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(54) **HEATING DEVICE**

HEIZVORRICHTUNG

DISPOSITIF DE CHAUFFAGE

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(73) Proprietor: **Denso Corporation**
Kariya-city
Aichi 448-8661 (JP)

(72) Inventors:
- **IRIE, Masashi**
  Kariya-city
  Aichi 448-8661 (JP)
- **FUKAZAWA, Takeshi**
  Kariya-city
  Aichi 448-8661 (JP)
- **YAMAGUCHI, Hironao**
  Kariya-city
  Aichi 448-8661 (JP)
- **HAYASHI, Naoto**
  Kariya-city
  Aichi 448-8661 (JP)

(74) Representative: **TBK**
Bavariaring 4-6
80336 München (DE)

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EP 2 768 276 B1

Description

Technical Field

[0001] The present invention relates to heating elements and heating devices. A resistance value of the heating element changes in a positive correlation according to a change of a heating temperature thereof. The heating device of a control section integrated-type is equipped with the heating element and a power supply control module. The power supply control module is capable of controlling a power supply from an electric power source to the heating element. The heating device of a control section integrated-type has a simple structure, provides a stable power supply control and detects an abnormality deterioration state of the heating element. In particular, the present invention is preferably applied to a glow plug of a control section integrated-type, which is mounted to a respective cylinder of a diesel internal combustion engine. The glow plug of a control section integrated-type is comprised of the heating element and the power supply control module assembled together in a housing casing having a cylindrical shape.

Background art

[0002] Conventional abnormality detection devices are known, which are capable of detecting abnormal wire break and abnormal over current in a glow plug. The glow plug assists ignition of a diesel engine. The conventional abnormality detection device has a current detection means such as a current sensor, a shunt resistance arranged between a glow plug and a switching means. The switching means adjusts a power supply to the glow plug. The current detection means calculates a resistance value of the glow plug on the basis of a current which flows in the glow plug and a voltage applied to the glow plug. A known conventional abnormality detection device detects deterioration of the glow plug and abnormal wire break on the basis of the calculated resistance value of the glow plug.

[0003] A patent document 1 discloses a deterioration detection device for a glow plug comprised of a detection means and a judgment means. The detection means detects a detection value corresponding to a resistance of a glow plug when a power supply device supplies an electric power to the glow plug. The glow plug assists ignition of an internal combustion engine. The judgment means instructs the power supply device to supply an electric power to the glow plug immediately after the internal combustion engine has stopped, and judges deterioration of the glow plug on the basis of a resistance value detected by the detection means.

[0004] A patent document 2 discloses a heater deterioration detection device comprised of a first voltage output means, a second voltage output means and a comparison judgment means. The first voltage output means converts a current which flows in a heater to a first voltage and outputs the converted first voltage. The second voltage output means is electrically connected to a power source, and outputs a second voltage which corresponds to a voltage of the power source. The comparison judgment means receives the first voltage supplied from the first voltage output means and the second voltage supplied from the second voltage output means. The comparison judgment means compares the first voltage with the second voltage. The comparison judgment means judges whether or not deterioration of the heater occurs on the basis of the comparison result.

[0005] A patent document 3 discloses a power supply control device for a heating device. The heating device has a heating resistance element. A resistance value of the heating resistance element changes in a positive correlation according to a change of a heating temperature thereof. The heating device generates heat energy when receiving an electric power. The power supply control device controls the power supply on the basis of a resistance value of the heating resistance element so that the resistance value of the heating resistance element becomes equal to a reference resistance value. The power supply control device for a heating device disclosed in the patent document 3 is comprised of a first obtaining means, an environmental information obtaining means, a calculation means and a power supply control means. The first obtaining means supplies an electric power to the heating resistance element while an internal combustion engine is stopping, to which the heating device is mounted. The environmental information obtaining means obtains environmental information around the heating device when the first obtaining means obtains the first resistance value of the heating resistance element. The calculation means calculates the reference resistance value on the basis of the first resistance value and the environmental information. The power supply control means controls the power supply to the heating resistance element so that the resistance value of the heating resistance element becomes equal to the reference resistance value when the internal combustion engine is driven.

[0006] A patent document 4 discloses a sheathed element glow plug which corresponds to a heating device as defined in the preamble of claim 1.

[0007] A document 5 discloses a fuel heater comprising a thin-walled heating tube that is received in a housing and surrounds a heating element. The heating element is produced from a material that exhibits a rise in its electrical resistance with increasing temperature. A control is conducted to switch off the heating element when the resistance of the heating element rises above a threshold.

[0008] A document 6 discloses a method for monitoring at least one glow plug of an internal combustion engine in which a time-dependent variable, which characterizes the current flowing through the at least one glow plug, is compared for fault recognition to at least one time-dependent minimum and/or maximum threshold value, and a fault is recognized if the time-dependent variable is greater and/or less than the minimum and/or maximum threshold value. The first derivative of the time-dependent variable is compared to the first derivative of the maximum threshold value and the second derivative of the time-dependent variable is compared to the second derivative of the maximum threshold value, and a fault is recognized if the first derivative of the time-dependent variable is less than the first derivative the maximum threshold value, and the second derivative of the time-dependent variable is less than the second derivative of the maximum threshold value.

[0009] A document 7 discloses a glow plug electrification control apparatus which maintains the same heater temperature even when resistance varies among glow plugs to be used. The apparatus includes temperature-raising-period-resistance acquisition means for temperature-raising-period resistances, etc. of glow plugs at predetermined timings during a temperature-raising period. The heater temperature is maintained at predetermined target temperatures after the temperature raising. Maintaining-period resistances of the glow plugs are acquired in a maintaining period.

Prior Art technical document

Patent document

[0010]

Patent document 1: Japanese patent laid open publication No. JP 2009-36092 A;
Patent document 2: Japanese patent laid open publication No. JP 2009-191842 A; and
Patent document 3: Japanese patent laid open publication No. JP 2010-127487 A.
Patent document 4: document EP 1 216 384 B1
Patent document 5: document US 2009 308362 A1
Patent document 6: document US 2010 286895 A1
Patent document 7: document EP 2 128 429 A2

Summary of the Invention

Problem to be solved by the Invention

[0011] The conventional deterioration judgment devices disclosed in the patent documents 1 and 2 use the current detection means and a shunt resistance, etc. The current detection means detects a current flowing in the glow plug. The shunt resistance is used as a threshold value in order to judge deterioration of the glow plug.

[0012] Because the resistance of the glow plug generally contains an unavoidable individual resistance value, a deterioration state of the glow plug neglects such unavoidable individual resistance value when the deterioration state of the glow plug is detected on the basis of a plug current, and a comparison result between a resistance value calculated by using a voltage supplied to the glow plug and a reference resistance having a constant resistance value.

[0013] For example, under a condition in which a glow plug has a high initial resistance value, and a temperature of the glow plug can reach a target temperature value even if the resistance value thereof slightly increases according to the use, there is a possibility of judging that the glow plug deteriorates when a detected resistance value of the glow plug exceeds a threshold value even though the glow plug has not deteriorated. On the other hand, when a glow plug has a low initial resistance, there is a possibility of judging that the glow plug has not deteriorated and correctly works even if a resistance value increases according to the use because the glow plug has the low initial resistance value and a resistance value of the glow plug does not exceed its threshold value.

[0014] Further, a power supply control device in a conventional power supply control device for a glow plug controls the power supply to all of plural glow plugs mounted to corresponding cylinders of an internal combustion engine. Because each of the glow plugs has an unavoidable individual resistance value, a PWM control determines an average voltage V_{AVG} to be supplied to the glow plugs on the basis of the minimum resistance value in the normal rated resistance value of the glow plugs and supplies an electric power determined by V_{AVR}^2/ R_{GP} to the glow plugs in order to avoid an excessive temperature rise of the glow plugs.

[0015] Accordingly, even if the PMW control avoids the excessive temperature rise of the glow plug having the minimum resistance value, there is a possibility of decreasing a reached temperature value and a temperature rising speed of the glow plug having a high resistance value.

[0016] Further, the glow plug power supply control device disclosed in the patent document 3 performs a complicated control because of using environmental information such as a temperature of the internal combustion engine. The glow plug power supply control device has a large circuit size because of requiring a CPU having a high arithmetic processing capability and an interrupt timer, etc. This introduces a difficulty to mount the glow plug power supply control device into a limited engine mounting space in which highly integrated electric control devices are arranged.

[0017] Further, in order to control a heating temperature of the glow plug with high accuracy and detect an abnormality state of the glow plug, the conventional glow plug power supply control device performs a A/D conversion of a plug current flowing in the glow plug and a plug voltage supplied to the glow plug, and transmits the converted values to the ECU. The ECU performs an arithmetic process of the converted values. The ECU stops the operation of the glow plug power supply control device and performs a temperature compensation process on the basis of the results of the arithmetic process. This requires a high performance CPU and a high speed data communication means such as CAN because a large amount of data must be transmitted between the glow plug power supply control device and the ECU. This increases a manufacturing cost therefor.

[0018] In addition, the method disclosed in the patent document 3 has a large problem of decreasing an actual temperature of the glow plug, which is lower than the target temperature, caused by the influence of swirl when a constant target power is supplied to the glow plug.

[0019] It is an object of the present invention to provide an improved heating device allowing to quickly detect occurrence of abnormality deterioration in the heating device with a simple structure. Specifically, a purpose of the present invention is to provide a heating device of a control section integrated-type having a simple and easy mounting structure. The heating device of a control section integrated-type is capable of judging occurrence of deterioration of a heating element having different individual characteristics, irreversibly present, and adjusting the heating element in each heating device independently with high accuracy when a plurality of the heating devices is used simultaneously in an internal combustion engine.

Means for solving the problem

[0020] This object is achieved by a heating device according to claim 1. Advantageous further developments are as set forth in the dependent claims.

[0021] According to an aspect of the invention, the heating device is comprised of a heating element, a power supply control module and a housing casing. The heating element and the power supply control module are assembled together in the housing casing. The power supply control module is comprised of a reference resistance value storage means, a resistance value change reflecting means and a deterioration judgment means. A resistance value of the heating element changes in a positive correlation to a temperature change of the heating element itself. The power supply control module controls a power supply from a power source to the heating element so that the resistance value of the heating element becomes equal to a reference resistance value. The reference resistance value storage means stores, as a reference resistance value, a resistance value of the heating element at a predetermined target temperature, which is previously measured by the power supply control module. A resistance value change reflecting means uses the reference resistance value as a threshold value, and allows the power supply to the heating element when the resistance value of the heating element is lower than the reference resistance value during the power supply to the heating element. The resistance value change reflecting means halts the power supply to the heating element when the resistance value of the heating element exceeds the reference resistance value during the power supply to the heating element in order to reflect, to the power supply control, the resistance value change due to the temperature change of the heating element. The deterioration judgment means judges whether or not the heating element is deteriorated on the basis of a deterioration power value in a deterioration state of the heating element, as a power threshold value, to be supplied to the heating element at a predetermined deterioration limit-temperature.

The deterioration power value in the deterioration state is calculated by multiplying together a predetermined rate and an initial power value, to be supplied to the heating element in a normal state at a predetermined temperature previously detected.

[0022] In another aspect of the invention, the reference resistance value of the heating element is adjusted by an electrical trimming.

[0023] In another aspect of the invention, the electrical trimming is a digital trimming by using a Zener zapping or a poly silicon fuse.

[0024] In another aspect of the invention, the heating element is a glow plug which is mounted to a respective cylinder of an internal combustion engine.

[0025] In another aspect of the invention, the deterioration judgment means performs a deterioration judgment of the heating element at a time selected from the time before a cranking of the internal combustion engine, the time immediately after the stop of the internal combustion engine, and the time during an idling stop operation.

Effects of the invention

[0026] According to an aspect of the invention, the heating element and the power supply control module are assembled together in the housing casing. This makes it possible to adjust the reference resistance value of each heating element having an unavoidable different individual resistance value generated in a manufacturing process. When considering a change of a resistance value accompanied with a temperature change, the resistance value change reflecting means performs a temperature control independently to the heating element with a high accuracy without considering the state of other heating devices.

[0027] In addition, because the heating device can perform a self-contained temperature control without using any external information such as a temperature of water used in the engine, like the conventional device, it is possible for the heating device according to the present invention to have a very simple and easy mounting structure, and decrease the manufacture cost of the heating device.

[0028] Furthermore, according to the invention, in addition to the effects described above, when the heating device performs the temperature control so that a resistance value of the heating element becomes equal to the reference resistance value, there is a possibility of increasing a resistance value of the heating element after the long use of time. This decreases an effective power value and an actual heating temperature of the heating device. But, the deterioration judgment means sets the effective power value to be not more than the power value when the heating element is deteriorated, and it is possible for the deterioration judgment means to judge occurrence of deterioration of the heating element when the heating temperature of the heating element is not more than a usable limit temperature. Accordingly, it is not necessary for the deterioration judgment means to use external environmental information, and transmit a lot of such information between the heating device and an external arithmetic processing device, and not necessary for the external arithmetic processing unit to perform the deterioration judgment process. On the other hand, the conventional heating device requires for the external arithmetic processing unit to perform the deterioration judgment process. It is therefore possible for the heating device according to the present invention to perform a fast and self-contained judgment process for judging occurrence of deterioration of each of the heating elements with a simple structure. This makes it possible to allow an operator to do prompt countermeasure against the occurrence of deterioration of the heating element.

[0029] According to another aspect of the invention, it is possible to form a desired reference resistance value by using a part of elements which form the power supply control module. This makes it possible to provide the heating device of a control section integrated-type capable of performing the deterioration judgment of the heating element with a simple structure and without increasing a size of the power supply control module because the heating device is equipped with the power supply control module capable of adjusting a temperature of the heating element with high accuracy.

[0030] According to another aspect of the invention, it is possible to easily adjust the reference resistance value corresponding to the different individual characteristics of the heating element by the digital trimming with high accuracy.

[0031] According to another aspect of the invention, it is possible to independently perform the temperature control of each of plural glow plugs without being affected to each other even if the glow plugs have different individual characteristics. It is further possible for the heating device of a control section integrated-type according to the invention to perform a fast judgment of detecting occurrence of deterioration of the glow plugs with a good accuracy. This makes it possible to provide the glow plug of a control section integrated-type with a simple structure and high accuracy.

[0032] According to another aspect of the invention, it is possible to perform a deterioration judgment of the glow plug with high accuracy and without being affected by the working state of the internal combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

[Figure 1] (a) is a view showing a schematic structure of a heating device of a control section integrated-type according to exemplary embodiments of the present invention, and (b) is an overall view of a glow plug equipped with a control section capable of independently adjusting a power supply to each of a plurality of glow plugs which is mounted to a respective cylinder of an internal combustion engine.

[Figure 2] shows a structure of the glow plug of a control section integrated-type equipped with the control section shown in Figure 1, (a) is a view showing a vertical cross section of the structure of the glow plug of a control section integrated-type equipped with the control section shown in Figure 1, (b) is a view showing a lateral cross section along the line A-A shown in (a) of Figure 2, (c) is a view showing a vertical cross section of a schematic structure of a metal heater to be used as a glow plug to which the present invention is applied, and (d) is a view showing a vertical cross section of a schematic structure of a ceramic heater to be used as the glow plug to which the present invention is applied.

[Figure 3] is a characteristic view showing a correlation between a temperature of a glow plug, to which the present invention is applied, and a resistance value of the glow plug, where R_{INT} indicates resistance temperature characteristics at an initial state (as initial resistance temperature characteristics), P_{ACT} indicates resistance temperature characteristics after a use of a constant time, and R_{WRN} indicates resistance temperature characteristics under deterioration.

[Figure 4] is a flow chart showing an initial temperature rise control method to be used in the heating device according to the present invention.

[Figure 5] is a flow chart showing a normal control method to be used in the heating device according to the present invention.

[Figure 6] is a timing chart of the heating device according to the present invention, (a) is a timing chart showing a drive signal in the heating device according to the present invention, (b) is a timing chart showing a change of a plug resistance, (c) is a timing chart showing a judgment result of a temperature change reflecting means, (d) is a timing chart showing an operation state of a semiconductor open/close element when a feedback control of a temperature change is performed, (e) is a timing chart showing a change of a current to be supplied to the heating device, and (f) is a timing chart showing a change of a heating temperature.

[Figure 7] is a timing chart of the heating device according to the present invention from an initial state to a deterioration state under a normal control mode, (a) is a timing chart showing a drive signal in the heating device according to the present invention, (b) is a timing chart showing a change of a plug resistance, (c) is a timing chart showing a judgment result of a temperature change reflecting means, (d) is a timing chart showing an operation state of a semiconductor open/close element when a feedback control of a temperature change is performed, (e) is a timing chart showing a change of a current to be supplied to the heating device, (f) is a timing chart showing a change of an average power, and (g) is a timing chart showing a change of a heating temperature.

[Figure 8] is a flow chart showing an after glow control method used by the heating device according to the present invention;

[Figure 9] shows effects of the present invention, (a) shows characteristics of a temperature control state during a normal control mode of the heating device according to the present invention, (b) shows characteristics of a temperature control state during a pre heating control mode of the heating device according to the present invention, (c) shows characteristics of a temperature control state during the after glow control mode of the heating device according to the present invention; and

[Figure 10] is a flow chart of judging occurrence of deterioration of the heating device according to the present invention.

Embodiments to execute the present invention

[0034] Next, a description will be given of a glow plug 1 of a control section integrated-type according to an exemplary embodiment of the present invention. The glow plug 1 is comprised of a heating element 10 mounted to a corresponding cylinder in a plurality of cylinders mounted to an internal combustion engine, a detail of which is omitted from the drawings, a power supply control module 20 and a housing casing 30. The power supply control module 20 performs a power supply control from a power source 6 to the heating element 10. The housing casing 30 accommodates the heating element 10 and the power supply control module 20 together.

[0035] As shown in FIG. 1, the glow plug 1 of a control section integrated-type according to the exemplary embodiment is comprised of the heating element 10, the power supply control module 20, and the housing casing 30. The heating element 10 generates heat energy when receiving an electric power. A resistance value of the heating element 10 changes in a positive correlation to its temperature change. The power supply control module 20 adjusts a power supply from the power source 6 to the heating element 10 so that the resistance value R_{GP} of the heating element 10 becomes equal to a target resistance value R_{TRG} (that is, the reference resistance value R_C). The housing casing 30 accommodates the heating element 10 and the power supply control module 20 so that the heating element 10, the power supply control module 20 and the housing casing 30 are integrated together. The power supply control module 20 is comprised of a reference resistance value storage means 231 and a resistance value change reflecting means 233. The reference resistance value storage means 231 stores a resistance value of the heating element 10, as the reference resistance value R_C, at a predetermined target temperature T_{TRG} measured in advance. The resistance value change reflecting means 233 uses the reference resistance value R_C as a threshold value, and allows the power source to supply electric power to the heating element 10 when the resistance value R_{GP} of the heating element 10 is lower than the reference resistance value R_C during the power supply. The resistance value change reflecting means 233 halts the power supply to the heating element 10 when the resistance value R_{GP} of the heating element 10 exceeds the reference resistance value R_C during the power supply to the heating element 10 in order to reflect, to the power supply control, the resistance value change due to the temperature change of the heating element 10.

[0036] The power supply control module 20 further has a deterioration judgment means 234. The deterioration judgment means 234 judges whether or not the heating element 10 is deteriorated on the basis of a deterioration power value P_{WRN} in a deterioration state, as a power threshold value P_{REF}, to be supplied to the heating element 10 at a predetermined deterioration limit-temperature $T_{WRN.}$ The power value P_{WRN} in a deterioration state is calculated by multiplying together a predetermined rate and an initial reference power value P_{INT}, to be supplied to the heating element 10 in a normal state, previously detected at a predetermined temperature.

[0037] The deterioration judgment means 234 according to the exemplary embodiment has a self-diagnosis means for determining occurrence of deterioration of the heating element and outputs a self-diagnosis signal DI. The self-diagnosis means judges the deterioration of the heating element when an effective power value P_{ACT} becomes not more than the predetermined deterioration limit-temperature $T_{WRN.}$ The effective power value P_{ACT} is calculated on the basis of a plug current I_{GP} actually flowing in the heating element 10 and a plug voltage V_{GP} applied to the heating element 10 while considering a target power P_{TRG} as a reference of a predetermined target temperature T_{TRG}.

[0038] It is possible to use, as a concrete value of the deterioration power value P_{WRN}, a value obtained by multiplying a constant rate (for example, 90 %) and the initial reference power value P_{INT} necessary for the heating element to reach a target temperature T_{TRG} determined at a manufacturing process.

[0039] A description will be given of the glow plug 1 of a control section integrated-type as the heating device according to the exemplary embodiment of the present invention with reference FIG. 1.

[0040] The glow plug 1 is comprised of the heating element 10 (1 ~ n) and the power supply control module 20 (1 ~ n) which are integrated together in the housing casing 30 (1 ~ n). The glow plug 1 of a control section integrated-type is connected to an engine control unit

(ECU) 7 through connector terminals (41, 42, 43). The heating element 10 (1 ~ n) is mounted to a respective cylinder of the internal combustion engine 8 (not shown in detail). The power supply control module $20_{(1 \sim n)}$ receives a drive signal SI transmitted from the ECU 7. A target temperature T_{TRG} is determined on the basis of the drive signal SI. The drive signal SI corresponds to a working state of the internal combustion engine 8. The power supply control module $20_{(1\sim n)}$ compares an actually-detected plug resistance value R_{GP} with the reference resistance value R_C, and adjusts the power supply from the power source 6 to the heating element $10_{(1\sim n)}$ in synchronization with the drive signal SI on the basis of the comparison result.

[0041] The power supply control module $20_{(1 \sim n)}$ has a mold package 200 which accommodates at least a semiconductor open/close element 21, a drive circuit section 22 and a heating element control IC 23. A power input terminal 201, a drive signal input terminal 202, a self-diagnosis signal output terminal 203, an output terminal 204 and a ground terminal 205 are outwardly arranged on the mold package 200 of the power supply control module 20.

[0042] The exemplary embodiment uses an N channel power MOS FET (hereinafter, referred as MOS 21) as the semiconductor open/close element 21.

[0043] The MOS 21 has a plurality of control MOS 210 (hereinafter, referred as main MOS 210) for opening/closing a large current flowing in the heating element 10. A current detection MOS 211 (hereinafter, referred to as a sense MOS 211) is used, as a part of the MOS 21, for detecting a current flowing in the heating element 10. The main MOS 210 and the sense MOS 211 make a current mirror circuit. A current detection resistance 212 is connected to the MOS 211.

[0044] The current detection resistance 212 is connected to a heating element control IC 23 through a sense terminal SEN. The heating element control IC 23 is equipped with a deterioration judgment means 234 which is a main section of the present invention.

[0045] In the exemplary embodiment, the drive circuit section (DRV) 22 is equipped with a booster means such as a charge pump. For example, the drive circuit section 22 outputs a predetermined drive voltage V_{GG} which is boosted in order to drive the MOS 21 in synchronization with a falling edge of the drive signal SI. The drive signal SI is outputted from the ECU 7 to the power supply control module 20 in order to determine a duty ratio T_{ON}/ T with which the heating element generates heat energy to reach a target temperature T_{TRG} which corresponds to the operation state of the internal combustion engine 8.

[0046] Timing charts shown in FIG. 6 and FIG. 7 show an example to initiate a power supply in synchronization with a falling edge of the drive signal SI. However, it is possible to optionally select one of a high level Hi and a low level Lo of the drive signal SI in order to drive the MOS 21 according to demand.

[0047] The charge pump is for example comprised of an operational amplifier 220, a charge capacitance 222, an output capacitance 224 and diodes 221 and 223. The charging operation and the discharging operation are repeatedly performed by a switching operation of the operational amplifier 220. The electric energy charged in the output capacitor 224 is discharged multiple times to boost the power source voltage V_B to a gate voltage V_{GG}. For example, the gate voltage V_{GG} is twice as much as the power source voltage V_B. The boosted gate voltage V_{GG} is supplied to a node between the gate and the source of the semiconductor open/close element 21.

[0048] FIG. 1 (a) shows the charge pump comprised of the operational amplifier 220, the diodes 221 and 223, and the capacitors 222 and 224. However, the concept of the present invention is not limited by the boosting structure shown in (a) in FIG. 1. It is acceptable to use a DC-DC converter of a chopper type comprised of a combination of a choke coil, a capacitor, a diode, etc. or a DC-DC converter of a fly-back type having a booster transformer, etc.

[0049] The heating element control IC 23 as a main part of the present invention is comprised of a resistance value arithmetic means 230, a reference resistance storage means (a reference resistance forming section) 231, a reference resistance adjusting means (Zener zap circuit) 232, a resistance value change reflecting means (F/B means) 233, an initial power reference resistance, an initial power reference resistance adjusting means (Zener zap circuit) and a deterioration judgment means 234. The resistance value arithmetic means 230 calculates a plug resistance value R_{GP} of the heating element 10 on the basis of the plug current I_{GP} detected by the current detection resistance 212 previously described, and the plug voltage V_{GP} (which is equal to the source voltage V_{SS} of the semiconductor open/close element 21) applied from the semiconductor open/close element 21 to the heating element 10.

[0050] Further, in the exemplary method previously described, the sense MOS 211 detects the current I_{GP} when the resistance value R_{GP} is calculated. However, the concept of the present invention is not limited by the exemplary method previously described.

[0051] For example, it is possible to detect the resistance value R_{GP} of the heating element 10 with a more high accuracy by detecting the plug voltage V_{GP} generated when a constant current within a relatively low range of several 10 mA to several 100 mA is supplied from the heating element control IC 23 to the heating element 10 under a condition when the MOS 21 is turned off.

[0052] The plug resistance value R_{GP} of the heating element 10 is determined on the basis of resistance temperature characteristics of the heating element 10. There is a constant correlation between the heating temperature of the heating element 10 and the plug resistance value R_{GP}.

[0053] After the heating element 10 is connected to the power supply control module 20 during a manufacturing process of the glow plug 1 of a control section integrated-type, a power is supplied to the heating element 10 to increase a temperature thereof to a predetermined target temperature (T_1). At this time, an external device measures a resistance value of the heating element at the temperature (T_1) thereof, and uses the detected temperature as the reference resistance value R_C. The reference resistance value R_C is stored in the reference resistance value storage means 231 (hereinafter, referred as "MEM 231") on the basis of a timing when receiving an external signal.

[0054] It is also acceptable to detect a resistance value of the heating element 10, to which the control module 20 is not connected, during the manufacturing process of the heating element 10, and then store the detected resistance value into the MEM 231 of the control module 20.

[0055] The resistance value change reflecting means (F/B means) 233 compares the reference resistance value R_C stored in the MEM 231 with the plug resistance R_{GP} detected when the heating element 10 is actually used. The resistance value change reflecting means (F/B means) 233 outputs the comparison result to perform the feedback control.

[0056] Because the power supply control is performed by opening and closing the semiconductor open/close element 21 in order to maintain the reference resistance value R_C of the heating element 10 on the basis of the reference resistance value R_C corresponding to the individual resistance temperature characteristics of the heating element 10, it is possible to adjust the temperature of the heating element 10 to a desired heating temperature with a high accuracy when compared with a case in which the power supply to a plurality of heating elements is adjusted on the basis of a single control condition.

[0057] By the way, a long use of the heating element 10 makes a diffusion of metal forming electrodes into an insulation layer, and occurs a migration in which conductive components move between the heating element to the insulation layer, or increases the plug resistance value R_{GP} because of increasing a contact resistance by separation of the electrodes and oxidation of the electrodes.

[0058] It is accordingly to judge the occurrence of deterioration of the heating element when a heating temperature of the heating element is decreased to the predetermined deterioration limit-temperature T_{WRN} (for example, 1,150 °C) from than the target temperature T_{TRG} (for example, 1,250 °C) by a constant value ΔT (for example, 100 °C).

[0059] However, the glow plug 1 of a control section integrated-type according to the present invention performs the temperature control of the heating element without detecting an actual temperature of the heating element, that is, performs the power supply control so that the resistance value R_{GP} becomes equal to the reference resistance value R_C. It is therefore impossible to judge whether or not deterioration of the heating element occurs on the basis of an actual heating temperature of the heating element 10.

[0060] Furthermore, it is difficult to maintain an accuracy of judging the deterioration of the heating element on the basis of an average current because the current value I_{GP} changes due to the battery voltage (as the power source voltage) +B.

[0061] An initial power reference resistance value R_{PINT} is obtained by performing an electric trimming of the initial reference power value P_{INT} at an initial target temperature T_{TRG}, for example, as a change of the effective power P_{ACT} when it is adjusted so that the plug resistance value R_{GP} is equal to the reference resistance value R_C in order for a temperature of the heating element to reach the target temperature T_{TRG}. The obtained initial power reference resistance value R_{PINT} is then stored. Occurrence of deterioration of the heating element is judged when the resistance of the heating element changes from the initial power reference resistance value P_{INT} by not less than a constant value and the effective power P_{ACT} becomes not more than the power threshold value P_{REF}.

[0062] The feature of the present invention is that the resistance value R_{GP} of the heating element 10 is not calculated and the judgment of the occurrence of deterioration of the heating element 10 is performed on the basis of a comparison result between the resistance value R_{GP} of the heating element 10 and the threshold value. That is, the feature of the present invention is to perform the power supply control so that the resistance value R_{GP} of the heating element 10 becomes equal to the reference resistance value R_C having a constant value. Further, the feature of the present invention is to detect the occurrence of deterioration of the heating element 10 when the resistance value R_{PG} at the predetermined temperature increases and the effective power P_{ACT} is decreased due to the deterioration of the heating element 10, when the heating temperature of the heating element 10 is maintained constant.

[0063] In order to store the initial reference power value P_{INT} as a reference value to be used for judging the occurrence of deterioration, it is possible to judge the deterioration of the heating element having different individual characteristics by using the resistance or a memory element which can be processed by a trimming process.

[0064] Specifically, the reference resistance adjusting means 232 performs an electric trimming of the initial power reference resistance value R_{PINT}. This allows the initial power reference resistance value R_{PINT} to become an adjustable resistance.

[0065] More specifically, the electric trimming is performed by a digital trimming which uses a Zener zapping or a poly silicon fuse.

[0066] It is possible to provide the reference resistance value R_C. This requires a microcomputer and increases significantly a circuit size.

[0067] A description will now be given of a structural feature of the glow plug 1 of a control section integrated-type as the heating device according to the exemplary embodiment of the present invention with reference to FIG. 2.

[0068] The glow plug 1 of a control section integrated-type has a structure in which the housing casing 30, the heating element 10, the power supply control module 20 and the connector section 40 are assembled together. The housing casing 30 has substantially a cylindrical shape. The heating element 10 is arranged at a front section of the housing casing 30. The housing casing 30 accommodates the power supply control module 20. The connector section 40 allows the glow plug to communicate with external devices.

[0069] It is possible for the present invention to use, as the heating element 10, a metal heater 10 shown in FIG. 2 (d) or a ceramic heater 10a shown in FIG. 2 (e).

[0070] The metal heater 10 is comprised of a metal protection tube 103, a heating coil 102, a control coil 104 and insulation material 100. The metal protection tube 103 has substantially a cylindrical shape having a base section, a distal end of the metal heater 10 is open, and a front section of the metal heater 10 is closed. Each of the heating coil 102 and the control coil 104 is made of metal resistance wire coil. The insulation material 100 is magnesia powder, etc. and stored in the metal protection tube 103. A ground section 101 arranged at the front side of the heating coil 102 is electrically connected to the metal protection tube 103. The distal end of the control coil 104 is connected to an input terminal 106. The input terminal 106 allows the power supply control module 20 to communicate with the metal heater 10. The heating coil 102 and the metal protection tube 103 are made of known material such as Fe-Cr-Al alloy, Fe-Cr alloy, Ni-Cr alloy and are formed to have a predetermined resistance value.

[0071] The ceramic heater 10a is comprised of a ceramic resistance member 102a, a pair of lead sections 103a and 104a, and an insulation member 100a. The ceramic resistance member 12a has a character U-like shape. Through the lead sections 103a and 104a, external devices communicate with the ceramic resistance member 102a. The insulation member 100a has substantially a rod-like shape with which the lead sections 103a and 104a are covered. One end part of the lead section 103a connected to one end part of the ceramic resistance member 102a is extended toward a direction of a side surface of the insulation member 100a. A ground terminal 101a is formed at the side surface of the insulation member 100a. A front end section of the lead section 104a connected to the other end part of the ceramic resistance member 102a is extended to the distal end section of the insulation member 100a, at which an input terminal 105a is formed. The input terminal 105a is connected to the power supply control module 20 through an input terminal metallic part 106a.

[0072] For example, the ceramic resistance member 102a is made of a conductive ceramic material, for example, a sintered member of a mixture of silicon nitride and tungsten carbide.

[0073] Further, the lead sections 103a and 104a are made of heat resistant metal material such as tungsten.

[0074] The insulation member 100a is made of insulation ceramic material such as silicon nitride.

[0075] The metal heater 10 or the ceramic heater 10a is supported and fixed by a heating-member supporting member having substantially a cylindrical shape.

[0076] The heating-member supporting member is made of metal such as SUS (Stainless steel in Japanese Industrial standards), and has substantially a cylindrical shape. The metal heater 10 or the ceramic heater 10a is supported and fixed in the inside of the heating-member supporting member. The heating-member supporting member is electrically connected to the metal protection tube 103 or the ground terminal 101a so that one end of the heating element 10 is grounded and connected to the internal combustion engine through the housing casing 30.

[0077] In the metal heater 10, the metal protection tube 103 is fixed together to the heating-member supporting member by a known method such as laser welding, brazing and screws.

[0078] In the ceramic heater 10a, the insulation member 100a and the heating-member supporting member are fitted together or fixed together by known methods such as brazing.

[0079] The housing casing 30 is comprised of a housing base member 300 which has substantially a cylindrical shape. A front side cylinder section is formed at the front side of the housing casing 30 in order to support the heating-member supporting member. A distal end cylindrical section of the heating-member supporting member is inserted into and fitted to the front side cylinder section of the housing casing 30 by welding, etc.

[0080] A screw section 303 is formed on an outer periphery of the housing casing 30 to screw and fix the glow plug 1 to the combustion chamber of the internal combustion engine.

[0081] The power supply control module 20 and the connector section 40 is accommodated in the inside of the distal end section of the housing casing 30. Through the connector section 40, the power supply control module 20 communicates with the external devices.

[0082] A hexagonal section 304 is formed at the outer periphery of the distal end side of the housing casing 30 to screw up the screw section 303.

[0083] The connector section 40 is covered with a collar which has substantially a cylindrical shape and fixed to the distal end side of the housing casing 30.

[0084] The connector section 40 is comprised of a resin formation section and the connector terminals 41, 42 and 43. The resin formed section is made of plastic resin, etc. and has substantially a cylindrical shape. The connector terminals 41, 42 and 43 are fixed to the inside of the resin formation section. The connector terminals 41, 42 and 43 communicate with the external devices. A fitting section 401 is formed at a distal end side of the connector section 40. The fitting section 401 has substantially a cylindrical shape. The fitting section 401 and a connector of the external device are fitted together. A terminal fixing section is formed at a middle part of the connector section 40. The connector terminals 41, 42 and 43 are inserted and fixed to the terminal fixing section. The connector terminals 41, 42 and 43 communicate with the external devices. The connector terminals 41, 42 and 43 correspond to the power input terminal, the drive signal input terminal and the self-diagnosis signal output terminal, respectively. It is possible to increase and decrease the number of the connector terminals according to a necessity.

[0085] For example, it is acceptable to form input terminals T_{ZP1}, T_{ZP2} for the Zener zap in order to adjust the reference resistance value R_C by using a Zener zap trimming, and a connector terminal for the Zener zap to communicate with the external devices.

[0086] In order to decrease the number of the terminals, it is possible to commonly use, as these terminals for the Zener zap, one or more of the drive signal input terminal 42, the self-diagnosis signal output terminal 43 and the power input terminal 41.

[0087] A control module accommodation space is partitioned by a front end side partition section. The control module accommodation space accommodates the power supply control module 20.

[0088] As shown in FIG. 2 (a), the power input terminal 41, the drive signal input terminal 42 and the self-diagnosis signal output terminal 43 are connected to the power input terminal 201, the drive signal input terminal 202 and the self-diagnosis signal output terminal 203 of the power supply control module 20, respectively

[0089] The output terminal 204 (source terminal V_{SS}) of the power supply control module 20 is connected to the heating element 10, 10a through a central axis 240 to supply electric power. A GND terminal 205 is connected to the housing casing 30 through a ground terminal 250, and further connected to the internal combustion engine through the housing casing 30.

[0090] In the power supply control module 20 according to the exemplary embodiment having the structure shown in FIG. 1, the MOS 21, DRV 22, JDG 23, etc. are assembled together, covered with epoxy resin and accommodated in the mold package 200. Further, lead frames are extended from the mold package 200 to form the power input terminal 41 (BAT), the drive signal input terminal 42 (SI), the self-diagnosis signal output terminal 43 (DI), the output terminal 204 (V_{SS}), and the ground terminal 205 (GND).

[0091] The power supply control module 20 shown in FIG. 1 is a DIP type (Dual Inline Package type) package. However, the concept of the present invention is not limited by the structure. It is possible to use a SIP type (Single Inline Package type) or another known IC package according to a necessity.

[0092] Specifically, in order to implement the power supply control module 20 into the housing casing 30 for the glow plug, it is preferable to use a small-size discrete semiconductor element package such as a TO-220 type package. That is, the input terminal, the ground terminal and the output terminal are sequentially arranged and expended from the small-size discrete semiconductor element package, in which a power MOS FET and a control IC can be implemented together, for example, made of mold resin package having a size of approximately 10 mm x 17 mm x 4.5 mm.

[0093] A description will be given of the temperature characteristics of heating element 10 used in the glow plug 1 of a control section integrated-type according to the present invention with reference FIG. 3.

[0094] FIG. 3 shows a normal state, that is, a relationship between a temperature of the heating element and a resistance value of the heating element under a saturation state of the temperature and the resistance value of the heating element after the elapse of a predetermined time counted from the time when an electric power is supplied to the heating element. In FIG. 3, the alternate long and short dash line indicates the initial resistance temperature characteristics R_{INT}, the dotted line indicates the resistance temperature characteristics R_{ACT}, and the solid line indicates the deterioration resistance temperature characteristics R_{WRN} under deterioration.

[0095] As shown in FIG. 3, the initial state and the deterioration state have the same slope of the resistance temperature characteristics, that is, the slope of the resistance temperature characteristics is not changed in the initial state and the deterioration state. The resistance temperature characteristics R_{WRN} of the heating element is shifted in parallel from the initial resistance temperature characteristics R_{INT} so that the resistance value of the heating element increases as deterioration goes on when compared with the initial resistance value thereof.

[0096] When the resistance to the target temperature T_{TRG} in the initial state is used as the reference resistance value R_C and an electric power is supplied in order to maintain the reference resistance value R_C, a heating temperature of the heating element decreases. It is necessary to output a warning, etc. because it is judged that the heating temperature is decreased to the predetermined deterioration limit-temperature T_{WRN}.

[0097] A description will be given of the power supply control method and the method of detecting deterioration of the glow plug 1 of a control section integrated-type according to the present invention with reference to FIG. 4 and FIG. 5.

[0098] FIG. 4 is a flow chart showing an initial temperature rising mode (M_{INT}). The process in step S100 starts the initial temperature rising mode (M_{INT}) starts when an operator turns on a key switch SW.

[0099] The process in step S110 recognizes a drive signal SI transmitted from the ECU 30. When the drive signal SI transmitted from the ECU 30 is detected, the operation flow goes to step S120. The process in step S120 starts the power supply to the heating element 10.

[0100] Next, the process in step S130 detects the plug voltage V_{GP} and the plug current I_{GP} flowing in the heating element 10.

[0101] Next, the process in step S140 calculates the plug resistance value R_{GP} on the basis of the detected plug current I_{GP} and the detected plug voltage V_{GP}.

[0102] Next, the process in step S150 compares the plug resistance value R_{GP} with the reference resistance value R_C corresponding to the target temperature at the initial state. Further, the process in step S150 detects whether or not the plug resistance value R_{GP} reaches the reference resistance value R_C, that is, whether or not the heating temperature of the heating element reaches the target temperature.

[0103] When the plug resistance value R_{GP} is not more than the reference resistance value R_C, the judgment result indicates No, and the operation returns to step S110 to maintain the initial temperature rising mode (M_{INT}).

[0104] When the plug resistance value R_{GP} is larger than the reference resistance value R_C, the judgment result indicates Yes. The initial temperature rising mode (M_{INT}) is completed and the operation returns to step S200 to perform the normal control mode.

[0105] In step S120, it is possible to perform a pre heating control mode (M_{PRE}) in steps S121, S122 and S123 in order to prevent excessive temperature rise.

[0106] Specifically, the process in step S121 compares the plug resistance value R_{GP} with a pre-heating control mode switching reference resistance value R_{CH}, where the pre-heating control mode switching reference resistance value R_{CH} indicates a resistance value (which corresponds to a pre-heating target temperature, for example, corresponding to 1,000 °C) which is slightly lower than the reference resistance value R_C. When the plug resistance value R_{GP}, is not more than the pre-heating control mode switching reference resistance value R_{CH}, the comparison result indicates No. The operation flow goes to step S123. The process in step S123 supplies an electric power having approximately 100 % duty which exceeds a normal rated power in order to quickly increase the temperature of the heating element 10 to the pre-heating target temperature.

[0107] In the pre-heating control mode switching judgment process in step S121, when the plug resistance value R_{GP} exceeds the pre-heating control mode switching reference resistance value R_{CH}, the judgment result indicates Yes. The operation flow goes to step S122 in order to perform the pre-heating control mode (M_{PRE}). The process in step S122 performs the on/off control of the pre-heating control mode so that a temperature of the heating element becomes a constant temperature which is lower than the target temperature during approximately one second only, for example, using the pre-heating control mode switching reference resistance value R_{CH} as a threshold value.

[0108] Specifically, it is possible to perform the pre-heating control mode M_{PRE} by the process in steps S1221 to S1225.

[0109] In the time-up judgment process in step S1221, it is judged whether or not a constant time t_{ref} is elapsed from the time at which the pre-heating control mode starts.

[0110] The judgment result indicates Yes before the constant time is not elapsed ($t < t_{ref}$) from the time at which the pre-heating control mode starts. The operation flow goes to step S1222. The process in step S1222 performs a power supply allowable judgment. The process in step S1222 compares the plug resistance value R_{GP} with the pre-heating control mode switching reference resistance value R_{CH} in order to judge whether or not there is a necessity of the power supply.

[0111] When the comparison result in step S1222 indicates $R_{GP} > R_{CH}$, the judgment result indicates Yes. The operation flow goes to step S1223. The process in step S1223 halts the power supply, i.e., the state of the power supply is turned off in step S1223. On the other hand, when the comparison result in step S1222 indicates $R_{GP} \leq R_{CH}$, the judgment result indicates No. The operation flow goes to step S1224. The process in step S1224 allows the power supply, i.e., the state of the power supply is turned on in step S1224. Further, the operation flow goes to step S1225 which performs the resistance value calculation process. In step S1225, the plug resistance value R_{GP} is calculated again. The operation flow returns to step S1221 and the operation loop is repeated.

[0112] When a predetermined time is elapsed from the time at which the pre-heating control mode starts, the operation flow completes the pre-heating control mode and goes to the main routine.

[0113] The pre-heating control mode (M_{PRE}) in step S122 prevents an over-heating of the heating element during the temperature rising process (transition mode M_{TRN}) to the normal control mode (M_{CST}) because of maintaining the heating element at a temperature which is lower than the target temperature of 1,250 °C, for example by approximately 250 °C for a predetermined period of time.

[0114] In addition, the deterioration judgment is not performed during the initial temperature rising mode (M_{INT}) because the plug resistance value R_{GP} changes according to the temperature rise of the heating element.

[0115] It is possible to use a plurality of pre-temperature control modes, for example, a first pre-temperature control mode having a first pre-heating target temperature of 1,000 °C, a second pre-temperature control mode having a second pre-heating temperature of 1,100°C, etc.

[0116] In these cases, it is possible to switch the first pre-heating target temperature and the second pre-heating target temperature by changing the duty ratio indicated by the drive signal SI. However, this requires for the ECU 7 to transmit large amounts of information regarding the plug resistance R_{GP}, and therefore increases the total size of information to be transmitted, like the conventional techniques.

[0117] The present invention stores in the control module 20 the information regarding the first pre-heating reference resistance and the second pre-heating reference resistance which correspond to the respective target temperatures in order for the control module 20 to independently process even if using a plurality of the pre-heating control modes.

[0118] Similar to the pre-heating control mode having a single pre-heating target temperature, it is possible for the control module 20 to perform the pre-heating control without the process of the ECU, that is, to judge whether or not there is a necessity of the power supply, for example, in step S121 or step S150, on the basis of the comparison result between the plug resistance value R_{GP} and the corresponding reference resistance value, and perform the on/off control of the MOS 21 so that the plug resistance value R_{GP} becomes equal to the corresponding reference resistance value.

[0119] Further, although it is not necessary when the power source 6 has an adequate amount of electric power, there is a possibility of delaying the temperature rising speed of the heating elements when the electric power is supplied simultaneously to a plurality of the heating elements 10 $_{(1 \sim n)}$ and a large amount of inrush current is generated and the power source 6 has a heavy load.

[0120] In the heating device according to the present invention, each of the glow plugs 1 $_{(1 \sim n)}$ of a control section integrated-type, which is mounted to the corresponding cylinder in the internal combustion engine, is independently equipped with the power supply control module 20. An electric power is supplied independently to the heating element 10 $_{(1 \sim 10)}$ of each of the glow plugs 1 $_{(1 \sim n)}$. In this structure, it is preferable for each of the glow plugs 1 $_{(1 \sim n)}$ to have a self-cylinder position judgment means and a driving-time delay means. The self-cylinder position judgment means detects a position of the cylinder which corresponds to the own glow plug 1. The driving-time delay means delays the timing to initiate the power supply according to the cylinder corresponding to the own glow plug 1.

[0121] FIG. 5 is a flow chart showing the normal control mode.

[0122] In the normal control mode in step S200, the power supply control is performed on the basis of the drive signal SI, and the reference resistance value R_C of each of the heating elements 10. Further, it is possible to provide the warning on the basis of the judgment result of deterioration of the heating element.

[0123] When the drive signal SI is detected in the drive signal input recognition process in step S210 after the normal control mode in step S200 is initiated, the operation flow goes to step S210. In step S210, the power supply to the heating element 10 is initiated.

[0124] In the current and voltage detection process in step S220, the plug current I_{GP} flowing in the heating element 10 and the plug voltage V_{GP} are detected.

[0125] Next, in the process of calculation the effective power and the plug resistance value in step S230, the effective power value P_{ACT} and the plug resistance value R_{GP} are calculated on the basis of the plug current I_{GP} and the plug voltage V_{GP}.

[0126] The following step S240 detects the occurrence of deterioration based on a comparison result between the effective power value P_{ACT} and the power threshold value P_{REF} by using a threshold value.

[0127] The deterioration power value P_{WRN} in the deterioration state is used as the power threshold value P_{REF}, which is a decreased power value, for example 90 % of the initial reference power value P_{INT} at the initial state.

[0128] In the deterioration judgment process in step S240, it is judged that the heating element is not deteriorated when the effective power value P_{ACT} is not less than the power threshold value P_{REF}. The judgment result indicates Yes and the operation flow goes to step S250 in order to perform the resistance value change reflecting means (F/B process).

[0129] In the deterioration judgment process in step S240, it is judged that the heating element is deteriorated when the effective power value P_{ACT} is lower than the power threshold value P_{REF} (for example, when the effective power value is not more than 90 % of the initial reference power value P_{INT}). The judgment result indicates No and the operation flow goes to step S260 in order to perform the abnormality judgment signal output process.

[0130] The resistance value change reflecting means (F/B process) in step S250 compares the plug resistance value R_{GP} with the reference resistance value R_C in order to perform the feedback of the plug resistance value. When the plug resistance value R_{GP} exceeds the reference resistance value R_C, the judgment result indicates Yes. The operation flow goes to step S270 in order to perform the power supply stop process. When the plug resistance value R_{GP} is not more than the reference resistance value R_C, the judgment result indicates No. The operation flow goes to step S280 in order to perform the power supply continuation process.

[0131] In the power supply stop process in step S270, the power supply is stopped because it is judged that the heating temperature of the heating element 10 reaches the target temperature value. The operation flow returns to step S210.

[0132] In the power supply continuation process in step S280, the power supply is continued because it is judged that the heating temperature value of the heating element does not reach the target temperature value.

[0133] The processes in step S210 to step S280 are repeated in order to control the power supply to the heating element and maintain the plug resistance value R_{GP} of each of the glow plugs 1 (1 ~ n) at a resistance value close to the individual reference resistance value R_C.

[0134] The abnormality judgment signal output process in step S260 outputs the self-diagnosis signal DI, in order for example to turn on a warning lamp, inform occurrence of the abnormality deterioration state, recommend the replacement of the glow plug to the driver of the motor vehicle, and/or stop the power supply to the heating element 10.

[0135] A description will be given of the operation of the glow plug 1 of a control section integrated-type as the heating device according to the exemplary embodiment of the present invention with reference to FIG. 6. FIG. 6 shows a control result without performing the preheating mode.

[0136] The drive signal SI determines the duty ratio in order to determine the target temperature T_{TRG} which corresponds to the driving state of the internal combustion engine. The MOS 21 is opened and closed in synchronization with a rising edge or a falling edge of the drive signal SI on the basis of the judgment result regarding the necessity of the power supply detected by the resistance value change reflecting means 233, as previously described.

[0137] As shown in FIG. 6 (a), when the drive signal SI transmitted from the ECU 7 is received, the power supply to the heating element 10 starts and a temperature of the heating element 10 increases.

[0138] As previously described, the judgment result in step S250 indicates yes when the plug resistance value R_{GP} exceeds the reference resistance value R_C. At this time, as shown in FIG. 6 (c), the resistance value change reflecting means 233 outputs a value of zero, and the power supply to the heating element 10 is not performed.

[0139] However, the power supply to the heating device 10 is not immediately stopped, but is continued by the duty ratio (for example, 90 % duty ratio) indicated by the drive signal SI after an elapse of one pulse. The MOS 21 is turned on at a following rising edge of the drive signal SI in order to halt the power supply to the heating element 10. When the plug resistance value R_{GP} becomes not more than the reference resistance value R_C, the judgment result in step S250 indicates No. The resistance value change reflecting means 233 outputs a value of one, and the MOS 21 is turned off at a falling edge of the following drive signal SI in order to perform the power supply to the heating element 10.

[0140] According to the present invention as previously described, the reference resistance value R_C is used to determine whether the power supply to the heating element 10 starts as shown in FIG. 6 (c). The MOS 21 is turned off in synchronization with a rising edge of the drive signal SI during the OFF state of the judgment result (JDG) shown in FIG. 6 (c), and the MOS 21 is turned on in synchronization with a falling edge of the drive signal SI during the ON state of the judgment result (JDG) shown in FIG. 6 (c).

[0141] Accordingly, because the operation of the MOS 21 is driven in synchronization with the rising edge or the falling edge of the drive signal SI as shown in FIG. 6 (d), the temperature change is slightly delayed from the change of the plug resistance R_{GP}, as shown in FIG. 6(e). However, the control module 20 in each heating device can independently perform the feedback F/B control of the plug resistance R_{GP} so that the plug resistance R_{GP} becomes equal to the reference resistance value R_C. This makes it possible to perform the control of the temperature of the heating element 10 to be equal to the target temperature T_{TRG} without using any temperature of engine cooling water and other temperature information.

[0142] A description will be given of the deterioration judgment method used by the heating device according to the present invention with reference to FIG. 7.

[0143] FIG. 7 shows timing charts from the initial state to the deterioration state of the heating element in the heating device during the normal control mode according to the present invention.

[0144] As shown in FIG. 7 (a), the ECU 7 outputs the drive signal SI which is determined according to the target temperature TTRG without regard for the deterioration state of the heating element 10.

[0145] As shown in FIG. 3, the heating element 10 is gradually deteriorated due to a long use thereof, and a resistance value R_{GP} of the heating element 10 to a constant heating temperature also gradually increases.

[0146] When the resistance value R_{GP} of the heating element 10 increases due to a long use, a timing is gradually increased, where the timing indicates a time when the resistance value R_{GP} of the heating element 10 exceeds the reference resistance value R_C after the power supply is started in synchronization with a falling edge of the drive signal SI. Further, when the power supply is performed on the basis of a constant duty ratio, the maximum value of the resistance value R_{GP} during a period also increases.

[0147] Accordingly, a time period in which the plug resistance value R_{GP} is higher than the reference resistance value R_C in the deterioration state of the heating element, the number of frequencies when the MOS 21 is turned off increases.

[0148] Accordingly, the plug current I_{GP} becomes low, as shown in FIG. 7 (e), and as a result, the effective power value P_{ACT} gradually decreases, as shown in FIG. 7 (f).

[0149] At this time, it is judged that the heating element is deteriorated when the effective power value P_{ACT} changes by not less than a constant rate of the initial reference power value PINT which corresponds to the predetermined temperature in the initial state and the effective power value P_{ACT} becomes not more than the power threshold value $P_{REF.}$

[0150] As shown in FIG. 7 (e), during the initial state, the heating temperature T of the heating element is maintained with the target temperature T_{TRG} and the heating temperature T is decreased by not less than ΔT together with the deterioration progress. Finally, the heating temperature is decreased to a value of not more than predetermined deterioration limit-temperature $T_{WRN.}$ In this case, the self-diagnosis signal DI is outputted.

[0151] During a manufacture process, the reference resistance value R_C and the initial reference power value

P_{INT} of each of the heating elements 10 are stored in the MEM 232. The power supply control module 20 corresponding to each of the heating elements 10 performs the power supply control and the abnormality deterioration judgment process on the basis of the corresponding reference resistance value R_C and initial reference power value P_{INT} of each of the heating elements 10. It is therefore possible to maintain the temperature of the heating element with high accuracy without being affected by deterioration of other glow plugs, and to provide warning information at an optimum and correct timing.

[0152] A description will be given of the power supply control method in an after glow control mode with reference to FIG. 8.

[0153] In the exemplary embodiment previously described, the deterioration of the heating element is detected in the normal control mode when the power supply to the glow plug 1 is performed, i.e. the pre-glow control is performed, where the pre-glow control assists the ignition of the internal combustion engine. However, it is possible to perform the deterioration judgment of the glow plug of a control section integrated-type according to the present invention in the afterglow control mode for protecting a miss fire and decreasing emission.

[0154] This case can perform the deterioration judgment which is substantially equal to that of the normal control mode. But, in the deterioration judgment process in step S340, the second deterioration current I_{WRN2} is used as a threshold value with which the plug current I_{GP} is compared. Further, the resistance value change reflecting means (F/B process) in step S350 compares the plug resistance value R_{GP} with a second reference resistance value R_{C2} which is calculated on the basis of the plug resistance value R_{GP} and the reference resistance value R_C in order to perform the threshold judgment.

[0155] Because the target temperature in the after glow control mode is lower than that in the normal control mode, the second deterioration power value P_{WRN2} and the second reference resistance value R_{C2} are lower than those in the normal control mode, respectively.

[0156] The conventional deterioration judgment devices perform the deterioration judgment of the glow plug within a limited period of time immediately after the power supply is stopped. On the other hand, the glow plug 1 of a control section integrated-type according to the present invention always performs the deterioration judgment of the glow plug 1 during both the normal control mode and the after glow control mode. This makes it possible to quickly detect occurrence of abnormality deterioration of the glow plug and take necessary measures.

[0157] FIG. 9 (a) is a characteristic view showing a temperature control state of the glow plug 1 of a control section integrated-type without performing the pre-heating control mode. FIG. 9 (b) is a characteristic view showing a temperature control state of the glow plug 1 of a control section integrated-type when the pre-heating control mode is performed. FIG. 9 (c) is a characteristic view showing a temperature control state of the glow plug 1 of a control section integrated-type in the after glow control mode.

[0158] As shown in FIG. 9 (a), a temperature of the heating element is quickly increased by using approximately 100 % duty ratio or an excessive power supply in the initial temperature rising mode (M_{INT}). Further, because the rapid temperature rapid rising control is switched to the temperature rising suppress control in the mode switching temperature T_{CH} which is lower than the first target temperature T_1, an excessive temperature rising of the glow plug is suppressed. Because the power supply control is performed on the basis of the feedback using the drive signal with the reference resistance value R_C as the threshold value corresponding to the resistance temperature characteristics of the individual glow plug after the temperature of the heating element reaches the first target temperature, it is possible to always perform the abnormality deterioration judgment during the normal control mode quickly detect the abnormality deterioration. Further, it is possible to maintain the temperature of the heating element at the second target temperature with high accuracy during the after glow control mode. Still further, it is possible to always perform the abnormality deterioration judgment during the after glow control mode and quickly detect the abnormality deterioration.

[0159] As previously described, when the pre-heating control mode M_{PRE}, as shown in FIG. 9 (b), it is possible to securely prevent an over-temperature rising of the heating element because the temperature of the heating element is maintained lower than the target temperature for a predetermined period of time. After the transition mode M_{TRN} is performed, the normal control mode M_{CST} is performed to maintain the heating element at the target temperature. In this case, the deterioration judgment is performed under the condition in which a temperature of the heating element under one of the pre-heating control mode M_{PRE} and the normal control mode M_{CST} becomes stable.

[0160] A description will be given of the explanation of determining an optimum period to perform the deterioration detection and the explanation of the judgment method of the deterioration detection with reference to FIG. 10.

[0161] The exemplary embodiment previously described show the method of detecting deterioration and the power supply control which are performed simultaneously during the normal control mode and the after glow control mode. The exemplary embodiment shown in FIG. 10 shows the method of performing the deterioration judgment before a cranking or a time immediately after the internal combustion engine has stopped, or during the idle stop control, as a method of eliminating disturbance caused by an operation state and detecting occurrence of deterioration with high accuracy.

[0162] For example, a rush current flows in a starter motor at the cranking, and a battery voltage is fluctuated. This causes a large fluctuation of the current I_{GP} flowing in the heating element 10 by the battery voltage +B, and it is therefore difficult to precisely detect the plug resistance current R_{GP}. Further, there is a possibility of fluctuating the battery voltage while the engine is driven, etc. and therefore difficult to precisely detect the plug resistance value R_{GP}.

[0163] It is therefore preferable to perform the deterioration detection according to the present invention before the cranking of the internal combustion engine 8, at a time immediately after the internal combustion engine has stopped, or during the idle stop control.

[0164] In the drive state recognition process in step S400 shown in FIG. 10, information regarding operation state such as engine rotation speed, etc. is inputted. In the deterioration judgment process in step S410, it is detected that the current state is one of the state before the cranking, the state immediately after the internal combustion engine has stopped, and the state during the idle stop control on the basis of the information input in step S400.

[0165] The judgment result indicates Yes when the current state is one of the state before the cranking, the state immediately after the internal combustion engine has stopped, and the state during the idle stop control. The operation flow goes to step S430. On the other hand, the judgment result indicates No when the current state is not one of the state before the cranking, the state immediately after the internal combustion engine has stopped, and the state during the idle stop control. The operation flow returns to step S400 without performing the deterioration detection process.

[0166] In the deterioration detection process in step S430, similar to the exemplary embodiment previously described, the effective power value P_{ACT} is calculated on the basis of the plug voltage V_{GP} applied to the heating element 10 and the plug current I_{GP} flowing in the heating element 10. The calculated effective power value P_{ACT} is compared with the predetermined power threshold value P_{REF}.

[0167] It is acceptable to always perform the deterioration detection process for the glow plug according to the operation state of the internal combustion engine detected by the ECU.

[0168] The exemplary embodiment shows the example in which the N channel power MOS FET is arranged at an upstream side of the load, and driven to open and close by using a high-side driver. The concept of the present invention is not limited by this structure. It is possible to arrange a P channel power MOS FET at a high side instead of the N channel power MOS FET.

[0169] In general, although such a P channel power MOS FET has a large ON resistance when compared with that of an N channel power MOS FET, it is possible to eliminate any gate voltage boosting means such as a charge pump circuit from the drive circuit 22 by using such a P channel power MOS FET.

[0170] It is possible to arrange the N channel power MOS FET in order to perform the open and close control by using a low side driver. Although this case causes a problem to supply a voltage to the glow plug during no operation of the glow plug, this does not require a boosting means such as a charge pump, and provides a simple circuit structure.

Explanation of reference numbers

[0171]

1 Glow plug of a control section integrated-type (Heating device),
10 Glow plug (Heating element),
20 Power supply module,
200 Mold package,
201 Power input terminal,
202 Drive signal input terminal,
203 Self-diagnosis signal output terminal,
204 Output terminal,
205 Ground terminal,
21 Semiconductor open/close element,
210 Control MOS,
211 Current detection MOS (Mirror circuit section),
212 Current detection resistance (Zener zap resistance),
22 Drive circuit section (DRV),
220 Operational amplifier,
221, 223 Diode,
222, 224 Capacitor,
23 Heating element control IC,
230 Resistance value arithmetic means (Current - Voltage detection section),
231 Reference resistance value storage section (Reference resistance forming section),
232 Reference resistance adjusting means (Zener zap circuit),
233 Resistance value change reflecting means (F/B means),
234 Deterioration judgment means,
30 Housing casing,
40 Connector section,
41 Power input terminal,
42 Drive signal input terminal,
43 Self-diagnosis signal output terminal, 6 Power source,
7 Engine control unit (ECU),
8 Internal combustion engine,
SI Drive signal,
P_{ACT} Effective power value,
P_{INT} Initial reference power value,
P_{REF} Power threshold value,
P_{WRN} Deterioration power value,
R_C Reference resistance value,
R_{CH} Reference resistance value,
$T_{ZP}1$, $T_{ZP}2$ Zener zap input terminals,
MINT Initial temperature rising mode,
M_{PRE} Pre-heating control mode,
M_{TRN} Transition mode, and
M_{CST} Normal control mode.

Claims

1. A heating device (1) comprising:

a heating element (10), a resistance value of which changes in a positive correlation to a temperature change of the heating element (10);
a power supply control module (20) configured to control a power supply from a power source (6) to the heating element (10) so that the resistance value of the heating element (10) becomes equal to a reference resistance value; and
a housing casing (30) in which the heating element (10) and the power supply control module (20) are assembled together;
characterized in that the power supply control module (20) comprises:

a reference resistance value storage means (231) configured to store, as a reference resistance value, a resistance value of the heating element (10) at a predetermined target temperature, which is previously measured by the power supply control module (20);
a resistance value change reflecting means (233) configured to use the reference resistance value as a threshold value, and to allow the power supply to the heating element (10) when the resistance value of the heating element (10) is lower than the reference resistance value during the power supply to the heating element (10), and to halt the power supply to the heating element (10) when the resistance value of the heating element (10) exceeds the reference resistance value during the power supply to the heating element (10) in order to reflect, to the power supply control, the resistance value change due to the temperature change of the heating element (10); and
a deterioration judgment means (234) configured to judge whether or not the heating element (10) is deteriorated on the basis of a deterioration power value in a deterioration state of the heating element (10), as a power threshold value, to be supplied to the heating element (10) at a predetermined deterioration limit-temperature, where the deterioration power value in the deterioration state is calculated by multiplying together a predetermined rate and an initial power value, to be supplied to the heating element (10) in a normal state at a predetermined temperature previously detected.

2. The heating device as claimed in claim 1, wherein the reference resistance value of the heating element (10) is adjusted by an electrically trimming.

3. The heating device as claimed in claim 2, wherein the electrical trimming is a digital trimming by using a Zener zapping or a poly silicon fuse.

4. The heating device as claimed in any one of claims 1 to 3, wherein the heating element (10) is a glow plug which is mounted to a respective cylinder of an internal combustion engine (B).

5. The heating device as claimed in claim 4, wherein the deterioration judgment means (234) is configured to perform the deterioration judgment of the heating element (10) at a time before a cranking of the internal combustion engine (B), immediately after the stop of the internal combustion engine (B) or an idle stop operation.

Patentansprüche

1. Heizvorrichtung (1) mit:

einem Heizelement (10), dessen Widerstandswert sich in einer positive Wechselbeziehung zu einer Temperaturänderung des Heizelements (10) ändert;
einem Leistungszufuhrsteuerungsmodul (20), das konfiguriert ist, eine Leistungszufuhr von einer Leistungsquelle (6) zu dem Heizelement (10) derart zu steuern, dass der Widerstandswert des Heizelements (10) gleich zu einem Referenzwiderstandswert wird; und
einem Unterbringungsgehäuse (30), in dem das Heizelement (10) und das Leistungszufuhrsteuerungsmodul (20) zusammengebaut sind;
dadurch gekennzeichnet, dass das Leistungszufuhrsteuerungsmodul (20) umfasst:

eine Referenzwiderstandswertspeichereinrichtung (231), die konfiguriert ist, als einen Referenzwiderstandswert einen Widerstandswert des Heizelements (10) bei einer vorbestimmten Solltemperatur zu speichern, der zuvor durch das Leistungszufuhrsteuerungsmodul (20) gemessen wird;
eine Widerstandswertänderungsreflektiereinrichtung (233), die konfiguriert ist, den Referenzwiderstandswert als einen Schwellenwert zu verwenden und die Leistungszufuhr zu dem Heizelement (10) zu erlauben, wenn der Widerstandswert des Heizelements (10) niedriger als der Referenzwiderstandswert während der Leistungszufuhr zu dem Heizelement (10) ist, und die Leistungszufuhr zu dem Heizelement (10) anzuhalten, wenn der Widerstandswert des

Heizelements (10) den Referenzwiderstandswert während der Leistungszufuhr zu dem Heizelement (10) überschreitet, um bei der Leistungszufuhrsteuerung die Widerstandswertänderung aufgrund der Temperaturänderung des Heizelements (10) zu reflektieren; und

eine Verschlechterungsbeurteilungseinrichtung (234), die konfiguriert ist zu beurteilen, ob das Heizelement (10) verschlechtert ist oder nicht, auf der Grundlage eines Verschlechterungsleistungswerts in einem Verschlechterungszustand des Heizelements (10) als ein Leistungsschwellenwert, der dem Heizelement (10) bei einer vorbestimmten Verschlechterungsgrenztemperatur zuzuführen ist, wobei der Verschlechterungsleistungswert in dem Verschlechterungszustand berechnet wird, indem eine vorbestimmte Rate und ein Anfangsleistungswert, der dem Heizelement (10) in einem normalen Zustand bei einer vorbestimmten Temperatur zuzuführen ist, die zuvor erfasst wird, multipliziert werden.

2. Heizvorrichtung nach Anspruch 1, wobei der Referenzwiderstandswert des Heizelements (10) durch ein elektrisches Trimmen justiert wird.

3. Heizvorrichtung nach Anspruch 2, wobei das elektrische Trimmen ein digitales Trimmen unter Verwendung einer Zener-Zapping- oder einer Polysiliziumsicherung ist.

4. Heizvorrichtung nach einem der Ansprüche 1 bis 3, wobei das Heizelement (10) eine Glühkerze ist, die bei einem jeweiligen Zylinder einer Brennkraftmaschine (B) angebracht wird.

5. Heizvorrichtung nach Anspruch 4, wobei die Verschlechterungsbeurteilungseinrichtung (234) konfiguriert ist, die Verschlechterungsbeurteilung des Heizelements (10) zu einer Zeit vor einem Ankurbeln der Brennkraftmaschine (B), unmittelbar nach dem Stopp der Brennkraftmaschine (B) oder bei einem Leerlaufstoppbetrieb auszuführen.

Revendications

1. Dispositif de chauffage (1) comprenant :

un élément de chauffage (10), dont une valeur de résistance change en corrélation positive avec un changement de température de l'élément de chauffage (10) ;

un module de commande d'alimentation en puissance (20) configuré pour contrôler une alimentation en puissance d'une source de puissance (6) vers l'élément chauffant (10) de sorte que la valeur de résistance de l'élément chauffant (10) devienne égale à une valeur de résistance de référence ; et

une enceinte (30) dans laquelle l'élément chauffant (10) et le module de commande d'alimentation en puissance (20) sont assemblés ensemble ;

caractérisé en ce que le module de commande d'alimentation en puissance (20) comprend :

des moyens de stockage de valeur de résistance de référence (231) configurés pour stocker, comme valeur de résistance de référence, une valeur de résistance de l'élément chauffant (10) à une température cible prédéterminée, qui est préalablement mesurée par le module de commande d'alimentation en puissance (20) ;

des moyens de réflexion de changement de valeur de résistance (233) configurés pour utiliser la valeur de résistance de référence comme une valeur de seuil, et pour permettre l'alimentation en puissance de l'élément chauffant (10) lorsque la valeur de résistance de l'élément chauffant (10) est inférieure à la valeur de résistance de référence pendant l'alimentation en puissance de l'élément chauffant (10), et pour arrêter l'alimentation en puissance de l'élément chauffant (10) lorsque la valeur de résistance de l'élément chauffant (10) dépasse la valeur de résistance de référence pendant l'alimentation en puissance de l'élément chauffant (10) afin de refléter, auprès de la commande d'alimentation en puissance, le changement de valeur de résistance du au changement de température de l'élément chauffant (10) ; et

un moyen de jugement de détérioration (234) configuré pour juger si l'élément chauffant (10) est détérioré ou non sur la base d'une valeur de puissance de détérioration dans un état de détérioration de l'élément chauffant (10), comme valeur de seuil d'énergie, à fournir à l'élément chauffant (10) à une température limite de détérioration prédéterminée, dans lequel la valeur de puissance de détérioration dans l'état de détérioration est calculée en multipliant ensemble une vitesse prédéterminée et une valeur d'énergie initiale, à fournir à l'élément chauffant (10) dans un état normal à une température prédéterminée préalablement détectée.

2. Dispositif de chauffage selon la revendication 1,

dans lequel la valeur de résistance de référence de l'élément chauffant (10) est ajustée par une compensation électrique.

3. Dispositif de chauffage selon la revendication 2, dans lequel la compensation électrique est une compensation numérique qui utilise un saut de Zener ou un fusible en polysilicium.

4. Dispositif de chauffage selon l'une quelconque des revendications 1 à 3, dans lequel l'élément chauffant (10) est une bougie de préchauffage qui est montée sur un cylindre respectif d'un moteur à combustion interne (B).

5. Dispositif de chauffage selon la revendication 4, dans lequel le moyen de jugement de détérioration (234) est configuré pour effectuer le jugement de détérioration de l'élément de chauffant (10) avant le démarrage du moteur à combustion interne (B), juste après l'arrêt du moteur à combustion interne (B), ou lors d'une opération de ralenti.

FIG.1

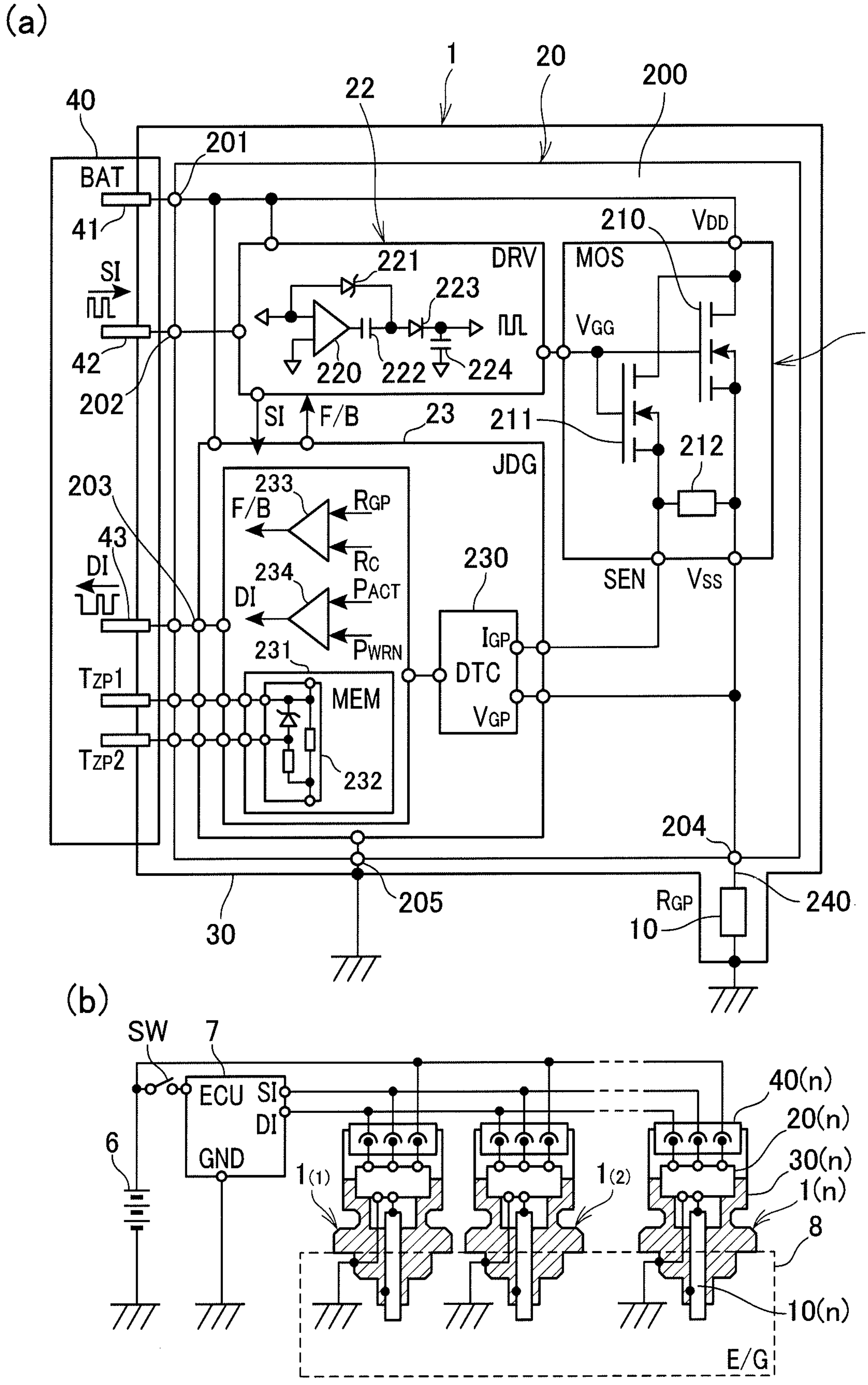

(a)
1
20
200
22
40
201
BAT
41
SI
42
202
221
DRV
223
210
VDD
MOS
VGG
21
220
222
224
SI
F/B
23
211
212
JDG
203
233
F/B
RGP
RC
43
DI
234
DI
PACT
PWRN
230
SEN
VSS
231
IGP
DTC
TZP1
MEM
VGP
TZP2
232
204
205
240
RGP
10
30
(b)
SW
7
ECU
SI
DI
GND
6
40(n)
20(n)
30(n)
1(1)
1(2)
1(n)
8
10(n)
E/G

FIG.2

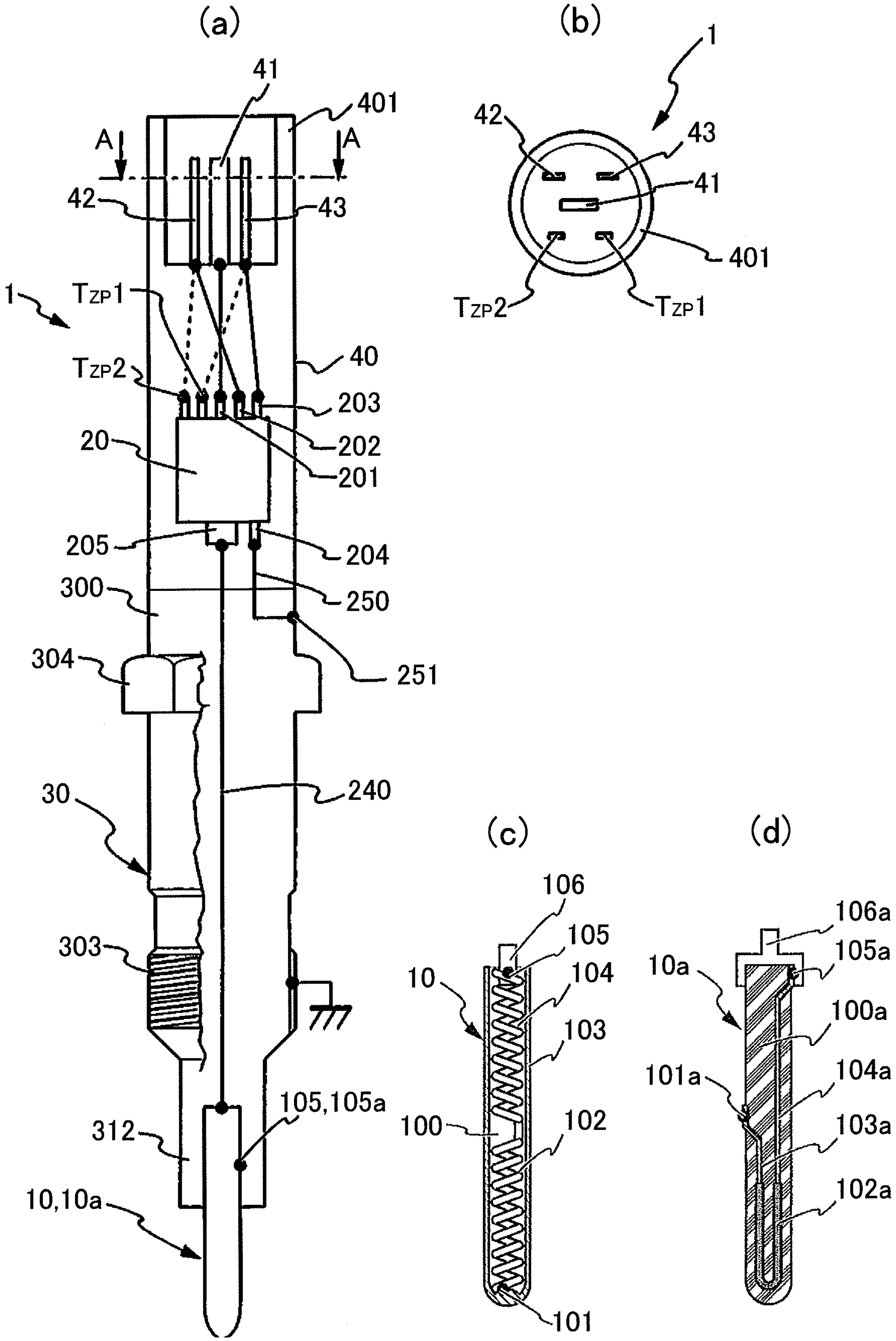

(a)
41
401
A
A
42
43
1
TZP1
40
TZP2
203
202
20
201
205
204
300
250
251
304
240
30
303
312
105,105a
10,10a
(b)
1
42
43
41
401
TZP2
TZP1
(c)
106
105
10
104
103
100
102
101
(d)
106a
105a
10a
100a
101a
104a
103a
102a

FIG.3

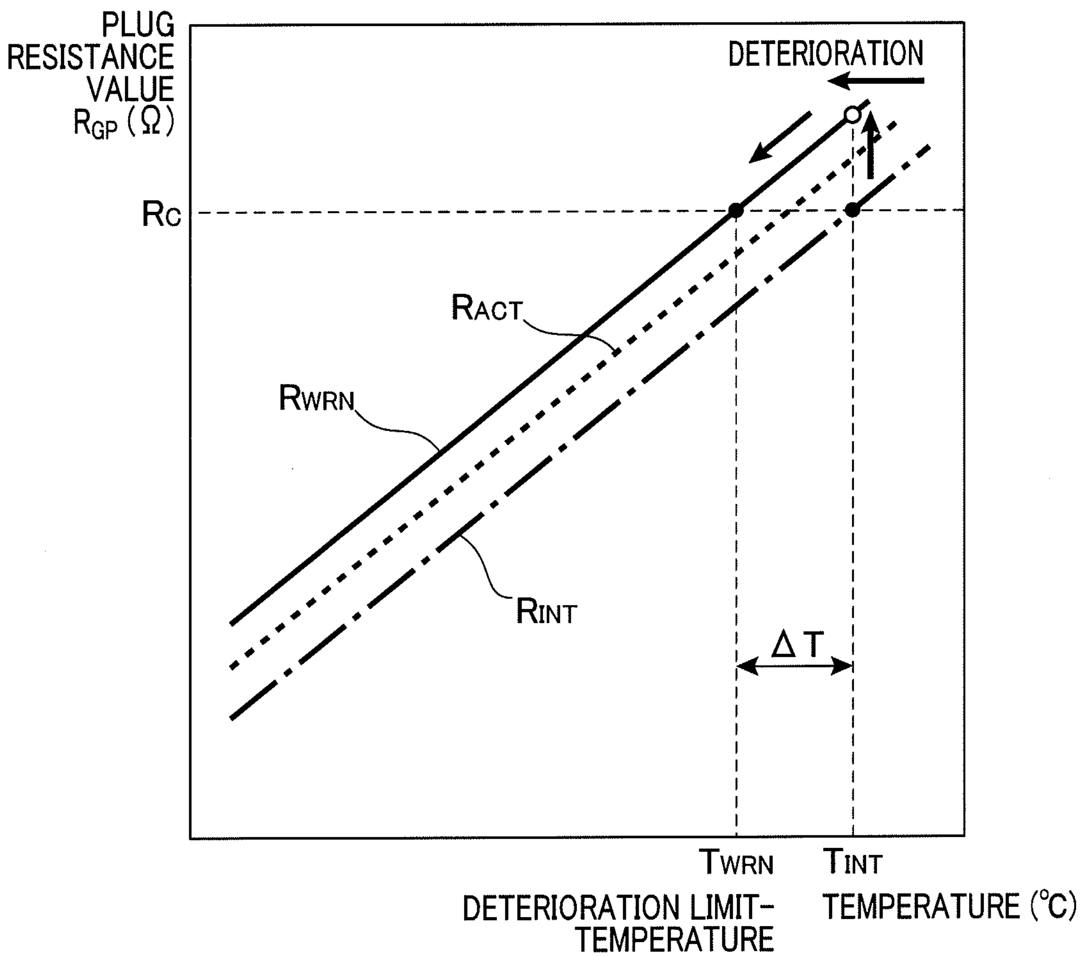

PLUG
RESISTANCE
VALUE
RGP (Ω)
DETERIORATION
Rc
RACT
RWRN
RINT
ΔT
TWRN
TINT
DETERIORATION LIMIT-
TEMPERATURE
TEMPERATURE (℃)

FIG.4

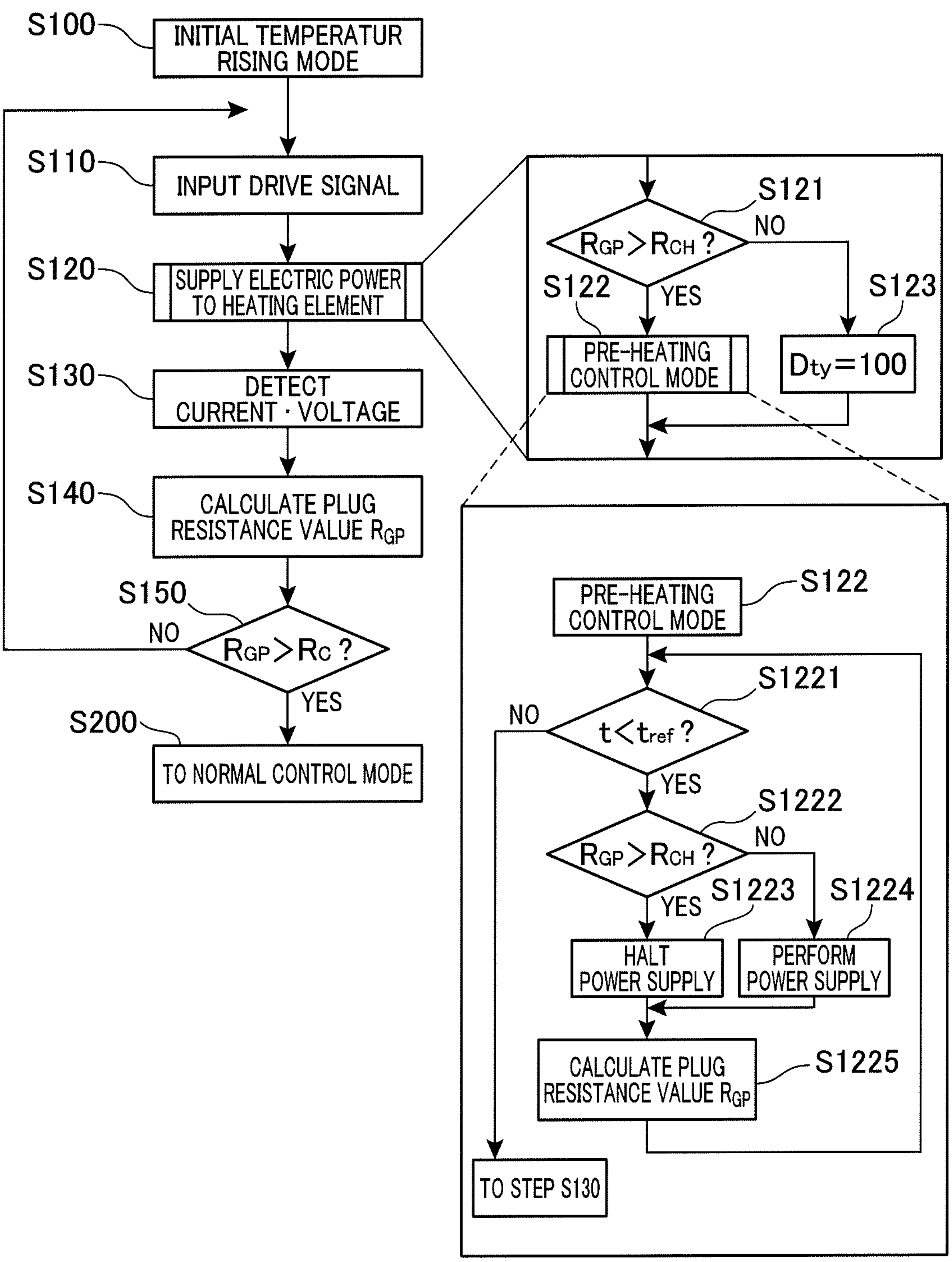

S100
INITIAL TEMPERATUR RISING MODE
S110
INPUT DRIVE SIGNAL
S120
SUPPLY ELECTRIC POWER TO HEATING ELEMENT
S130
DETECT CURRENT · VOLTAGE
S140
CALCULATE PLUG RESISTANCE VALUE RGP
S150
NO
RGP>RC ?
YES
S200
TO NORMAL CONTROL MODE
S121
NO
RGP>RCH ?
S122
YES
S123
PRE-HEATING CONTROL MODE
Dty=100
PRE-HEATING CONTROL MODE
S122
S1221
NO
t<tref ?
YES
S1222
NO
RGP>RCH ?
YES
S1223
S1224
HALT POWER SUPPLY
PERFORM POWER SUPPLY
CALCULATE PLUG RESISTANCE VALUE RGP
S1225
TO STEP S130

FIG.5

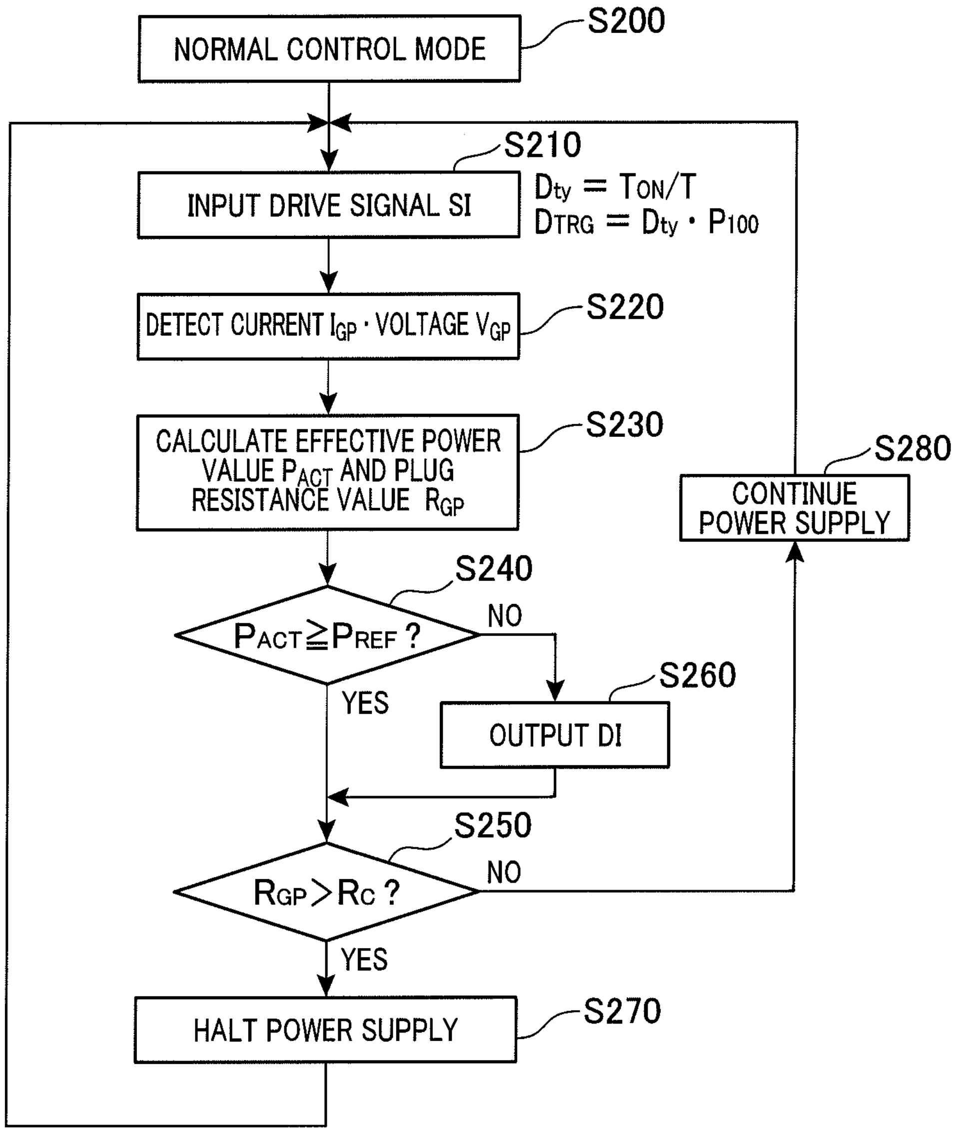

NORMAL CONTROL MODE
S200
S210
INPUT DRIVE SIGNAL SI
$D_{ty} = T_{ON}/T$
$D_{TRG} = D_{ty} \cdot P_{100}$
DETECT CURRENT I_{GP} · VOLTAGE V_{GP}
S220
CALCULATE EFFECTIVE POWER VALUE P_{ACT} AND PLUG RESISTANCE VALUE R_{GP}
S230
S280
CONTINUE POWER SUPPLY
S240
$P_{ACT} \geqq P_{REF}$?
NO
YES
S260
OUTPUT DI
S250
$R_{GP} > R_C$?
NO
YES
HALT POWER SUPPLY
S270

FIG.6

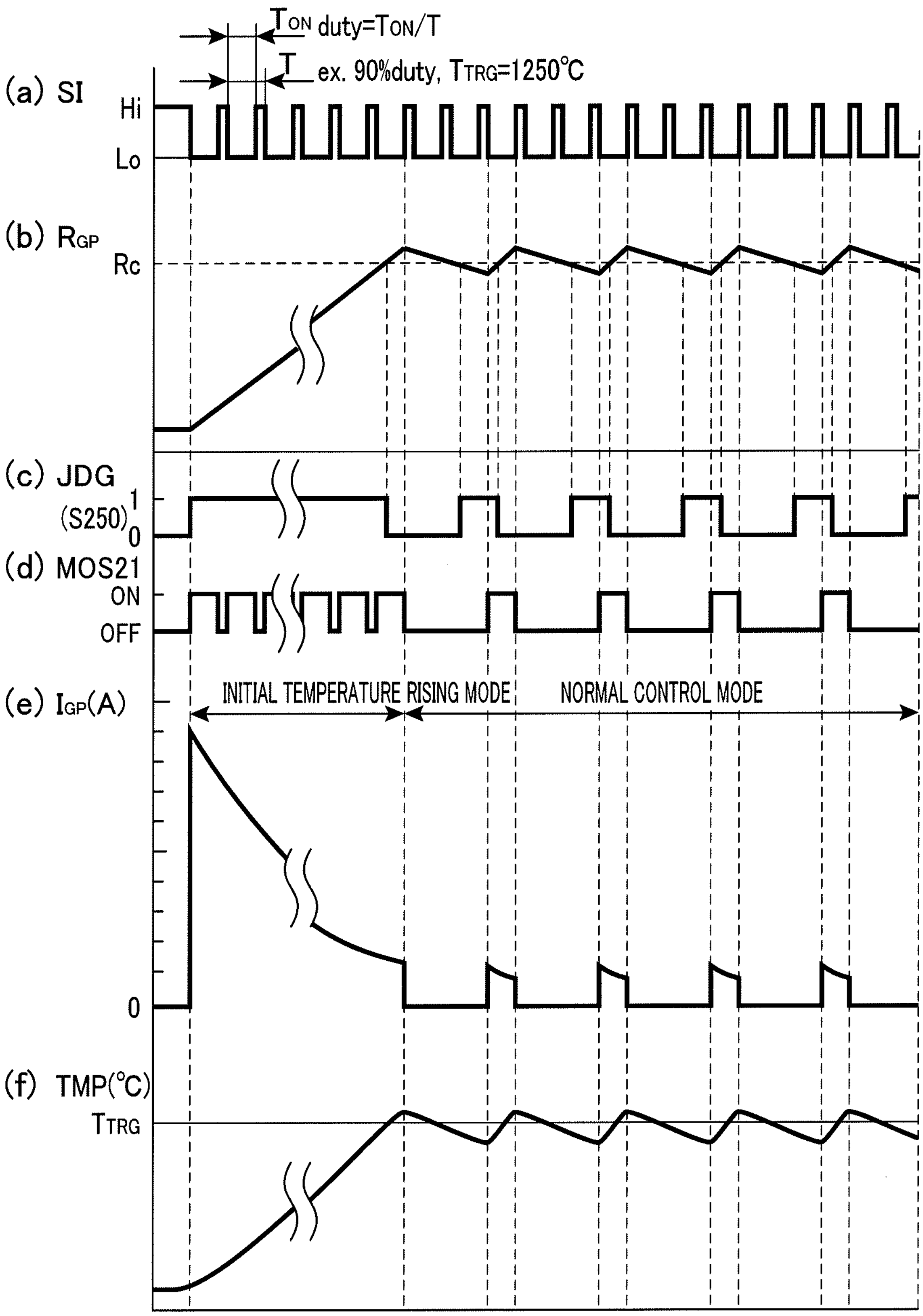

TON duty=TON/T
T ex. 90%duty, TTRG=1250°C
(a) SI
Hi
Lo
(b) RGP
Rc
(c) JDG
(S250)
1
0
(d) MOS21
ON
OFF
(e) IGP(A)
INITIAL TEMPERATURE RISING MODE
NORMAL CONTROL MODE
0
(f) TMP(°C)
TTRG

FIG.7

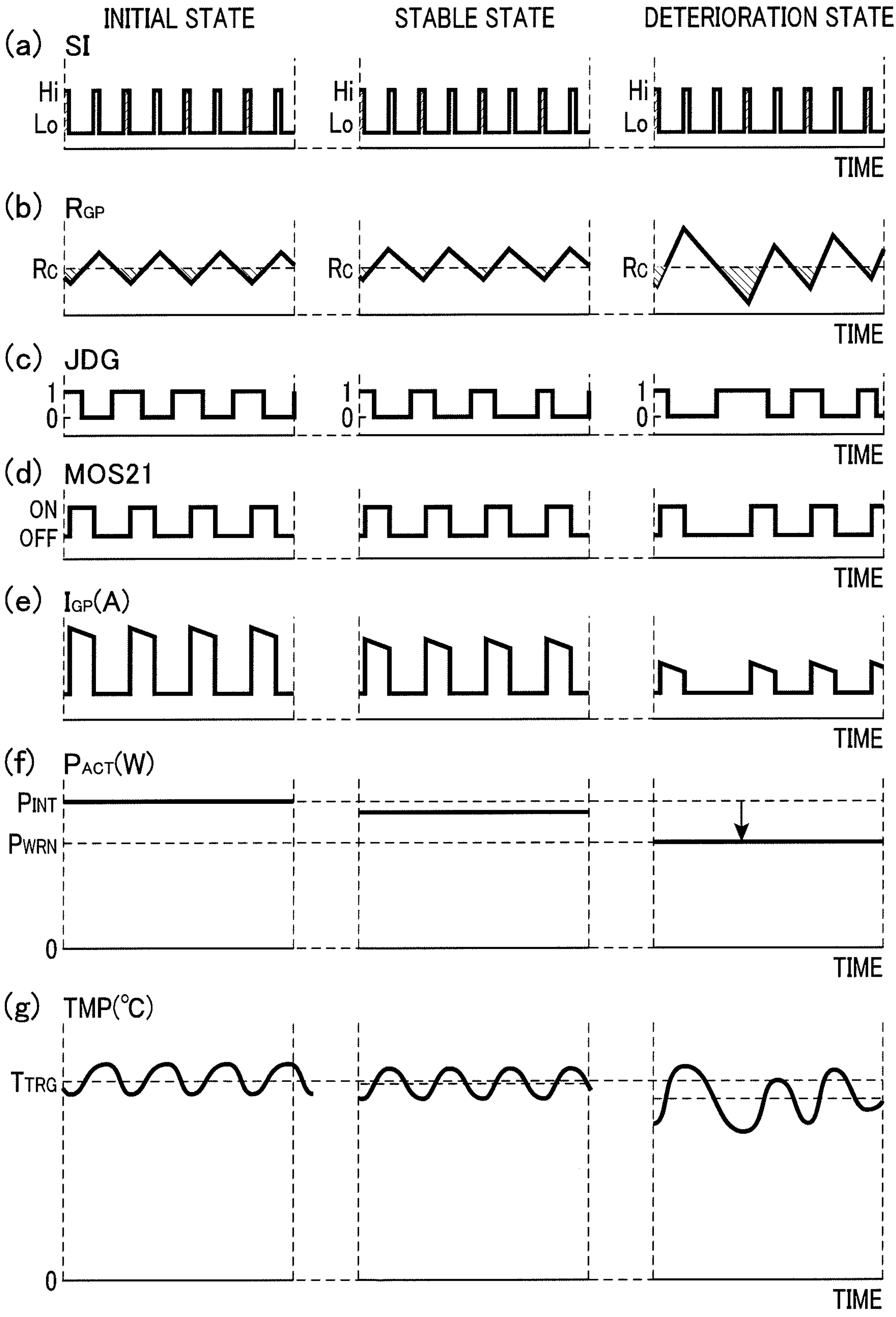

INITIAL STATE
STABLE STATE
DETERIORATION STATE
(a) SI
Hi
Lo
TIME
(b) RGP
Rc
TIME
(c) JDG
1
0
TIME
(d) MOS21
ON
OFF
TIME
(e) IGP(A)
TIME
(f) PACT(W)
PINT
PWRN
0
TIME
(g) TMP(°C)
TTRG
0
TIME

FIG.8

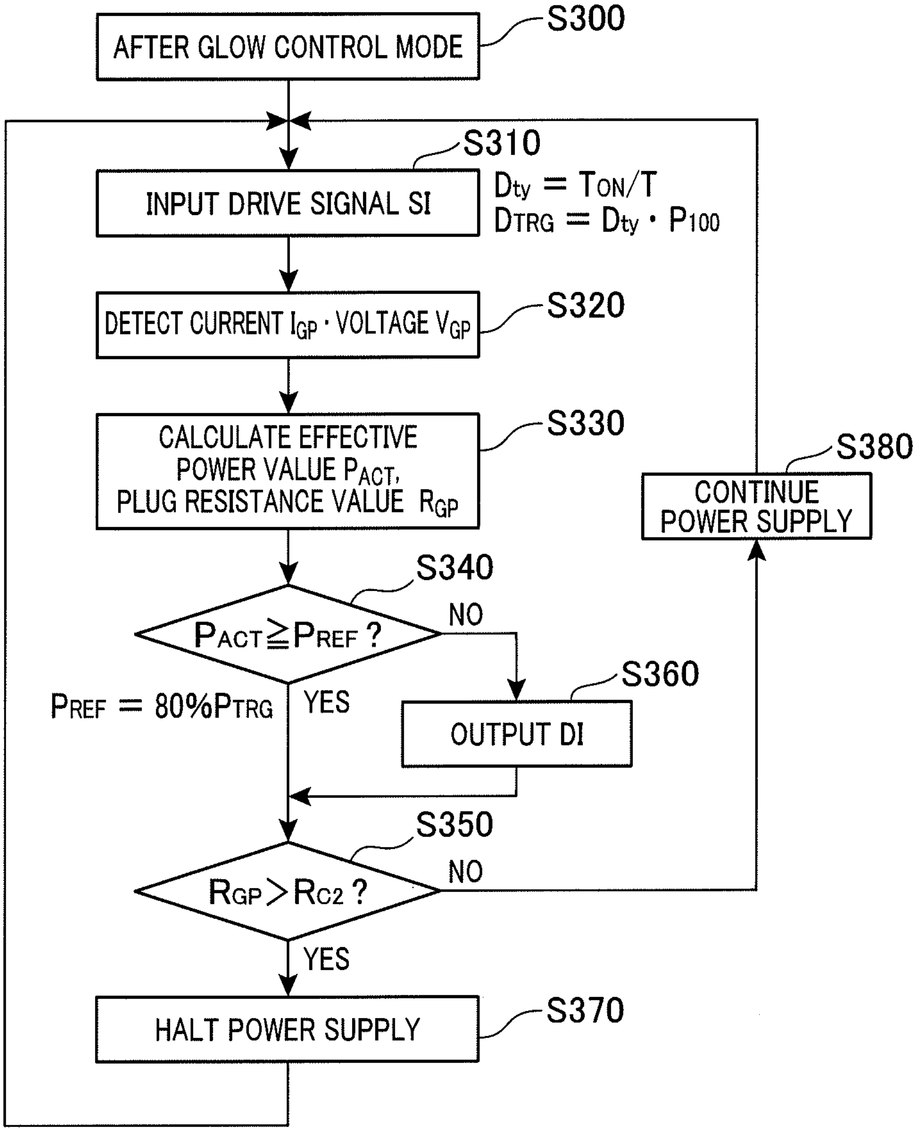

AFTER GLOW CONTROL MODE
S300
S310
INPUT DRIVE SIGNAL SI
Dty = TON/T
DTRG = Dty · P100
DETECT CURRENT IGP · VOLTAGE VGP
S320
CALCULATE EFFECTIVE POWER VALUE PACT, PLUG RESISTANCE VALUE RGP
S330
S380
CONTINUE POWER SUPPLY
S340
PACT≧PREF ?
NO
S360
PREF = 80%PTRG
YES
OUTPUT DI
S350
NO
RGP>RC2 ?
YES
HALT POWER SUPPLY
S370

FIG.9

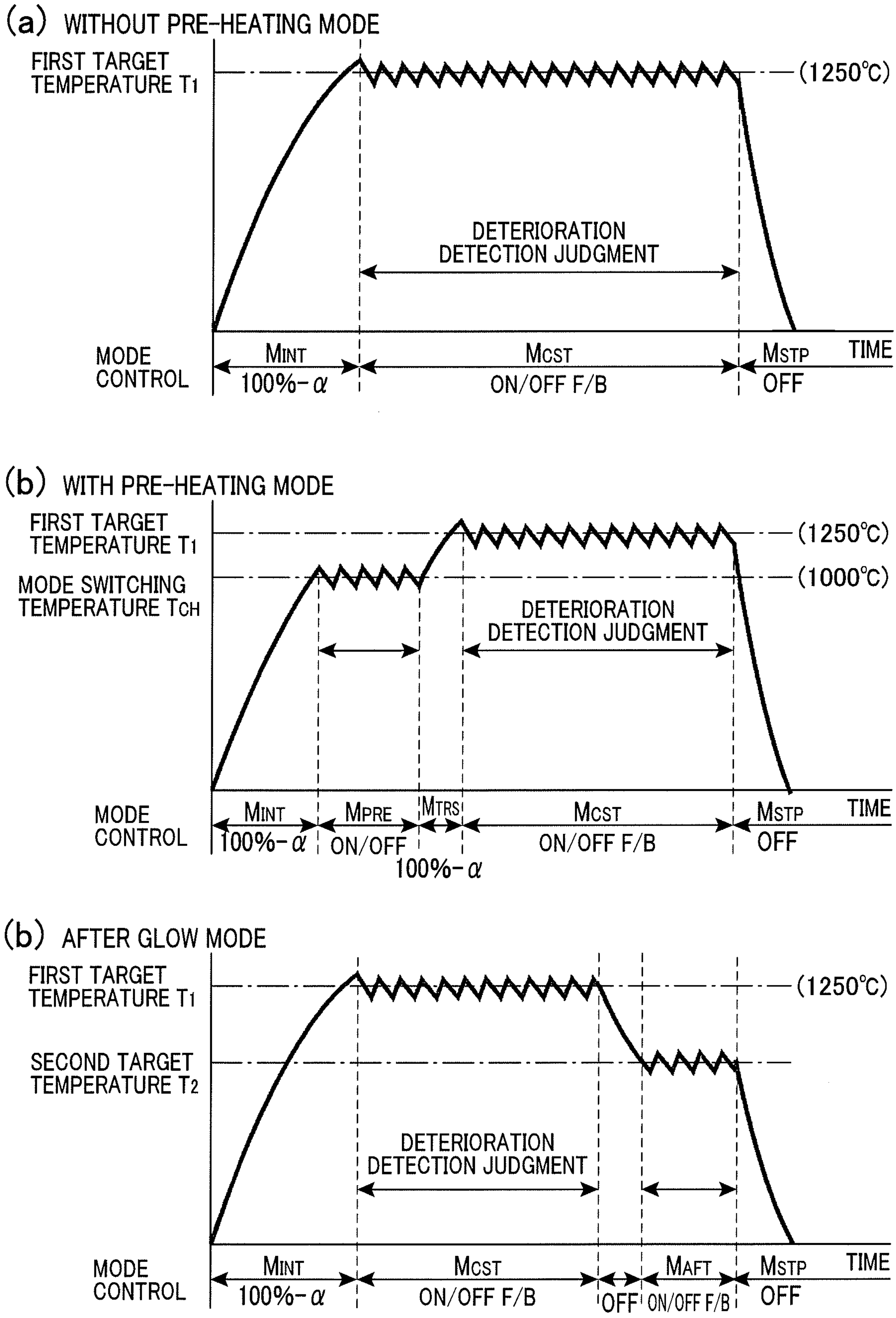
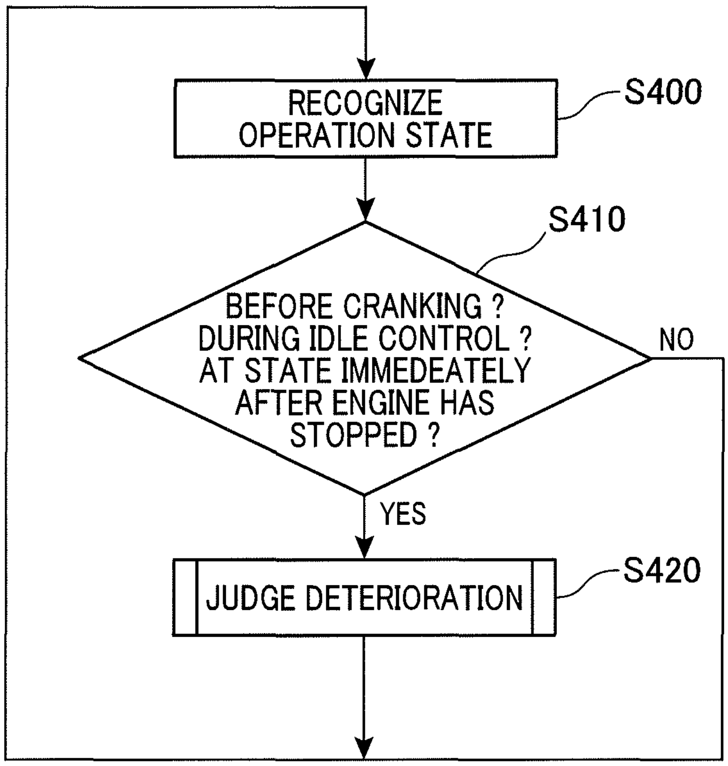

(a) WITHOUT PRE-HEATING MODE
FIRST TARGET TEMPERATURE T1
(1250°C)
DETERIORATION DETECTION JUDGMENT
MODE CONTROL
MINT
100%-α
MCST
ON/OFF F/B
MSTP
OFF
TIME
(b) WITH PRE-HEATING MODE
FIRST TARGET TEMPERATURE T1
(1250°C)
MODE SWITCHING TEMPERATURE TCH
(1000°C)
DETERIORATION DETECTION JUDGMENT
MODE CONTROL
MINT
100%-α
MPRE
ON/OFF
MTRS
100%-α
MCST
ON/OFF F/B
MSTP
OFF
TIME
(b) AFTER GLOW MODE
FIRST TARGET TEMPERATURE T1
(1250°C)
SECOND TARGET TEMPERATURE T2
DETERIORATION DETECTION JUDGMENT
MODE CONTROL
MINT
100%-α
MCST
ON/OFF F/B
OFF
MAFT
ON/OFF F/B
MSTP
OFF
TIME

FIG.10


RECOGNIZE
OPERATION STATE
S400
S410
BEFORE CRANKING ?
DURING IDLE CONTROL ?
AT STATE IMMEDEATELY
AFTER ENGINE HAS
STOPPED ?
NO
YES
JUDGE DETERIORATION
S420

REFERENCES CITED IN THE DESCRIPTION

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- JP 2009191842 A **[0010]**
- JP 2010127487 A **[0010]**
- EP 1216384 B1 **[0010]**
- US 2009308362 A1 **[0010]**
- US 2010286895 A1 **[0010]**
- EP 2128429 A2 **[0010]**