the control unit 120 directly compares the second temperature index with the target value in order to determine termination of the section S3, the temperature of the heating unit 130 may have further dropped from the target temperature at the end of the section S3. If the temperature of the heating unit 130 is too low, the amount of aerosol generated from the aerosol generating substrate reduces, and the tobacco flavor decreases. In this embodiment, therefore, in the section S3, the control unit 120 corrects the second temperature index so as to compensate for the delay of change of the second temperature index, and compares the corrected index value with the target value, thereby determining whether the temperature of the heating unit 130 has reached the second temperature H2. To correct the second temperature index, the control unit 120 uses a predetermined relationship between the first temperature index and the second temperature index. For example, in a section (for example, the section S0) preceding the section S3, the control unit 120 acquires the second temperature index based on the output value from the thermistor 155, in addition to the first temperature index based on the electrical resistance value of the heating unit 130. Then, prior to the start of the section S3, the control unit 120 determines the relationship between the acquired first and second temperature indices.

[0099] FIG. 9 is an explanatory diagram for explaining the relationship between the first and second temperature indices. A solid-line graph 61 represents an example of a

temporal change of the value of the first temperature index when temperature control is performed till T4 in accordance with the heating profile 50 explained with reference to FIG. 7. A graph 62 of an alternate long and short dash line represents an example of a temporal change of the value of the second temperature index when temperature control is performed till T4 in accordance with the same heating profile 50. As can be understood from the comparison of the two graphs 61 and 62, the first temperature index and the second temperature index are almost linear loci especially in the beginning (for example, the section S0) of the preheating period, but a temperature change rate (a gradient g_2 in the drawing) indicated by the second temperature index is relatively smaller than a temperature change rate (a gradient g_1 in the drawing), so even after the first temperature index has reached the target value at T1, the second temperature index has not reached the target value. The difference between the second temperature index and the target value gradually decreases from the section S1 to the section S2 (because heat of the heating unit 130 is conducted to the thermistor 155 via the heat insulating member 108), but a difference d_1 from the target value still remains even at T3. When the section S3, that is, an OFF section starts at T3, the first temperature index and the second temperature index draw substantially linear graphs again while falling.

[0100] Assume, as a simple model, that the gradient difference between the two temperature indices when the temperature of the heating unit 130 drops is equal to the gradient difference ($g_1 - g_2$) between the two temperature indices when the temperature rises (however, the sign is inverted). Then, the control unit 120 can calculate a correction value to be applied to the second temperature index in the section S3, based on the temperature difference d_1 indicated by the two indices at the starting point in time of the section S3 and the difference ($g_1 - g_2$) between the temperature change rate acquired in the section S0. To simplify the explanation, assume that the temperature value is used to determine the termination condition of the section S3 instead of the resistance value. In this case, a correction value $\Delta h(t)$ to be added to the value of the second temperature index at the point in time when a time t has elapsed from the start of the section S3 can be calculated as indicated by an equation below:

$$\Delta h(t) = d_1 - (g_1 - g_2) \cdot t \quad (3)$$

[0101] Note that instead of individually acquiring the gradient g_1 of the first temperature index and the gradient g_2 of the second temperature index, the control unit 120 can acquire, for example, the difference ($g_1 - g_2$) between the two gradients by dividing the difference (d_2 in FIG. 9) between the index values at the point in time at which the value of the second temperature index reaches the value corresponding to the second temperature H2 by the time elapsed until that point in time.

[0102] The above-described relationship between the first temperature index and the second temperature index can also be acquired and stored in the storage unit 121 before heating is started, not in the sections S0 to S2 immediately before the section S3. As the first example, the relationship between the first temperature index and the second temperature index can be acquired in an evaluation test before the aerosol generating device 10 is shipped. As the second example, the control unit 120 can acquire and record the values of the first and second temperature indices at the start

and end of the section S3 in each session. In this case, to determine the termination condition of the section S3 in a new session, the control unit 120 can calculate the above-described correction value $\Delta h(t)$ of the second temperature index based on the difference between the change rates of two temperature index values already recorded in the past, and use the calculation result. As a derivation of the second example, the two temperature index values can also be recorded in relation to the environmental temperature measured by a temperature sensor, and the control unit 120 may also calculate the correction value of the second temperature index based on the record corresponding to the environmental temperature at the point in time of a new session. The aerosol generating device 10 may have a temperature sensor for measuring the environmental temperature, or receive environmental temperature data from another device via the wireless I/F 127 or the connection I/F 128.

[0103] As described above, the control unit 120 can avoid the temperature of the heating unit 130 from excessively falling from the second temperature H2 in the section S3 and prevent a decrease in tobacco flavor, by using the index value so corrected as to compensate for the delay of change of the second temperature index in order to determine the termination condition.

[0104] <2-6. Temperature-Maintaining after Temperature Fall (S4)>

[0105] "Section type" of the section S4 is "PID control section". That is, the control unit 120 restarts the supply of electric power from the battery 140 to the heating unit 130 in response to the transition of temperature control from the section S3 to the section S4. "Target temperature" of the section S4 is the second temperature H2. "Target temperature resistance value" is the resistance value R2 corresponding to the second temperature H2. "PID control type" of the section S4 can be "constant". "Gains" of the section S4 can be the same as that set in the section S1 and the section S2. "Time length" of the section S4 can be set to, for example, tens of seconds to a few minutes. "Termination condition" of the section S4 is the condition C1, more specifically, the elapse of time indicated by "time length". If the control unit 120 determines that the time indicated by "Time length" has elapsed, the control unit 120 terminates the section S4 and causes temperature control to transition to the section S5.

[0106] When the section S3 is terminated because the time indicated by "Time length" of the section S3 has elapsed, there is a possibility that the temperature of the heating unit 130 at the terminating point in time is significantly higher than the second temperature H2. Meanwhile, "Gains" of the section S4 has values tuned for the purpose of maintaining the temperature constant. Therefore, if PID control is resumed by setting the target temperature at the second temperature H2 in the section S4, the temperature of the heating unit 130 may behave unstably due to the divergence of the temperature at the start of the section S4 from the second temperature H2. Therefore, if the temperature of the heating unit 130 at the terminating point in time of the section S3 is higher than the second temperature H2, the control unit 120 can handle the temperature at that point in time as the target temperature of the section S4. That is, the control unit 120 can reset the target temperature resistance value corresponding to the temperature at the terminating point in time of the section S3 as the target value of PID control in the section S4. This can stabilize the temperature of the heating unit 130 in the section S4. FIG. 10 shows two

examples (temperature profiles **41a** and **41b**) of the temperature profile in a case where the target value of PID control in the section **S4** is reset to the target temperature resistance value corresponding to the temperature at the terminating point in time of the section **S3**, in comparison with the temperature profile **40** shown in FIG. 7. The temperature profile **41a** is an example in a case where a temperature **H2a** at the terminating point in time of the section **S3** is lower than the third temperature **H3**. The temperature profile **41b** is an example in a case where a temperature **H2b** at the terminating point in time of the section **S3** is higher than the third temperature **H3**.

[0107] Though an example in which “Termination condition” of the section **S3** is the condition **C3** has been explained above, “Termination condition” of the section **S3** may be the condition **C2** as the first modification. In this case, the control unit **120** maintains temperature control in the section **S3** until the temperature indicated by the second temperature index reaches the second temperature **H2**, regardless of the time elapsed from the start of the section **S3**. This can avoid the situation in which the temperature of the heating unit **130** diverges from the second temperature **H2** when the section **S4** starts. In this modification, if the temperature of the heating unit **130** reaches the target temperature **H2** later than the time point (for example, **T4** in FIG. 7) at which “Time length” of the section **S3** elapses from the start of the section **S3**, the control unit **120** may subtract, from “time length” of the section **S4**, the overtime with respect to that time point (that is, the section **S4** may be shortened). This can avoid the time length of the whole heating period from excessively prolonging, and prevent a decrease in tobacco flavor caused by depletion of the aerosol source. FIG. 11 shows a temperature profile **42** in a case where the section **S4** is shortened as a result of prolongation of the section **S3** in the first modification, in comparison with the temperature profile **40** shown in FIG. 7. In the temperature profile **42**, the temperature of the heating unit **130** reaches the second temperature **H2** at **T4a** after **T4**. Consequently, the time length of the section **S4** is reduced by the overtime (**T4a-T4**).

[0108] As the second modification, “Termination condition” of the section **S3** is the condition **C2**, but the control unit **120** may reset the target temperature of the section **S3** from the second temperature **H2** to the third temperature **H3** at a point in time when the time indicated by “Time length” of the section **S3** has elapsed. If the temperature of the heating unit **130** reaches the target temperature **H3** later than the time point (for example, **T4** in FIG. 7) at which “time length” of the section **S3** elapses, the control unit **120** may subtract, from “time length” of the section **S4**, the overtime with respect to that time point (that is, the section **S4** may be shortened), in this modification as well. This can avoid the time length of the whole heating period from excessively prolonging. FIG. 12 shows a temperature profile **43** in a case where the section **S4** is shortened as a result of prolongation of the section **S3** in the second modification, in comparison with the temperature profile **40** shown in FIG. 7. In the temperature profile **43**, the target temperature is reset to the third temperature **H3** at **T4**, and the temperature of the heating unit **130** reaches the third temperature **H3** at **T4b**. Consequently, the time length of the section **S4** is reduced by the overtime (**T4b-T4**).

[0109] <2-7. Temperature Rerise (S5)>

[0110] “Section type” of the section **S5** is “PID control section”. “Target temperature” of the section **S5** is the third temperature **H3**. “Target temperature resistance value” is a resistance value (to be referred to as **R3** hereinafter) corresponding to the third temperature **H3**. “PID control type” of the section **S5** is “linear interpolation”. That is, the control unit **120** raises the target value of PID control step by step from the target value (for example, the resistance value **R2**) of the section **S4** to the resistance value **R3** from the start to the end of this section. “Gains” of the section **S5** can be either the same as or different from that set in the section **S4**. “Time length” of the section **S5** can be set to, for example, tens of seconds to a few minutes. “Termination condition” of the section **S5** is the condition **C1**. More specifically, when the time indicated by “Time length” has elapsed from the start of the section **S5**, the control unit **120** terminates the section **S5** and causes temperature control to transition to the section **S6**.

[0111] Note that if “Termination condition” of the section **S3** is the condition **C2** as in the first modification explained in relation to the section **S4**, there is a possibility that the overtime to be subtracted becomes larger than “Time length” predefined for the section **S4** as a result of a large delay of the termination of the section **S3**. In this modification, therefore, if the temperature of the heating unit **130** has reached the target temperature **H2** later than the time point (for example, **T5** in FIG. 7) at which the total time of “time length” of the section **S3** and “time length” of the section **S4** has elapsed from the start of the section **S3**, the control unit **120** may subtract, from “Time length” of the section **S5**, the overtime with respect to that time point (that is, the section **S5** may be shortened). In this case, the section **S4** is skipped. FIG. 13 shows a temperature profile **44** in a case where the section **S4** is skipped and the section **S5** is shortened as a result of prolongation of the section **S3** in the first modification, in comparison with the temperature profile **40** shown in FIG. 7. In the temperature profile **44**, the temperature of the heating unit **130** reaches the second temperature **H2** at **T5a** after **T5**. Consequently, the time length of the section **S5** is reduced by the overtime (**T5a-T5**).

[0112] The method of shortening the section **S5** shown in FIG. 13 can also be combined with the second modification explained in relation to the section **S4**. FIG. 14 shows a temperature profile **45** in a case where the section **S4** is skipped and the section **S5** is shortened as a result of prolongation of the section **S3**, in comparison with the temperature profile **40** shown in FIG. 7. In the temperature profile **45**, the temperature of the heating unit **130** reaches the third temperature **H3** (the reset target temperature) at **T5b** after **T5**. Consequently, the time length of the section **S5** is reduced by the overtime (**T5b-T5**).

[0113] <2-8. Temperature-Maintaining after Temperature Rerise (S6)>

[0114] “Section type” of the section **S6** is “PID control section”. “Target temperature” of the section **S6** is the third temperature **H3**. “Target temperature resistance value” is the resistance value **R3** corresponding to the third temperature **H3**. “PID control type” of the section **S6** can be “constant”. “Gains” of the section **S6** can be the same as those set in the section **S1**, the section **S2**, and the section **S4**. “Time length” of the section **S6** can be set at a value within the range of, for example, tens of seconds. “Termination condition” of the section **S6** is the condition **C1**, more specifically, the elapse of time indicated by “Time length”. If the control unit **120**

determines that the time indicated by “Time length” has elapsed, the control unit 120 terminates the section S6 and causes temperature control to transition to the section S7.

[0115] Like the section S4, “Gains” of the section S6 has values tuned for the purpose of maintaining the temperature constant. Although the target temperature of the section S6 is the third temperature H3, if PID control is resumed by setting the target value of the section S6 at the resistance value R3 when the temperature at the start of the section S6 significantly diverges from the third temperature H3, the temperature of the heating unit 130 may behave unstably. Therefore, if the temperature of the heating unit 130 at a certain reference point in time (for example, at the starting point in time of the section S6) significantly diverges from the third temperature H3 (for example, is higher than the third temperature H3), the control unit 120 may handle the temperature at that point in time as the target temperature of the section S6. That is, the control unit 120 may reset the target value of PID control in the section S6 to a target temperature resistance value corresponding to the current temperature at the reference point in time. This can stabilize the temperature of the heating unit 130 in the section S6. FIG. 15 shows a temperature profile 46 in a case where the target value of PID control in the section S6 is reset to the target temperature resistance value corresponding to the current temperature at the starting point in time of the section S6, in comparison with the temperature profile 40 shown in FIG. 7. In the temperature profile 46, the target temperature is reset to a current temperature H3a higher than the third temperature at T6, and the temperature of the heating unit 130 is maintained at the temperature H3a throughout the section S6.

[0116] <2-9. Termination (S7)>

[0117] “Section type” of the section S7 is “OFF section”. In the section S7, the temperature of the heating unit 130 falls toward the environmental temperature H0. “Target temperature”, “Target temperature resistance value”, and “Gains” of the section S7 need not be set. “Time length” of the section S7 can be set at a value within the range of, for example, a few seconds to tens of seconds. “Termination condition” of the section S7 is the condition C1, more specifically, the elapse of time indicated by “Time length”. If the control unit 120 determines that the time indicated by “Time length” has elapsed, the control unit 120 terminates the heating period. At the start of the section S7, the control unit 120 can notify the user of an approach of the end of the inhalable period, by the light emission of the light emitting unit 125 or the vibration of the vibration unit 126. The control unit 120 can also notify the user of the end of the inhalable period at the end of the section S7, by the light emission of the light emitting unit 125 or the vibration of the vibration unit 126.

[0118] <2-10. Recovery (S4a)/Maintaining (S4b) after Excessive Temperature Fall>

[0119] An example has been described above where, when the second temperature index has reached the resistance value R2 corresponding to the second temperature H2, the section S3 is terminated and temperature control is caused to transition to the section S4. In this case, if correction of the second temperature index is performed with high accuracy, the temperature of the heating unit 130 is substantially equal to the second temperature H2 at the time of transition to the section S4. In practice, however, the corrected second temperature index contains an error to some extent, so the

temperature of the heating unit 130 may significantly diverge from the second temperature H2 (for example, the temperature has fallen to a lower temperature) at the time of transitioning to the section S4. As a third modification, therefore, the control unit 120 may acquire a first temperature index when starting the section S4, and, in the section S4, control the supply of electric power from the battery 140 to the heating unit 130 by using a control parameter set that differs in accordance with the temperature of the heating unit 130 indicated by the acquired first temperature index.

[0120] Let H_{2c} be the temperature of the heating unit 130 indicated by the first temperature index when starting the section S4. In this third modification, if the temperature H_{2c} is lower than the second temperature H2 ($H_{2c} < H2$), the control unit 120 uses a first control parameter set for recovering (raising) the temperature of the heating unit 130 to the second temperature H2. On the other hand, if the temperature H_{2c} is equal to or higher than the second temperature H2 ($H_{2c} \geq H2$), the control unit 120 uses a second control parameter set for maintaining the temperature of the heating unit 130 at the temperature H_{2c} . For example, the first control parameter set includes a value K_{p1} of the proportional gain of feedback control, the second control parameter set includes K_{p2} of the proportional gain of feedback control, and K_{p1} is larger than K_{p2} . In addition, the values of one or both of the integral gain and the differential gain can be different between the first control parameter set and the second control parameter set. By thus switching between the control parameter sets of feedback control depending on the temperature of the heating unit 130 at the start of the section S4, it is possible to prevent the temperature of the heating unit 130 from deviating from a desired temperature (for example, the second temperature H2) in the middle of the session, and thereby it is possible to mitigate a decrease in the tobacco flavor.

[0121] If it is determined that the temperature of the heating unit 130 is recovered to the second temperature H2 by temperature control using the first control parameter set, the control unit 120 may switch the control parameter set from the first control parameter set to the second control parameter set. Typically, it is assumed that even when the temperature of the heating unit 130 excessively drops due to the error in the corrected second temperature index, the degree of this temperature drop is small. Therefore, the stability of the temperature of the heating unit 130 in the section S4 can be increased by switching the control parameter set to the second control parameter set after the temperature of the heating unit 130 is recovered within a short time.

[0122] FIG. 16 shows an example of a temperature profile in a case where the section S4 includes a recovery section in the third modification. In this example shown in FIG. 16, the temperature H_{2c} when the section S4 is started is lower than the second temperature H2. Therefore, the control unit 120 sets a recovery section S4a at the beginning of the section S4, and performs PID control by using the first control parameter set including the value K_{p1} of a larger proportional gain. The target value of this PID control can be the resistance value R2 corresponding to the second temperature H2. This PID control brings the temperature of the heating unit 130 back to the second temperature H2 at T4c. Then, the control unit 120 causes temperature control to transition from the recovery section S4a to a maintaining section S4b, and switches the control parameter set for PID control to the

second control parameter set including the value K_{p2} of the proportional gain. Consequently, the temperature of the heating unit 130 is maintained near the second temperature H2 until T5.

[0123] Note that when determining whether the first temperature index has reached the target value R2 in the recovery section S4a, the control unit 120 may perform threshold determination taking account of the above-described coefficient β representing the allowable deviation. Moreover, a condition that the first temperature index reached the threshold value M times may be used as the condition to terminate the recovery section S4a (that is, transition to the maintain section S4b).

[0124] The first control parameter set for use in the recovery section S4a may be the same as the control parameter set used to initially raise the temperature of the heating unit 130 in the section S0. For example, the value K_{p1} of the proportional gain of the first control parameter set may be equal to the value of the proportional gain used when initially raising the temperature. By thus reusing the control parameter set between sections having a similar control purpose (for example, a rapid temperature rise, a moderate temperature rise, or temperature maintaining), it is possible to avoid increasing the size of profile data describing the heating profile, and save the memory resource for storing the data (and the communication resource for communicating the data).

[0125] <2-11. Configuration Example of Profile Data>

[0126] It is useful to define a structuralized standard data format capable of describing the operational specification of each section of the heating profile 50 explained so far. The standard data format makes it easy to switch between the heating profiles 50 and change behavior of temperature control, in various scenes such as upgrading the operational specification, a change of the type of a tobacco article, and selection of a temperature profile that matches a user preference. Several examples of the configuration of the profile data 51 describing the heating profile 50 will be explained below.

[0127] FIG. 17A is an explanatory diagram for explaining the first example of the configuration of the profile data 51. Referring to FIG. 17A, the profile data 51 contains seven information elements, that is, Section Number 52, Control Method 53, Target Temperature 54, Target Temperature Resistance Value 55, Gains 56, Time Length 57, and Termination Condition 58.

[0128] Section Number 52 is a number (identifier) for identifying each section. Control Method 53 is an information element for designating a control method to be applied to temperature control of each section from a plurality of control methods. In this example, the control method 53 is equivalent to a combination of the above-described control parameters “Section type” and “PID control type”, and can take one of values “0”, “1”, and “2”. In the example shown in FIG. 17A, Control Method 53 of a section S_n indicates the value “1”, and this value represents that the control method to be applied to this section is PID control and the control target value must be maintained constant in the section. Control Method 53 of a section S_{n+1} indicates the value “0”, and this value represents that the control method to be applied to this section is stopping power supply to the heating unit 130. That is, the section S_{n+1} in this example is an OFF section. Control Method 53 of a section S_{n+2} indicates the value “2”, and this value represents the control

method to be applied to this section is PID control and the control target value must be changed linearly in this section.

[0129] Target Temperature 54 and Target Temperature Resistance Value 55 are information elements for respectively designating the control parameters “Target temperature” and “Target temperature resistance value”. Note that when temperature control is performed by using the temperature itself as a controlled variable, Target Temperature Resistance Value 55 may be omitted from the profile data 51. Gains 56 is an information element for designating the above-described control parameter set “Gains”. Gains 56 can be blank for an OFF section. Time Length 57 and Termination Condition 58 are information elements for respectively designating the above-described control parameters “Time length” and “Termination condition”.

[0130] FIG. 17B is an explanatory diagram showing the second example of the configuration of the profile data 51. Referring to FIG. 17B, the profile data 51 contains a common area 51a and a sectional area 51b.

[0131] The common area 51a is a data area for describing information that is common over a plurality of sections. In this example shown in FIG. 17B, the common area 51a includes three information elements 59a, 59b, and 59c. The information element 59a designates a number (identifier) for uniquely identifying a control profile to be described by this profile data. The information element 59b designates a first gain set K_1 , and the information element 59c designates a second gain set K_2 . The gain set K_1 contains a proportional gain value K_{p1} , an integral gain value K_{i1} , and a differential gain value K_{d1} , and the gain set K_2 contains a proportional gain value K_{p2} , an integral gain value K_{i2} , and a differential gain value K_{d2} .

[0132] The sectional area 51b is a data area for describing information unique to each section. In the example shown in FIG. 17B, the sectional area 51b contains six information elements, that is, Section Number 52, Target Temperature 54, Target Temperature Resistance Value 55, Gains 56, Time Length 57, and Termination Condition 58. In this example, Control Method 53 shown in FIG. 17A is omitted. Instead, if the value of Target Temperature 54 indicates a value larger than 0, this value represents that the PID control method must be applied to the section. In addition, if the value of Target Temperature 54 indicates 0, this value represents that the section is an OFF section. In the example shown in FIG. 17B, Target Temperature 54 indicates 0 for the section S_{n+1} , so the section S_{n+1} is an OFF section. In this manner, by assigning meanings of two or more control parameters to a single information element in the profile data 51, the number of information elements of the profile data 51 can be reduced. Furthermore, Gains 56 designates one of the gain set K_1 and the gain set K_2 , instead of specific values of the three types of gains as shown in the example of FIG. 17A. For example, the gain set K_1 is designated for the section S_n , and the gain set K_2 is designated for the section S_{n+2} and a section S_{n+3} . In this manner, by enabling, in the sectional area 51b, to designate one of the limited number of choices defined in the common area 51a, repetitions of redundant value definition can be avoided and data size of the profile data 51 can be reduced. Not only the gains but also another control parameter such as the temperature or the resistance value may be designated by this technique using the common area 51a.

[0133] It is possible to allocate the structuralized standard data format such as the profile data 51 described above to a

predetermined data area of the storage unit **121**, thereby making data in the data area rewritable. This makes it possible to change behavior of temperature control to be executed by the control unit **120** by only rewriting the profile data **51** without changing any control program. In this case, all the control unit **120** needs to do is reading out the latest contents from the same data area of the storage unit **121**, and use the readout data.

[0134] The configurations of the profile data **51** are not limited to the examples shown in FIGS. 17A and 17B. The profile data **51** may contain additional information elements, or some of the information elements shown in the drawings may be omitted. For example, the profile data **51** may contain one of the followings as information that is common over a plurality of sections:

[0135] The name of the heating profile

[0136] The version number of the heating profile

[0137] The number of sections forming the heating profile

[0138] A calibration value (that can be written based on the result of a test before product shipment) to be added to a temperature or a resistance value, in order to absorb a manufacturing tolerance of the resistive-temperature characteristic of the heating unit of each product

[0139] Also, the profile data **51** may additionally contain one of the followings as information that can be designated for each section:

[0140] Whether to determine the duty ratio of power supply to the heating unit by PID control or to use a maximum duty ratio

[0141] Whether to reset the cumulative deviation of the integral term of PID control at the start of a section

[0142] Types of abnormality to be detected

[0143] In this specification, an example has been mainly described where power supply to the heating unit **130** is stopped and no pulse for measuring the temperature or the resistance value is applied to the heating unit **130** in an OFF section. However, control methods that can be designated by the profile data **51** may include a method in which power supply (for heating) to the heating unit **130** is stopped but a pulse for measuring the temperature or the resistance value can be applied to the heating unit **130**. A section for which such a control method is designated may also be called "OFF section". In addition, the profile data **51** may also designate a termination condition other than the conditions C1 to C3 described above for each section. For example, the designatable termination conditions include a condition based on the detected count of inhalation or the detected total time of inhalation.

[0144] Some of the control parameters of the heating profile **50** explained in this clause may be described in a separate storage area instead of being described in the profile data **51**, or may be described by a program code of a control program.

[0145] <<3. Abnormality Detection>>

[0146] The control unit **120** monitors whether there is an abnormality in the operation of the aerosol generating device **10** while performing temperature control in accordance with the heating profile **50** described in the profile data **51**. When an abnormality is detected, the control unit **120** stops the supply of electric power from the battery **140** to the heating unit **130**, stores an error code indicating the type of the detected abnormality in the storage unit **121**, and notifies the user of the occurrence of the abnormality. Several abnor-

malities types detectable by the control unit **120** in relation to temperature control of the heating unit **130** will be explained below.

[0147] <<3-1. Trouble of Measurement Circuit>>

[0148] If a trouble occurs in the measurement circuit **150** and no accurate temperature index can be acquired, the control unit **120** cannot recognize this state even when the temperature of the heating unit **130** becomes excessively high. To prevent a situation like this, the control unit **120** monitors an amount of change in the first temperature index per predetermined time interval while supplying electric power to the heating unit **130** in the section S0. Then, if the amount of change in the first temperature index becomes smaller than a threshold value, the control unit **120** determines that a trouble may have occurred in the measurement circuit **150**, and stops power supply from the battery **140** to the heating unit **130**. In this case, the threshold value can be a temperature change of 10° C. (a change in resistance value equivalent to 10° C.) during a time interval of three seconds.

[0149] <<3-2. Preheating Failure>>

[0150] If the temperature of the heating unit **130** does not reach the target value (for example, the first temperature H1) even when electric power is supplied to the heating unit **130** over a sufficient time in the preheating period, there is a possibility that the power supply route from the battery **140** to the heating unit **130** has a trouble or the environment has an abnormality, for example, the environmental temperature is abnormally low. To detect a situation like this and prevent the waste of electric power, if the control unit **120** determines from the first temperature index that the temperature of the heating unit **130** has not reached the target temperature at a point in time when a predetermined time has elapsed from the start of heating in the section S0, the control unit **120** stops power supply from the battery **140** to the heating unit **130**. The predetermined time herein may be equal to the time length designated for the section S0 by the heating profile **50** (or may be defined independently of the heating profile **50**), and may be, for example, 60 seconds.

[0151] <<3-3. Overheating (When Heating Is Resumed)>>

[0152] As described previously, the second temperature index based on the output value from the thermistor **155** has a delay or an error to some extent. Therefore, determining from the first temperature index whether the temperature of the heating unit **130** is excessively high at the termination point in time of the section S3 as an OFF section can further improve safety of the device. More specifically, when the time length designated by the heating profile **50** has elapsed from the start of the section S3 (before transitioning to the section S4), the control unit **120** compares the temperature of the heating unit **130** indicated by the first temperature index with the first temperature H1. Then, if the temperature of the heating unit **130** is found to be higher than the first temperature H1, the control unit **120** determines that the heating unit **130** is overheating, and terminates the temperature control conforming to the heating profile **50**. Note that the detection of overheating based on the first temperature index may be performed not only when heating is resumed but also periodically in sections other than an OFF section.

[0153] <<3-4. Overheating (OFF Section)>>

[0154] To make the overheating state of the heating unit **130** detectable even in an OFF state, the control unit **120** may compare the temperature of the heating unit **130** indicated by the second temperature index with the first temperature H1 in the section S3. If the temperature of the

heating unit 130 is found to be higher than the first temperature H1, the control unit 120 determines that the heating unit 130 is overheating, and terminates the temperature control conforming to the heating profile 50. This can increase the possibility to detect an overheating state caused by a certain trouble during an OFF period early.

[0155] <<4. Process Flow>>

[0156] In this clause, flows of main portions of the control process to be executed by the control unit 120 of the aerosol generating device 10 described above will be explained by using several flowcharts. In the following explanation, a processing step will be abbreviated as S (step).

[0157] Note that for the sake of descriptive simplicity, each flowchart does not show processing steps for abnormality detection explained in the previous clause. Abnormality detection may periodically be performed in a part of a normal control routine of the control unit 120, and may also be performed at a specific timing, for example, the start of heating or a transition between sections. Alternatively, a detection circuit different from the control unit 120 may detect an abnormality and notify the control unit 120 of the detected abnormality (by an interrupt signal or the like).

[0158] <4-1. Aerosol Generation Process>

[0159] FIG. 18 is a flowchart showing an example of the overall flow of an aerosol generation process according to an embodiment.

[0160] First, in S101, the control unit 120 monitors an input signal from the input detection unit 122, and waits for a user input (for example, long press of a button) requesting the start of heating. If a user input requesting the start of heating is detected, the process advances to S103.

[0161] In S103, the control unit 120 checks the state of the aerosol generating device 10 in order to start heating. This state check can include certain check conditions such as whether the residual power amount of the battery 140 is sufficient, and whether the front panel 102 has not fallen off. If one or more check conditions are not met, heating is not started, and the process returns to S101. If all the check conditions are met, the process advances to S105.

[0162] In S105, the control unit 120 reads out the profile data 51 from a predetermined storage area of the storage unit 121. S107 to S133 after that are repeated for each of a plurality of sections included in the heating profile 50 described in the profile data 51.

[0163] In S107, the control unit 120 determines whether the current section is a PID control section or an OFF section based on "Section type" designating a control method to be applied to the current section. If the current section is a PID control section, the process advances to S110. On the other hand, if the current section is an OFF section, the process advances to S120.

[0164] In S110, the control unit 120 executes a temperature control process for a PID control section so that the temperature of the heating unit 130 becomes a temperature designated for the current section. A more specific flow of the temperature control process to be executed in this step will be explained later.

[0165] In S120, the control unit 120 executes a temperature control process for an OFF section so that the temperature of the heating unit 130 drops to the temperature designated for the current section. A more specific flow of the temperature control process to be executed in this step will be explained later.

[0166] When the temperature control process in S110 or S120 is terminated because the termination condition is met, the control unit 120 determines in S131 whether the heating profile 50 has the next section. If the heating profile 50 has the next section, temperature control transitions to the next section in S131, and S107 to S133 described above are repeated for the next section set as the current section. If there is no next section, the aerosol generation process shown in FIG. 18 ends.

[0167] <4-2. Temperature Control Process in PID Control Section>

[0168] FIG. 19 is a flowchart showing an example of the flow of the temperature control process for a PID control section, which is executed in S110 of FIG. 18.

[0169] First, in S111, the control unit 120 acquires the target temperature and the time length designated for the current section by the heating profile 50, and sets the termination condition of the current section. For example, if the termination condition is the condition C1 or C3, the control unit 120 sets the designated time length in a timer and activates the timer. If the termination condition is the condition C2 or C3, the control unit 120 sets a control threshold (for example, a threshold taking account of an allowable deviation) to be compared with the first temperature index, based on the designated target temperature.

[0170] Then, in S112, the control unit 120 sets PID control parameters of the current section. For example, the control unit 120 sets the target temperature resistance value as the target value of PID control, the proportional gain, the integral gain, and the differential gain at the values designated for the current section by the heating profile 50.

[0171] S113 to S118 after that are repeated for each control cycle. First, in S113, the control unit 120 determines whether to linearly interpolate the target value of PID control. If "linear interpolation" is designated as "PID control type" of the heating profile 50 for the current section, the control unit 120 resets the target value of PID control by linear interpolation in S114 such that they change step by step for each control cycle. If "constant" is set as "PID control type" for the current section, S114 is skipped.

[0172] In S115, the control unit 120 acquires the first temperature index based on the electrical resistance value of the heating unit 130 by using the measurement circuit 150. This index value acquired in this step can be, for example, an average value as a result of a plurality of times of resistance value measurement as explained with reference to FIG. 5.

[0173] In S116, the control unit 120 determines whether the termination condition of the current section set in S111 is met. If it is determined that the termination condition of the current section is not met, the process advances to S117.

[0174] In S117, the control unit 120 calculates the duty ratio of PWM for the latest control cycle in accordance with the PID control equation explained by using equation (1). Then, in S118, the control unit 120 outputs control pulses having a pulse width based on the calculated duty ratio to the first switch 131 and the second switch 132, thereby causing electric power to be supplied from the battery 140 to the heating unit 130.

[0175] After one control cycle is thus completed, the process advances to the next control cycle, and S113 to S118 described above are repeated. If it is determined in S116 that the termination condition of the current section is met, the temperature control process shown in FIG. 19 is terminated.

[0176] <4-3. Temperature Control Process in OFF Section>

(1) First Example

[0177] FIG. 20A is a flowchart showing the first example of the flow of the temperature control process for an OFF section, which is executed in S120 of FIG. 18.

[0178] First, in S121, the control unit 120 acquires the target temperature and the time length designated for the current section by the heating profile 50, and sets the termination condition of the current section. The same examples for setting respective termination conditions as explained in relation to S111 of FIG. 19 may be applied here.

[0179] Then, in S122, the control unit 120 acquires the second temperature index based on the output value from the thermistor 155. Then, in S123, the control unit 120 corrects the value of the second temperature index acquired in S122 by using the previously determined relationship between the first temperature index and the second temperature index, so as to compensate for a delay of a change in value.

[0180] In S124, the control unit 120 determines whether the termination condition of the current section set in S121 is met, based on the value of the second temperature index corrected in S123. If it is determined that the termination condition of the current section is not met, the process returns to S122, and S122 to S124 described above are repeated. If it is determined that the termination condition of the current section is met, the temperature control process shown in FIG. 20A is terminated.

(2) Second Example

[0181] FIG. 20B is a flowchart showing the second example of the flow of the temperature control process for an OFF period, which is executed in S120 of FIG. 18.

[0182] S121 to S124 shown in FIG. 20B can be the same processing steps as S121 to S124 shown in FIG. 20A, so explanations thereof will be omitted.

[0183] If it is determined in S124 that the termination condition of the current section is met, the control unit 120 determines in S125 whether the current section ends earlier than a predetermined time. The predetermined time herein is the time point at which the time length acquired in S121 elapses from the start time of the current section. If the current section ends earlier than the predetermined time, the control unit 120 adds, in S126, a residual time until the predetermined time to the time length designated by the heating profile 50 for the subsequent section of the current section.

[0184] If it is determined in S125 that the current section does not end earlier than the predetermined time (ends at the predetermined time), the time length of the subsequent section is not changed, and the temperature control process shown in FIG. 20B is terminated.

(3) Third Example

[0185] FIG. 20C is a flowchart showing the third example of the flow of the temperature control process for an OFF section, which is executed in S120 of FIG. 18.

[0186] S121 to S126 shown in FIG. 20C can be the same as S121 to S126 shown in FIG. 20B except that the process advances to S127 if it is determined in S125 that the current section does not end earlier than the predetermined time, so explanations thereof will be omitted.

[0187] In S127, the control unit 120 determines whether the current section ends later than a predetermined time. If the current section ends later than the predetermined time, the control unit 120 subtracts, in S128, an overtime with respect to the predetermined time from the time length designated by the heating profile 50 for the subsequent section of the current section.

[0188] If it is determined in S127 that the current section does not end later than the predetermined time (ends at the predetermined time), the time length of the subsequent section is not changed, and the temperature control process shown in FIG. 20C is terminated.

[0189] Note that in S128, if the time length designated for the subsequent section by the heating profile 50 is shorter than the overtime from the predetermined time, the control unit 120 may skip temperature control of the subsequent section, and perform time subtraction from the time length designated for the further next section.

[0190] <4-4. Termination Determination Process (Section S0)>

[0191] FIG. 21 is a flowchart showing an example of the flow of a termination determination process corresponding to S116 in FIG. 19, which is applicable to the section S0. Note that in the third modification described above, this termination determination process shown in FIG. 21 may also be applied to the recovery section S4a.

[0192] First, in S141, the control unit 120 acquires a control threshold equal to the product of the target value of temperature control of the current section and a coefficient representing an allowable deviation. Note that this processing step need only be performed once at the beginning of each section.

[0193] Then, in S142, the control unit 120 determines whether the index value of the first temperature index exceeds the control threshold acquired in S141. If the index value of the first temperature index exceeds the determination threshold, the process advances to S143. On the other hand, if the index value of the first temperature index does not exceed the determination threshold, the process advances to S145.

[0194] In S143, the control unit 120 adds 1 to (increments) the counter N_{COUNT} for counting the number of times of threshold fulfillment. Note that the counter N_{COUNT} is initialized to 0 at the beginning of each section. Then, in S144, the control unit 120 determines whether the counter N_{COUNT} has reached the determination threshold M. If the counter N_{COUNT} has reached the determination threshold M, the process advances to S146. On the other hand, if the counter N_{COUNT} has not reached the determination threshold M, the process advances to S145.

[0195] In S145, the control unit 120 determines that the termination condition of the current section is not met yet. On the other hand, in S146, the control unit 120 determines that the termination condition of the current section is met. Then, the termination determination process shown in FIG. 21 ends.

[0196] <4-5. Termination Determination Process (Section S3)>

[0197] FIG. 22 is a flowchart showing an example of the flow of a termination determination process corresponding to S124 in FIG. 20A or 20B, which is applicable to the section S3.

[0198] First, in S151, the control unit 120 acquires a value currently indicated by a timer activated at the start of the

current section. Then, in S152, the control unit 120 determines whether a predetermined time has elapsed from the start of the current section, based on the acquired value of the timer. The length of the predetermined time may be a time length designated for the current section by the heating profile 50. If it is determined that the predetermined time has elapsed, the process advances to S157. On the other hand, if it is determined that the predetermined time has not elapsed, the process advances to S153.

[0199] In S153, the control unit 120 determines whether the corrected index value of the second temperature index has reached a target value. If the corrected index value has reached the target value, the process advances to S154. On the other hand, if the corrected index value has not reached the target value, the process advances to S156.

[0200] In S154, the control unit 120 adds 1 to (increments) the counter N_{COUNT} . Then, S155, the control unit 120 determines whether the counter N_{COUNT} has reached the determination threshold M. If the counter N_{COUNT} has reached the determination threshold M, the process advances to S157. On the other hand, if the counter N_{COUNT} has not reached the determination threshold M, the process advances to S156.

[0201] In S156, the control unit 120 determines that the termination condition of the current section is not met yet. On the other hand, in S157, the control unit 120 determines that the termination condition of the current section is met. Then, the termination determination process shown in FIG. 22 ends.

[0202] <4-6. Control Parameter Selection Process (Section S4)>

[0203] FIG. 23 is a flowchart showing an example of the flow of a control parameter selection process that can be executed at the beginning (for example, S112 in FIG. 19) of the section S4 in the above-described third modification.

[0204] First, in S161, the control unit 120 acquires the first temperature index based on the electrical resistance value of the heating unit 130 by using the measurement circuit 150. Then, in S162, the control unit 120 acquires a control threshold equal to the product of the target value of temperature control in the current section and a coefficient representing an allowable deviation.

[0205] Then, in S163, the control unit 120 determines whether the index value of the first temperature index is equal to or larger than the control threshold. If the index value of the first temperature index is smaller than the control threshold, the control unit 120 sets, in S164, control parameters for PID control of the current section based on a first control parameter set for recovering the temperature of the heating unit 130. On the other hand, if the index value of the first temperature index is equal to or larger than the control threshold, the control unit 120 sets, in S165, control parameters for PID control of the current section based on a second control parameter set for maintaining the temperature of the heating unit 130. In this step, the control unit 120 may also reset the target value of temperature control of the current section to the current temperature of the heating unit 130.

5. SUMMARY

[0206] The various embodiments and modifications of this disclosure have been explained so far with reference to FIGS. 1 to 23. An aerosol generating device according to an embodiment of this disclosure includes

[0207] a heating unit configured to generate aerosol by heating an aerosol source,

[0208] a power supply configured to supply electric power to the heating unit,

[0209] a thermistor configured to output a value depending on a temperature of the heating unit, and

[0210] a control unit configured to control the supply of electric power from the power supply to the heating unit in accordance with a control sequence including at least

[0211] a first section in which electric power is supplied from the power supply to the heating unit by setting a target value of temperature control of the heating unit at a value corresponding to a first temperature,

[0212] a second section which follows the first section and in which the supply of electric power from the power supply to the heating unit is stopped so that the temperature of the heating unit falls toward a second temperature lower than the first temperature, and

[0213] a third section which follows the second section and in which electric power is supplied from the power supply to the heating unit.

[0214] The control unit

[0215] controls the supply of electric power from the power supply by using a first temperature index based on an electrical resistance value of the heating unit, in the first section and the third section, and

[0216] the control unit determines a timing to terminate the second section by using a second temperature index based on the output value from the thermistor.

[0217] According to this configuration, in the second section for dropping the temperature of the heating unit toward the second temperature, no pulse needs to be applied to the heating unit in order to measure the temperature, so it is possible to completely stop the supply of electric power from the power supply to the heating unit to cause the temperature of the heating unit to efficiently reach the second temperature. Since the arrival at the target temperature in the second section is determined based on the output value from the thermistor, the timing to transition from the second section to the third section is not missed even without applying any pulse to the heating unit. Also, in the section in which heating is not stopped, the supply of electric power is controlled by using a temperature index based on the electrical resistance value of the heating unit. This makes it possible to well maintain the followability of the measured temperature to the real temperature in order to perform temperature control.

[0218] An aerosol generating device according to another embodiment of this disclosure includes

[0219] a heating unit configured to generate aerosol by heating an aerosol source,

[0220] a power supply configured to supply electric power to the heating unit, and

[0221] a control unit configured to control the supply of electric power from the power supply to the heating unit by using a temperature index related to a temperature of the heating unit, in accordance with a control sequence including a plurality of sections.

[0222] The control sequence is described by structuralized data containing a first information element that

designates, from a plurality of control methods, a control method to be applied to temperature control in each section, and

[0223] the plurality of control methods include a first method for performing feedback control using the temperature index, and a second method for stopping the supply of electric current from the power supply to the heating unit.

[0224] According to this configuration, even after the control behavior of temperature control are once tuned, it is possible to rewrite the contents of the control sequence, and flexibly change when to apply respective control methods to temperature control. This can suppress an increase in cost caused by trial and error when designing the control sequence, and makes it easy to switch the behavior of temperature control to an optimum one when, for example, the environment has changed or the type of tobacco article has changed.

[0225] An aerosol generating device according to still another embodiment of this disclosure includes

[0226] a heating unit configured to generate aerosol by heating an aerosol source,

[0227] a power supply configured to supply electric power to the heating unit, and

[0228] a control unit configured to control the supply of electric power from the power supply to the heating unit, in accordance with a control sequence including a plurality of sections that include

[0229] a first section for changing the temperature of the heating unit from a first temperature to a second temperature, and

[0230] a second section, which follows the first section, for maintaining the temperature of the heating unit.

[0231] The control sequence designates a first time length for the first section, and a second time length for the second section,

[0232] the control unit terminates the first section when the temperature of the heating unit has reached the second temperature, and

[0233] in a case of terminating the first section earlier than a first time point at which the first time length elapses from the start of the first section, the control unit continues the second section over a total time of a residual time until the first time point and the second time length.

[0234] According to this configuration, even when a time shorter than the first time length is necessary to change the temperature of the heating unit to the second temperature in the first section, a time during which the user can enjoy inhalation is compensated for by the residual time of the first section. Accordingly, it is possible to maintain adequate temperature control and avoid a situation in which early termination of the session spoils the user experience at the same time.

[0235] The foregoing description of the exemplary embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications, thereby enabling others skilled in the art to

understand the invention for various embodiments with various modifications suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.

What is claimed is:

1. An aerosol generating device comprising:

a heating unit configured to generate aerosol by heating an aerosol source;

a power supply configured to supply electric power to the heating unit; and

a control unit configured to control the supply of electric power from the power supply to the heating unit in accordance with a control sequence that consists of a plurality of sections including:

a first section for changing a temperature of the heating unit from a first temperature toward a second temperature, and

a second section, which follows the first section, for maintaining the temperature of the heating unit,

wherein the control sequence designates a first time length for the first section and a second time length for the second section,

the control unit is configured to terminate the first section when the temperature of the heating unit has reached the second temperature, and

the control unit is configured to, in a case of terminating the first section earlier than a first time point at which the first time length elapses from the start of the first section, continue the second section over a total time of a residual time until the first time point and the second time length.

2. The aerosol generating device according to claim 1, wherein the second temperature is lower than the first temperature, and

the control unit is configured to stop, in the first section, the supply of electric power from the power supply to the heating unit so that the temperature of the heating unit falls toward the second temperature.

3. The aerosol generating device according to claim 1, wherein the control unit is configured to, in a case of terminating the first section later than the first time point, continue the second section over a time obtained by subtracting, from the second time length, an overtime with respect to the first time point.

4. The aerosol generating device according to claim 3, wherein the control sequence further includes a third section, which follows the second section, for changing the temperature of the heating unit to a third temperature, and

the control unit is configured to, in a case where the first section is terminated later than the first time point and an overtime with respect to the first time point is larger than the second time length, skip the second section after termination of the first section to transition to the third section.

5. The aerosol generating device according to claim 4, wherein the control sequence designates a third time length for the third section, and

the control unit is configured to, in a case of terminating the first section later than a second time point at which the first time length and then the second time length elapse from the start of the first section, continue the third section over a time obtained by subtracting, from the third time length, an overtime with respect to the second time point.

6. The aerosol generating device according to claim 4, wherein the third temperature is higher than the second temperature, and

the control unit is configured to control, in the third section, the supply of electric power from the power supply to the heating unit such that the temperature of the heating unit is raised toward the third temperature.

7. The aerosol generating device according to claim 1, wherein the control unit is configured to:

terminate the first section when the first time length elapses from the start of the first section, and set a target value of temperature control of the heating unit in the second section based on the temperature of the heating unit at a point in time when the first section is terminated.

8. The aerosol generating device according to claim 7, wherein the control unit is configured to:

in a case where the temperature of the heating unit at the point in time when the first section is terminated is a fourth temperature higher than the second temperature, set the target value of temperature control of the heating unit in the second section to a value corresponding to the fourth temperature, and

in a case where the temperature of the heating unit at the point in time when the first section is terminated is a fifth temperature equal to or lower than the second temperature, set the target value of temperature control of the heating unit in the second section to a value corresponding to the second temperature.

9. The aerosol generating device according to claim 1, wherein the control sequence further includes one or more preceding sections that precede the first section, and a time length of at least one of the one or more preceding sections is variable.

10. A control method for controlling generation of aerosol in an aerosol generating device, wherein the aerosol generating device includes a heating unit configured to generate aerosol by heating an aerosol source, and a power supply configured to supply electric power to the heating unit, the control method comprising:

obtaining a control sequence that consists of a plurality of sections, the control sequence designating a first time

length for a first section and a second time length for a second section that follows the first section;

in the first section, changing a temperature of the heating unit from a first temperature toward a second temperature;

when the temperature of the heating unit has reached the second temperature, terminating the first section;

in a case of terminating the first section earlier than a first time point at which the first time length elapses from the start of the first section, maintaining the temperature of the heating unit in the second section while causing the second section to continue over a total time of a residual time until the first time point and the second time length.

11. A non-transitory computer-readable storage medium having stored therein a computer program for controlling generation of aerosol in an aerosol generating device,

wherein the aerosol generating device includes a heating unit configured to generate aerosol by heating an aerosol source, and a power supply configured to supply electric power to the heating unit, and

the computer program, when executed by a processor of the aerosol generating device, causes the processor to:

obtain a control sequence that consists of a plurality of sections, the control sequence designating a first time length for a first section and a second time length for a second section that follows the first section;

in the first section, change a temperature of the heating unit from a first temperature toward a second temperature;

when the temperature of the heating unit has reached the second temperature, terminate the first section;

in a case of terminating the first section earlier than a first time point at which the first time length elapses from the start of the first section, maintain the temperature of the heating unit in the second section while causing the second section to continue over a total time of a residual time until the first time point and the second time length.

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