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(54) **INDUCTION HEATING COOKER**

INDUKTIONSHERD

CUISINIÈRE À INDUCTION

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Description

Technical Field

[0001] The present invention relates to an induction heating cooking apparatus.

Background Art

[0002] An existing induction heating cooking apparatus determines the temperature of a heating target on the basis of an input current or a control variable of an inverter (see, e.g., Patent Literature 1 and 2). The induction heating cooking apparatus in Patent Literature 1 includes a control unit that controls the inverter so that an input current of the inverter is constant. When a control variable is changed by a predetermined amount or more within a predetermined time, the induction heating cooking apparatus determines a change in the temperature of the heating target is large and reduces the output of the inverter. In addition, it is disclosed that when the control variable is changed by the predetermined amount or less within the predetermined time, the induction heating cooking apparatus determines that water boiling is completed, and decreases a drive frequency to reduce the output of the inverter.

[0003] Patent Literature 2 proposes an induction heating cooking apparatus that includes an input current change amount detection unit that detects the amount of change in input current and a temperature determination processing unit that determines the temperature of a heating target on the basis of the amount of change in input current detected by the input current change amount detection unit. It is disclosed that when the temperature determination unit determines that the temperature of the heating target reaches the boiling temperature, a stop signal is output to stop heating.

Citation List

Patent Literature

[0004]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2008-181892 (Paragraph [0025], Fig. 1)
Patent Literature 2: Japanese Unexamined Patent Application Publication No. 5-62773 (Paragraph [0017], Fig. 1)

[0005] EP 2 506 672 A2 discloses an induction heating cooker and a control method thereof that prevents the occurrence of an error, such error may be caused during recognition of a container in an induction heating cooker that performs cooking regardless of where the container is placed on a cooking plate. It includes a plurality of heating coils disposed below a cooking plate, current detectors to detect values of current flowing in the respective heating coils, and a controller to determine whether a container is placed on the respective heating coils based on the detected current values of the heating coils and change amounts of the current values.

Summary of Invention

Technical Problem

[0006] However, when the induction heating cooking apparatus is merely stopped when a predetermined temperature is reached as in the induction heating cooking apparatus in Patent Literature 1 or 2, there is a problem in that temperature control suitable for the contents in the heating target cannot be performed after the heating target is heated. That is, when the contents in the heating target are to be maintained at a predetermined temperature (e.g., in a boiled state), an amount of heat to be supplied is different depending on a heat load of the heating target at the initial stage of heating (the initial temperature and the amount of the contents and other factors). For example, if a great amount of heat is supplied when the initial temperature of the contents in the heating target is high, electric power is wasted, but when the initial temperature of the contents in the heating target is low, the contents in the heating target cannot be maintained at a predetermined temperature unless an amount of heat that is appropriate to the low temperature is supplied.

[0007] The present invention has been made to solve the above-described problem, and an object of the present invention is to provide an induction heating cooking apparatus that is able to efficiently perform optimal operation depending on a heat load of the contents in a heating target.

Solution to Problem

[0008] An induction heating cooking apparatus according to the present invention includes a heating coil configured to inductively heat a heating target; a drive circuit configured to supply high-frequency power to the heating coil; and a control unit configured to control driving of the drive circuit to control the high-frequency power supplied to the heating coil. The control unit obtains an amount of temporal change (ΔI) of at least one of an input current to the drive circuit and a coil current flowing through the heating coil, in a state where a drive frequency of the drive circuit is fixed; measures a first time (t1) from start of power supply to the heating coil until the amount of temporal change (ΔI) becomes equal to or less than a set value; and controls the high-frequency power supplied to the heating coil depending on the first time (t1) and an amount of current change (I1) of at least one of the input current and the coil current during the first time (t1).

Advantageous Effects of Invention

[0009] According to the present invention, it is possible to efficiently perform optimal operation depending on the heat load of the contents in the heating target. In addition, it is possible to provide an energy-saving and easy-to-use induction heating cooking apparatus that is able to perform a temperature-retaining operation while reducing wasted power supply.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is an exploded perspective view showing an induction heating cooking apparatus according to Embodiment 1.
[Fig. 2] Fig. 2 is a diagram showing an example of a drive circuit of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 3] Fig. 3 is a functional block diagram showing an example of a control unit of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 4] Fig. 4 is a load determination characteristic diagram of a heating target based on a relationship between a heating coil current and an input current in the induction heating cooking apparatus according to Embodiment 1.
[Fig. 5] Fig. 5 is a correlation diagram of the input current relative to a drive frequency at the time of change in the temperature of the heating target in the induction heating cooking apparatus according to Embodiment 1.
[Fig. 6] Fig. 6 is an enlarged diagram of a portion indicated by a dotted line in Fig. 5.
[Fig. 7] Fig. 7 is a diagram showing a relationship between time and drive frequency, temperature, and input current in a water boiling mode 1 of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 8] Fig. 8 is a diagram showing a relationship between time and drive frequency, temperature, and input current in a water boiling mode 2 of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 9] Fig. 9 is an enlarged diagram of the portion indicated by the dotted line in Fig. 5.
[Fig. 10] Fig. 10 is a flowchart showing an example of operation in the water boiling mode 2 of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 11] Fig. 11 is a flowchart showing an example of operation of initial water temperature detection in Fig. 11.
[Fig. 12] Fig. 12 is a diagram showing a relationship between a reference time and a reference amount of current change, and a heat load at the initial stage of heating.
[Fig. 13] Fig. 13 is a diagram showing a relationship between time and drive frequency, temperature, and input current in a water boiling mode 3 of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 14] Fig. 14 is a diagram showing another drive circuit of the induction heating cooking apparatus according to Embodiment 1.
[Fig. 15] Fig. 15 is a diagram showing a part of a drive circuit of an induction heating cooking apparatus according to Embodiment 2.
[Fig. 16] Fig. 16 is a diagram showing an example of driving signals of a half-bridge circuit according to Embodiment 2.
[Fig. 17] Fig. 17 is a diagram showing a part of a drive circuit of an induction heating cooking apparatus according to Embodiment 3.
[Fig. 18] Fig. 18 is a diagram showing an example of driving signals of a full-bridge circuit according to Embodiment 3.

Description of Embodiments

Embodiment 1

(Configuration)

[0011] Fig. 1 is an exploded perspective view showing an induction heating cooking apparatus according to Embodiment 1.

[0012] As shown in Fig. 1, an induction heating cooking apparatus 100 includes, at an upper portion thereof, a top plate 4 on which a heating target 5 such as a pot is placed. The top plate 4 has a first heating port 1, a second heating port 2, and a third heating port 3 as heating ports for inductively heating the heating target 5. A first heating unit 11, a second heating unit 12, and a third heating unit 13 are each arranged for a corresponding one of the heating ports, and are able to each inductively heat a heating target 5 placed on corresponding one of heating ports.

[0013] In Embodiment 1, the first heating unit 11 and the second heating unit 12 are provided to be laterally aligned at the front side of a main body, and the third heating unit 13 is provided at substantially the center at the back side of the main body.

[0014] The arrangement of each heating port is not limited thereto. For example, the three heating ports may be arranged laterally in a substantially straight line. Alternatively, the first heating unit 11 and the second heating unit 12 may be arranged so that the position of the center of the first heating unit 11 and the position of the center of the second heating unit 12 are different from each other in the depth direction.

[0015] The top plate 4 is entirely formed from a material that transmits infrared rays, such as heat-resistant reinforced glass, crystallized glass, and other glass, and is fixed in a water tight state with a rubber packing or a sealing material interposed between the top plate 4 and the periphery of an opening of the upper surface of the main body of the induction heating cooking apparatus 100. On the top plate 4, circular pot position indicators indicating general placement positions of pots are formed by applying paints, printing, or other methods to correspond to heating ranges (heating ports) of the first heating unit 11, the second heating unit 12, and the third heating unit 13.

[0016] At the front side of the top plate 4, an operation unit 40a, an operation unit 40b, and an operation unit 40c (hereinafter, may be collectively referred to as operation unit 40) are provided as input devices that set heating power and cooking menus (water boiling mode, frying mode, or other modes) in heating the heating target 5 by the first heating unit 11, the second heating unit 12, and the third heating unit 13. Moreover, in the vicinity of the operation unit 40, a display unit 41a, a display unit 41b, and a display unit 41c that display an operating state of the induction heating cooking apparatus 100, input and operation contents from the operation unit 40, and other information are provided as a notification unit 42. The present invention is not particularly limited to the case where the operation units 40a to 40c and the display units 41a to 41c are provided for the respective heating ports, the case where the operation unit 40 and the display unit 41 are provided collectively for the heating ports or other cases.

[0017] Below the top plate 4 and in the main body, the first heating unit 11, the second heating unit 12, and the third heating unit 13 are provided, and each heating unit includes a heating coil (not shown).

[0018] In the main body of the induction heating cooking apparatus 100, drive circuits 50 that supply high-frequency power to the respective heating coils of the first heating unit 11, the second heating unit 12, and the third heating unit 13, and a control unit 45 that controls operation of the entire induction heating cooking apparatus including the drive circuits 50 are provided.

[0019] Each heating coil has a substantially circular planar shape, and is configured by winding a conductive wire made of an optional insulation-coated metal (for example, copper, aluminum, or other metals) in a circumferential direction, and an induction heating operation is performed when the high-frequency power is supplied from the drive circuit 50 to each heating coil.

[0020] Fig. 2 is a diagram showing the drive circuit of the induction heating cooking apparatus according to Embodiment 1. The drive circuits 50 are provided for the respective heating units, and the circuit configurations thereof may be the same, or may be changed for the respective heating units. Fig. 2 shows only one drive circuit 50. As shown in Fig. 2, the drive circuit 50 includes a DC power supply circuit 22, an inverter circuit 23, and a resonant capacitor 24a.

[0021] An input current detection unit 25a detects an electric current input from an AC power supply (commercial power supply) 21 to the DC power supply circuit 22, and outputs a voltage signal corresponding to the input current value, to the control unit 45.

[0022] The DC power supply circuit 22 includes a diode bridge 22a, a reactor 22b, and a smoothing capacitor 22c, converts an AC voltage input from the AC power supply 21 to a DC voltage, and outputs the DC voltage to the inverter circuit 23.

[0023] The inverter circuit 23 is a half-bridge type inverter in which IGBTs 23a and 23b as switching elements are connected in series to the output of the DC power supply circuit 22, and diodes 23c and 23d as flywheel diodes are connected in parallel to the IGBTs 23a and 23b, respectively. The inverter circuit 23 converts the DC power output from the DC power supply circuit 22 to high-frequency AC power of about 20 kHz to 50 kHz and supplies the high-frequency AC power to a resonant circuit including a heating coil 11a and the resonant capacitor 24a. The resonant capacitor 24a is connected in series to the heating coil 11a, and the resonant circuit has a resonant frequency corresponding to the inductance of the heating coil 11a, the capacitance of the resonant capacitor 24a, and the like. The inductance of the heating coil 11a changes depending on the characteristics of the heating target 5 (metal load) when the metal load is magnetically coupled, and the resonant frequency of the resonant circuit changes depending on the change in inductance.

[0024] Due to such a configuration, a high-frequency current of about several tens of amperes flows through the heating coil 11a, and the heating coil 11a inductively heats the heating target 5 placed on the top plate 4 directly above the heating coil 11a, by a high-frequency magnetic flux generated by the high-frequency current flowing therethrough. The IGBTs 23a and 23b, which are switching elements, are formed of, for example, silicon-based semiconductors, but may be formed of wide bandgap semiconductors made of silicon carbide, a gallium nitride-based material, or other materials.

[0025] Use of the wide bandgap semiconductors for the switching elements allows for reduction of energization loss in the switching elements. Moreover, even when a switching frequency (drive frequency) is set to a high frequency (high speed), the drive circuit radiates heat satisfactorily, thus it is possible to make a radiator fin for the drive circuit small, so that it is possible to achieve reduction in size and cost of the drive circuit.

[0026] The coil current detection unit 25b is connected between the heating coil 11a and the resonant capacitor 24a. For example, the coil current detection unit 25b detects an electric current flowing through the heating coil 11a, and outputs a voltage signal corresponding to the heating coil current value, to the control unit 45.

[0027] The temperature detection unit 30 is composed of, for example, a thermistor, and detects a temperature on the basis of heat transferred from the heating target 5 to the top plate 4. The temperature detection unit 30 is not limited to the thermistor, and any sensor such as an infrared sensor may be used.

[0028] Fig. 3 is a functional block diagram showing an example of the control unit of the induction heating cooking apparatus according to Embodiment 1. The control unit 45 will be described with reference to Fig. 3.

[0029] The control unit 45 is composed of a microcomputer, a digital signal processor (DSP), or another device that controls operation of the induction heating cooking apparatus 100, and includes a drive control unit 31, a load determination unit 32, a drive frequency setting unit 33, a current change detection unit 34, a period measurement unit 35, and an input/output control unit 36.

[0030] The drive control unit 31 outputs driving signals DS to the IGBTs 23a and 23b of the inverter circuit 23 to cause the IGBTs 23a and 23b to perform switching operation, thereby driving the inverter circuit 23. Then, the drive control unit 31 controls the high-frequency power that is to be supplied to the heating coil 11a, thereby controlling heating of the heating target 5. Each of the drive signals DS is, for example, a signal having a predetermined drive frequency of about 20 to 50 kHz with a predetermined on-duty ratio (for example, 0.5).

[0031] The load determination unit 32 performs a load determination process on the heating target 5, and determines the material of the heating target 5 as a load. The load determination unit 32 determines the material of the heating target 5 (pot), which is a load, by broadly dividing the material into, for example, a magnetic material such as iron and SUS430, a high-resistance non-magnetic material such as SUS304, and a low-resistance non-magnetic material such as aluminum and copper.

[0032] The drive frequency setting unit 33 sets a drive frequency f of the driving signals DS that are to be output to the inverter circuit 23 when supplying power from the inverter circuit 23 to the heating coil 11a. In particular, the drive frequency setting unit 33 has a function of automatically setting the drive frequency f depending on a determination result of the load determination unit 32. Specifically, the drive frequency setting unit 33 has stored, for example, a table for determining the drive frequency f depending on the material of the heating target 5 and the set heating power. When a result of the load determination and the set heating power are input to the drive frequency setting unit 33, the drive frequency setting unit 33 refers to the table to determine a value fd of the drive frequency f. The drive frequency setting unit 33 sets a frequency that is higher than the resonant frequency of the resonant circuit, so that the input current does not become excessively high.

[0033] In this manner, the drive frequency setting unit 33 drives the inverter circuit 23 at the drive frequency f corresponding to the material of the heating target 5 based on the result of the load determination, thereby reducing an increase in the input current. Thus, it is possible to reduce an increase in the temperature of the inverter circuit 23 to enhance the reliability.

[0034] The current change detection unit 34 detects, when the inverter circuit 23 is driven at the drive frequency f = fd set in the drive frequency setting unit 33, an amount of temporal change AI of the input current per predetermined time period. The predetermined time period may be a preset period or may be a period changeable through operation of the operation unit 40.

[0035] The period measurement unit 35 measures a heating time t1 from start of power supply to the heating coil 11a until the amount of temporal change ΔI in the current change detection unit 34 becomes equal to or less than a set value. In addition, the period measurement unit 35 measures an amount of current change I1 of the input current during the heating time t1.

[0036] The heating time t1 corresponds to a "first time" in the present invention.

[0037] The drive control unit 31 decreases the electric power that is to be supplied to the heating coil 11a, depending on the heating time t1 and the amount of current change I1 measured by the period measurement unit 35. The drive control unit 31 releases fixation of the drive frequency f = fd, increases the drive frequency f by an increment amount Δf (f = fd + Δf), and drives the inverter circuit 23. In particular, the drive control unit 31 sets the increment amount Δf so that the increment amount Δf is larger as the heating time t1 is shorter and the amount of current change I1 is smaller.

(Operation)

[0038] Next, an example of operation of the induction heating cooking apparatus 100 according to Embodiment 1 will be described.

[0039] First, an operation in the case where the heating target 5 placed on the heating port of the top plate 4 is inductively heated with heating power that is set with the operation unit 40, will be described.

[0040] When a user places the heating target 5 on the heating port and makes an instruction to start heating (turn on heating power) on the operation unit 40, the load determination unit 32 of the control unit 45 performs the load determination process.

[0041] Fig. 4 is a graph showing a state where the input current with respect to the drive frequency in the drive circuit in Fig. 3 changes due to change of the temperature of the heating target.

[0042] Here, the material of the heating target 5 (pot), which is a load, is broadly divided into a magnetic material such as iron and SUS430, a high-resistance non-magnetic material such as SUS304, and a low-resistance non-magnetic material such as aluminum and copper.

[0043] As shown in Fig. 4, a relationship between the coil current and the input current is different depending on the material of the pot load placed on the top plate 4. The control unit 45 has previously stored therein a load determination table that represents the relationship between the coil current and the input current shown in Fig. 4, in a table form. Since the load determination table is stored in the load determination unit 32, it is possible to configure the load determination unit 32 with an inexpensive configuration.

[0044] In the load determination process, the control unit 45 drives the inverter circuit 23 with specific driving signals for load determination, and detects the input current on the basis of an output signal from the input current detection unit 25a. At the same time, the control unit 45 detects the coil current on the basis of an output signal from the coil current detection unit 25b. The control unit 45 determines the material of the placed heating target (pot) 5 on the basis of the detected coil current, input current and the load determination table, which represents the relationship in Fig. 4. In this manner, the control unit 45 (load determination unit 32) determines the material of the heating target 5 placed above the heating coil 11a, on the basis of the correlation between the input current and the coil current.

[0045] After the load determination process described above is performed, the control unit 45 performs a control operation based on the load determination result.

[0046] If the load determination result is a low-resistance non-magnetic material, heating is impossible with the induction heating cooking apparatus 100 of Embodiment 1, and thus the notification unit 42 is notified that heating is impossible, thereby promoting the user to change the pot. In this case, the high-frequency power is not supplied from the drive circuit 50 to the heating coil 11a.

[0047] Also if the load determination result is no load, the notification unit 42 is notified that heating is impossible, thereby promoting the user to place a pot. In this case as well, similarly, the high-frequency power is not supplied to the heating coil 11a.

[0048] If the load determination result is a magnetic material or a high-resistance non-magnetic material, the materials of these pots are materials that can be heated with the induction heating cooking apparatus 100 of Embodiment 1, and thus the control unit 45 determines a drive frequency corresponding to the determined pot material. The drive frequency is set to a frequency that is higher than the resonant frequency, so that the input current does not become excessively high. It is possible to determine the drive frequency by referring to, for example, a table of the frequency corresponding to the material of the heating target 5 and the set heating power. The control unit 45 fixes the determined drive frequency and drives the inverter circuit 23 to start an induction heating operation.

[0049] Fig. 5 is a graph showing a state where the input current with respect to the drive frequency in the drive circuit in Fig. 3 changes due to change of the temperature of the heating target. In Fig. 5, a thin line indicates characteristics when the temperature of the heating target 5 (pot) is low, and a thick line indicates characteristics when the temperature of the heating target 5 is high.

[0050] The reason why the characteristics change in response to the temperature of the heating target 5 as shown in Fig. 5 is that due to the temperature rise, the electric resistivity of the heating target 5 increases and the magnetic permeability thereof decreases, whereby changing magnetic coupling between the heating coil 11a and the heating target 5.

[0051] The control unit 45 of the induction heating cooking apparatus 100 according to Embodiment 1 determines a frequency higher than the frequency at which the input current shown in Fig. 5 is at its maximum, as a drive frequency, fixes the drive frequency, and controls the inverter circuit 23.

[0052] Fig. 6 is an enlarged graph of a portion indicated by a dotted line in the graph in Fig. 5.

[0053] When the drive frequency that is determined in the above-described load determination process and corresponds to the pot material is fixed and the inverter circuit 23 is controlled, as the temperature of the heating target 5 changes from a low temperature to a high temperature, an input current value (operating point) at this drive frequency changes from point A to point B; and the input current gradually decreases as the temperature of the heating target 5 rises.

[0054] At this time, the control unit 45 obtains an amount of change per time period (amount of temporal change ΔI) of the input current in a state where the drive frequency of the inverter circuit 23 is fixed, and detects a change in the temperature of the heating target 5 on the basis of the amount of temporal change ΔI.

[0055] Thus, it is possible to detect a change in the temperature of the heating target 5 regardless of the material of the heating target 5. In addition, since it is possible to detect a change in the temperature of the heating target 5 on the basis of the change in the input current, it is possible to detect a change in the temperature of the heating target 5 at a high speed as compared to a temperature sensor or another related device.

[0056] The material of the heating target 5 placed above the heating coil 11a is determined, the drive frequency of the inverter circuit 23 is determined depending on the material of the heating target 5, and the inverter circuit 23 is driven at the drive frequency. Thus, it is possible to fix and drive the inverter circuit 23 at the drive frequency corresponding to the material of the heating target 5, and it is possible to reduce an increase in the input current. Therefore, it is possible to reduce an increase in the temperature of the inverter circuit 23, so that it is possible to improve the reliability.

(Water Boiling Mode 1)

[0057] Next, an operation performed when a water boiling mode of performing an operation of boiling water that is put in the heating target 5 is selected as a cooking menu (operating mode) with the operation unit 40 will be described.

[0058] The control unit 45 performs a load determination process similarly as in the above-described operation, determines a drive frequency corresponding to the determined pot material, and drives the inverter circuit 23 with the determined drive frequency being fixed, to perform an induction heating operation. Then, the control unit 45 determines completion of boiling on the basis of the amount of temporal change ΔI of the input current. Here, an elapsed time and a change in each characteristic when water is boiled will be described with reference to Fig. 7.

[0059] Fig. 7 is a graph showing time courses of temperature and input current when the inverter circuit 23 is driven at a predetermined drive frequency in Fig. 3.

[0060] In Fig. 7, an elapsed time and a change in each characteristic when water is put into the heating target 5 and an operation is performed in a water boiling mode are shown, Fig. 7 (a) shows drive frequency, Fig. 7 (b) shows temperature (water temperature), and Fig. 7 (c) shows input current.

[0061] When the drive frequency is fixed and the inverter circuit 23 is controlled as shown in Fig. 7 (a), the temperature (water temperature) of the heating target 5 gradually rises until the water is boiled, and the temperature becomes constant at about 100 degrees C when the water is boiled, as shown in Fig. 7 (b). At this time, as shown in Fig. 7 (c), the input current gradually decreases in response to the rise of the temperature of the heating target 5, and when the water is boiled so that the temperature becomes constant, the input current also becomes constant. That is, if the input current becomes constant, the water is boiled and the water boiling is completed.

[0062] Due to this, the control unit 45 in Embodiment 1 obtains an amount of change per time period (amount of temporal change ΔI) of the input current in a state where the drive frequency of the inverter circuit 23 is fixed, and if the amount of temporal change ΔI becomes equal to or less than a set value, it is determined that the water boiling is completed.

[0063] Information on the set value may be previously set in the control unit 45, or may be inputtable through the operation unit 40 or another related device.

[0064] Then, the control unit 45 sends a notification that the water boiling is completed, by using the notification unit 42. Here, a method of the notification unit 42 is not particularly limited, and, for example, completion of boiling is displayed on the display unit 41, or a speaker (not shown) is used to notify a user with a sound.

[0065] As described above, in a water boiling mode in which an operation of boiling water is set, in a state where the drive frequency of the inverter circuit 23 is fixed, the amount of temporal change ΔI of the input current is obtained, and when the amount of temporal change ΔI becomes equal to or less than the set value, the notification unit 42 is caused to send the notification that the water boiling is completed.

[0066] Thus, it is possible to immediately notify that the water boiling is completed, and it is possible to obtain an easy-to-use induction heating cooking apparatus.

[0067] The control unit 45 does not need a high-accuracy microcomputer when obtaining an amount of temporal change ΔI of the input current, so that it is possible to obtain an induction heating cooking apparatus capable of detecting water boiling by a low-cost method.

(Water Boiling Mode 2)

[0068] Next, another control operation performed when a water boiling mode is selected with the operation unit 40 will be described.

[0069] The control unit 45 performs a load determination process similarly as in the above-described operation, determines a drive frequency corresponding to the determined pot material, and drives the inverter circuit 23 with the determined drive frequency being fixed, to perform an induction heating operation. Then, the control unit 45 determines completion of boiling on the basis of the amount of temporal change ΔI of the input current.

[0070] Moreover, if the amount of temporal change ΔI obtained in the state where the drive frequency of the inverter circuit 23 is fixed becomes equal to or less than the set value, the control unit 45 releases the fixation of the drive frequency. Then, the control unit 45 varies the drive frequency of the inverter circuit 23 depending on the heating time t1 until the amount of temporal change ΔI becomes equal to or less than the set value, and the amount of current change I1 of the input current during the heating time t1, to vary the high-frequency power supplied to the heating coil 11a. The details of such an operation will be described with reference to Figs. 8 to 11.

[0071] Fig. 8 is a diagram showing a relationship between time and drive frequency, temperature, and input current in the water boiling mode 2 of the induction heating cooking apparatus according to Embodiment 1.

[0072] Fig. 8 shows an elapsed time and a change in each characteristic when water is put into the heating target 5 and is boiled.

[0073] Figs. 8 (a) to 8 (c) show characteristics when the initial temperature of the water put into the heating target 5 is high, Fig. 8 (a) shows drive frequency, Fig. 8 (b) shows temperature (water temperature), and Fig. 8 (c) shows input current.

[0074] Figs. 8 (d) to 8 (f) show characteristics when the initial temperature of the water put into the heating target 5 is low, Fig. 8 (d) shows drive frequency, Fig. 8 (e) shows temperature (water temperature), and Fig. 8 (f) shows input current.

[0075] Fig. 9 is an enlarged diagram of the portion indicated by the dotted line in Fig. 5.

[0076] Here, the initial temperature refers to the temperature in a range from start of heating until a predetermined period elapses, and is not limited to the temperature at the time of start of heating.

[0077] A description will be given on the assumption that in Fig. 8, the amount of the water (contents) when the initial temperature is high is substantially equal to that when the initial temperature is low. That is, the heat load of the contents in the heating target 5 at the initial stage of heating is determined on the basis of the temperature and amount of the contents, and the heat load depends on the initial temperature if the amount of the contents is the same.

[0078] Fig. 10 is a flowchart showing an example of operation in the water boiling mode 2 of the induction heating cooking apparatus according to Embodiment 1.

[0079] Fig. 11 is a flowchart showing an example of operation of initial water temperature detection in Fig. 11.

[0080] Hereinafter, a description will be given on the basis of the flowcharts in Figs. 10 and 11 with reference to Figs. 8 and 9.

[0081] First, the user places the heating target 5 on the heating port of the top plate 4 and makes an instruction to start heating (turn on heating power) on the operation unit 40. Accordingly, the load determination unit 32 determines the material of the placed heating target (pot) 5 as a load by using the load determination table that shows the relationship between the input current and the coil current (step ST1). If it is determined that a result of the load determination is no load or a material that it is impossible to heat, the result is notified from the notification unit 42, and control is performed so that the high-frequency power is not supplied from the drive circuit 50 to the heating coil 11a.

[0082] Next, the drive frequency setting unit 33 determines a value fd of the drive frequency f corresponding to the pot material determined on the basis of the load determination result of the load determination unit 32 (step ST2). At this time, the drive frequency f is set to a frequency fd that is higher than the resonant frequency of the resonant circuit, so that the input current does not become excessively high.

[0083] Thereafter, the drive control unit 31 fixes the drive frequency f at fd and drives the inverter circuit 23, thereby starting an induction heating operation (step ST3). Along with the start of the induction heating operation by start of power supply, measurement of the heating time t1 and the amount of current change I1 by the period measurement unit 35 is started.

[0084] After the drive frequency is fixed and heating is started (Figs. 8 (a) and 8 (d)), the temperature (water temperature) of the heating target 5 gradually rises until the water is boiled (Figs. 8 (b) and 8 (e)). In the control with fixation of the drive frequency, as shown in Fig. 9, the input current value (operating point) at this drive frequency changes from point A to point B, and the input current gradually decreases with the rise of the temperature of the heating target 5.

[0085] While the induction heating operation is performed, the current change detection unit 34 calculates the amount of temporal change ΔI at a predetermined sampling interval (step ST4).

[0086] Then, it is determined whether the amount of temporal change ΔI is equal to or less than a set value (Iref) (step ST5). As the temperature of the heating target 5 changes from a low temperature to a high temperature, the amount of temporal change ΔI decreases (Figs. 8 (c) and 8 (f)). When the water is boiled so that the temperature thereof becomes constant, the input current also becomes constant (Figs. 8 (c) and 8 (f)). Thus, at the heating time t1, the control unit 45 determines that the amount of temporal change ΔI of the input current becomes equal to or less than the set value (Iref).

[0087] Then, when the amount of temporal change ΔI becomes equal to or less than the set value, the period measurement unit 35 detects the heating time t1 (step ST6). In addition, the period measurement unit 35 detects the amount of current change I1 of the input current (step ST7) from the start of heating to the heating time t1.

[0088] Thereafter, the drive control unit 31 performs a process of initial water temperature detection, and determines the increment amount Δf of the drive frequency f on the basis of the heating time t1 and the amount of current change I1 (step ST8).

[0089] Since the driving is performed with the drive frequency being fixed during the heating time t1, the heating time t1 and the amount of current change I1 change depending on the initial temperature of the water put into the heating target 5. That is, if the initial temperature (TO) of the water is high (Fig. 8 (b)), the heating time t1 becomes short, and the amount of current change I1 becomes small. On the other hand, if the initial temperature of the water is low (Fig. 8 (e)), the heating time t1 becomes long and the amount of current change I1 becomes large.

[0090] Thus, it is possible to determine the initial temperature of the water (a heat load at the initial stage of heating) on the basis of the heating time t1 and the amount of current change I1.

[0091] The details of the process of initial water temperature detection will be described with reference to Fig. 11.

[0092] The control unit 45 determines whether the heating time t1 is shorter than a predetermined reference time t_ref1 and the amount of current change I1 is smaller than a predetermined reference amount of current change I_ref1 (step ST81).

[0093] If the conditions in step ST81 are satisfied, the control unit 45 determines that the initial temperature of the water is high (high hot start) (step ST82). For example, if the amount of the water is known, it is possible to infer that the initial temperature (TO) of the water is equal to or higher than T_ref1.

[0094] On the other hand, if the conditions in step ST81 are not satisfied, the control unit 45 determines whether the heating time t1 is equal to or less than a predetermined reference time t_ref2 and the amount of current change I1 is equal to or less than a predetermined reference amount of current change I_ref2 (step ST83). Here, the reference time t_ref2 is longer than the reference time t_ref1. The reference amount of current change I_ref2 is larger than the reference amount of current change I_ref1.

[0095] If the conditions in step ST83 are satisfied, the control unit 45 determines that the initial temperature of the water is lower than the above high hot start (low hot start) (step ST84). For example, if the amount of the water is known, it is possible to infer that the initial temperature (TO) of the water is equal to or higher than T_ref2 and less than T_ref1.

[0096] On the other hand, if the conditions in step ST83 are not satisfied, the control unit 45 determines that the initial temperature of the water is lower than the above low hot start (normal heating) (step ST85). For example, if the amount of the water is known, it is possible to infer that the initial temperature (TO) of the water is less than T_ref2.

[0097] Fig. 12 is a diagram showing a relationship between a reference time and a reference amount of current change, and a heat load at the initial stage of heating.

[0098] As shown in Fig. 12, through the process of initial water temperature determination in steps ST81 to ST85, depending on the heating time t1 and the amount of current change I1, the control unit 45 infers that the heat load of the contents in the heating target 5 is lower (the temperature of the water is higher) as the heating time t1 is shorter and the amount of current change I1 is smaller.

[0099] Here, the case where the number of reference times and the number of reference amounts of current change each are two has been described, but three or more reference times and three or more reference amounts of current change may be set and determination may be performed.

[0100] Here, since the heating time t1 and the amount of current change I1 change depending on not only the initial temperature but also the amount of the water, each reference time and each reference amount of current change need to be set depending on the amount of the water in the process of initial water temperature determination in steps ST81 to ST85. Thus, for example, information on each reference time and each reference amount of current change corresponding to the amount of water (the amount of contents) may be previously stored in a table, and information on the amount of water (the amount of contents) may be obtained, whereby determining each reference time and each reference amount of current change. Accordingly, it is possible to more accurately detect the initial temperature (heat load) of the water. The information on the amount of the water may be inputtable through the operation unit 40 or another related device, or the amount of the water may be determined, for example, on the basis of the weight of the heating target 5 with a gravity sensor or another related device. Regarding the amount of the water, it is not necessary to obtain an exact value, and, for example, the amount of the water may be represented in three stages, small, middle, and large.

[0101] Next, the drive control unit 31 of the control unit 45 releases the fixation of the drive frequency and increases the drive frequency of the inverter circuit 23, thereby decreasing the input current to decrease the high-frequency power (the heating power) supplied to the heating coil 11a. That is, at the time of retaining the temperature of the heating target 5, heating power that increases temperature is not necessary, and thus the amount of heat from the heating coil 11a to the heating target 5 is decreased.

[0102] At this time, the drive control unit 31 of the control unit 45 controls the high-frequency power supplied to the heating coil 11a, depending on the inferred initial temperature (heat load). At the drive control unit 31, the drive frequency f of the inverter circuit 23 is changed from fd to fd + Δf, and the decreased high-frequency power is supplied from the inverter circuit 23 to the heating coil 11a (step ST86, Figs. 8 (a) and 8 (d)).

[0103] Here, the increment amount (Δf) of the drive frequency will be described.

[0104] If the heating time t1 is short and the amount of current change I1 is small, that is, in the case of high hot start, as shown in Fig. 8 (a), the drive control unit 31 increases the drive frequency f to a large degree and drives the inverter circuit 23 with driving signals DS having a drive frequency f = fd + Δf1.

[0105] On the other hand, if the heating time t1 is long and the amount of current change I1 is large, that is, in the case of low hot start, as shown in Fig. 8 (d), the drive control unit 31 increases the drive frequency f to a small degree and drives the inverter circuit 23 with driving signals DS having a drive frequency f = fd + Δf2.

[0106] If the heating time t1 is further long and the amount of current change I1 is further large, that is, in the case of normal heating, the drive control unit 31 increases the drive frequency f by an amount less than Δf2 and drives the inverter circuit 23.

[0107] The information on the increase amounts Δf1 and Δf2 of the drive frequency may be previously set in the control unit 45, or may be inputtable through the operation unit 40 or another related device.

[0108] As shown in Fig. 9, the increase amounts Δf1 and Δf2 are set so that, even when the drive frequency f is increased to decrease the heating power, the water temperature almost does not decrease and is maintained at a constant temperature, and the operating point changes from point B to point C1 (or point C2). Then, even when the drive frequency f is increased to decrease the heating power, the water temperature almost does not decrease and a temperature-retaining state is maintained.

[0109] As described above, regarding the high-frequency power (the heating power) applied after the heating time t1, if the heat load at the initial stage of heating is low (the initial temperature is high), the heating power is set to be small, and if the heat load at the initial stage of heating is high (the initial temperature is low), the heating power is set to be high.

[0110] Thus, it is possible to obtain an energy-saving and easy-to-use induction heating cooking apparatus that is capable of performing a temperature-retaining operation while reducing wasted power supply.

[0111] In particular, in the case of a water boiling (boiling of water) mode, since the water temperature does not become equal to or higher than 100 degrees C even when the heating power is increased more than necessity, even when the drive frequency f is increased to decrease the heating power, it is possible to maintain a boiling state.

[0112] As described above, if the amount of temporal change ΔI of the input current becomes equal to or less than the set value, driving of the inverter circuit 23 is controlled to decrease the high-frequency power supplied to the heating coil 11a, and thus it is possible to reduce input power to save energy.

[0113] That is, in the case where the drive frequency f is merely increased to a predetermined value when the amount of temporal change ΔI reaches a set value as in the related art, there is a problem in that it is impossible to maintain an optimum temperature-retaining state depending on the heat load (temperature and amount) of the contents. For example, if the initial temperature of the contents in the heating target 5 is low, the amount of heat is not sufficient, the temperature gradually decreases, and thus reheating is required. On the other hand, if the initial temperature of the contents in the heating target 5 is high, excessive electric power is consumed.

[0114] In Embodiment 1, a focus is on the fact that if the heat load (temperature and amount) of the contents in the heating target 5 is different, even when the drive frequency f is the same (the heating power is the same), the heating time t1 and the amount of current change I1 are different; and the drive control unit 31 determines the increment amount Δf depending on the heating time t1 and the amount of current change I1 and changes the drive frequency f in retaining temperature. Thus, it is possible to supply necessary and sufficient electric power to the heating coil 11a depending on the heat load of the heating target 5, and hence it is possible to efficiently save energy.

[0115] Fig. 10 will be referred to again. After step ST8, the drive control unit 31 notifies the user of completion of the water boiling with the notification unit 42 after the amount of temporal change ΔI becomes equal to or less than the set value and a predetermined additional time Δt has elapsed (t2 = t1 + Δt) (step ST9).

[0116] If the heating time t1 is shorter than the reference time t_ref1 (time reference value) and the amount of current change I1 is smaller than the reference amount of current change I_ref1 (current reference value) (in the case of high hot start), when the amount of temporal change ΔI becomes equal to or less than the set value, the control unit 45 may notify completion of the water boiling with the notification unit 42.

(Water Boiling Mode 3)

[0117] Next, another control operation performed when a water boiling mode is selected with the operation unit 40 will be described.

[0118] The control unit 45 performs a load determination process similarly as in the above-described operation, determines a drive frequency corresponding to the determined pot material, and drives the inverter circuit 23 with the determined drive frequency being fixed, to perform an induction heating operation. Then, the control unit 45 determines completion of boiling on the basis of the amount of temporal change ΔI of the input current.

[0119] Moreover, after the amount of temporal change ΔI obtained in the state where the drive frequency of the inverter circuit 23 is fixed becomes equal to or less than the set value, the control unit 45 performs the same control continuously for a predetermined time period. After the predetermined time period has elapsed, the control unit 45 releases the fixation of the drive frequency and varies the drive frequency of the inverter circuit 23 to vary the high-frequency power supplied to the heating coil 11a. The details of such an operation will be described with reference to Figs. 9 to 13.

[0120] Fig. 13 is a diagram showing a relationship between time and drive frequency, temperature, and input current in the water boiling mode 3 of the induction heating cooking apparatus according to Embodiment 1.

[0121] Fig. 13 shows an elapsed time and a change in each characteristic when water is put into the heating target 5 and is boiled.

[0122] Figs. 13 (a) to 13 (c) show characteristics when the initial temperature of the water put into the heating target 5 is high, Fig. 13 (a) shows drive frequency, Fig. 13 (b) shows temperature (water temperature), and Fig. 13 (c) shows input current.

[0123] Figs. 13 (d) to 13 (f) show characteristics when the initial temperature of the water put into the heating target 5 is low, Fig. 13 (d) shows drive frequency, Fig. 13 (e) shows temperature (water temperature), and Fig. 13 (f) shows input current.

[0124] A description will be given on the assumption that in Fig. 13, the amount of the water (contents) when the initial temperature is high is substantially equal to that when the initial temperature is low. That is, the heat load of the contents in the heating target 5 at the initial stage of heating is determined on the basis of the temperature and amount of the contents, and the heat load depends on the initial temperature if the amount of the contents is the same.

[0125] Similarly as in the operation in the above-described water boiling mode 1, after the drive frequency is fixed and heating is started (Figs. 13 (a) and 13 (d)), the temperature (water temperature) of the heating target 5 gradually rises until the water is boiled (Figs. 13 (b) and 13 (e)). In the control with fixation of the drive frequency, as shown in Fig. 9, the input current value (operating point) at this drive frequency changes from point A to point B, and the input current gradually decreases with the rise of the temperature of the heating target 5.

[0126] The reason why the input current gradually decreases with the rise of the temperature of the heating target 5 as described above is that due to the temperature rise, the electric resistivity and the magnetic permeability of the heating target 5 change, whereby changing magnetic coupling between the heating coil 11a and the heating target 5. That is, a state where the input current becomes constant means that the temperature of the heating target 5 (in particular, a portion close to the heating coil 11a) becomes constant.

[0127] At the heating time t1 at which the input current becomes constant in Figs. 13 (c) and 13 (f), the temperature of the heating target 5 reaches about 100 degrees C, but the water put into the heating target 5 has unevenness of temperature, and may not be boiled as a whole of the water.

[0128] In the water boiling mode 3, by driving the inverter circuit 23 with the drive frequency being fixed until a heating time t2 obtained by adding the additional time Δt to the heating time t1, it is possible to assuredly boil the entire water in a short time. At the heating time t2, the control unit 45 determines that the water boiling is completed.

[0129] The additional time Δt corresponds to a "second time" in the present invention.

[0130] Here, the heating time t2 and the additional time Δt will be described.

[0131] The additional time Δt is the difference between the heating time t2 and the heating time t1 and is represented as $\Delta t = t2 - t1$. In the water boiling mode 3, the control unit 45 measures the heating time t1 until the input current becomes constant after heating is started, and changes the additional time Δt depending on the length of the heating time t1 and the magnitude of the amount of current change I1 until the heating time t1.

[0132] At the initial stage of heating in the water boiling mode 3, since driving is performed with the drive frequency being fixed, the heating time t1 and the amount of current change I1 change depending on the heat load (initial temperature and amount) of the water put into the heating target 5. That is, when the initial temperature of the water is high (Fig. 13 (b)), the heating time t1 becomes short, and the amount of current change I1 becomes small. In addition, when the initial temperature of the water is low (Fig. 13 (e)), the heating time t1 becomes long, and the amount of current change I1 becomes large. When the heating time t1 is short and the amount of current change I1 is large, as shown in Fig. 13 (c), the control unit 45 sets the additional time Δt to be short. On the other hand, when the heating time t1 is long and I1 is large, as shown in Fig. 13 (f), the control unit 45 sets the additional time Δt to be long.

[0133] When the initial temperature of the water is low, as compared to the case where the initial temperature of the water is high, unevenness of the temperature of the water in the heating target 5 often becomes great, and a longer time is required to assuredly boil the entire water.

[0134] Therefore, in the water boiling mode 3, the initial temperature of the water in the heating target 5 is detected by measuring the heating time t1 and the amount of current change I1, and the additional time Δt is set depending on the initial temperature of the water. Thus, it is possible to obtain an energy-saving and easy-to-use induction heating cooking apparatus that is able to reduce wasted power supply required for boiling and is able to assuredly boil the water in a short time.

[0135] Next, after the additional time Δt has elapsed from the heating time t1, the control unit 45 releases the fixation of the drive frequency and increases the drive frequency of the inverter circuit 23 to decrease the input current, thereby decreasing the high-frequency power supplied to the heating coil 11a (the heating power). The control to increase the drive frequency is the same as in the above water boiling mode 2. Even when the drive frequency is increased to decrease the heating power, the water temperature almost does not decrease, and thus the operating point moves (changes) from point B to point C1 (point C2) as shown in Fig. 9.

[0136] In addition, at the heating time t2, the control unit 45 increases the drive frequency of the inverter circuit 23 and also notifies the user of completion of the water boiling with the notification unit 42. The notification to the user may be performed before or after the drive frequency is increased.

[0137] In the above description, the method for controlling the high-frequency power (heating power) by changing the drive frequency has been described, but a method for controlling the heating power by changing the on-duty ratio (on-off ratio) of the switching elements of the inverter circuit 23 may be used.

[0138] By utilizing the temperature information detected by the temperature detection unit 30, it is possible to obtain an induction heating cooking apparatus having higher reliability.

(Configuration Example of Another Drive Circuit)

[0139] Next, an example of using another drive circuit will be described.

[0140] Fig. 14 is a diagram showing another drive circuit of the induction heating cooking apparatus according to Embodiment 1.

[0141] The drive circuit 50 shown in Fig. 14 is obtained by adding a resonant capacitor 24b to the configuration shown in Fig. 2. The other configuration is the same as in Fig. 2, and the same portions are designated by the same reference signs.

[0142] As described above, since the heating coil 11a and the resonant capacitors form the resonant circuit, the capacitance of the resonant capacitors is determined by the maximum heating power (maximum input power) required for the induction heating cooking apparatus. In the drive circuit 50 shown in Fig. 10, by connecting the resonant capacitors 24a and 24b in parallel, it is possible to cause the capacitance of each of the resonant capacitors 24a and 24b to be half, and it is possible to obtain a low-cost control circuit even when the two resonant capacitors are used.

[0143] By disposing the coil current detection unit 25b between the resonant capacitor 24a and the resonant capacitor 24b connected in parallel, the current flowing through the coil current detection unit 25b becomes half of the current flowing through the heating coil 11a, and thus it is possible to use the coil current detection unit 25b that is small in size and has a low capacitance, so that it is possible to obtain a small-size and low cost control circuit and it is possible to obtain a low-cost induction heating cooking apparatus.

[0144] In Embodiment 1, the example has been described in which the amount of temporal change of the input current detected by the input current detection unit 25a is detected. Instead of the input current, the amount of temporal change ΔI of the coil current detected by the coil current detection unit 25b may be detected, or the amounts of temporal change ΔI of both the input current and the coil current may detected.

[0145] In Embodiment 1, the half-bridge type inverter circuit 23 has been described, but a configuration using a full-bridge type or single-switch voltage resonant type inverter or another related inverter may be adopted.

[0146] The method in which the relationship between the coil current and the primary current is used in the load determination process at the load determination unit 32 has been described, but a method of performing the load determination process by detecting a resonant voltage at both ends of the resonant capacitor may be adopted, and the method for load determination is not particularly limited.

[0147] The case has been described in which the initial temperature of the water put into the heating target is determined according to the above embodiment, but, for example, a threshold may be set for each determination result of the load determination unit 32, and the initial temperature of the water put into the heating target may be inferred depending on the determination result of the load determination unit 32.

Embodiment 2

[0148] In Embodiment 2, the drive circuit 50 according to Embodiment 1 described above will be described in detail.

[0149] Fig. 15 is a diagram showing a part of a drive circuit of an induction heating cooking apparatus according to Embodiment 2. Fig. 15 illustrates only the configuration of a part of the drive circuit 50 according to Embodiment 1 described above.

[0150] As shown in Fig. 15, the inverter circuit 23 includes an arm including two switching elements (IGBTs 23a and 23b) connected in series with each other between positive and negative buses, and the diodes 23c and 23d each connected in inverse parallel to corresponding one of the switching elements.

[0151] The IGBT 23a and the IGBT 23b are driven to be turned on and off with driving signals output from the control unit 45.

[0152] The control unit 45 outputs the driving signals for alternately turning on and off the IGBT 23a and the IGBT 23b so that the IGBT 23b is deactivated while the IGBT 23a is activated and the IGBT 23b is activated while the IGBT 23a is deactivated.

[0153] In this manner, the IGBT 23a and the IGBT 23b form a half-bridge inverter that drives the heating coil 11a.

[0154] The IGBT 23a and the IGBT 23b form a "half-bridge inverter circuit" according to the present invention.

[0155] The control unit 45 inputs the driving signals having a high frequency to the IGBT 23a and the IGBT 23b depending on the applied electric power (heating power) to adjust a heating output. The driving signals, which are output to the IGBT 23a and the IGBT 23b, are varied in a range of the drive frequency that is higher than the resonant frequency of a load circuit that includes the heating coil 11a and the resonant capacitor 24a, to control an electric current flowing through the load circuit to flow in a lagging phase as compared to a voltage applied to the load circuit.

[0156] Next, the operation of controlling the applied electric power (heating power) with the drive frequency and the on-duty ratio of the inverter circuit 23 will be described.

[0157] FIG. 16 is a diagram showing an example of the drive signals of a half bridge circuit according to Embodiment 2. Fig. 16 (a) is an example of the driving signals of the respective switches in a high heating power state. Fig. 16 (b) is an example of the driving signals of the respective switches in a low heating power state.

[0158] The control unit 45 outputs the driving signals having a high frequency that is higher than the resonant frequency of the load circuit, to the IGBT 23a and the IGBT 23b of the inverter circuit 23.

[0159] By varying the frequency of each of the driving signals, the output of the inverter circuit 23 increases or decreases.

[0160] For example, as shown in Fig. 16 (a), when the drive frequency is decreased, the frequency of the high frequency current supplied to the heating coil 11a approaches the resonant frequency of the load circuit, so that the electric power applied to the heating coil 11a increases.

[0161] On the other hand, as shown in Fig. 16 (b), when the drive frequency is increased, the frequency of the high frequency current supplied to the heating coil 11a deviates from the resonant frequency of the load circuit, so that the electric power applied to the heating coil 11a decreases.

[0162] Furthermore, the control unit 45 varies the drive frequency to control the applied electric power as described above, and may also vary the on-duty ratio of the IGBT 23a and the IGBT 23b of the inverter circuit 23 to control a period for which the output voltage of the inverter circuit 23 is applied, to control the electric power applied to the heating coil 11a.

[0163] In the case of increasing the heating power, a ratio (on-duty ratio) of an activation time of the IGBT 23a (deactivation time of the IGBT 23b) in one period of the drive signals is increased to increase a voltage applying time width in one period.

[0164] On the other hand, in the case of decreasing the heating power, the ratio (on-duty ratio) of the activation time of the IGBT 23a (deactivation time of the IGBT 23b) in one period of the drive signals is decreased to decrease the voltage applying time width in one period.

[0165] In the example of Fig. 16 (a), the case where ratios of an activation time T11a of the IGBT 23a (deactivation time of the IGBT 23b) and a deactivation time T11b of the IGBT 23a (activation time of the IGBT 23b) in one period T11 of the drive signals are the same (on-duty ratio of 50%) is illustrated.

[0166] On the other hand, in the example of Fig. 16 (b), the case where ratios of an activation time T12a of the IGBT 23a (deactivation time of the IGBT 23b) and a deactivation time T12b of the IGBT 23a (activation time of the IGBT 23b) in one period T12 of the driving signals are the same (on-duty ratio of 50%) is illustrated.

[0167] The control unit 45 sets the on-duty ratio of the IGBT 23a and the IGBT 23b of the inverter circuit 23 to the fixed state in the state where the drive frequency of the inverter circuit 23 is fixed in obtaining the amount of temporal change ΔI per predetermined time period of the input current (or the coil current) as described above in Embodiment 1.

[0168] In this manner, it is possible to obtain the amount of temporal change ΔI per predetermined time period of the input current (or the coil current) in a state where the electric power applied to the heating coil 11a is fixed.

Embodiment 3

[0169] In Embodiment 3, the inverter circuit 23 using a full-bridge circuit will be described.

[0170] Fig. 17 is a diagram showing a part of a drive circuit of an induction heating cooking apparatus according to Embodiment 3. In Fig. 17, only the difference from the drive circuit 50 in Embodiment 1 described above is illustrated.

[0171] In Embodiment 3, two heating coils are provided to one heating port. For example, the two heating coils have different diameters and are arranged concentrically. Hereinafter, the heating coil having a smaller diameter is referred to as inner coil 11b, and the heating coil having a larger diameter is referred to as outer coil 11c.

[0172] The number and the arrangement of the heating coils are not limited thereto. For example, a configuration in which a plurality of heating coils are arranged around a heating coil arranged at the center of the heating port may be adopted.

[0173] The inverter circuit 23 includes three arms each including two switching elements (IGBTs) connected in series with each other between positive and negative buses, and diodes each connected in inverse parallel to corresponding one of the switching elements. Hereinafter, of the three arms, one arm is referred to as a common arm, and each of the other two arms are referred to as an inner coil arm and an outer coil arm.

[0174] The common arm is an arm connected to the inner coil 11b and the outer coil 11c and includes an IGBT 232a, an IGBT 232b, a diode 232c, and a diode 232d.

[0175] The inner coil arm is an arm connected to the inner coil 11b and includes an IGBT 231a, an IGBT 231b, a diode 231c, and a diode 231d.

[0176] The outer coil arm is an arm connected to the outer coil 11c and includes an IGBT 233a, an IGBT 233b, a diode 233c, and a diode 233d.

[0177] The IGBT 232a and the IGBT 232b of the common arm, the IGBT 231a and the IGBT 231b of the inner coil arm, and the IGBT 233a and the IGBT 233b of the outer coil arm are driven to be turned on and off with driving signals output from the control unit 45.

[0178] The control unit 45 outputs driving signals for alternately turning on and off the IGBT 232a and the IGBT 232b of the common arm so that the IGBT 232b is deactivated while the IGBT 232a is activated and the IGBT 232b is activated while the IGBT 232a is deactivated.

[0179] Similarly, the control unit 45 outputs driving signals for alternately turning on and off the IGBT 231a and the IGBT 231b of the inner coil arm and the IGBT 233a and the IGBT 233b of the outer coil arm.

[0180] In this manner, the common arm and the inner coil arm form a full-bridge inverter for driving the inner coil 11b. In addition, the common arm and the outer coil arm form a full-bridge inverter for driving the outer coil 11c.

[0181] The common arm and the inner coil arm form a "full-bridge inverter circuit" according to the present invention. In addition, the common arm and the outer coil arm form a "full-bridge inverter circuit" according to the present invention.

[0182] A load circuit that includes the inner coil 11b and a resonant capacitor 24c is connected between an output point (a connection point between the IGBT 232a and the IGBT 232b) of the common arm and an output point (a connection point between the IGBT 231a and the IGBT 231b) of the inner coil arm.

[0183] A load circuit that includes the outer coil 11c and a resonant capacitor 24d is connected between the output point of the common arm and an output point (a connection point between the IGBT 233a and the IGBT 233b) of the outer coil arm.

[0184] The inner coil 11b is a heating coil that is wound in a substantially circular shape and has a small outer shape, and the outer coil 11c is disposed at the outer periphery of the inner coil 11b.

[0185] The coil current flowing through the inner coil 11b is detected by a coil current detection unit 25c. The coil current detection unit 25c detects, for example, a peak of the electric current flowing through the inner coil 11b and outputs a voltage signal corresponding to the peak value of the heating coil current, to the control unit 45.

[0186] The coil current flowing through the outer coil 11c is detected by a coil current detection unit 25d. The coil current detection unit 25d detects, for example, a peak of the electric current flowing through the outer coil 11c and outputs a voltage signal corresponding to the peak value of the heating coil current, to the control unit 45.

[0187] The control unit 45 inputs the driving signals having a high frequency to the switching elements (IGBTs) of each arm depending on the applied electric power (heating power) to adjust the heating output.

[0188] The drive signals that are output to the switching elements of the common arm and the inner coil arm are varied in a range of the drive frequency that is higher than a resonant frequency of the load circuit that includes the inner coil 11b and the resonant capacitor 24c, to control an electric current flowing through the load circuit to flow in a lagging phase as compared to a voltage applied to the load circuit.

[0189] Further, the drive signals that are output to the switching elements of the common arm and the outer coil arm are varied in a range of the drive frequency that is higher than a resonant frequency of the load circuit that includes the outer coil 11c and the resonant capacitor 24d, to control an electric current flowing through the load circuit to flow in a lagging phase as compared to a voltage applied to the load circuit.

[0190] Next, an operation of controlling the applied electric power (heating power) with a phase difference between the arms of the inverter circuit 23 will be described.

[0191] Fig. 18 is a diagram showing an example of the driving signals of the full-bridge circuit according to Embodiment 3.

[0192] Fig. 18 (a) is an example of the driving signals of the respective switches and energization timings of the respective heating coils in the high heating power state.

[0193] Fig. 18 (b) is an example of the driving signals of the respective switches and energization timings of the respective heating coils in the low heating power state.

[0194] The energization timings shown in Figs. 18 (a) and 18 (b) relate to a potential difference of the output point (the connection point between the IGBT and the IGBT) of each arm, and a state where the output point of the common arm is lower than the output point of the inner coil arm and the output point of the outer coil arm is indicated by "ON". In addition, a state where the output point of the common arm is higher than the output point of the inner coil arm and the output point of the outer coil arm and a state of the same potential are indicated by "OFF".

[0195] As shown in FIG. 18, the control unit 45 outputs driving signals having a high frequency that is higher than the resonant frequency of the load circuit, to the IGBT 232a and the IGBT 232b of the common arm.

[0196] In addition, the control unit 45 outputs driving signals that advance in phase relative to the driving signals of the common arm, to the IGBT 231a and the IGBT 231b of the inner coil arm and the IGBT 233a and IGBT 233b of the outer coil arm. The frequencies of the drive signals of the respective arms are the same, and the on-duty ratios thereof are also the same.

[0197] To the output point (the connection point between the IGBT and the IGBT) of each arm, a positive bus potential and a negative bus potential that is an output of the DC power supply circuit is output alternately at the high frequency depending on the activation/deactivation state of the IGBTs. Thus, the potential difference between the output point of the common arm and the output point of the inner coil arm is applied to the inner coil 11b. In addition, the potential difference between the output point of the common arm and the output point of the outer coil arm is applied to the outer coil 11c.

[0198] Therefore, by increasing or decreasing the phase difference between the drive signals to the common arm and the drive signals to the inner coil arm and the outer coil arm, it is possible to adjust high frequency voltages to be applied to the inner coil 11b and the outer coil 11c, and control high frequency output currents and the input currents that flow through the inner coil 11b and the outer coil 11c.

[0199] In the case of increasing the heating power, a phase α between the arms is increased to increase the voltage applying time width in one period. The upper limit of the phase α between the arms is in the case of a reverse phase (phase difference of 180 degrees), and an output voltage waveform at this time is a substantially rectangular wave.

[0200] In the example of Fig. 18 (a), the case where the phase α between the arms is 180 degrees is illustrated. In addition, the case where the on-duty ratio of the drive signals of each arm is 50%, that is, the case where ratios of an activation time T13a and a deactivation time T13b in one period T13 are the same is illustrated.

[0201] In this case, an energization activation time width T14a and an energization deactivation time width T14b of the inner coil 11b and the outer coil 11c in one period T14 of the drive signals have the same ratio.

[0202] In the case of decreasing the heating power, the phase α between the arms is decreased as compared to the high heating power state to decrease the voltage applying time width in one period. The lower limit of the phase α between the arms is set to such a level as to prevent an overcurrent from flowing through and destroying the switching elements in relation to, for example, the phase of the electric current flowing through the load circuit when the switching elements are turned on.

[0203] In the example of Fig. 18 (b), the case where the phase α between the arms is decreased as compared to FIG. 18 (a) is illustrated. The frequency and the on-duty ratio of the drive signals of each arm are the same as in FIG. 18 (a).

[0204] In this case, the energization activation time width T14a of the inner coil 11b and the outer coil 11c in one period T14 of the drive signals is a time period corresponding to the phase α between the arms.

[0205] In this manner, it is possible to control the electric power applied to the inner coil 11b and the outer coil 11c (heating power), on the basis of the phase difference between the arms.

[0206] In the above description, the case where both the inner coil 11b and the outer coil 11c perform the heating operation has been described, but the driving of the inner coil arm or the outer coil arm may be stopped so that only one of the inner coil 11b and the outer coil 11c may perform the heating operation.

[0207] The control unit 45 sets each of the phase α between the arms and the on-duty ratio of the switching elements of each arm to a fixed state in the state where the drive frequency of the inverter circuit 23 is fixed in obtaining the amount of temporal change ΔI of the input current (or the coil current) per predetermined time period as described above in Embodiment 1. The other operations are similar to those of Embodiment 1 described above.

[0208] Thus, it is possible to obtain the amount of temporal change ΔI of the input current (or the coil current) per predetermined time period in a state where the electric power applied to the inner coil 11b and the outer coil 11c is fixed.

[0209] In Embodiment 3, the coil current flowing through the inner coil 11b and the coil current flowing through the outer coil 11c are detected by the coil current detection unit 25c and the coil current detection unit 25d, respectively.

[0210] Therefore, in the case where both the inner coil 11b and the outer coil 11c perform the heating operation, even if one of the coil current detection unit 25c and the coil current detection unit 25d cannot detect the coil current value due to a fault or another related factor, it is possible to detect the amount of temporal change ΔI of the coil current per predetermined time period, on the basis of a value detected by the other of the coil current detection unit 25c and the coil current detection unit 25d.

[0211] Moreover, control unit 45 may obtain the amount of temporal change ΔI, per predetermined time period, of the coil current detected by the coil current detection unit 25c and the amount of temporal change ΔI, per predetermined time period, of the coil current detected by the coil current detection unit 25d and may use the larger one of the amounts of temporal change ΔI to perform each determination operation described above in Embodiment 1. Furthermore, an average value of each amount of temporal change ΔI may be used to perform each determination operation described above in Embodiment 1.

[0212] By performing such control, it is possible to more accurately obtain the amount of temporal change ΔI of the coil current per predetermined time period even in the case where one of the coil current detection unit 25c and the coil current detection unit 25d has low detection accuracy.

[0213] In Embodiments 1 to 3 described above, the IH cooking heater has been described as an example of the induction heating cooking apparatus according to the present invention, but the present invention is not limited thereto. The present invention is applicable to any induction heating cooking apparatus employing an induction heating method, such as a rice cooker that performs cooking by induction heating.

Reference Signs List

[0214] 1 first heating port, 2 second heating port, 3 third heating port, 4 top plate, 5 heating target, 11 first heating unit, 11a heating coil, 11b inner coil, 11c outer coil, 12 second heating unit, 13 third heating unit, 21 AC power supply, 22 DC power supply circuit, 22a diode bridge, 22b reactor, 22c smoothing capacitor, 23 inverter circuit, 23a, 23b IGBT, 23c, 23d diode, 24a to 24d resonant capacitor, 25a input current detection unit, 25b to 25d coil current detection unit, 30 temperature detection unit, 31 drive control unit, 32 load determination unit, 33 drive frequency setting unit, 34 current change detection unit, 35 period measurement unit, 36 input/output control unit, 40a to 40c operation unit, 41a to 41c display unit, 42 notification unit, 45 control unit, 50 drive circuit, 100 induction heating cooking apparatus, 231a, 231b IGBT, 232a, 232b IGBT, 233a, 233b IGBT, 231c, 231d diode, 232c, 232d diode, 233c, 233d diode

Claims

1. An induction heating cooking apparatus (100) comprising:

a heating coil (11a) configured to inductively heat a heating target (5);
a drive circuit (50) configured to supply high-frequency power to the heating coil (11a); and
a control unit (45) configured to control driving of the drive circuit (50) to control the high-frequency power supplied to the heating coil (11a),
the control unit (45) obtaining an amount of temporal change (ΔI) of at least one of an input current to the drive circuit (50) and a coil current flowing through the heating coil (11a), in a state where a drive frequency of the drive circuit (50) is fixed,
the control unit (45) measuring a first time (t1) from start of power supply to the heating coil (11a) until the amount of temporal change (ΔI) becomes equal to or less than a set value,
the control unit (45) controlling the high-frequency power supplied to the heating coil (11a) depending on the first time (t1) and an amount of current change (I1) of at least one of the input current and the coil current during the first time (t1).

2. The induction heating cooking apparatus (100) of claim 1, wherein the control unit (45) decreases the high-frequency power supplied to the heating coil (11a), as the first time (t1) is shorter and the amount of current change (I1) is smaller.

3. The induction heating cooking apparatus (100) of claim 1 or 2, wherein

the control unit (45) infers that a heat load of a content of the heating target (5) at an initial stage of heating is smaller as the first time (t1) is shorter and the amount of current change (I1) is smaller, and
the control unit (45) controls the high-frequency power supplied to the heating coil (11a) depending on the inferred heat load.

4. The induction heating cooking apparatus (100) of any one of claims 1 to 3, wherein
the control unit (45) decreases the high-frequency power supplied to the heating coil (11a), when a second time (Δt) elapses after the amount of temporal change (ΔI) obtained in the state where the drive frequency of the drive circuit (50) is fixed becomes equal to or less than the set value, and
the control unit (45) determines the second time (Δt) depending on the first time (t1) and the amount of current change (I1).

5. The induction heating cooking apparatus (100) of claim 4, wherein the control unit (45) decreases the second time (Δt) as the first time (t1) is shorter and the amount of current change (I1) is smaller.

6. The induction heating cooking apparatus (100) of any one of claims 1 to 5, wherein
the control unit (45) increases the drive frequency of the drive circuit (50) to decrease the high-frequency power supplied to the heating coil (11a), after the amount of temporal change (ΔI) obtained in the state where the drive frequency of the drive circuit (50) is fixed becomes equal to or less than the set value, and
the control unit (45) determines an increment amount of the drive frequency depending on the first time (t1) and the amount of current change (I1).

7. The induction heating cooking apparatus (100) of claim 6, wherein the control unit (45) decreases the increment amount of the drive frequency as the first time (t1) is shorter and the amount of current change (I1) is smaller.

8. The induction heating cooking apparatus (100) of any one of claims 1 to 7, wherein the control unit (45) varies the drive frequency of the drive circuit (50) or an on-duty ratio of a switching element of the drive circuit (50) to decrease the high-frequency power supplied to the heating coil (11a).

9. The induction heating cooking apparatus (100) of any one of claims 1 to 8, further comprising:

an operation unit (40) configured to be operated for selecting an operating mode; and
a notification unit (42), wherein
the control unit (45) drives the drive circuit (50) if a water boiling mode of setting a water boiling operation is selected as the operating mode, and after the amount of temporal change (ΔI) becomes equal to or less than the set value, the control unit (45) causes the notification unit (42) to send a notification that water boiling is completed.

10. The induction heating cooking apparatus (100) of claim 9, wherein if the first time (t1) is shorter than a time reference value and the amount of current change (I1) is smaller than a current reference value, when the amount of temporal change (ΔI) becomes equal to or less than the set value, the control unit (45) causes the notification unit (42) to send a notification that water boiling is completed.

11. The induction heating cooking apparatus (100) of any one of claims 1 to 10, further comprising a load determination unit (32) configured to perform a load determination process on the heating target (5), wherein the control unit (45) sets a drive frequency for driving the drive circuit (50) depending on a determination result of the load determination unit (32).

12. The induction heating cooking apparatus (100) of any one of claims 1 to 11, wherein the control unit (45) sets an on-duty ratio of a switching element of the drive circuit (50) to a fixed state in the state where the drive frequency of the drive circuit (50) is fixed.

13. The induction heating cooking apparatus (100) of any one of claims 1 to 11, wherein
the drive circuit (50) includes a full-bridge inverter circuit including at least two arms each including two switching elements connected in series, and
the control unit (45) sets a drive phase difference of the switching elements between the two arms and an on-duty ratio of the switching elements to a fixed state, in a state where a drive frequency of the switching elements of the full bridge inverter circuit is fixed.

14. The induction heating cooking apparatus (100) of any one of claims 1 to 11, wherein
the drive circuit (50) includes a half-bridge inverter circuit including an arm including two switching elements connected in series, and
the control unit (45) sets an on-duty ratio of the switching elements to a fixed state, in a state where a drive frequency of the switching elements of the half-bridge inverter circuit is fixed.

Patentansprüche

1. Induktionsheizkochvorrichtung (100), umfassend:

eine Heizspule (11a), die zum induktiven Heizen eines Heizziels (5) ausgelegt ist;

einen Betriebsschaltkreis (50), der zum Liefern einer Hochfrequenzleistung an die Heizspule (11a) ausgelegt ist; und

eine Steuereinheit (45), die zum Steuern eines Betriebs des Betriebsschaltkreises (50) ausgelegt ist, um die Hochfrequenzleistung zu steuern, die an die Heizspule (11a) geliefert wird,
die Steuereinheit (45) erhaltend einen Umfang einer zeitlichen Änderung (ΔI) von wenigstens einem aus einem Eingangsstrom zu dem Betriebsschaltkreis (50) und einem Spulenstrom, der durch die Heizspule (11a) fließt, in einem Zustand, in dem eine Betriebsfrequenz des Betriebsschaltkreises (50) fest ist,
die Steuereinheit (45) messend eine erste Zeit (t1) vom Start einer Leistungsversorgung an die Heizspule (11a) bis der Umfang einer zeitlichen Änderung (ΔI) gleich oder kleiner als ein eingestellter Wert wird,
die Steuereinheit (45) steuernd die Hochfrequenzleistung, die der Heizspule (11a) geliefert wird, abhängig von der ersten Zeit (t1) und einem Umfang einer Stromänderung (I1) von wenigstens einem aus dem Eingangsstrom und dem Spulenstrom während der ersten Zeit (t1).

2. Induktionsheizkochvorrichtung (100) gemäß Anspruch 1, bei welcher die Steuereinheit (45) die Hochfrequenzleistung verringert, welche der Heizspule (11a) geliefert wird, während die erste Zeit (t1) kürzer ist und der Umfang einer Stromänderung (I1) kleiner ist.

3. Induktionsheizkochvorrichtung (100) gemäß Anspruch 1 oder 2, bei welcher
die Steuereinheit (45) ableitet, dass eine Wärmelast eines Inhalts des Heizziels (5) in einem anfänglichen Heizzustand kleiner ist, während die erste Zeit (t1) kürzer ist und der Umfang einer Stromänderung (I1) kleiner ist, und
die Steuereinheit (45) die Hochfrequenzleistung, die der Heizspule (11a) geliefert wird, abhängig von der abgeleiteten Heizlast steuert.

4. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 3, bei welcher
die Steuereinheit (45) die Hochfrequenzleistung verringert, die der Heizspule (11a) geliefert wird, wenn eine zweite Zeit (Δt) abläuft, nachdem der Umfang einer zeitlichen Änderung (ΔI) erhalten in dem Zustand, in dem die Betriebsfrequenz des Betriebsschaltkreises (50) fest ist, gleich oder kleiner als der eingestellte Wert wird, und
die Steuereinheit (45) die zweite Zeit (Δt) abhängig von der ersten Zeit (t1) und dem Umfang einer Stromänderung (I1) bestimmt.

5. Induktionsheizkochvorrichtung (100) gemäß Anspruch 4, bei welcher die Steuereinheit (45) die zweite Zeit (Δt) verringert, während die erste Zeit (t1) kürzer ist und der Umfang einer Stromänderung (I1) kleiner ist.

6. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 5, bei welcher
die Steuereinheit (45) die Betriebsfrequenz des Betriebsschaltkreises (50) erhöht, um die Hochfrequenzleistung zu verringern, die der Heizspule (11a) geliefert wird, nachdem der Umfang einer zeitlichen Änderung (ΔI) erhalten in dem Zustand, in dem die Betriebsfrequenz des Betriebsschaltkreises (50) fest ist, gleich oder kleiner als der eingestellte Wert wird, und
die Steuereinheit (45) einen Erhöhungsumfang der Betriebsfrequenz abhängig von der ersten Zeit (t1) und dem Umfang einer Stromänderung (I1) bestimmt.

7. Induktionsheizkochvorrichtung (100) gemäß Anspruch 6, bei welcher die Steuereinheit (45) den Erhöhungsumfang der Betriebsfrequenz vermindert, während die erste Zeit (t1) kürzer ist und der Umfang einer Stromänderung (I1) kleiner ist.

8. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 7, bei welcher die Steuereinheit (45) die Betriebsfrequenz des Betriebsschaltkreises (50) oder ein Einschaltverhältnis eines Schaltelements des Betriebsschaltkreises (50) verändert, um die Hochfrequenzleistung zu verringern, die der Heizspule (11a) geliefert wird.

9. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 8, weiterhin umfassend:

eine Betriebseinheit (40), die zum Betreiben eines Auswählens eines Betriebsmodus ausgelegt ist; und
eine Benachrichtigungseinheit (42),
wobei die Steuereinheit (45) den Betriebsschaltkreis (50) betreibt, wenn ein Wasserkochmodus des Einstellens eines Wasserkochbetriebs als der Betriebsmodus ausgewählt ist, und
wobei, nachdem der Umfang einer zeitlichen Änderung (ΔI) gleich oder kleiner wird als der eingestellte Wert, die Steuereinheit (45) die Benachrichtigungseinheit (42) veranlasst, eine Benachrichtigung zu senden, dass ein Wasserkochen beendet ist.

10. Induktionsheizkochvorrichtung (100) gemäß Anspruch 9, bei welcher dann, wenn die erste Zeit (t1) kleiner ist als ein Zeitreferenzwert und der Umfang einer Stromänderung (I1) kleiner ist als ein Stromreferenzwert, wenn der Umfang einer zeitlichen Änderung (ΔI) gleich oder kleiner wird als der eingestellte Wert, die Steuereinheit (45) die Benachrichtigungseinheit (42) veranlasst, eine Benachrichtigung zu senden, dass ein Wasserkochen beendet ist.

11. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 10, weiterhin umfassend eine Lastbestimmungseinheit (32), die zum Ausführen eines Lastbestimmungsprozesses beim Heizziel (5) ausgelegt ist, wobei die Steuereinheit (45) eine Betriebsfrequenz zum Betreiben des Betriebsschaltkreises (50) abhängig von einem Bestimmungsergebnis der Lastbestimmungseinheit (32) einstellt.

12. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 11, bei welcher die Steuereinheit (45) ein Einschaltverhältnis eines Schaltelements des Betriebsschaltkreises (50) auf einen festen Zustand einstellt, in dem Zustand, in dem die Betriebsfrequenz des Betriebsschaltkreises (50) fest ist.

13. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 11, bei welcher der Betriebsschaltkreis (50) einen Vollbrückenwechselrichterkreis umfasst, der wenigstens zwei Arme umfasst, von denen jeder zwei in Reihe verbundene Schaltelemente umfasst, und
die Steuereinheit (45) eine Betriebsphasendifferenz der Schaltelemente zwischen den zwei Armen und ein Einschaltverhältnis der Schaltelemente auf einen festen Zustand einstellt, in einem Zustand, in dem eine Betriebsfrequenz der Schaltelemente des Vollbrückenwechselrichterkreises fest ist.

14. Induktionsheizkochvorrichtung (100) gemäß irgendeinem von Ansprüchen 1 bis 11, bei welcher der Betriebsschaltkreis (50) einen Halbbrückenwechselrichterkreis umfasst, der einen Arm umfasst, der zwei in Reihe verbundene Schaltelemente umfasst, und
die Steuereinheit (45) ein Einschaltverhältnis der Schaltelemente auf einen festen Zustand einstellt, in einem Zustand, in dem eine Betriebsfrequenz der Schaltelemente des Halbbrückenwechselrichterkreises fest ist.

Revendications

1. Appareil de cuisson à chauffage par induction (100) comprenant :

un serpentin de chauffage (11a) configuré de façon à chauffer par induction une cible à chauffer (5) ;
un circuit de commande (50) configuré de façon à fournir une puissance à haute fréquence au serpentin de chauffage (11a) ; et
une unité de commande (45) configurée de façon à commander le circuit de commande (50) de manière à commander la puissance à haute fréquence fournie au serpentin de chauffage (11a) ;
l'unité de commande (45) permettant d'obtenir la quantité de modification temporelle (ΔI) de l'un au moins du courant d'entrée dans le circuit de commande (50), et du courant de serpentin qui circule à travers le serpentin de chauffage (11a), dans un état où la fréquence de commande du circuit de commande (50) est fixée ;
l'unité de commande (45) mesurant une première durée (t1) à partir du début de l'alimentation du serpentin de chauffage (11a) jusqu'à ce que la quantité de modification temporelle (ΔI) soit égale ou inférieure à une valeur réglée ;
l'unité de commande (45) commandant la puissance à haute fréquence fournie au serpentin de chauffage (11a) selon la première durée (t1) et une quantité de modification du courant (I1) de l'un au moins du courant d'entrée et du courant de serpentin au cours de la première durée (t1).

2. Appareil de cuisson à chauffage par induction (100) selon la revendication 1, dans lequel l'unité de commande (45) réduit la puissance à haute fréquence fournie au serpentin de chauffage (11a), lorsque la première durée (t1) est plus courte, et lorsque la quantité de modification du courant (11) est plus petite.

3. Appareil de cuisson à chauffage par induction (100) selon la revendication 1 ou la revendication 2, dans lequel :

l'unité de commande (45) conclut que la charge thermique d'un contenu de la cible à chauffer (5) à une étape de chauffage initiale, est plus petite lorsque la première durée (t1) est plus courte, et lorsque la quantité de modification du courant (I1) est plus petite ; et
l'unité de commande (45) commande la puissance à haute fréquence fournie au serpentin de chauffage (11a) selon la conclusion qui concerne la charge thermique.

4. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 3, dans lequel :

l'unité de commande (45) réduit la puissance à haute fréquence fournie au serpentin de chauffage (11a), quand une seconde durée (Δt) s'écoule une fois que la quantité de modification temporelle (ΔI) obtenue dans l'état où la fréquence de commande du circuit de commande (50) est fixée, est devenue égale ou inférieure à la valeur réglée ; et

l'unité de commande (45) détermine la seconde durée (Δt) selon la première durée (t1) et la quantité de modification du courant (I1).

5. Appareil de cuisson à chauffage par induction (100) selon la revendication 4, dans lequel l'unité de commande (45) réduit la seconde durée (Δt) lorsque la première durée (t1) est plus courte, et lorsque la quantité de modification du courant (I1) est plus petite.

6. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 5, dans lequel :

l'unité de commande (45) accroît la fréquence de commande du circuit de commande (50) de façon à réduire la puissance à haute fréquence fournie au serpentin de chauffage (11a), une fois que la quantité de modification temporelle (ΔI) obtenue dans l'état où la fréquence de commande du circuit de commande (50) est fixée, est devenue égale ou inférieure à la valeur réglée ; et

l'unité de commande (45) détermine une quantité d'accroissement de la fréquence de commande selon la première durée (t1) et la quantité de modification du courant (I1).

7. Appareil de cuisson à chauffage par induction (100) selon la revendication 6, dans lequel l'unité de commande (45) réduit la quantité d'accroissement de la fréquence de commande lorsque la première durée (t1) est plus courte, et lorsque la quantité de modification du courant (I1) est plus petite.

8. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 7, dans lequel l'unité de commande (45) fait varier la fréquence de commande du circuit de commande (50) ou le rapport cyclique d'un élément de commutation du circuit de commande (50) de façon à réduire la puissance à haute fréquence fournie au serpentin de chauffage (11a).

9. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 8, comprenant en outre :

une unité opérationnelle (40) configurée de façon à être actionnée de manière à sélectionner un mode de fonctionnement ; et

une unité de notification (42), dans lequel :

l'unité de commande (45) commande le circuit de commande (50) si un mode de mise en ébullition de l'eau consistant à exécuter une opération de mise en ébullition de l'eau, est sélectionné en tant que mode de fonctionnement ; et

une fois que la quantité de modification temporelle (ΔI) est devenue égale ou inférieure à la valeur réglée, l'unité de commande (45) provoque l'envoi par l'unité de notification (42) d'une notification selon laquelle la mise en ébullition de l'eau est exécutée.

10. Appareil de cuisson à chauffage par induction (100) selon la revendication 9, dans lequel, si la première durée (t1) est plus courte qu'une valeur de référence de durée et si la quantité de modification du courant (I1) est plus petite qu'une valeur de référence de courant, lorsque la quantité de modification temporelle (ΔI) devient égale ou inférieure à la valeur réglée, l'unité de commande (45) provoque l'envoi par l'unité de notification (42), d'une notification selon laquelle la mise en ébullition de l'eau est exécutée.

11. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 10, comprenant en outre une unité de détermination de charge (32) configurée de façon à exécuter un procédé de détermination de charge sur la cible à chauffer (5), dans lequel l'unité de commande (45) détermine une fréquence de commande destinée à commander le circuit de commande (50) selon le résultat de la détermination par l'unité de détermination de charge (32).

12. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 11, dans lequel l'unité de commande (45) définit le rapport cyclique d'un élément de commutation du circuit de commande (50) à un état fixé dans l'état où la fréquence de commande du circuit de commande (50) est fixée.

13. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 11, dans lequel :

le circuit de commande (50) comprend un circuit inverseur en pont complet qui comprend au moins deux branches, chacune d'elles comprenant deux éléments de commutation connectés en série ; et

l'unité de commande (45) détermine la différence de phase de commande des éléments de commutation entre les deux branches, et le rapport cyclique des éléments de commutation à un état fixé, dans un état où la fréquence de commande des éléments de commutation du circuit inverseur en pont complet, est fixée.

14. Appareil de cuisson à chauffage par induction (100) selon l'une quelconque des revendications 1 à 11, dans lequel :

le circuit de commande (50) comprend un circuit inverseur en demi-pont qui comprend une branche qui comprend deux éléments de commutation connectés en série ; et
l'unité de commande (45) détermine le rapport cyclique des éléments de commutation à un état fixé, dans un état où la fréquence de commande des éléments de commutation du circuit inverseur en demi-pont, est fixée.

FIG. 1

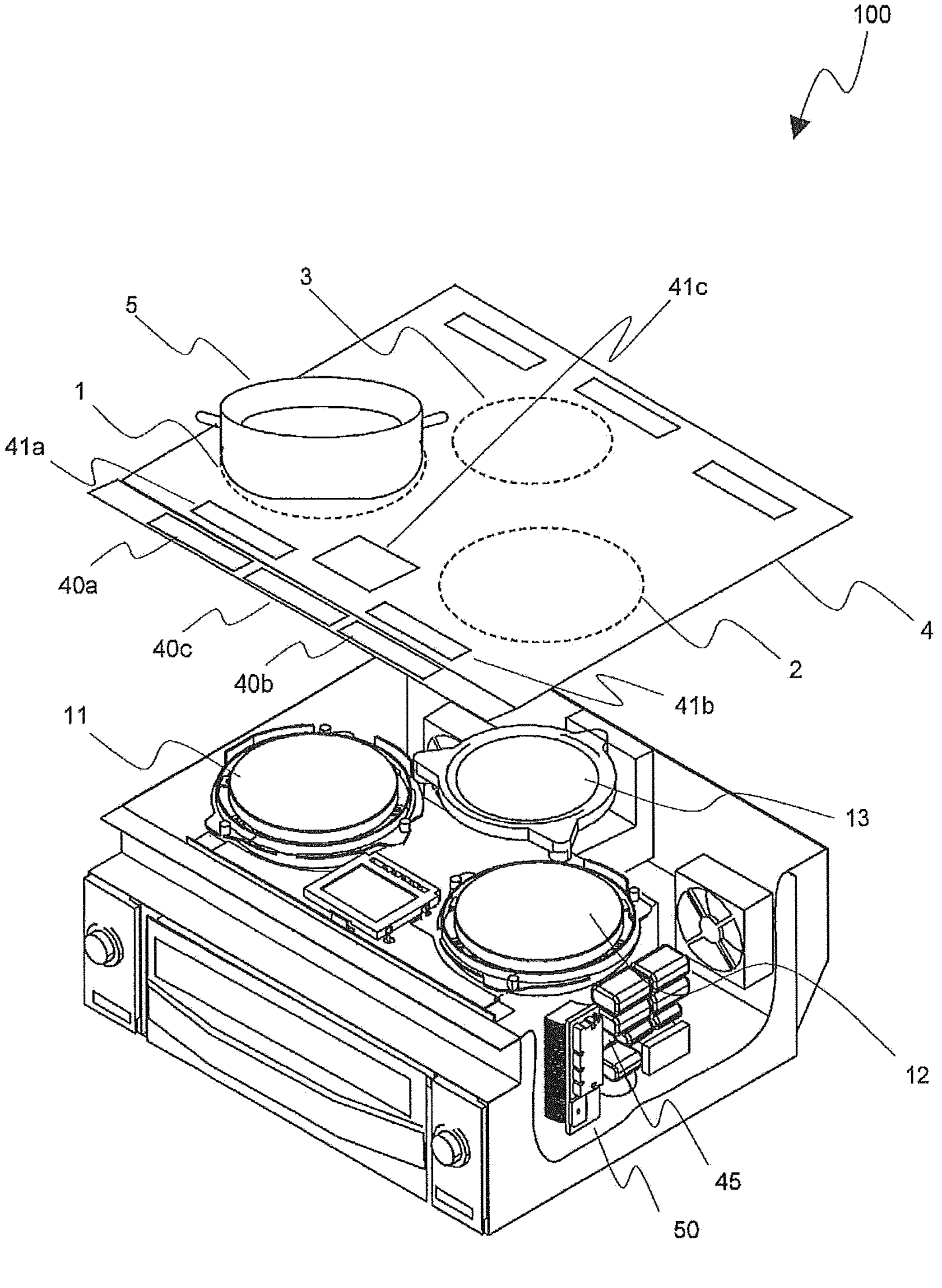


FIG. 2

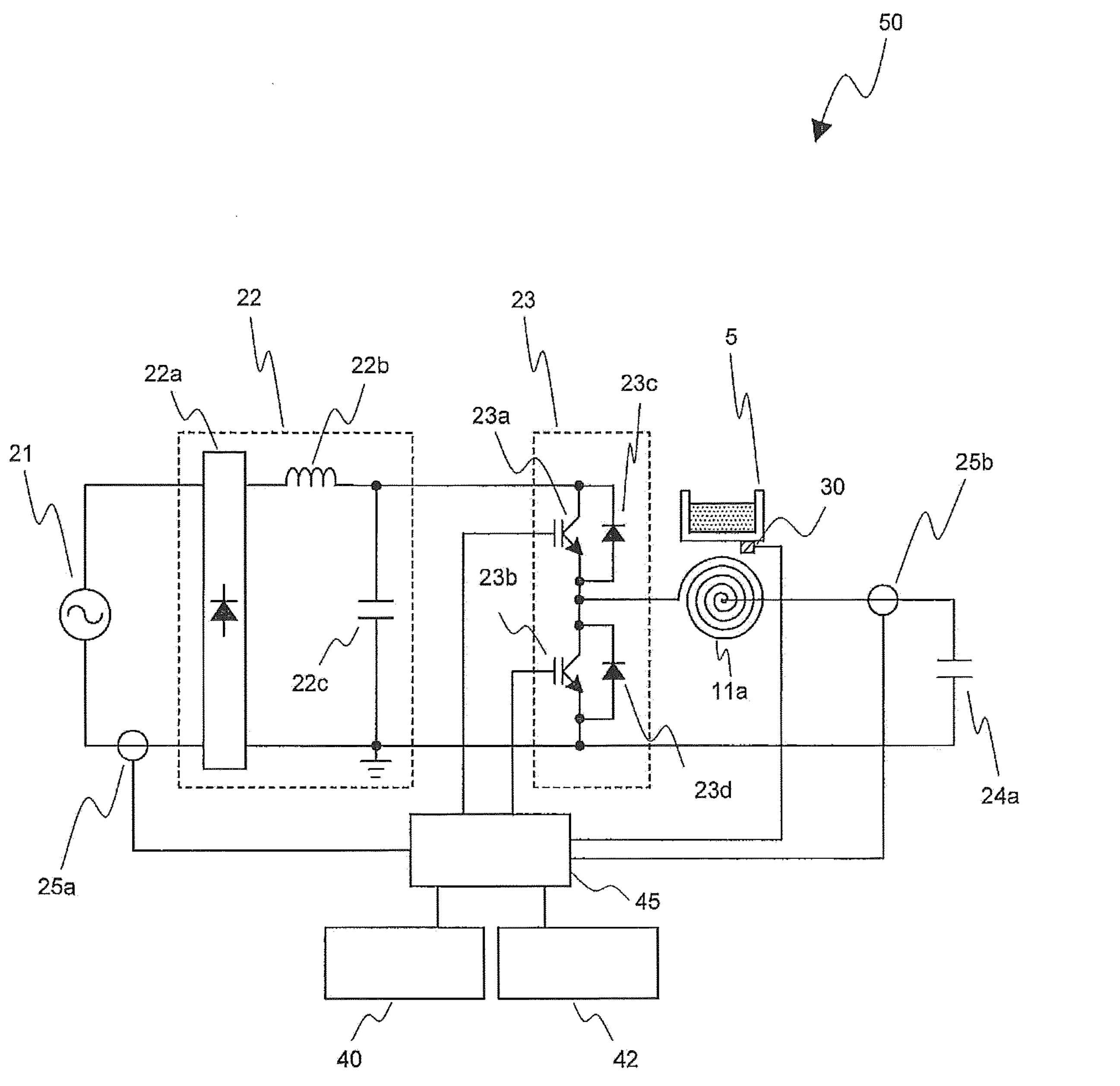

50
22
23
5
22a
22b
23c
23a
21
30
25b
23b
22c
11a
24a
23d
25a
45
40
42

FIG. 3

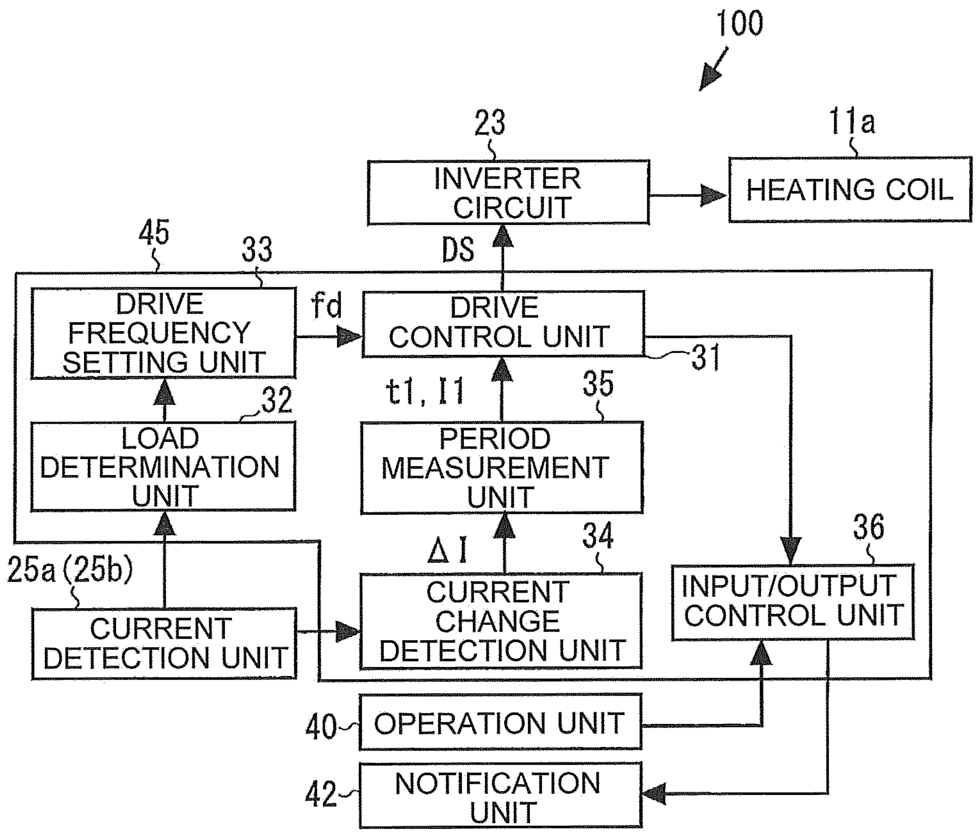

100
23
INVERTER CIRCUIT
11a
HEATING COIL
45
33
DS
DRIVE FREQUENCY SETTING UNIT
fd
DRIVE CONTROL UNIT
31
t1, I1
35
32
LOAD DETERMINATION UNIT
PERIOD MEASUREMENT UNIT
ΔI
34
36
25a (25b)
CURRENT DETECTION UNIT
CURRENT CHANGE DETECTION UNIT
INPUT/OUTPUT CONTROL UNIT
40
OPERATION UNIT
42
NOTIFICATION UNIT

FIG. 4

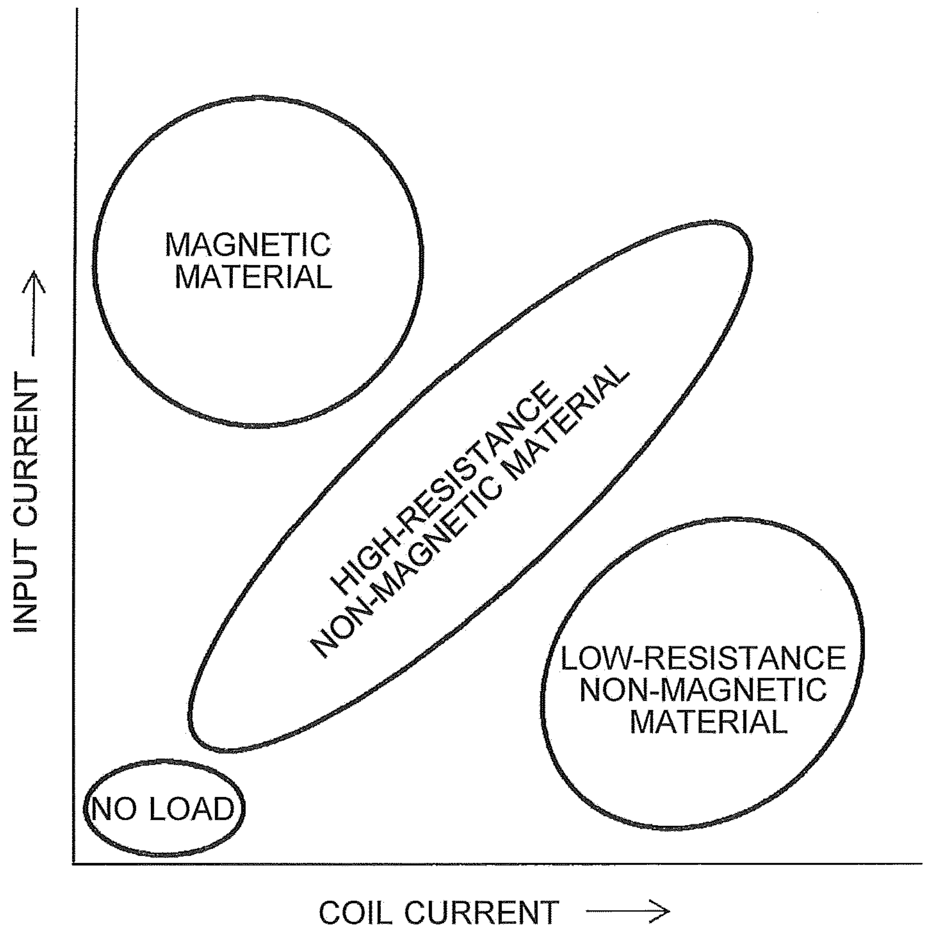

MAGNETIC MATERIAL
HIGH-RESISTANCE NON-MAGNETIC MATERIAL
LOW-RESISTANCE NON-MAGNETIC MATERIAL
NO LOAD
INPUT CURRENT
COIL CURRENT

FIG. 5

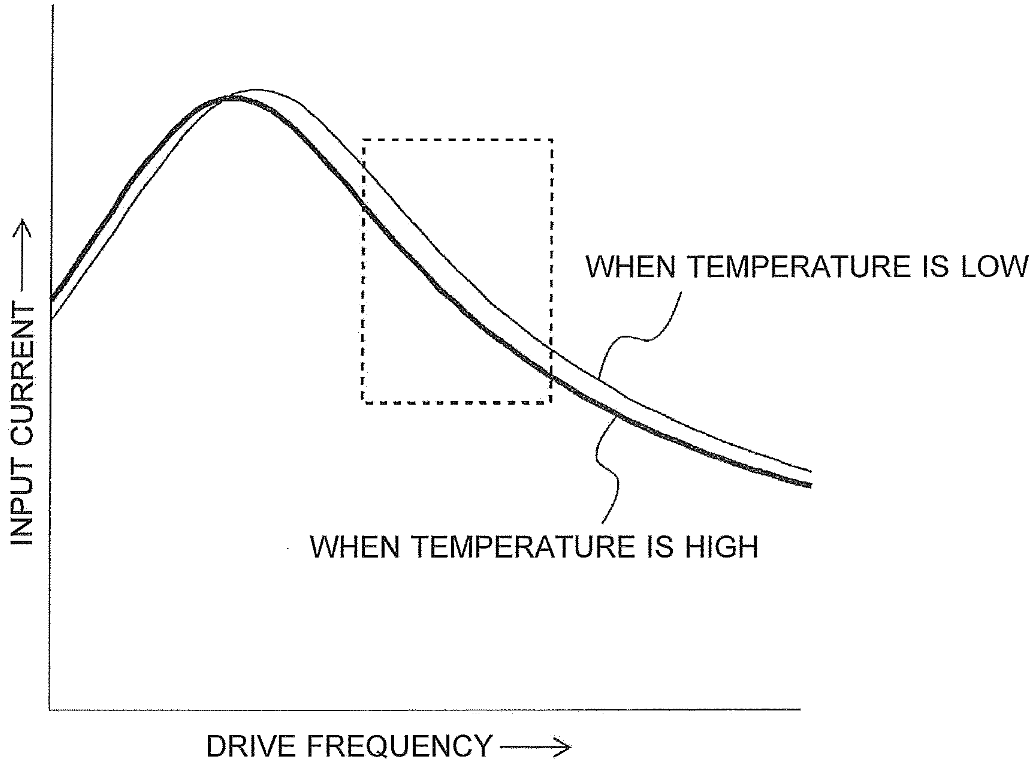

INPUT CURRENT
WHEN TEMPERATURE IS LOW
WHEN TEMPERATURE IS HIGH
DRIVE FREQUENCY

FIG. 6

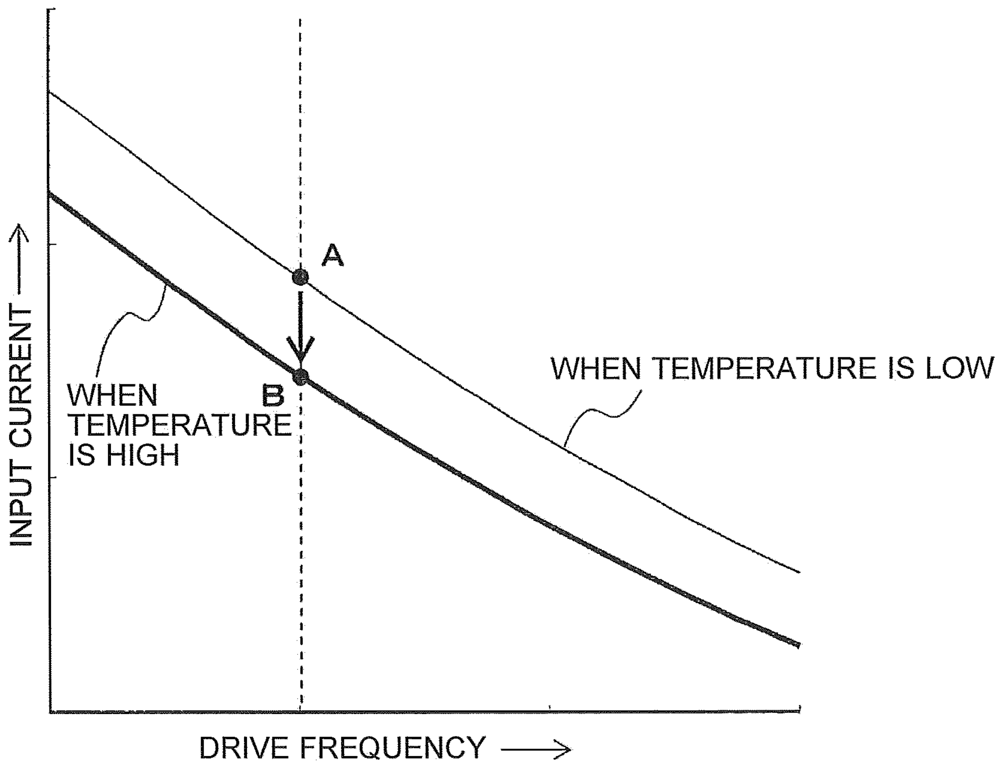

INPUT CURRENT
A
B
WHEN TEMPERATURE IS HIGH
WHEN TEMPERATURE IS LOW
DRIVE FREQUENCY

FIG. 7

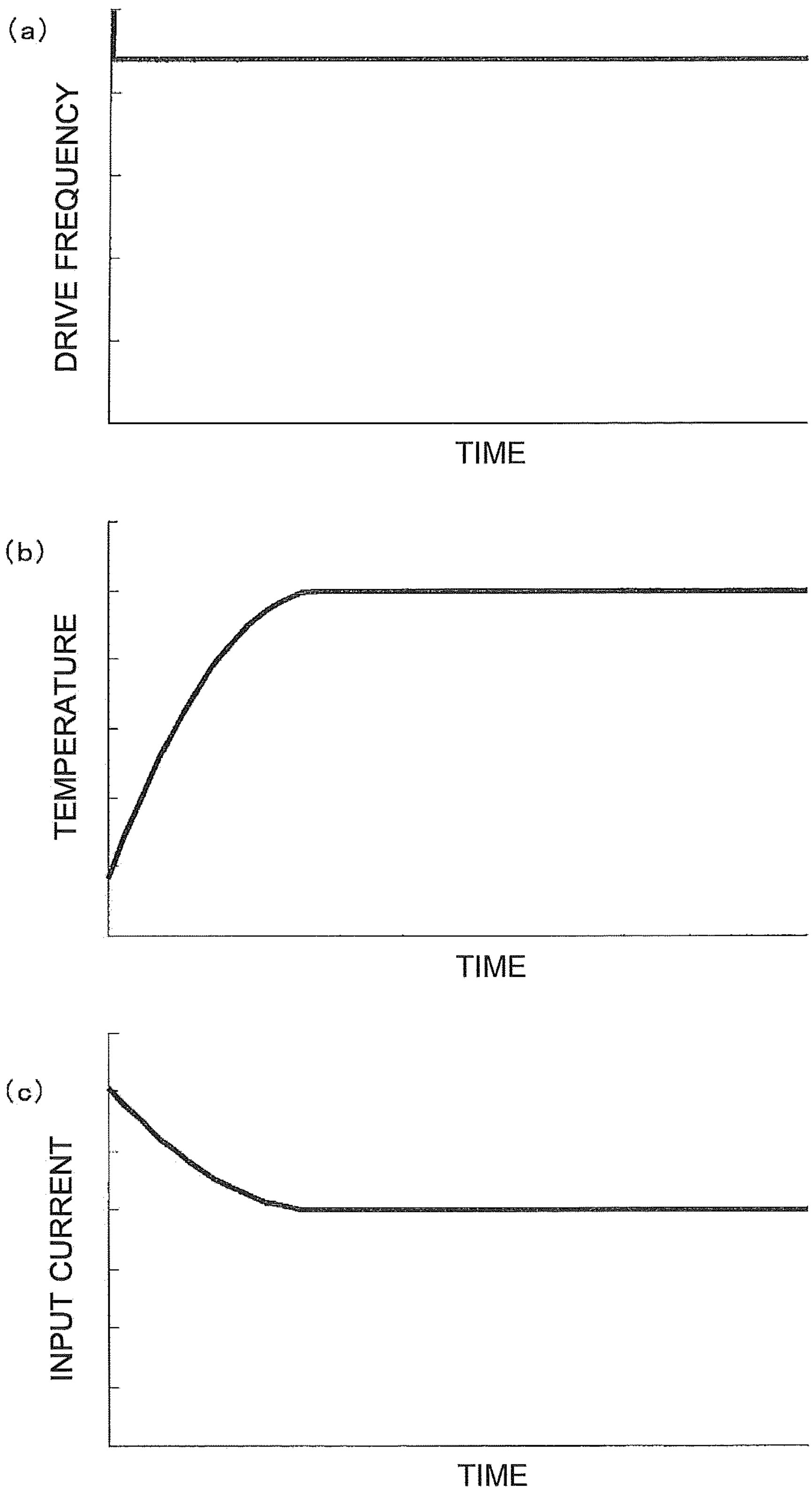
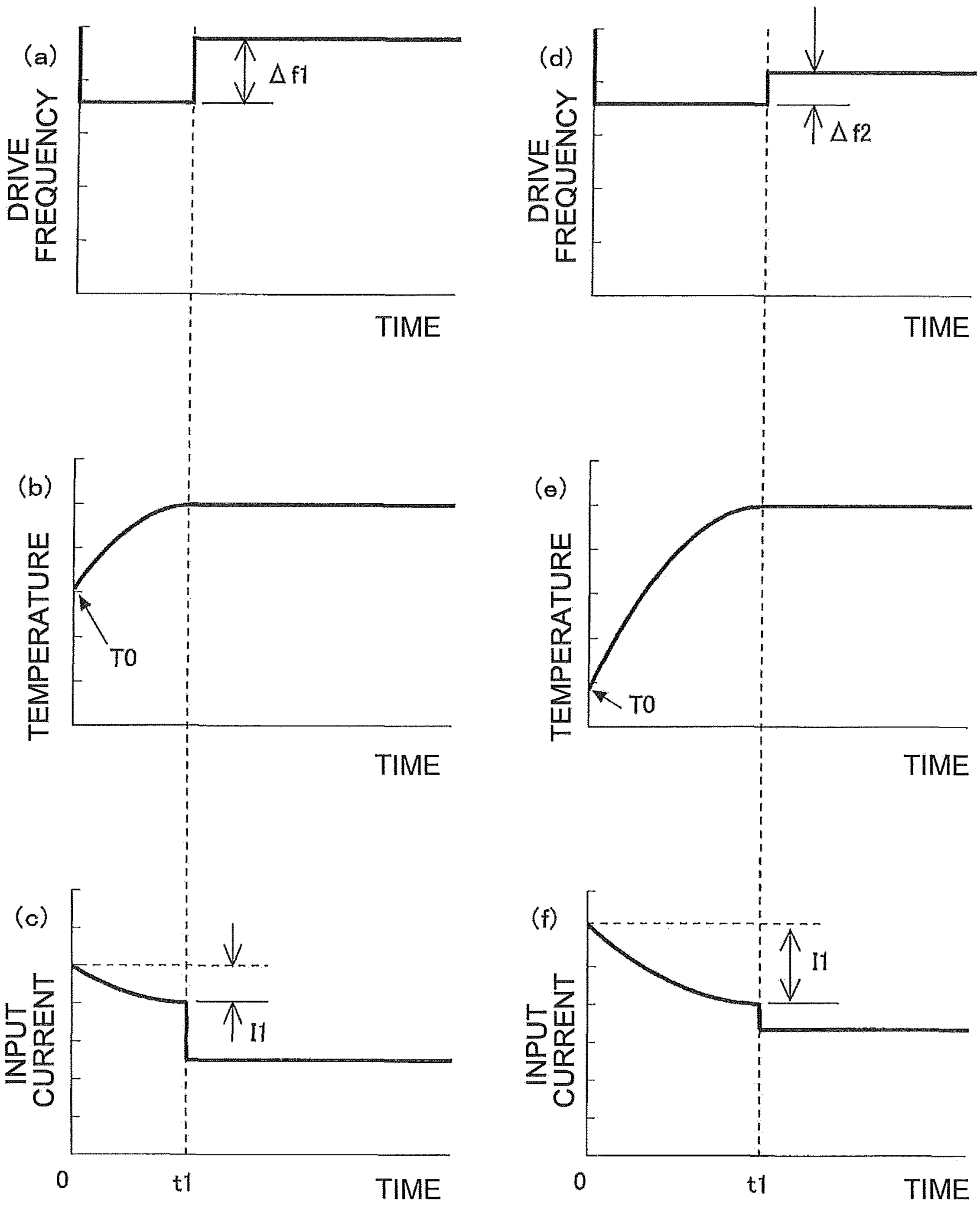

(a)
DRIVE FREQUENCY
TIME
(b)
TEMPERATURE
TIME
(c)
INPUT CURRENT
TIME

FIG. 8



(1) INITIAL TEMPERATURE: HIGH

(2) INITIAL TEMPERATURE: LOW

FIG. 9

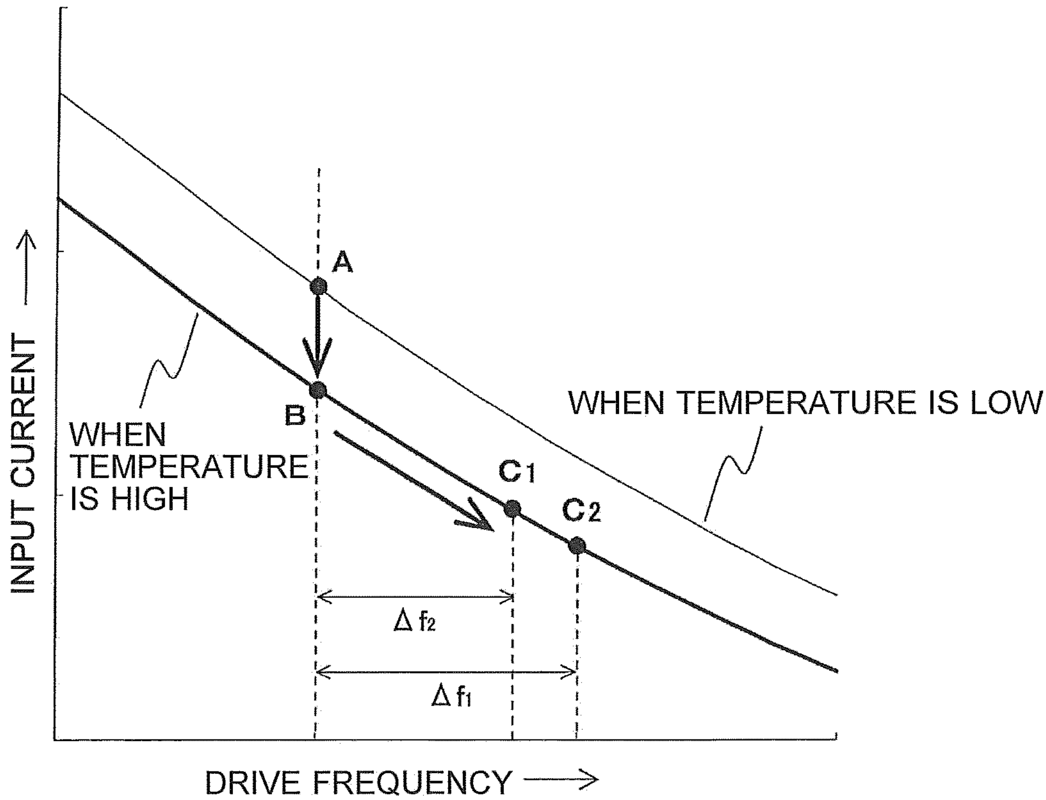

INPUT CURRENT
A
B
WHEN TEMPERATURE IS LOW
WHEN TEMPERATURE IS HIGH
C1
C2
Δf2
Δf1
DRIVE FREQUENCY

FIG. 10

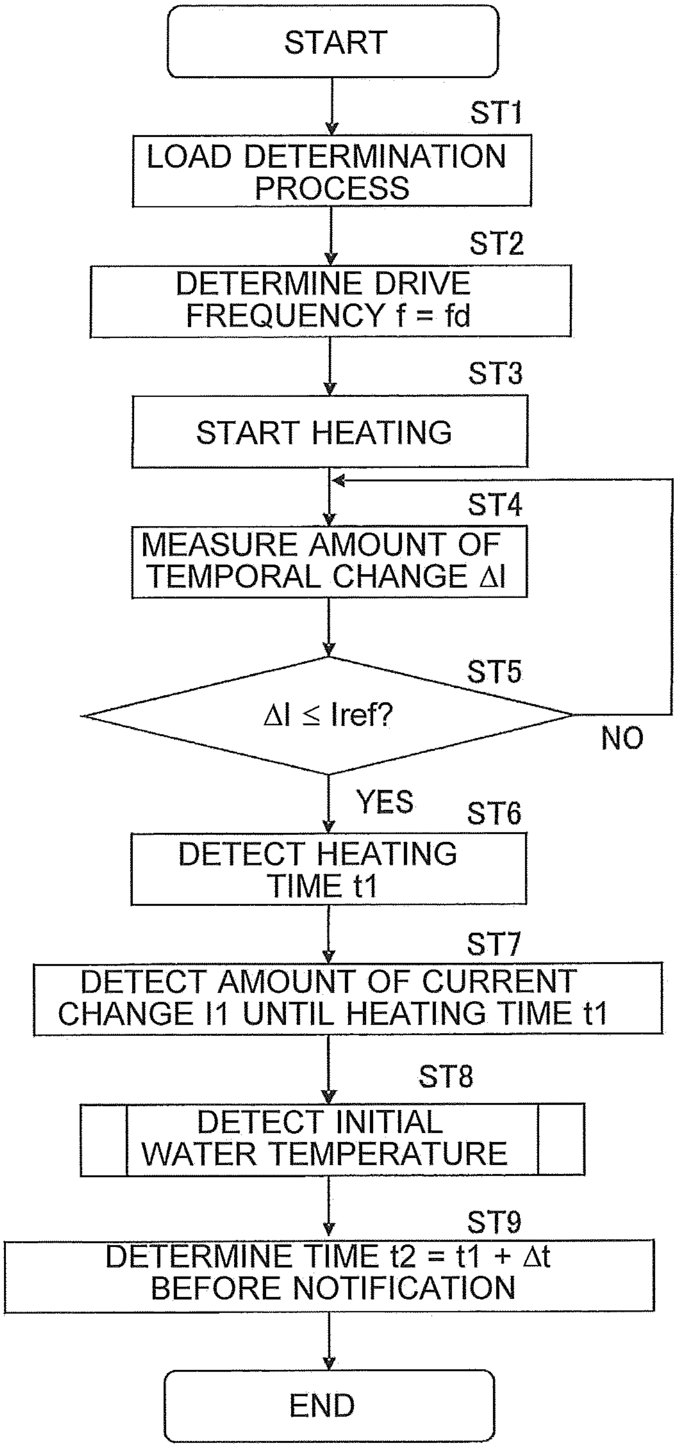

START
ST1
LOAD DETERMINATION PROCESS
ST2
DETERMINE DRIVE FREQUENCY f = fd
ST3
START HEATING
ST4
MEASURE AMOUNT OF TEMPORAL CHANGE ΔI
ST5
ΔI ≤ Iref?
NO
YES
ST6
DETECT HEATING TIME t1
ST7
DETECT AMOUNT OF CURRENT CHANGE I1 UNTIL HEATING TIME t1
ST8
DETECT INITIAL WATER TEMPERATURE
ST9
DETERMINE TIME t2 = t1 + Δt BEFORE NOTIFICATION
END

FIG. 11

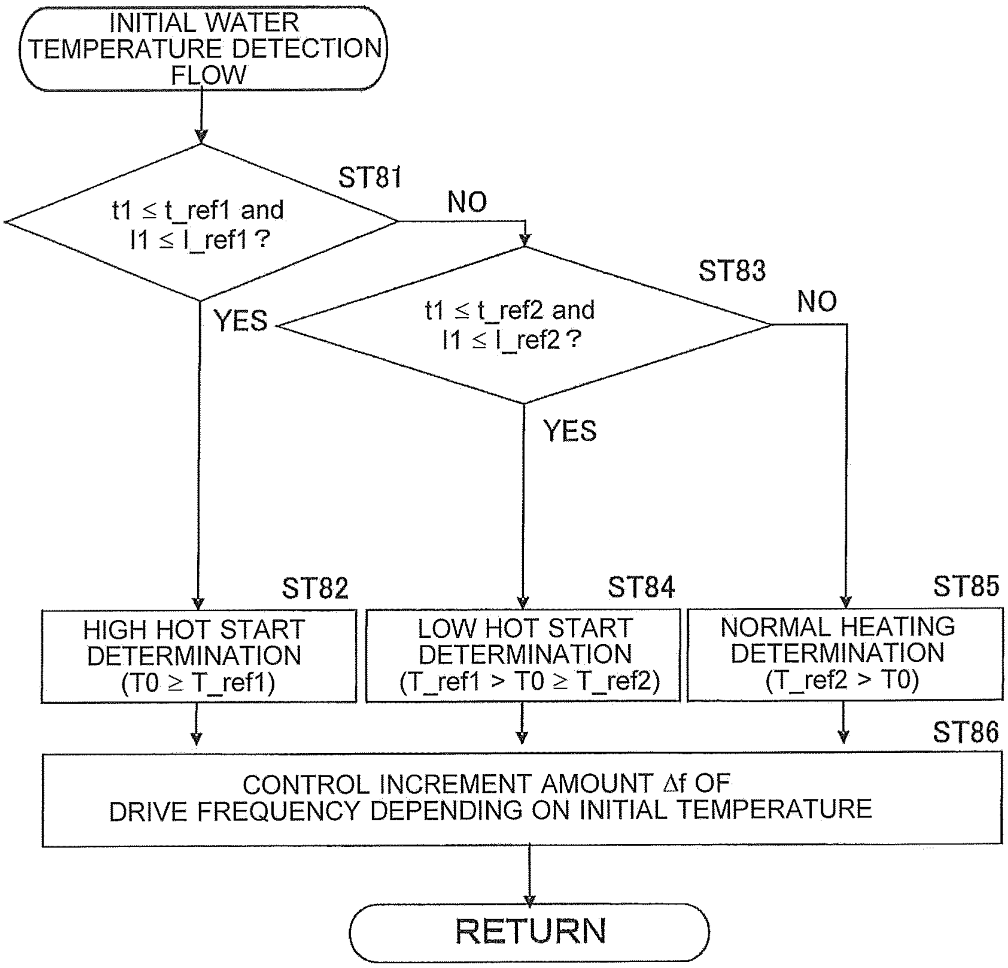

INITIAL WATER TEMPERATURE DETECTION FLOW
ST81
t1 ≤ t_ref1 and I1 ≤ I_ref1 ?
NO
YES
ST83
t1 ≤ t_ref2 and I1 ≤ I_ref2 ?
NO
YES
ST82
HIGH HOT START DETERMINATION (T0 ≥ T_ref1)
ST84
LOW HOT START DETERMINATION (T_ref1 > T0 ≥ T_ref2)
ST85
NORMAL HEATING DETERMINATION (T_ref2 > T0)
ST86
CONTROL INCREMENT AMOUNT Δf OF DRIVE FREQUENCY DEPENDING ON INITIAL TEMPERATURE
RETURN

FIG. 12

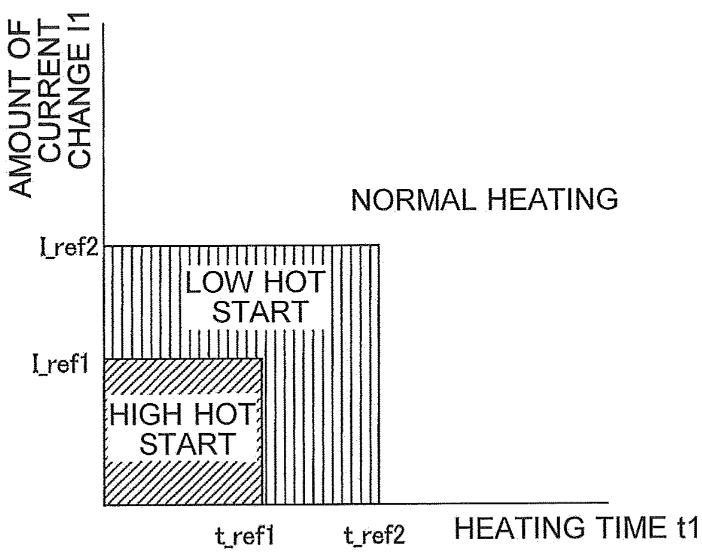
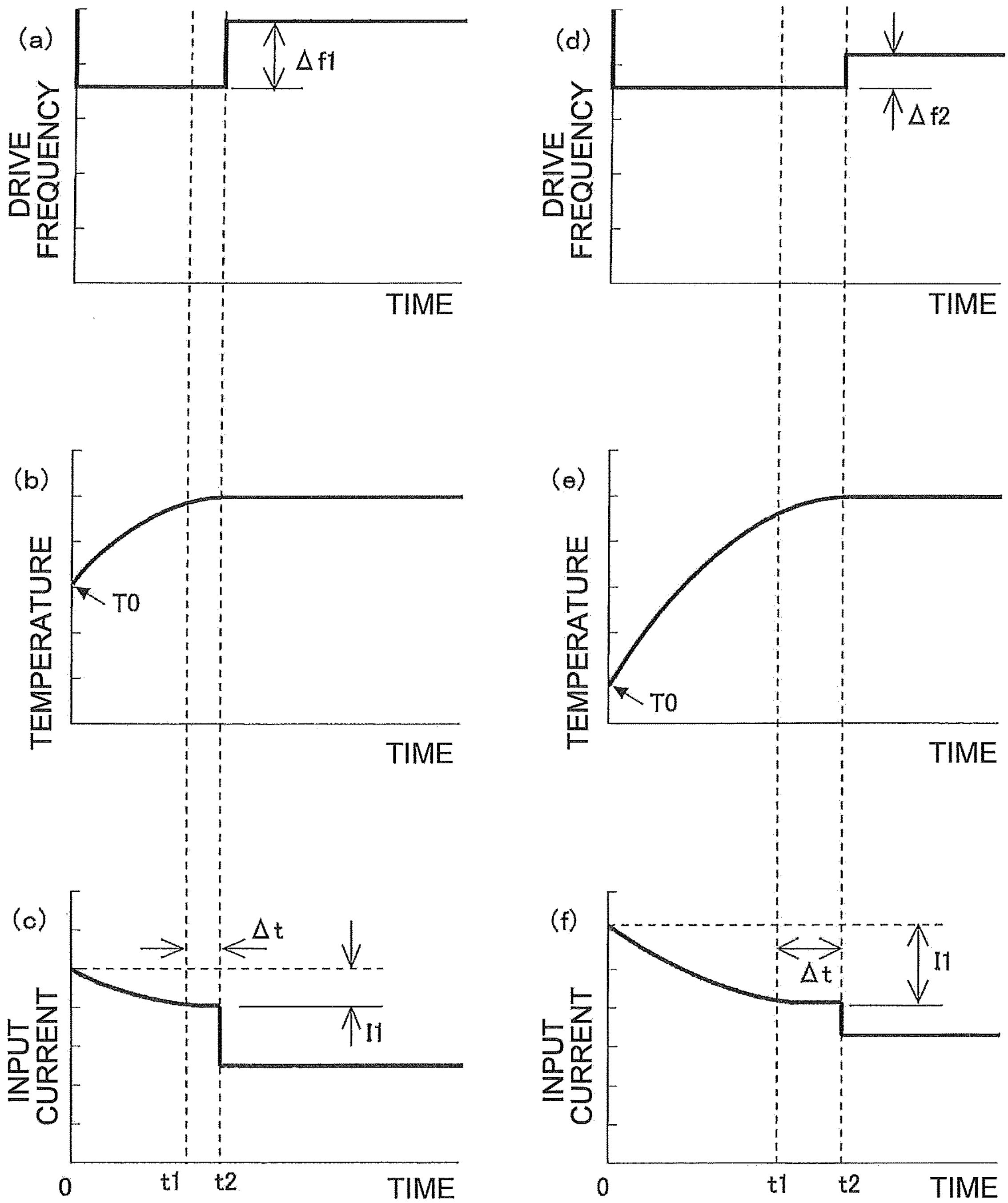

AMOUNT OF CURRENT CHANGE I1
NORMAL HEATING
I_ref2
LOW HOT START
I_ref1
HIGH HOT START
t_ref1
t_ref2
HEATING TIME t1

FIG. 13



(1) INITIAL TEMPERATURE: HIGH

(2) INITIAL TEMPERATURE: LOW

FIG. 14

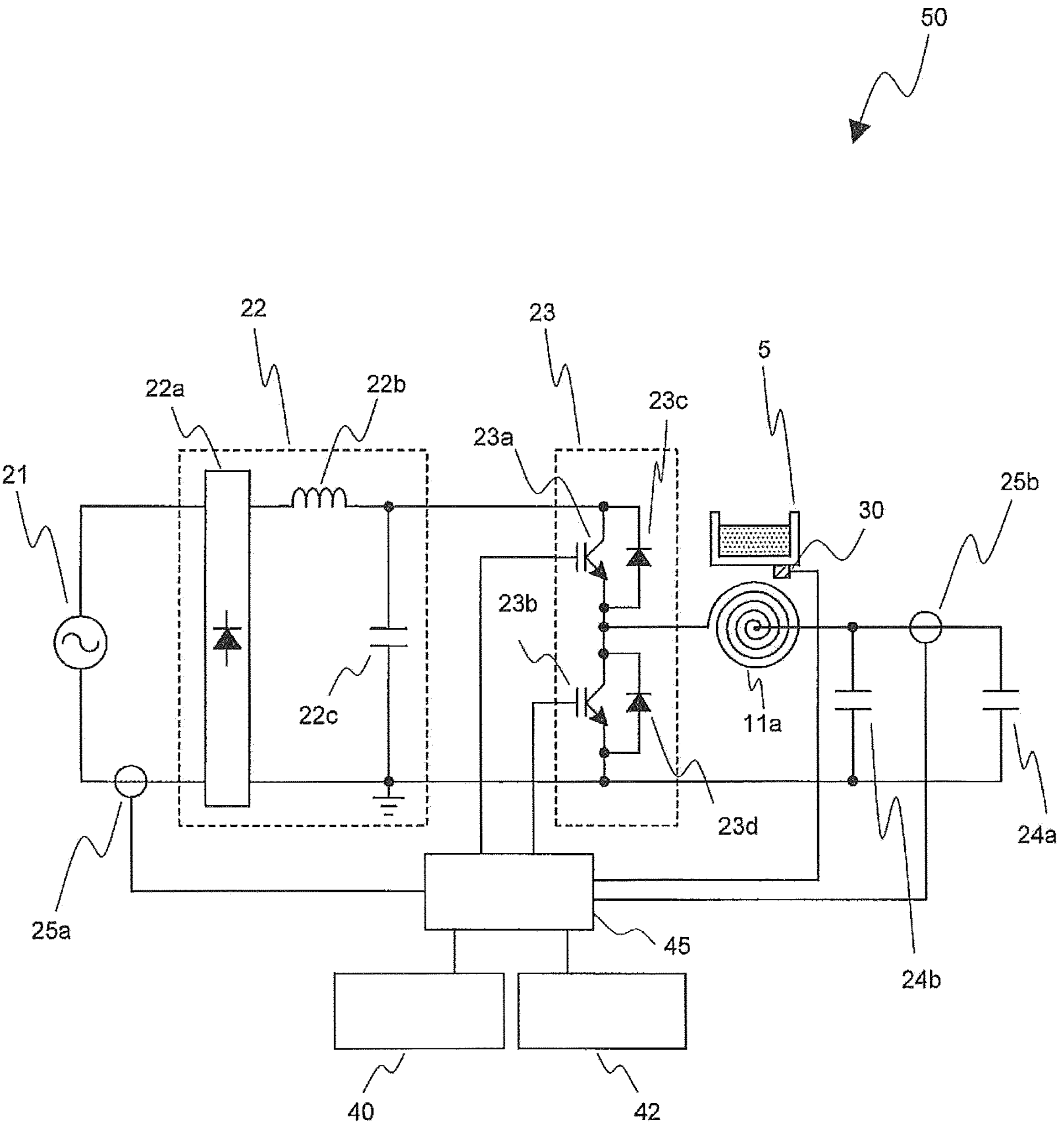

50
22
23
5
22a
22b
23c
23a
21
30
25b
23b
22c
11a
23d
24a
25a
45
24b
40
42

FIG. 15

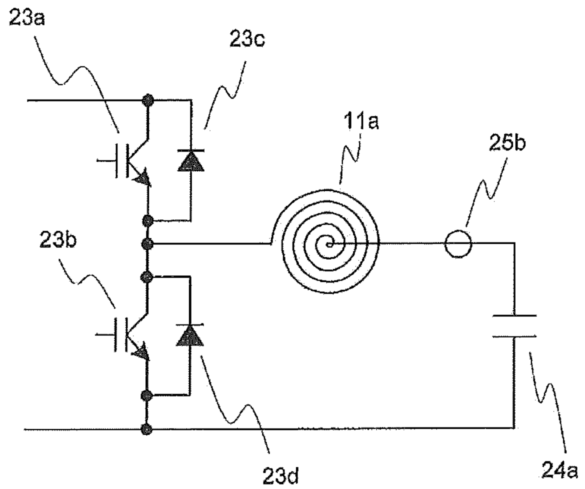

23a
23c
11a
25b
23b
23d
24a

FIG. 16

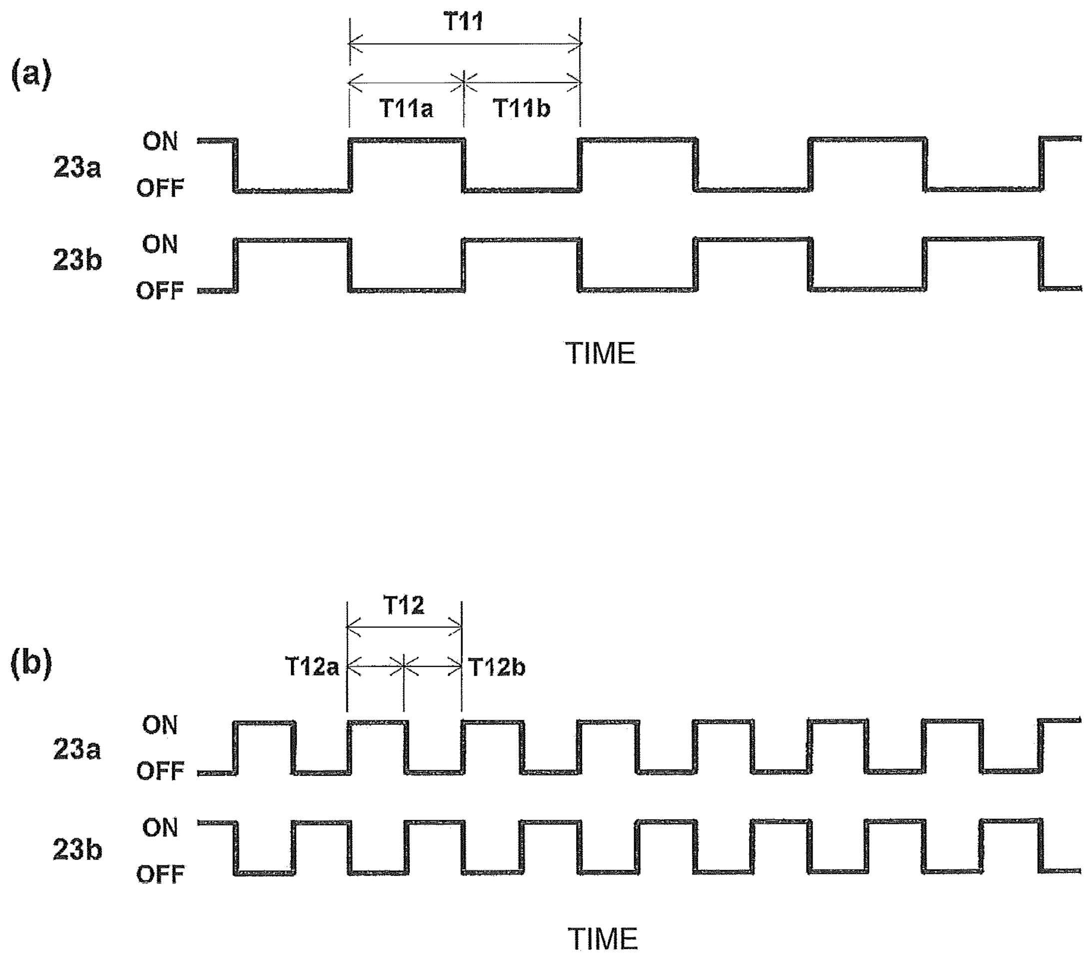

(a)
T11
T11a
T11b
ON
23a
OFF
ON
23b
OFF
TIME
(b)
T12
T12a
T12b
ON
23a
OFF
ON
23b
OFF
TIME

FIG. 17

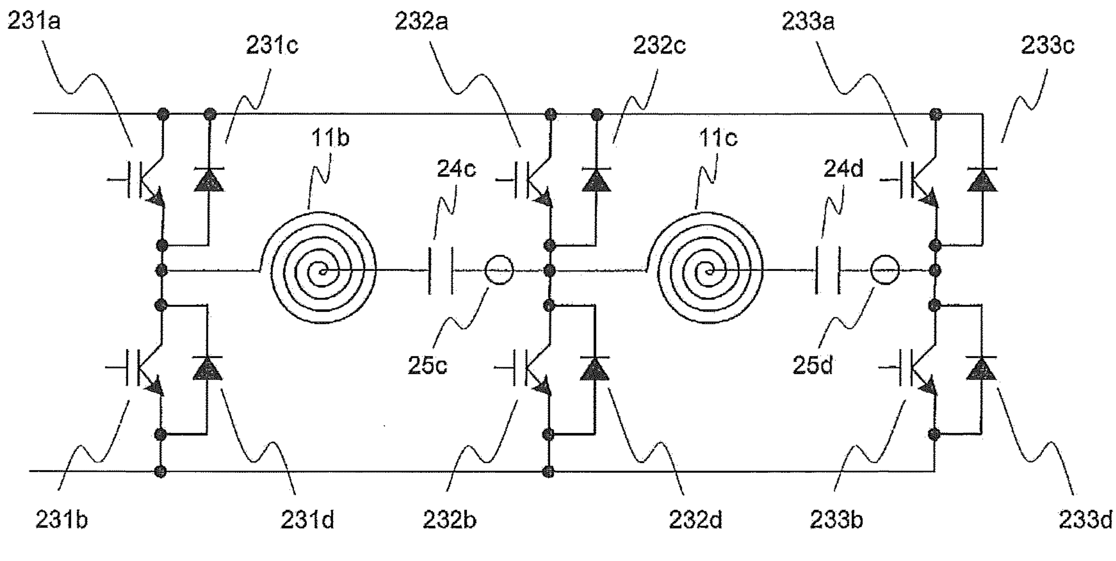
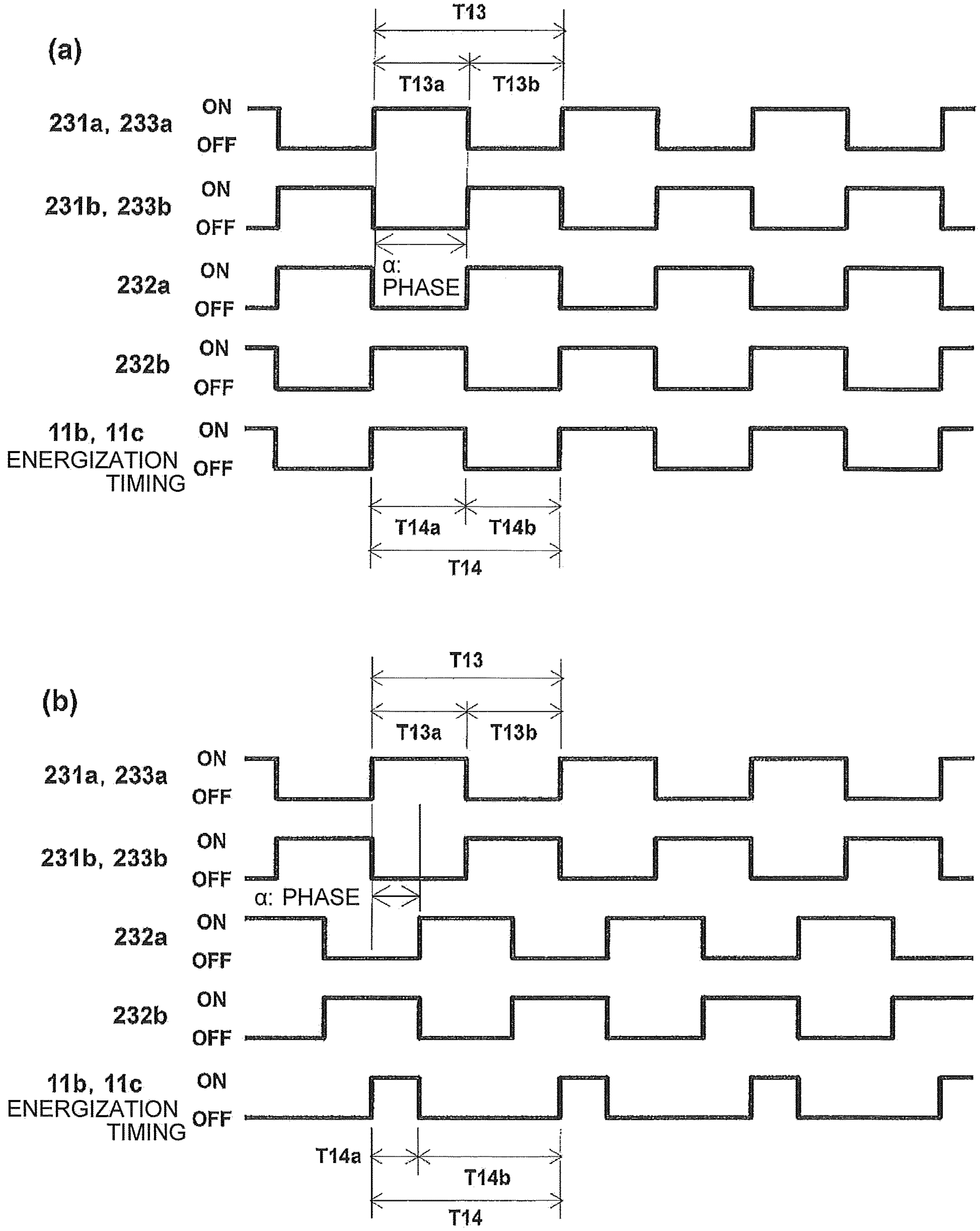

231a
231c
232a
232c
233a
233c
11b
24c
11c
24d
25c
25d
231b
231d
232b
232d
233b
233d

FIG. 18


(a)
T13
T13a
T13b
231a, 233a
231b, 233b
232a
232b
11b, 11c
ENERGIZATION
TIMING
ON
OFF
α:
PHASE
T14a
T14b
T14
(b)
T13
T13a
T13b
231a, 233a
231b, 233b
α: PHASE
232a
232b
11b, 11c
ENERGIZATION
TIMING
ON
OFF
T14a
T14b
T14

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008181892 A **[0004]**
- JP 5062773 A **[0004]**
- EP 2506672 A2 **[0005]**