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(54) **HEATING DEVICE, HEATER STATE ESTIMATING DEVICE, AND HEATER STATE ESTIMATING METHOD**

(57) To improve accuracy of detecting the state of a heater, such as abnormality of a heating unit, wear of a base, and the like.

A heating device includes: a heater including an electric conductor, a heating unit that generates heat by energization, and a ceramic base that holds the electric conductor and the heating unit so that the electric conductor and the heating unit are buried in the ceramic base so as to be isolated from each other; and an energization unit that causes the heater to generate heat by energizing the heating unit. The heating device includes: a detection unit that detects an electric resistance of the base between the electric conductor and the heating unit; and an estimation unit that estimates a state of the heater on the basis of the electric resistance detected by the detection unit when the heating unit is energized under a predetermined condition.

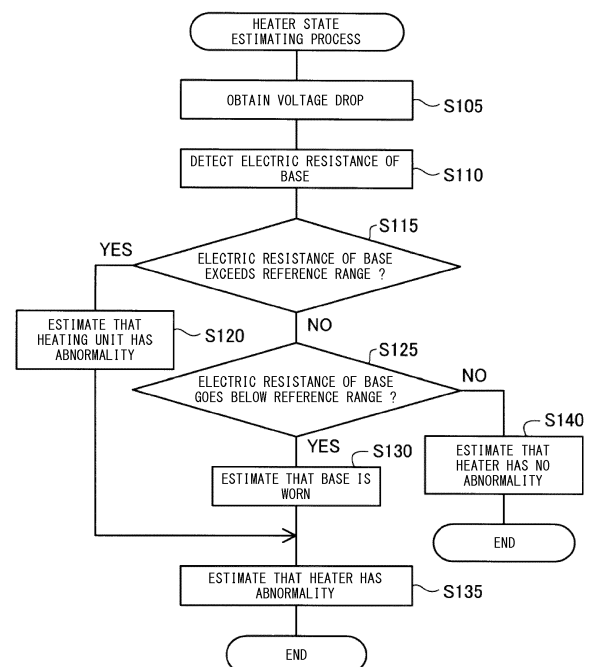


FIG. 6

Description

[Technical Field]

[0001] The present invention relates to estimation of the state of a heater.

[Background Art]

[0002] A glow plug includes a heater that includes a heating unit and a base in which the heating unit is held. The glow plug is used as an auxiliary heat source for a compression ignition type internal combustion engine (e.g., a diesel engine or the like). When the glow plug is used at a high temperature, abnormality such as a crack may occur in the heating unit. This abnormality causes an increase in the resistance of the heating unit, and the temperature of the heater becomes less likely to increase. As a result, startability of the engine may be degraded, or a soot component in exhaust gas may increase. Patent Document 1 discloses a technique of detecting abnormality of a heating unit on the basis of an increase in the resistance of the heating unit.

[Prior Art Document]

[Patent Document]

[0003] [Patent Document 1] Japanese Patent No. 4780056

[Summary of the Invention]

[Problems to be Solved by the Invention]

[0004] The resistance of the heating unit in the case where abnormality occurs in the heating unit increases only slightly as compared to that in the normal state. Therefore, in the technique of Patent Document 1, abnormality of the heating unit should be detected on the basis of the very small change in the resistance of the heating unit. Accordingly, the detection accuracy is poor, and slight abnormality of the heating unit cannot be detected. Thus, a technique for improving the accuracy of detecting abnormality of the heating unit has been demanded. Meanwhile, since the base is exposed to the atmosphere in a combustion chamber or the like, the base may be worn due to corrosion caused by chemical reaction with components contained in fuel and oil, or erosion caused by high-pressure fuel injection and swirl in the engine. If the wear of the base progresses, the strength of the base is reduced due to reduction in the diameter thereof, which may cause the heater to break. Therefore, detection of wear of the base has been demanded. As described above, a technique for improving the accuracy of estimating the state of the heater, such as abnormality of the heating unit and wear of the base, has been demanded. The above problems are not limited

to glow plugs but are common to all heaters having heating units and bases.

[Means for Solving the Problems]

[0005] The present invention has been made to solve the above-described problem, and can be embodied in the following modes.

(1) According to one mode of the present invention, a heating device is provided, which includes: a heater including an electric conductor, a heating unit that generates heat by energization, and a ceramic base that holds the electric conductor and the heating unit so that the electric conductor and the heating unit are buried in the ceramic base so as to be isolated from each other; and an energization unit that causes the heater to generate heat by energizing the heating unit. The heating device includes: a detection unit that detects an electric resistance of the base between the electric conductor and the heating unit; and an estimation unit that estimates a state of the heater on the basis of the electric resistance detected by the detection unit when the heating unit is energized under a predetermined condition. According to the heating device of this mode, since the state of the heater is estimated on the basis of the electric resistance of the base which greatly changes with respect to change in the temperature of the heater, the accuracy of estimating the state of the heater can be improved.

(2) In the heating device, the estimation unit may estimate that the heater has abnormality when the electric resistance is outside a predetermined range. According to the heating device of this mode, since the criterion is definite, degradation of the determination accuracy is suppressed, whereby the accuracy of estimating the state of the heater can be improved.

(3) In the heating device, the estimation unit may estimate that the heating unit has abnormality, as abnormality of the heater, when the electric resistance exceeds the predetermined range. According to the heating device of this mode, abnormality of the heating unit can be accurately estimated.

(4) In the heating device, the estimation unit may estimate that the base is worn, as abnormality of the heater, when the electric resistance goes below the predetermined range. According to the heating device of this mode, wear of the base can be accurately estimated.

(5) In the heating device, the energization unit may energize the heating unit at a predetermined voltage as the predetermined condition. According to the heating device of this mode, the circuit for detecting the electric resistance of the base is prevented from being complicated, and the electric resistance of the base can be easily detected.

[0006] The present invention can be realized in various modes. For example, the present invention can be realized as a heater state estimating device, a heater state estimating method, a glow plug abnormality detecting device, and the like.

[Brief Description of the Drawings]

[0007]

[FIG. 1] Explanatory view showing the schematic configuration of a heating device which is one embodiment of the present invention.

[FIG. 2] Partial cross-sectional view showing the specific configuration of a glow plug 1.

[FIG. 3] Enlarged cross-sectional view showing the structure of a front end portion of the glow plug 1.

[FIG. 4] Graph showing the relationship between base resistance R_{11} and the temperature of a heater 10.

[FIG. 5] Explanatory view showing examples of the base resistance R_{11} depending on different states of the heater 10.

[FIG. 6] Flowchart showing the procedure of a heater state estimating process.

[FIG. 7] Graph showing the relationship between the electric resistance of an energization heating unit 2 and the temperature of the heater 10, as a comparative example.

[FIG. 8] Flowchart showing the procedure of a heater state estimating process according to Modification 2.

[Modes for Carrying Out the Invention]

A. Embodiment:

A-1. Device configuration:

[0008] FIG. 1 is an explanatory view showing the schematic configuration of a heating device which is one embodiment of the present invention. The heating device 100 according to the present embodiment is mounted on a diesel engine vehicle, and heats a combustion chamber 610 of the diesel engine 600 to assist ignition of fuel injected from an injector 459 of the diesel engine 600.

[0009] The heating device 100 includes a glow plug 1 and a controller 50. The glow plug 1 is a ceramic glow plug. The glow plug 1 is mounted to a cylinder head 620 of the diesel engine 600 with a front end portion thereof being exposed in the combustion chamber 610. The configuration of the glow plug 1 will be described later in detail.

[0010] The controller 50 includes an electronic control unit (ECU) 52, a first glow relay 53, a battery 54, a second glow relay 531, a relay 55, a DC power supply 51, a resistor 521, and a potentiometer 522. The ECU 52 is configured as a microcomputer including a CPU, a RAM, and a ROM, and controls heat generation of the glow plug 1.

The ECU 52 includes a resistance detecting unit 60 and a state estimating unit 70. The resistance detecting unit 60 detects an electric resistance of a base described later. The state estimating unit 70 estimates the state of a heater on the basis of the electric resistance of the base in a heater state estimating process described later.

[0011] The first glow relay 53 is disposed between a positive electrode of the battery 54 and an external lead wire 233 of the glow plug 1. A negative electrode of the battery 54 is connected to the cylinder head 620 via the second glow relay 531, and is electrically connected to the cylinder head 620 when the second glow relay 531 is in its on state. Since the potential of the cylinder head 620 is the ground potential, the negative electrode of the battery 54 is grounded when the second glow relay 531 is in the on state. The ECU 52 turns on the first glow relay 53 and the second glow relay 531 to supply power from the battery 54 to the glow plug 1 via the external lead wire 233, and thereby causes the glow plug 1 to generate heat. The ECU 52 controls the ratio between the on time and the off time of the first glow relay 53 to control the heat generation of the glow plug 1. The second glow relay 531 is constantly in the on state while heating is executed, and is turned off when heating is stopped.

[0012] The relay 55 is disposed between the resistor 521 and an external lead wire 333 of the glow plug 1. The relay 55 turns on and off power supply from the DC power supply 51 to the glow plug 1. A negative electrode of the DC power supply 51 is grounded by being connected to the cylinder head 620. The resistor 521 is connected to a positive electrode of the DC power supply 51. The potentiometer 522 measures a voltage value that drops (voltage drop) in the resistor 521.

[0013] The ECU 52 is electrically connected to an external water temperature sensor 525 and an external rotation speed sensor 526. The water temperature sensor 525 measures the temperature of engine cooling water. The rotation speed sensor 526 measures the rotation speed of the engine. The ECU 52 obtains these values and uses them for control of heat generation of the glow plug 1.

[0014] FIG. 2 is a partial cross-sectional view showing the configuration of the glow plug 1 in detail. FIG. 3 is an enlarged cross-sectional view showing the structure of a front end portion of the glow plug 1. FIG. 3 shows the state where the glow plug 1 is mounted to the cylinder head 620. In FIGS. 2 and 3, an axis OL of the glow plug 1 is shown by an alternate long and short dash line. In the following description, in the glow plug 1, a side where a later-described heater 10 is disposed is referred to as a "front side", and a side where the external lead wires 233 and 333 are disposed is referred to as a "rear side".

[0015] As shown in FIG. 2, the glow plug 1 includes a housing 4, a rubber bush 421, a heater 10, two terminal portions 23 and 31, two external lead wires 233 and 333, and two internal lead wires 33 and 231.

[0016] The housing 4 forms an outline of the glow plug 1, and includes a metallic shell 47, a protection tube 42,

and a sheath 41. The metallic shell 47 has a substantially tubular appearance extending along the axis OL, and is located on the front side in the housing 4. On an outer peripheral surface of the metallic shell 47 on the front side, an external thread portion 43 is formed. The external thread portion 43 is screwed into an internal thread portion (not shown) formed on the cylinder head 620 of the diesel engine 600. The protection tube 42 has a substantially tubular appearance extending along the axis OL, and is located on the rear side in the housing 4. The protection tube 42 has opening portions on the front side and the rear side. The front-side opening portion of the protection tube 42 is attached to a rear end portion of the metallic shell 47. The rear-side opening portion of the protection tube 42 is closed by the rubber bush 421. The rubber bush 421 has a substantially cylindrical appearance, and is made of a rubber. The rubber bush 421 inserted in the protection tube 42 seals a space on the front side relative to the rubber bush 421. The sheath 41 has a ring-shaped appearance, is made of a metal, and is disposed on the front end portion of the metallic shell 47.

[0017] The heater 10 has a hemispheric front end portion, and has a substantially rod-like appearance extending along the axis OL. The heater 10 is fixed by the sheath 41 so that a rear end portion thereof is housed in the housing 4 and a front end portion thereof is exposed from the housing 4. As shown in FIG. 3, the heater 10 includes a base 11, an energization heating unit 2, an electrode 3, and two lead wires 21 and 22.

[0018] The base 11 holds the energization heating unit 2 and the electrode 3 so that the energization heating unit 2 and the electrode 3 are buried in the base 11 so as to be isolated from each other. In the present embodiment, the base 11 is made of a ceramic containing silicon nitride (Si_3N_4) as a principal component, and has high insulating property.

[0019] The energization heating unit 2 has a U-shaped appearance, and is buried in the front end portion of the heater 10. The energization heating unit 2 is made of a silicon nitride-based ceramic to which electrical conductivity is given, and generates heat by energization. The electric resistance of the energization heating unit 2 is smaller than the electric resistance of the base 11. On both end portions of the U-shaped energization heating unit 2, the lead wires 21 and 22 are connected, respectively. The lead wires 21 and 22 buried in the base 11. One end of the energization heating unit 2 is connected to the terminal portion 23 via the lead wire 21. The other end of the energization heating unit 2 is connected to the sheath 41 via the lead wire 22.

[0020] The electrode 3 has a rod-shaped appearance extending in the direction along the axis OL. One end of the electrode 3 is connected to the terminal portion 31, and the other end thereof is disposed near the front end of the energization heating unit 2. The electrode 3 is used to detect the electric resistance of the base 11, and is made of an electrically conductive ceramic.

[0021] The terminal portion 23 is disposed on an outer peripheral surface of the base 11 with a gap between the terminal portion 23 and an inner peripheral surface of the housing 4. The terminal portion 23 electrically communicates with the housing 4 via the heater 10 and the sheath 41. The terminal portion 31 is disposed in contact with the rear end portion of the heater 10.

[0022] As shown in FIG. 2, the external lead wires 233 and 333 penetrate the rubber bush 421, and communicate with the inside of the glow plug 1. The external lead wire 233 is connected to the terminal portion 23 via a connection terminal 232 and the internal lead wire 231. The external lead wire 333 is connected to the terminal portion 31 via a connection terminal 332 and the internal lead wire 33.

[0023] In the present embodiment, the energization heating unit 2 corresponds to a subordinate concept of a heating unit in claims, the electrode 3 corresponds to a subordinate concept of an electric conductor in claims, the controller 50 corresponds to a subordinate concept of an energization unit in claims, the resistance detecting unit 60 corresponds to a subordinate concept of a detection unit in claims, and the state estimating unit 70 corresponds to a subordinate concept of an estimation unit in claims.

A-2. Detection of electric resistance of base:

[0024] The housing 4 is mounted on the cylinder head 620 as shown in FIG. 1, and therefore electrically communicates with the cylinder head 620 at the ground potential. Therefore, when the glow relays 53 and 531 are turned on, a closed circuit is formed, and a voltage from the battery 54 is applied to the energization heating unit 2. Then, a current flows in the energization heating unit 2, and the heater 10 is heated. When the relay 55 is turned on and the DC power supply 51 and the electrode 3 electrically communicate with each other, a potential difference occurs between the electrode 3 and the energization heating unit 2. The electric resistance of the base 11 (hereinafter also referred to as "base resistance R_{11} ") is detected on the basis of the potential difference. In the present embodiment, the base resistance R_{11} means the electric resistance of the base 11 between the energization heating unit 2 and the electrode 3.

[0025] The base 11 is made of a ceramic having high insulating property, and therefore has high electric resistance. However, since the electric resistance of the base 11 is finite, when a high voltage is applied to the electrode 3, a small amount of current flows in the base 11. This current flows through the electric conductors embedded in the base 11 and the electric conductors in contact with the base 11, and finally flows to the cylinder head 620. The electric conductors embedded in the base 11 correspond to the energization heating unit 2 and the lead wires 21 and 22. The electric conductors in contact with the base 11 correspond to the terminal portions 23 and 31, and the sheath 41.

[0026] By the way, the energization heating unit 2 generates heat in the state where it is embedded in the front end portion of the heater 10. Therefore, the temperature of the base 11 on the front side, adjacent to the energization heating unit 2, is more likely to increase as compared to the temperature of the base 11 on the rear side. Generally, insulating ceramics have the following properties. That is, the higher the temperature of an insulating ceramic is, the more the electric resistance thereof decreases, and more current flows therethrough. The lower the temperature of the insulating ceramic is, the more the electric resistance thereof increases, and less current flows therethrough. Therefore, a greater part of the current flowing in the base 11 flows from near the front end of the electrode 3 to near the front end of the energization heating unit 2.

[0027] Therefore, in detecting the base resistance R_{11} , the current that flows in the portion other than the electrode 3 is ignored. Further, the electric resistance of the energization heating unit 2 is ignored because it is very small as compared to the base resistance R_{11} . That is, the energization heating unit 2 is treated as an electric conductor in the present embodiment.

[0028] Based on the above assumption, the base resistance R_{11} is calculated by the following formula (5). In the following formulae (1) to (5), V_{11} represents a potential difference between the energization heating unit 2 and the electrode 3, I represents a current that flows in the resistor 521, V_0 represents a voltage of the DC power supply 51, V_{521} represents voltage drop in the resistor 521, and R_{521} represents an electric resistance of the resistor 521.

$$R_{11} = V_{11}/I \cdots (1)$$

$$V_{11} = V_0 - V_{521} \cdots (2)$$

$$I = V_{521}/R_{521} \cdots (3)$$

Formulae (2) and (3) are substituted into formula (1) to obtain formula (4).

$$R_{11} = (V_0 - V_{521})/(V_{521}/R_{521}) \cdots (4)$$

Since $V_{521} \ll V_0$ in the present embodiment, formula (4) is transformed to obtain formula (5).

$$R_{11} = V_0 \times R_{521}/V_{521} \cdots (5)$$

[0029] FIG. 4 is a graph showing the relationship between the base resistance R_{11} and the temperature of the heater 10. The vertical axis indicates the base resist-

ance R_{11} (Ω) represented as a logarithm to a certain value A, and the horizontal axis indicates the temperature ($^{\circ}\text{C}$) of the heater 10. As the certain value A, 10 k Ω or the like may be adopted. In the present embodiment, the temperature of the heater 10 means the maximum value of the surface temperature of the base 11. The surface temperature of the base 11 varies depending on positions in the base 11. Usually, a portion near the front end of the energization heating unit 2 has the maximum temperature value. As shown in FIG. 4, the base resistance R_{11} decreases with increase in the temperature of the heater 10, and increases with decrease in the temperature of the heater 10.

[0030] When abnormality such as a crack occurs in the energization heating unit 2, the electric resistance of the energization heating unit 2 increases, and the energization heating unit 2 may be broken in some cases. If the energization heating unit 2 is energized so as to significantly exceed the heat-resistant temperature thereof, atoms of the energization heating unit 2 are diffused due to migration effect, and the energization heating unit 2 is made porous, resulting in increase in the electric resistance of the energization heating unit 2. If a voltage is applied to the energization heating unit 2 under the situation that such abnormality occurs, since the temperature of the energization heating unit 2 is less likely to increase, the temperature of the heater 10 is lower than that in the normal state. Therefore, based on the relationship shown in FIG. 4, the base resistance R_{11} increases more than that in the normal state.

[0031] On the other hand, when a voltage is applied to the energization heating unit 2 in the state where the energization heating unit 2 is in the normal state and the base 11 is worn, the temperature of the heater 10 is likely to increase due to reduction in the diameter of the base 11, and becomes higher than that in the normal state. Therefore, based on the relationship shown in FIG. 4, the base resistance R_{11} decreases more than that in the normal state.

[0032] FIG. 5 is an explanatory view showing examples of the base resistance R_{11} depending on different states of the heater 10. In FIG. 5, assuming that a reference resistance value of the base resistance R_{11} of the heater 10 in the normal state is B(Ω), the base resistance R_{11} of the heater 10 having abnormality of the energization heating unit 2 and the base resistance R_{11} of the heater 10 having the worn base 11 are represented as ratios to B. In FIG. 5, the base resistances R_{11} detected when a constant voltage (7 V) is applied to the energization heating unit 2 are shown together with the respective temperatures of the heater 10.

[0033] As shown in FIG. 5, the temperature of the heater 10 in the case where the energization heating unit 2 has abnormality is lower than that in the normal state. Therefore, the base resistance R_{11} increases more than that in the normal state. The temperature of the heater 10 in the case where the base 11 is worn is higher than that in the normal state. Therefore, the base resistance

R_{11} decreases more than that in the normal case. In the heating device 100 according to present embodiment, the heater state estimating process described later is executed, whereby the state of the heater 10 such as abnormality of the energization heating unit 2 and wear of the base 11 can be estimated based on the base resistance R_{11} .

A-3. Heater state estimating process:

[0034] FIG. 6 is a flowchart showing the procedure of the heater state estimating process. The heater state estimating process is executed when, at start-up of the diesel engine 600, a predetermined voltage is applied to the energization heating unit 2 to energize the glow plug 1, and thereby the diesel engine 600 enters its idle state.

[0035] The ECU 52 obtains the voltage drop V_{521} in the resistor 521 by using the potentiometer 522 (step S105). The resistance detecting unit 60 detects the base resistance R_{11} on the basis of the above formula (5) (step S110). The state estimating unit 70 determines whether or not the base resistance R_{11} exceeds a reference range (exceeds an upper limit value) (step S115).

[0036] The reference range of the base resistance R_{11} is set on the basis of data obtained through an experiment in advance. For example, assuming that the reference resistance value of the base resistance R_{11} in the heater 10 in the normal state is B (Ω), the reference range of the base resistance R_{11} in the heater 10 in the normal state can be set to $B \times 0.5$ (Ω) to $B \times 2.5$ (Ω), for example. In the present embodiment, the "heater 10 in the normal state" means the heater 10 in the state where heat generation is not hindered. The "abnormality of the energization heating unit 2" means the state where a crack or the like, exceeding a predetermined degree, occurs in the energization heating unit 2 (e.g., the state where a predetermined number or more of cracks having a predetermined size occur). This state can be paraphrased as "the state where heat generation of the heater 10 is hindered", for example. The "wear of the base 11" means the state where the base 11 is worn by a predetermined degree or more (e.g., by a predetermined percentage or more of the entire volume of the base 11). This state also can be paraphrased as "the state where heat generation of the heater 10 is hindered", for example.

[0037] When it is determined that the base resistance R_{11} exceeds the reference range (step S115: YES), the state estimating unit 70 estimates that the energization heating unit 2 has abnormality (step S120), and proceeds to step S135 described later. On the other hand, when it is determined that the base resistance R_{11} does not exceed the reference range (step S115: NO), the state estimating unit 70 determines whether or not the base resistance R_{11} goes below the reference range (is less than a lower limit value) (step S125).

[0038] When it is determined that the base resistance R_{11} goes below the reference range (step S125: YES), the state estimating unit 70 estimates that the base 11

is worn (step S130). After step S120 and step S130, the state estimating unit 70 estimates that the heater 10 has abnormality (step S135), and the heater state estimating process is ended.

[0039] On the other hand, when it is determined that the base resistance R_{11} does not go below the reference range (step S125: NO), since the base resistance R_{11} is within the reference range, the state estimating unit 70 estimates that the heater 10 does not have abnormality (step S140), and the heater state estimating process is ended.

[0040] In the present embodiment, when the result of the heater state estimating process is that the heater 10 has abnormality, the user is notified of the abnormality of the heater 10 by ECU 52.

[0041] In the heating device 100 according to the present embodiment, when the base resistance R_{11} is outside the predetermined range, it is estimated that the heater 10 has abnormality such as abnormality of the energization heating unit 2 and wear of the base 11. As shown in FIG. 4, the base resistance R_{11} exponentially changes with respect to change in the temperature of the heater 10. Therefore, by executing the heater state estimating process based on the base resistance R_{11} , the accuracy of estimating the state of the heater 10 can be improved. In addition, since the user is notified of the detected abnormality of the heater 10, the user can take an appropriate countermeasure (e.g., replacement of the glow plug 1). Accordingly, it is possible to suppress degradation of startability of the engine and increase in the soot component in the exhaust gas, which are caused by the abnormality of the energization heating unit 2. In addition, it is possible to suppress breakage of the heater 10 due to reduction in the strength of the heater 10, which is caused by wear of the base 11. Further, since the criterion as to whether the base resistance R_{11} is outside the predetermined range is definite, reduction in the determination accuracy is suppressed, resulting in improved accuracy of estimating the state of the heater 10.

[0042] Preferably, detection of the base resistance R_{11} is performed under substantially fixed conditions. In the heating device 100 according to the present embodiment, the heater state estimating process is executed when the diesel engine 600 enters the idle state. Therefore, parameters having influences on the temperature of the heater 10, such as the temperature of the engine cooling water, the rotation speed of the engine, and the like, are relatively stable, whereby detection errors of the base resistance R_{11} can be reduced, resulting in improved accuracy of estimating the state of the heater 10. Further, since the heater state estimating process can be executed somewhat periodically, abnormality of the energization heating unit 2 and wear of the base 11, which gradually progress, can be estimated, whereby convenience for the user can be improved.

[0043] Since the resistance detecting unit 60 detects the base resistance R_{11} when the predetermined voltage is applied to the energization heating unit 2, the circuit

for the detection is prevented from being complicated, and the base resistance R_{11} can be easily detected. In addition, when the conditions such as the temperature of the engine cooling water, the rotation speed of the engine, and the like are fixed, errors in the temperature of the heater 10 when the predetermined voltage is applied to the energization heating unit 2 are small. Therefore, by detecting the base resistance R_{11} when the predetermined voltage is applied, detection errors in the base resistance R_{11} can be reduced, whereby the accuracy of estimating the state of the heater 10 can be improved.

[0044] The state estimating unit 70 estimates the state of the heater 10 by performing the determination on the basis of the result of the comparison between the preset reference range of the base resistance R_{11} and the base resistance R_{11} detected by the resistance detecting unit 60. Since the determination is performed on the basis of the absolute value, load on the ECU 52 can be reduced.

[0045] In the heating device 100 according to the present embodiment, as abnormality of the heater 10, abnormality of the energization heating unit 2 and wear of the base 11 can be separately estimated. Therefore, it is easy to specify the cause of the abnormality of the heater 10, whereby convenience for the user can be improved.

B. Comparative example:

[0046] FIG. 7 is a graph showing, as a comparative example, the relationship between the electric resistance of the energization heating unit 2 and the temperature of the heater 10. The vertical axis indicates the electric resistance (Ω) (hereinafter also referred to as "heating unit resistance R_2 ") of the energization heating unit 2, and the horizontal axis indicates the temperature ($^{\circ}\text{C}$) of the heater 10. For example, as a certain value C on the vertical axis, 3Ω or the like may be adopted.

[0047] The heating unit resistance R_2 in the case where abnormality occurs in the energization heating unit 2 increases only slightly as compared to the heating unit resistance R_2 in the normal state. Therefore, as shown in FIG. 7, the rate of change in the heating unit resistance R_2 with respect to change in the temperature of the heater 10 is very small. Accordingly, the configuration of detecting abnormality of the energization heating unit 2 on the basis of the heating unit resistance R_2 has poor detection accuracy, and cannot detect slight abnormality such as a minute crack or the like generated in the energization heating unit 2. In contrast, since the heating device 100 according to the present embodiment estimates the state of the heater 10 on the basis of the base resistance R_{11} that exponentially and greatly changes with respect to change in the temperature of the heater 10, the accuracy of estimating the state of the heater 10 can be improved. Further, in addition to abnormality of the energization heating unit 2, wear of the base 11 can also be estimated.

C. Modifications:

[0048] The present invention is not limited to the above embodiment and modes and may be embodied in various other forms without departing from the scope of the invention. For example, the following modifications are possible.

C-1. Modification 1:

[0049] While in the above embodiment, the state of the heater 10 is estimated on the basis of the base resistance R_{11} detected when the predetermined voltage is applied to the energization heating unit 2, the present invention is not limited thereto. The base resistance R_{11} may be detected under any other energization condition as long as the energization condition is the same as that for detection of the base resistance R_{11} previously set as a reference range. For example, as an energization condition for detection of the base resistance R_{11} , the energization heating unit 2 may be caused to generate heat at predetermined power, or may be caused to generate heat to provide a predetermined current, or may be caused to generate heat so that the electric resistance of the energization heating unit 2 has a predetermined value. Also this configuration achieves the same effect as the heating device 100 according to the embodiment.

C-2. Modification 2:

[0050] While in the above embodiment, the state estimating unit 70 estimates abnormality of the energization heating unit 2 and wear of the base 11 to be distinguished from each other, the state estimating unit 70 may estimate the state of the heater 10 without distinguishing abnormality of the energization heating unit 2 and wear of the base 11 from each other.

[0051] FIG. 8 is a flowchart showing the procedure of a heater state estimating process according to Modification 2. The heater state estimating process according to Modification 2 is different from the heater state estimating process according to the embodiment shown in FIG. 6 in that step S115a is executed instead of step S115 and steps S120 to S130 are omitted. Since other steps and the configuration of the heating device 100 in the heater state estimating process according to Modification 2 are identical to those of the above embodiment, the same components are designated by the same reference numerals, and detailed description thereof is omitted.

[0052] The state estimating unit 70 determines whether or not the base resistance R_{11} is within a predetermined range (step S115a). When it is determined that the base resistance R_{11} is not within the predetermined range (step S115a: NO), the state estimating unit 70 may estimate that the heater 10 has abnormality (step S135). When it is determined that the base resistance R_{11} is within the predetermined range (step S115a: YES), the state estimating unit 70 may estimate that the heater 10

has no abnormality (step S140). This configuration also achieves the same effect as the heating device 100 according to the embodiment.

C-3. Modification 3:

[0053] While in the heating device 100 according to the above embodiment, the heater state estimating process is executed when the diesel engine 600 enters the idle state, the present invention is not limited thereto. The heater state estimating process may be executed at any other timing as long as the base resistance R_{11} is detected under the same detection condition as that for the base resistance R_{11} previously set as the reference range. For example, the heater state estimating process may be executed at the time of idle stop, or fuel cut, or engine stop. Alternatively, the heater state estimating process may be executed after a predetermined period has passed from a certain time. For example, the heater state estimating process may be executed after a predetermined period has passed from start of energization of the glow plug 1. Alternatively, the heater state estimating process may be executed after determination as to whether or not the parameters such as the temperature of the engine cooling water and the rotation speed of the engine are within a predetermined range. Also this configuration achieves the same effect as the heating device 100 according to the above embodiment.

C-4. Modification 4:

[0054] While in the above embodiment, the state estimating unit 70 estimates the state of the heater 10 by using the preset reference range of the base resistance R_{11} , the present invention is not limited thereto. The ECU 52 may store an initial value of the base resistance R_{11} , and a difference between the initial value of the base resistance R_{11} and the detected base resistance R_{11} may be calculated to perform estimation based on the difference. For example, assuming that the initial value of the base resistance R_{11} in the heater 10 in the normal state is D (Ω), when the absolute value of a difference between the initial value of the base resistance R_{11} and the detected base resistance R_{11} is outside the range from $D \times 0.5$ (Ω) to $D \times 2.5$ (Ω), it may be estimated that the heater 10 has abnormality. In this configuration, since the estimation is performed on the basis of the relative value, influence of variation in the base resistance R_{11} due to individual differences of the glow plug 1 can be reduced, whereby the accuracy of estimating the state of the heater 10 can be improved.

C-5. Modification 5:

[0055] While in the above embodiment, the state estimating unit 70 estimates the state of the heater 10 by using one preset reference range of the base resistance R_{11} , the state estimating unit 70 may estimate the state

of the heater 10 by using two or more reference ranges. For example, assuming that the reference resistance value of the base resistance R_{11} in the heater 10 in the normal state is B (Ω), a first reference range may be set to $B \times 0.5$ (Ω) to $B \times 2.5$ (Ω) and a second reference range may be set to $B \times 0.75$ (Ω) to $B \times 2$ (Ω) or the like, whereby the state of the heater 10 may be estimated in two stages. In this configuration, when the detected base resistance R_{11} is within the first reference range but is outside the second reference range, the heater 10 can be set to a desired temperature by changing the applied voltage.

C-6. Modification 6:

[0056] The configuration of the heating device 100 according to the above embodiment is merely an example, and can be modified in various ways. For example, the base 11 may be made of, instead of the silicon nitride-based ceramic, any other insulating ceramics such as titanium diboride, alumina, or sialon. The electrode 3 may be made of a metal material instead of the electrically conductive ceramic. Also this configuration achieves the same effect as the heating device 100 according to the above embodiment.

[0057] While in the above embodiment, the ECU 52 executes the heater state estimating process, the present invention is not limited thereto. A glow control unit that exclusively control the glow plug 1 may be arranged separately from the ECU 52, and the glow control unit may execute the heater state estimating process. In this configuration, the glow control unit may receive the temperature of the engine cooling water, the rotation speed of the engine, and the like from the ECU 52. This configuration also achieves the same effect as the heating device 100 according to the above embodiment.

[0058] Further, the circuit configuration for detecting the base resistance R_{11} may be modified. For example, a voltage may be applied between the pair of external lead wires 233 and 333 to measure a current value. In this configuration, it is easy to grasp the voltage applied between the energization heating unit 2 and the electrode 3, whereby the accuracy of detecting the base resistance R_{11} can be improved.

C-7. Modification 7:

[0059] While in the above embodiment, the present invention is applied to the heating device 100 including the glow plug 1, the present invention may be applied to any other ceramic heater instead of the glow plug 1. For example, the present invention may be applied to heaters, heat sources for soldering iron, warm-water toilet seats, heat sources for semiconductor manufacturing devices, heat sources for measurement equipment, parts of chemical equipment, and the like.

[0060] The present invention is not limited to the above embodiments and modifications/variations and can be embodied in various forms without departing from the

scope of the present invention. For example, it is feasible to appropriately replace or combine any of the technical features of the aspects of the present invention described in "Summary of the Invention" and the technical features of the embodiments and modifications/variations of the present invention in order to solve part or all of the above-mentioned problems or achieve part or all of the above-mentioned effects. Any of these technical features, if not explained as essential in the present specification, may be deleted as appropriate.

[Description of Reference Numerals]

[0061]

1 ... glow plug
 2 ... energization heating unit
 3 ... electrode
 4 ... housing
 10 ... heater
 11 ... base
 21 ... lead wire
 22 ... lead wire
 23 ... terminal portion
 31 ... terminal portion
 33 ... internal lead wire
 41 ... sheath
 42 ... protection tube
 43 ... external thread portion
 47 ... metallic shell
 50 ... controller
 51 ... DC power supply
 53 ... first glow relay
 54 ... battery
 55 ... relay
 60 ... resistance detecting unit
 70 ... state estimating unit
 100 ... heating device
 231 ... internal lead wire
 232 ... connection terminal
 233 ... external lead wire
 332 ... connection terminal
 333 ... external lead wire
 421 ... rubber bush
 459 ... injector
 521 ... resistor
 522 ... potentiometer
 525 ... water temperature sensor
 526 ... rotation speed sensor
 531 ... second glow relay
 600 ... diesel engine
 610 ... combustion chamber
 620 ... cylinder head
 A ... certain value of base resistance
 B ... reference resistance value of base resistance
 C ... certain value of heating unit resistance
 D ... initial value of base resistance
 OL ... axis

Claims

1. A heating device (100) comprising:

5 a heater (10) including an electric conductor (3), a heating unit (2) that generates heat by energization, and a ceramic base (11) that holds the electric conductor (3) and the heating unit (2) so that the electric conductor (3) and the heating unit (2) are buried in the ceramic base (11) so as to be isolated from each other; and
 10 an energization unit (50) that causes the heater (10) to generate heat by energizing the heating unit (2);

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the heating device (100) comprising:

a detection unit (60) that detects an electric resistance of the base (11) between the electric conductor (3) and the heating unit (2); and
 20 an estimation unit (70) that estimates a state of the heater (10) on the basis of the electric resistance detected by the detection unit (60) when the heating unit (2) is energized under a predetermined condition.

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2. The heating device (100) according to claim 1, wherein
 the estimation unit (70) estimates that the heater (10) has abnormality when the electric resistance is outside a predetermined range.

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3. The heating device (100) according to claim 2, wherein
 the estimation unit (70) estimates that the heating unit (2) has abnormality, as abnormality of the heater (10), when the electric resistance exceeds the predetermined range.

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4. The heating device (100) according to claim 2 or 3, wherein
 the estimation unit (70) estimates that the base (11) is worn, as abnormality of the heater (10), when the electric resistance goes below the predetermined range.

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5. The heating device (100) according to any one of claims 1 to 4, wherein
 the energization unit (50) energizes the heating unit (2) at a predetermined voltage as the predetermined condition.

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6. A heater state estimating device for estimating a state of a heater (10), the heater (10) comprising: an electric conductor (3); a heating unit (2) that generates heat by energization; and a ceramic base (11) that holds the electric conductor (3) and the heating unit (2) so that the electric conductor (3) and the heat-

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ing unit (2) are buried in the ceramic base (11) so as to be isolated from each other,
the heater state estimating device comprising:

a detection unit (60) that detects an electric resistance of the base (11) between the electric conductor (3) and the heating unit (2); and
an estimation unit (70) that estimates a state of the heater (10) on the basis of the electric resistance detected by the detection unit (60) when the heating unit (2) is energized under a predetermined condition.

7. A method for estimating a state of a heater (10), the heater (10) comprising: an electric conductor (3); a heating unit (2) that generates heat by energization; and a ceramic base (11) that holds the electric conductor (3) and the heating unit (2) so that the electric conductor (3) and the heating unit (2) are buried in the ceramic base (11) so as to be isolated from each other, and
the method comprising:

(a) a step of energizing the heating unit (2) under a predetermined condition;
(b) a step of detecting an electric resistance of the base (11) between the electric conductor (3) and the heating unit (2) during execution of the step (a); and
(c) a step of estimating a state of the heater (10) on the basis of the electric resistance detected in the step (b).

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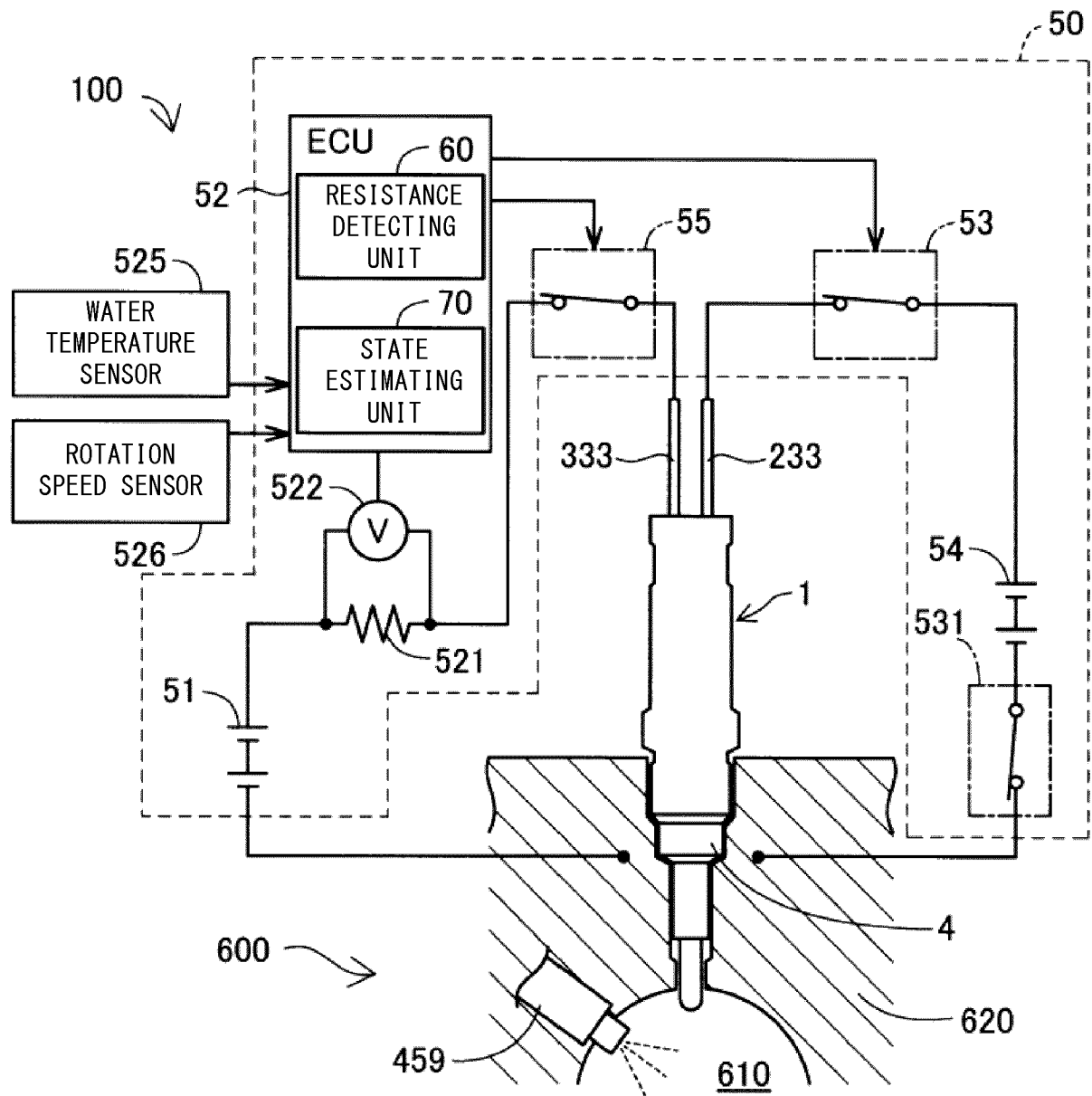


FIG. 1

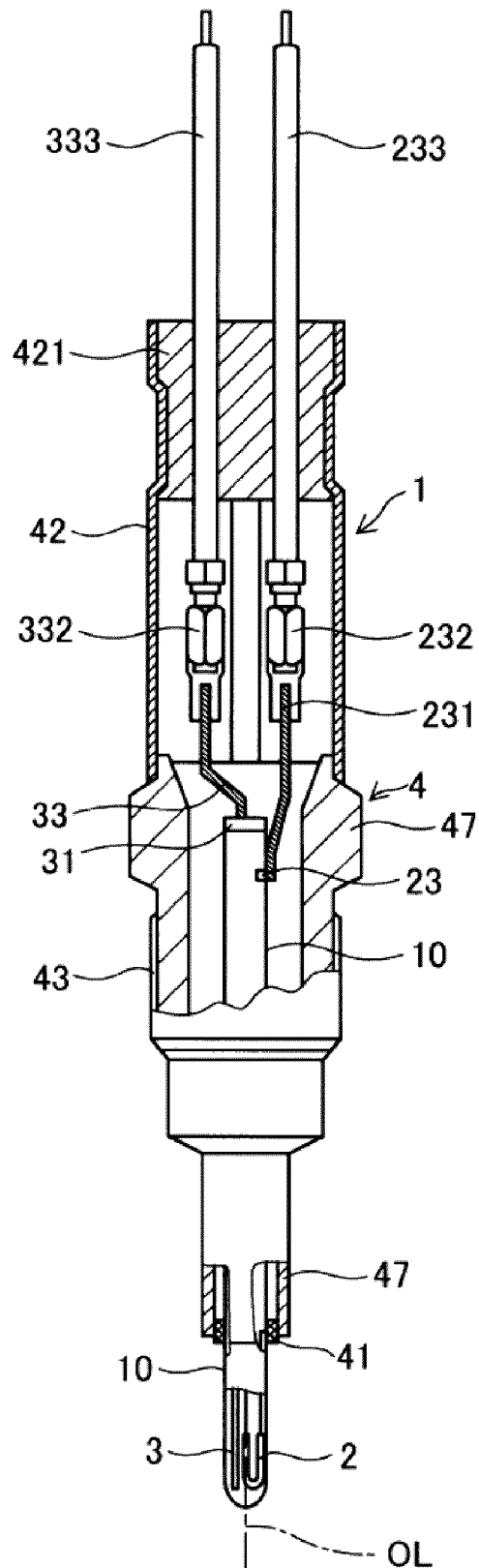


FIG. 2

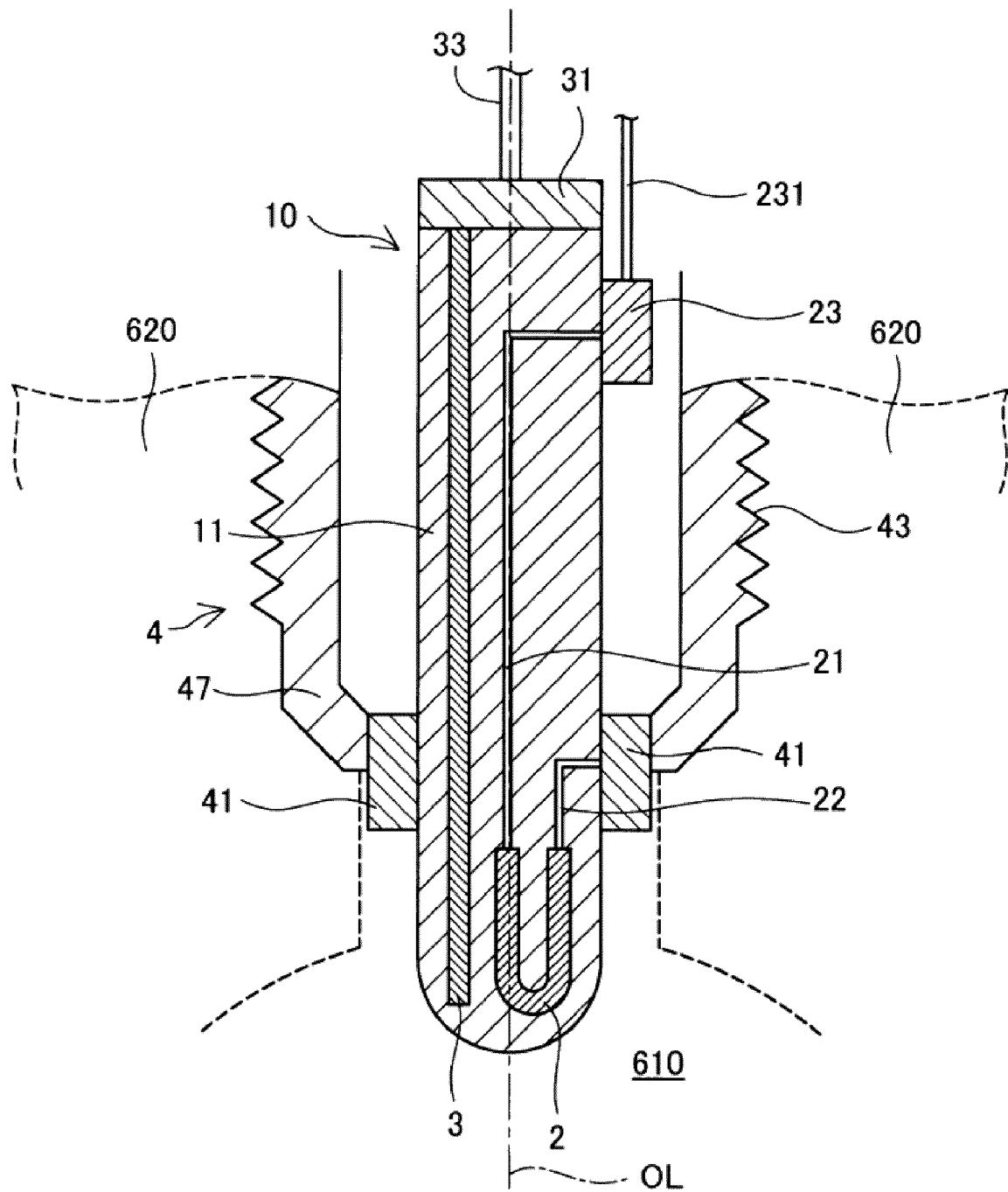


FIG. 3

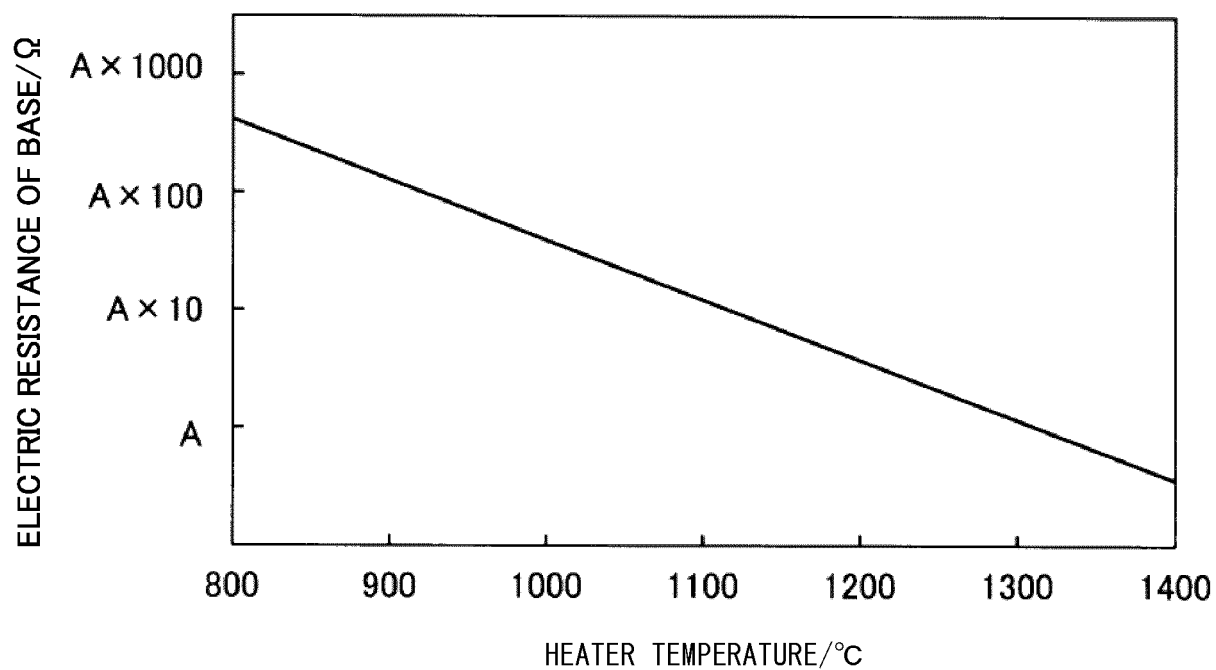


FIG. 4

	APPLIED VOLTAGE (V)	TEMPERATURE OF HEATER ($^{\circ}\text{C}$)	RESISTANCE OF BASE (Ω)
NORMAL	7	1140	B
ABNORMALITY OF ENERGIZATION HEATING UNIT	7	1030	$B \times 3$
WARE OF BASE	7	1240	$B \times 0.3$

FIG. 5

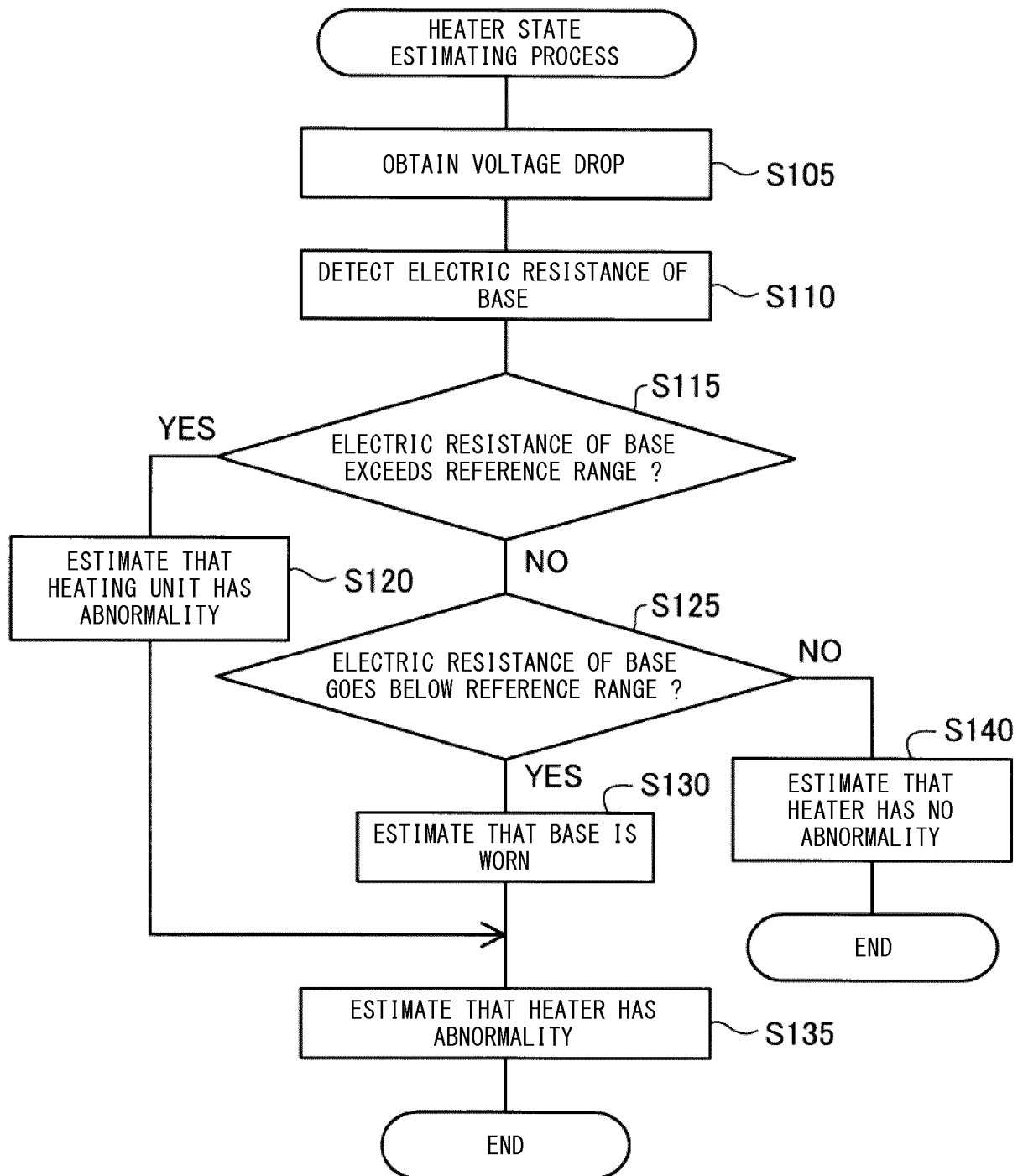


FIG. 6

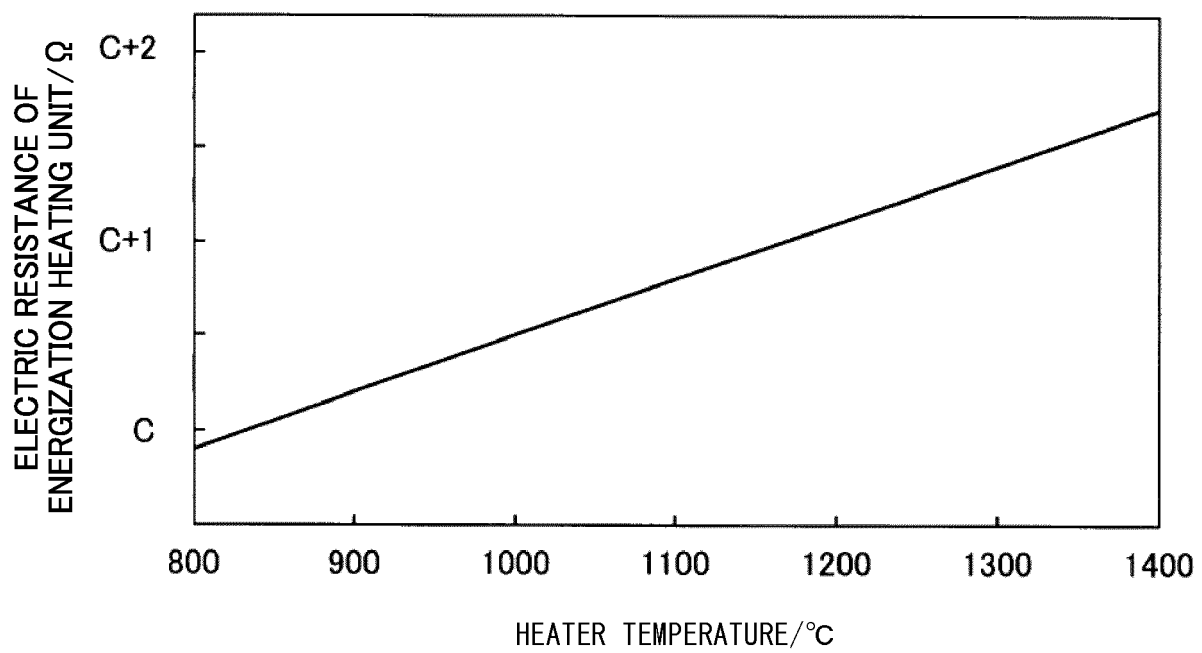


FIG. 7

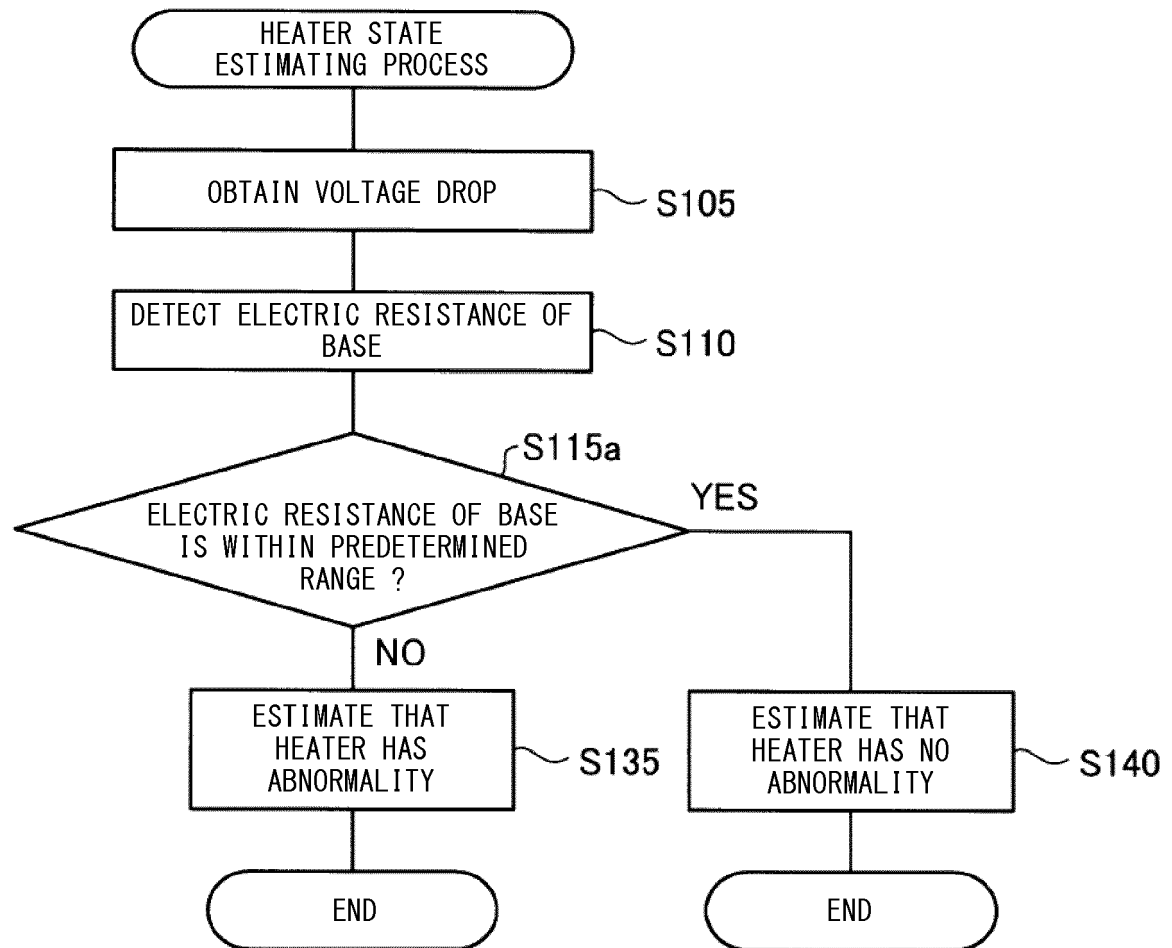


FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4780056 B [0003]