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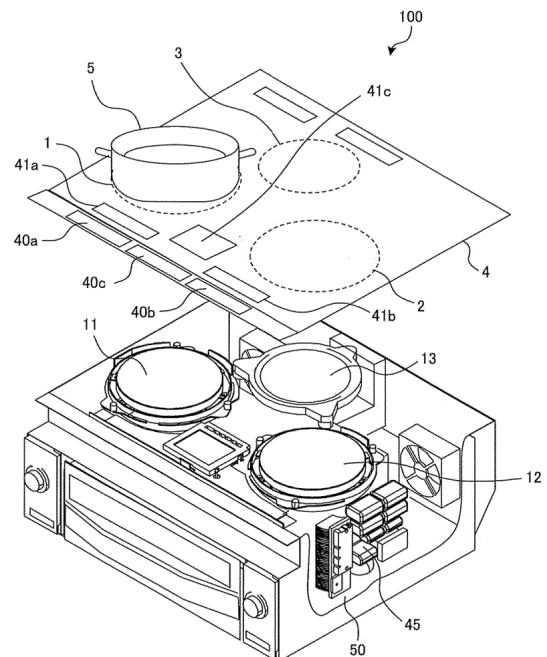
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(54) **INDUCTION HEATING COOKER**

(57) An induction heating cooker according to an embodiment of the present disclosure includes a driver circuit configured to supply a high-frequency current to each of a plurality of heating coils including an inner coil and an outer coil, a switcher unit configured to switch each of the plurality of heating coils into one of a conduction state and a non-conduction state, and a controller configured to determine whether a heating target is present above the inner coil while the inner coil is in the conduction state and the outer coil is in the non-conduction state, and when the controller determines that no heating target is present above the inner coil, the controller stopping an operation of the driver circuit.

FIG. 1



Description

Technical Field

[0001] The present disclosure relates to an induction heating cooker including a plurality of coils.

Background Art

[0002] An induction heating cooker in which a current is supplied to a plurality of coils by one inverter circuit has been proposed. For example, in an induction heating cooker disclosed in Patent Literature 1, a calculation control circuit controls an inverter circuit to supply currents of at least two types of frequencies to a plurality of coils. The calculation control circuit calculates a current ratio of the plurality of coils at each of the frequencies from currents measured by a measurement circuit, and determines a size of a heating target based on relative relationship of the current ratios at the respective frequencies.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2006-310006

Summary of Invention

Technical Problem

[0004] The induction heating cooker disclosed in Patent Literature 1 calculates the current ratio of the plurality of coils at each of the frequencies, and determines a load based on the relative relationship of the current ratio at the respective frequencies. Therefore, it takes a long time to determine the load. Accordingly, in a no-load state where no heating target is placed, it is not possible to rapidly stop a load determination operation.

[0005] The present disclosure is made to solve the above-described issues, and to provide an induction heating cooker that has a configuration in which a plurality of heating coils is driven by one driver circuit and can rapidly stop a load determination operation in a no-load state.

Solution to Problem

[0006] An induction heating cooker according to an embodiment of the present disclosure includes: a plurality of heating coils including an inner coil disposed on an innermost circumference and an outer coil disposed on an outermost circumference; a driver circuit configured to supply a high-frequency current to each of the plurality of heating coils; a switcher unit configured to switch each of the plurality of heating coils into one of a conduction

state in which the high-frequency current is supplied from the driver circuit and a non-conduction state in which no high-frequency current is supplied from the driver circuit; and a controller configured to control an operation of the driver circuit and an operation of the switcher unit. When the inner coil is in the conduction state and the outer coil is in the non-conduction state, the controller is configured to determine whether a heating target is present above the inner coil. When the controller determines that no heating target is present above the inner coil, the controller is configured to stop an operation of the driver circuit.

Advantageous Effects of Invention

[0007] In the embodiment of the present disclosure, when the inner coil is in the conduction state and the outer coil is in the non-conduction state, the controller determines whether the heating target is present above the inner coil. When the controller determines that no heating target is present above the inner coil, the controller stops the operation of the driver circuit. Accordingly, in the configuration in which the plurality of heating coils are driven by one driver circuit, it is possible to rapidly stop a load determination operation in a no-load state.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is an exploded perspective view illustrating an induction heating cooker according to Embodiment 1.

[Fig. 2] Fig. 2 is a plan view illustrating a first induction heating unit of the induction heating cooker according to Embodiment 1.

[Fig. 3] Fig. 3 is a block diagram illustrating a configuration of the induction heating cooker according to Embodiment 1.

[Fig. 4] Fig. 4 is a diagram illustrating a driver circuit of the induction heating cooker according to Embodiment 1.

[Fig. 5] Fig. 5 is a flowchart illustrating a heating operation of the induction heating cooker according to Embodiment 1.

[Fig. 6] Fig. 6 is a load determination characteristic diagram based on relationship between a coil current and an input current in the induction heating cooker according to Embodiment 1.

[Fig. 7] Fig. 7 is a diagram illustrating a composite heating target that is induction-heated by the induction heating cooker according to Embodiment 1.

[Fig. 8] Fig. 8 is a diagram illustrating heating coils and the heating target of the induction heating cooker according to Embodiment 1.

[Fig. 9] Fig. 9 is a diagram to explain an operation state of a first switcher unit and an operation state of a second switcher unit in a preheating mode of

the induction heating cooker according to Embodiment 1.

[Fig. 10] Fig. 10 is a diagram to explain the operation state of the first switcher unit and the operation state of the second switcher unit in a small-diameter heating operation of the induction heating cooker according to Embodiment 1.

[Fig. 11] Fig. 11 is a diagram to explain the operation state of the first switcher unit and the operation state of the second switcher unit in a large-diameter heating operation of the induction heating cooker according to Embodiment 1.

[Fig. 12] Fig. 12 is a diagram illustrating a configuration of a switcher unit in Modification 1 of the induction heating cooker according to Embodiment 1.

[Fig. 13] Fig. 13 is a diagram illustrating another configuration of the switcher unit in Modification 1 of the induction heating cooker according to Embodiment 1.

[Fig. 14] Fig. 14 is a plan view illustrating a first induction heating unit in Modification 2 of the induction heating cooker according to Embodiment 1.

[Fig. 15] Fig. 15 is a plan view illustrating a first induction heating unit of an induction heating cooker according to Embodiment 2.

[Fig. 16] Fig. 16 is a block diagram illustrating a configuration of the induction heating cooker according to Embodiment 2.

[Fig. 17] Fig. 17 is a diagram illustrating a circuit configuration of the induction heating cooker according to Embodiment 2.

[Fig. 18] Fig. 18 is a flowchart illustrating a heating operation of the induction heating cooker according to Embodiment 2.

[Fig. 19] Fig. 19 is a flowchart illustrating the heating operation of the induction heating cooker according to Embodiment 2.

[Fig. 20] Fig. 20 is a diagram illustrating a configuration of a switcher unit in Modification 1 of the induction heating cooker according to Embodiment 2.

[Fig. 21] Fig. 21 is a diagram illustrating another configuration of the switcher unit in Modification 1 of the induction heating cooker according to Embodiment 2.

[Fig. 22] Fig. 22 is a diagram illustrating a circuit configuration of an induction heating cooker according to Embodiment 3.

Description of Embodiments

Embodiment 1.

[0009] Fig. 1 is an exploded perspective view illustrating an induction heating cooker according to Embodiment 1.

[0010] As illustrated in Fig. 1, an induction heating cooker 100 includes, at an upper part thereof, a top plate 4 on which a heating target 5 such as a pot is to be placed.

The top plate 4 includes, as heating ports to inductively heat the heating target 5, a first induction heating port 1 and a second induction heating port 2. The first induction heating port 1 and the second induction heating port 2 are provided side by side in a lateral direction on a front side of the top plate 4. The induction heating cooker 100 according to Embodiment 1 further includes a third induction heating port 3 as a third heating port. The third induction heating port 3 is provided at a center in the lateral direction of the top plate 4 beyond the first induction heating port 1 and the second induction heating port 2.

[0011] A first induction heating unit 11, a second induction heating unit 12, and a third induction heating unit 13 each heating the heating target 5 placed on the corresponding heating port are provided respectively below the first induction heating port 1, the second induction heating port 2, and the third induction heating port 3. Each of the heating units includes heating coils (see Fig. 2).

[0012] The top plate 4 is wholly made of a material allowing infrared rays to pass therethrough, such as heat-resistant tempered glass and crystallized glass. Further, in the top plate 4, pot position display circles each indicating a rough pot placement position are displayed by paint coating, printing, or the like, corresponding to heating ranges of the first induction heating unit 11, the second induction heating unit 12, and the third induction heating unit 13.

[0013] On the front side of the top plate 4, an operation unit 40 is provided as an input device to set input power, a cooking menu, and the like when the heating target 5 is heated by each of the first induction heating unit 11, the second induction heating unit 12, and the third induction heating unit 13. The cooking menu includes a pre-heating mode, a convection mode, and a normal heating mode described below. Note that, in Embodiment 1, as the operation unit 40, an operation unit 40a, an operation unit 40b, and an operation unit 40c are provided for the respective induction heating coils.

[0014] Further, as a notification unit, a display unit 41 displaying an operation state of each of the induction heating coils, input from the operation unit 40, operation contents, and the like is provided near the operation unit 40. Note that, in Embodiment 1, as the display unit 41, a display unit 41a, a display unit 41b, and a display unit 41c are provided for the respective induction heating coils.

[0015] The operation unit 40 and the display unit 41 may be provided for each of the induction heating units as described above or may be provided to be shared by the induction heating units, without particular limitation. The operation unit 40 includes, for example, mechanical switches such as a push switch and a tact switch, and a touch switch detecting input operation from variation of an electrostatic capacitance of an electrode. The display unit 41 includes, for example, an LCD or an LED.

[0016] The operation unit 40 and the display unit 41 may be integrally configured as an operation display unit

43. The operation display unit 43 includes, for example, a touch panel in which touch switches are arranged on a top surface of the LCD.

[0017] Note that LCD is an abbreviation of liquid crystal device. Further, LED is an abbreviation of light emitting diode.

[0018] A driver circuit 50 and a controller 45 are provided inside the induction heating cooker 100. The driver circuit 50 supplies high-frequency power to each of the coils of the first induction heating unit 11, the second induction heating unit 12, and the third induction heating unit 13. The controller 45 controls an operation of the entire induction heating cooker including the driver circuit 50.

[0019] When the driver circuit 50 supplies the high-frequency power to each of the first induction heating unit 11, the second induction heating unit 12, and the third induction heating unit 13, a high-frequency magnetic field is generated from each of the coils of the induction heating units. A detailed configuration of the driver circuit 50 is described below.

[0020] For example, the first induction heating unit 11, the second induction heating unit 12, and the third induction heating unit 13 each have the following configuration. The first induction heating unit 11, the second induction heating unit 12, and the third induction heating unit 13 each have a similar configuration. Therefore, the configuration of the first induction heating unit 11 is described below as a representative.

[0021] Fig. 2 is a plan view illustrating the first induction heating unit of the induction heating cooker according to Embodiment 1.

[0022] The first induction heating unit 11 includes a plurality of ring-shaped heating coils that are different in diameter and are concentrically arranged. Fig. 2 illustrates the first induction heating unit 11 as two ring-shaped coils. The first induction heating unit 11 includes an inner coil 111 disposed at a center of the first induction heating port 1 and an outer coil 112 disposed on an outer circumference of the inner coil 111. In other words, the inner coil 111 is a heating coil disposed on an innermost circumference among the plurality of heating coils configuring the first induction heating unit 11. The outer coil 112 is a heating coil disposed on an outermost circumference among the plurality of heating coils configuring the first induction heating unit 11.

[0023] Each of the inner coil 111 and the outer coil 112 is configured by winding a conductive wire made of an insulation-coated metal. As a material of the conductive wire, for example, an optional metal such as copper and aluminum is usable. Further, each of the inner coil 111 and the outer coil 112 is configured by independently winding the conductive wire.

[0024] In the following description, the inner coil 111 and the outer coil 112 are collectively referred to as the coils in some cases.

[0025] Fig. 3 is a block diagram illustrating a configuration of the induction heating cooker according to Embodiment 1.

bodiment 1.

[0026] As illustrated in Fig. 3, the inner coil 111 and the outer coil 112 are electrically connected in series. The inner coil 111 and the outer coil 112 are driven and controlled by one driver circuit 50.

[0027] A switcher unit 60 includes a first switcher unit 61 connected in parallel with the inner coil 111, and a second switcher unit 62 connected in parallel with the outer coil 112. The first switcher unit 61 switches the inner coil 111 into one of a conduction state in which a high-frequency current is supplied from the driver circuit 50 and a non-conduction state in which no high-frequency current is supplied from the driver circuit 50. The second switcher unit 62 switches the outer coil 112 into one of the conduction state in which the high-frequency current is supplied from the driver circuit 50 and the non-conduction state in which no high-frequency current is supplied from the driver circuit 50. Each of the first switcher unit 61 and the second switcher unit 62 includes, for example, a relay in which a contact switch is switched by an electric signal, or a switching element made of a semiconductor material.

[0028] When the high-frequency current is supplied from the driver circuit 50 to the inner coil 111 while the inner coil 111 is in the conduction state, a high-frequency magnetic field is generated from the inner coil 111. Further, when the high-frequency current is supplied from the driver circuit 50 to the outer coil 112 while the outer coil 112 is in the conduction state, a high-frequency magnetic field is generated from the outer coil 112.

[0029] The controller 45 includes dedicated hardware, or a CPU executing programs stored in a memory 48. The controller 45 further includes a load determination unit 46 determining presence/absence and a material of the heating target 5 placed above each of the inner coil 111 and the outer coil 112.

[0030] Note that CPU is an abbreviation of central processing unit. Further, the CPU is also referred to as a central processing device, a processing device, a calculation device, a microprocessor, a microcomputer, or a processor.

[0031] In a case where the controller 45 includes the dedicated hardware, the controller 45 is, for example, a single circuit, a composite circuit, an ASIC, an FPGA, or a combination thereof. Functional units realized by the controller 45 may be realized by individual hardware or may be realized by one hardware.

[0032] Note that ASIC is an abbreviation of application specific integrated circuit. Further, FPGA is an abbreviation of field-programmable gate array.

[0033] In a case where the controller 45 includes the CPU, each of the functions performed by the controller 45 is realized by software, firmware, or a combination of software and firmware. The software and the firmware are described as programs and are stored in the memory 48. The CPU reads out and executes the programs stored in the memory 48, to realize the functions of the controller 45. Examples of the memory 48 include a nonvolatile or

volatile semiconductor memory such as a RAM, a ROM, a flash memory, an EPROM, and an EEPROM.

[0034] A part of the functions of the controller 45 may be realized by dedicated hardware, and the other functions may be realized by software or firmware.

[0035] Note that RAM is an abbreviation of random access memory. ROM is an abbreviation of read only memory. EPROM is an abbreviation of erasable programmable read only memory. EEPROM is an abbreviation of electrically erasable programmable read-only memory.

[0036] Fig. 4 is a diagram illustrating the driver circuit of the induction heating cooker according to Embodiment 1.

[0037] Although the driver circuit 50 is provided for each of the heating units, the circuit configurations may be the same or different for each heating unit. Fig. 4 illustrates the driver circuit 50 driving the first induction heating unit 11.

[0038] As illustrated in Fig. 4, the driver circuit 50 includes a direct-current power supply circuit 22, an inverter circuit 23, and a resonance capacitor 24. The driver circuit 50 is connected to a resonance circuit that includes the inner coil 111, the outer coil 112, and the resonance capacitor 24. As illustrated in Fig. 4, the driver circuit 50 and the resonance circuit are connected at a terminal A and a terminal B.

[0039] The direct-current power supply circuit 22 includes a diode bridge 22a, a reactor 22b, and a smoothing capacitor 22c, converts an alternating-current voltage input from an alternating-current power supply 21 into a direct-current voltage, and outputs the direct-current voltage to the inverter circuit 23.

[0040] In the inverter circuit 23, an IGBT 23a and an IGBT 23b as switching elements are connected in series with an output of the direct-current power supply circuit 22. In the inverter circuit 23, a diode 23c and a diode 23d as flywheel diodes are respectively connected in parallel with the IGBT 23a and the IGBT 23b. The inverter circuit 23 is what is called a half-bridge inverter including one arm in which two switching elements are connected in series.

[0041] The IGBT 23a and the IGBT 23b are turned on or off by driving signals output from the controller 45. The controller 45 turns off the IGBT 23b while the IGBT 23a is turned on, and the controller 45 turns on the IGBT 23b while the IGBT 23a is turned off. The controller 45 outputs the driving signals alternately turns on and off the IGBT 23a and the IGBT 23b. As a result, the inverter circuit 23 converts direct-current power output from the direct-current power supply circuit 22 into a high-frequency alternating-current power of about 20 kHz to about 100 kHz, and supplies the power to the resonance circuit that includes the inner coil 111, the outer coil 112, and the resonance capacitor 24.

[0042] The resonance capacitor 24 is connected in series with the inner coil 111 and the outer coil 112. The resonance circuit that includes the inner coil 111, the outer coil 112, and the resonance capacitor 24 has a reso-

nance frequency corresponding to inductance of the inner coil 111 and the outer coil 112 and a capacitance of the resonance capacitor 24. The inductance of the inner coil 111 and the outer coil 112 is varied based on characteristics of a metal load when the heating target 5 as the metal load is magnetically coupled, and the resonance frequency of the resonance circuit is varied based on the variation of the inductance.

[0043] With such a configuration, the high-frequency current of about several tens A flows through the inner coil 111 in the conduction state. The heating target 5 placed on the top plate 4 just above the inner coil 111 is induction-heated by a high-frequency magnetic flux generated by the high-frequency current flowing through the inner coil 111.

[0044] Further, the high-frequency current of about several tens A flows through the outer coil 112 in the conduction state. The heating target 5 placed on the top plate 4 just above the outer coil 112 is induction-heated by a high-frequency magnetic flux generated by the high-frequency current flowing through the outer coil 112.

[0045] The IGBT 23a and the IGBT 23b as the switching elements are each made of, for example, a silicon semiconductor; however, the IGBT 23a and the IGBT 23b may be made of a wide band gap semiconductor material such as a silicon carbide material and a gallium nitride material.

[0046] Using the wide band gap semiconductor for the switching elements makes it possible to reduce a conduction loss of each of the switching elements. Even when a driving frequency is increased, namely, even when switching is performed at high speed, heat radiation of the driver circuit 50 is excellent. This enables downsizing of a heat radiation fin of the driver circuit 50, which makes it possible to realize downsizing and cost reduction of the driver circuit 50.

[0047] An input current detection unit 25a includes, for example, a current sensor. The input current detection unit 25a detects a current input from the alternating-current power supply 21 to the driver circuit 50, and outputs a voltage signal corresponding to a value of the input current to the controller 45.

[0048] A coil current detection unit 25b is connected to the resonance circuit that includes the inner coil 111, the outer coil 112, and the resonance capacitor 24. The coil current detection unit 25b includes, for example, a current sensor. The coil current detection unit 25b detects a current flowing through the inner coil 111 and the outer coil 112 and outputs a voltage signal corresponding to a value of the coil current to the controller 45.

[0049] Although the half-bridge driver circuit is illustrated in Fig. 4, the driver circuit of the present disclosure is not limited thereto. The inverter circuit 23 may be what is called a full-bridge inverter including two arms in which two switching elements are connected in series.

(Operation)

[0050] Next, an operation of the induction heating cooker according to Embodiment 1 is described.

[0051] Fig. 5 is a flowchart illustrating a heating operation of the induction heating cooker according to Embodiment 1.

[0052] In the following, the heating operation of the induction heating cooker 100 is described based on steps in Fig. 5.

[0053] When a user places the heating target 5 on the heating port and instructs the operation display unit 43 to start heating (input heating power), the controller 45 starts the heating operation.

[0054] The controller 45 opens the first switcher unit 61 to put the inner coil 111 into the conduction state, and closes the second switcher unit 62 to put the outer coil 112 into the non-conduction state (step S1). The load determination unit 46 determines presence/absence and a material of the heating target 5 above the inner coil 111 while the inner coil 111 is in the conduction state and the outer coil 112 is in the non-conduction state (step S2).

[0055] Fig. 6 is a load determination characteristic diagram based on relationship between the coil current and the input current in the induction heating cooker according to Embodiment 1.

[0056] As illustrated in Fig. 6, the relationship between the coil current and the input current is changed based on presence/absence and the material of the load placed above each of the inner coil 111 and the outer coil 112. The controller 45 previously stores a load determination table representing the relationship between the coil current and the input current illustrated in Fig. 6 in a table format, in the memory 48.

[0057] In the load determination operation in step S2, the controller 45 drives the inverter circuit 23 by a specific driving signal for the load determination, and detects the input current from an output signal of the input current detection unit 25a. At the same time, the controller 45 detects the coil current from an output signal of the coil current detection unit 25b. The load determination unit 46 of the controller 45 determines presence/absence and the material of the load placed above each of the coils, from the detected coil current, the detected input current, and the load determination table representing the relationship of Fig. 6. As described above, the load determination unit 46 of the controller 45 determines presence/absence and the material of the heating target 5 placed above each of the coils, based on correlation between the input current and the coil current.

[0058] The material of the heating target 5 as the load is roughly classified into a magnetic material such as iron and ferritic stainless steel (SUS430), and a nonmagnetic material such as aluminum and copper. Further, as the material of the heating target 5, there is a composite in which the magnetic material is attached to the nonmagnetic material.

[0059] Fig. 7 is a diagram illustrating a composite heat-

ing target that is induction-heated by the induction heating cooker according to Embodiment 1. Fig. 7 is a diagram of the heating target 5 as viewed from a bottom surface.

[0060] As illustrated in Fig. 7, the composite heating target 5 is formed by attaching a magnetic material 6 such as stainless steel to a center of a bottom of a frying pan made of the nonmagnetic material such as aluminum. The magnetic material 6 is attached to the nonmagnetic material by using an optional method, for example, bonding, welding, thermal spraying, pressure bonding, fitting, caulking, or embedding.

[0061] In the composite heating target 5, the magnetic material 6 is commonly attached to a flat center part of a bottom surface of a base made of the nonmagnetic material, and no magnetic material 6 is attached to a curved outer circumferential part of the bottom surface. When such a heating target 5 is placed on the heating port, the magnetic material and the nonmagnetic material are placed at positions that are above the plurality of heating coils. In other words, in the load determination, the load characteristics of a coil above which the magnetic material and the nonmagnetic material are placed become characteristics in a "composite region" that is a region between characteristics of the magnetic material and characteristics of the nonmagnetic material.

[0062] The material of the load placed above each of the coils, determined by the load determination unit 46 is a material of the load just above each of the coils. For example, in the case of the composite heating target 5 illustrated in Fig. 7, the magnetic material 6 is placed just above the inner coil 111, and the nonmagnetic material as the base of the heating target 5 is placed further above the magnetic material 6. In this case, the load determination unit 46 determines that the material of the load placed above the inner coil 111 is the magnetic material.

[0063] Referring back to Fig. 5, after step S2, the controller 45 determines whether the heating target 5 is present above the inner coil 111, based on the determination result of the load determination unit 46 (step S3). In a case where no heating target 5 is present above the inner coil 111, the controller 45 stops the operation of the driver circuit 50 (step S4). In other words, in the case where no heating target 5 is present above the inner coil 111, the controller 45 ends the load determination operation without determining presence/absence and the material of the heating target 5 above the outer coil 112.

[0064] In a case where the heating target 5 is present above the inner coil 111, the controller 45 determines the material of the heating target 5 above the inner coil 111 based on the determination result of the load determination unit 46 (step S5). In a case where the material of the heating target 5 above the inner coil 111 is the nonmagnetic material, the controller 45 stops the operation of the driver circuit 50 (step S4). In other words, in the case where the heating target 5 made of the nonmagnetic material is placed above the inner coil 111, the controller 45 determines that the heating target 5 is a load not suitable

for induction heating, and ends the load determination operation without determining presence/absence and the material of the heating target 5 above the outer coil 112.

[0065] In contrast, in a case where the material of the heating target 5 above the inner coil 111 is the magnetic material, the controller 45 closes the first switcher unit 61 to put the inner coil 111 into the non-conduction state, and opens the second switcher unit 62 to put the outer coil 112 into the conduction state (step S6). The load determination unit 46 determines presence/absence and the material of the heating target 5 above the outer coil 112 while the inner coil 111 is in the non-conduction state and the outer coil 112 is in the conduction state (step S7).

[0066] Next, the controller 45 determines whether the heating target 5 is present above the outer coil 112 and determines whether the material of the heating target 5 is the magnetic material or a material containing the non-magnetic material, based on the determination result of the load determination unit 46 (step S8). In a case where the load characteristics are in the composite region, the controller 45 determines that the material of the heating target 5 is a material containing the nonmagnetic material.

[0067] In a case where the material of the heating target 5 above the outer coil 112 contains the nonmagnetic material, the controller 45 determines that the heating target 5 is the composite, and performs the heating operation of the heating target 5 by a composite heating operation described below (step S9). In a case where no heating target 5 is present above the outer coil 112, the controller 45 determines that the heating target 5 is the magnetic material having a small diameter, and performs the heating operation of the heating target 5 by a small-diameter heating operation described below (step S10). In a case where the material of the heating target 5 above the outer coil 112 is the magnetic material, the controller 45 determines that the heating target 5 is the magnetic material having a large diameter, and performs the heating operation of the heating target 5 by a large-diameter heating operation described below (step S11).

[0068] In the following, each of the composite heating operation, the small-diameter heating operation, and the large-diameter heating operation is described in detail.

(Composite Heating Operation)

[0069] Fig. 8 is a diagram illustrating the heating coils and the heating target of the induction heating cooker according to Embodiment 1. Fig. 8 schematically illustrates a vertical cross-section in a state where the composite heating target 5 is placed on the heating port. Further, in Fig. 8, only a right side of a center C of each of the inner coil 111 and the outer coil 112 is illustrated, and illustration of the top plate 4 is omitted.

[0070] As illustrated in Fig. 8, in a case where the composite heating target 5 is placed on the heating port of the induction heating cooker 100, the load determination

unit 46 determines that the magnetic material is placed above the inner coil 111, by the above-described operation. Further, the load determination unit 46 determines that the nonmagnetic material is placed above the outer coil 112.

[0071] In a case where the material of the heating target 5 above the inner coil 111 is the magnetic material and the material of the heating target 5 above the outer coil 112 contains the nonmagnetic material, the controller 45 performs the following operation as the composite heating operation.

[Preheating Mode]

[0072] The preheating mode in the composite heating operation is a heating mode in which a temperature of the heating target 5 is increased to a preset temperature in a state where a cooking material and the like are not put into the heating target 5. In the preheating mode, the controller 45 performs heating attaching importance to the outer circumferential part of the composite heating target 5.

[0073] A heat capacity of the heating target 5 depends on the material. For example, a heat capacity of the non-magnetic material such as aluminum and copper is smaller than a heat capacity of the magnetic material such as iron and ferritic stainless steel (SUS430). Further, in a case where the bottom surface of the heating target 5 is curved at the outer circumferential part, a distance between the outer coil 112 and the heating target 5 may be separated more than a center part of the heating target 5, and the outer circumferential part of the heating target 5 may be difficult to be induction-heated. Therefore, increasing the temperature of the outer circumferential part of the heating target 5 before the cooking material and the like are put into the composite heating target 5 makes it possible to suppress nonuniformity of the temperature of the heating target 5 in the normal heating mode described below.

[0074] Fig. 9 is a diagram to explain an operation state of the first switcher unit and an operation state of the second switcher unit in the preheating mode of the induction heating cooker according to Embodiment 1.

[0075] As illustrated in Fig. 9, the controller 45 closes the first switcher unit 61 to put the inner coil 111 into the non-conduction state, and opens the second switcher unit 62 to put the outer coil 112 into the conduction state. In other words, the controller 45 stops supply of the high-frequency current to the inner coil 111 and supplies the high-frequency current to the outer coil 112. Further, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to the outer coil 112, to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz.

[0076] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 90 kHz. As a result, the outer circumferential part of the com-

posite heating target 5 placed on the top plate 4 is induction-heated.

[0077] When the controller 45 operates in a mode in which the controller 45 opens the first switcher unit 61 to put the inner coil 111 into the conduction state and closes the second switcher unit 62 to put the outer coil 112 into the non-conduction state, for a short time in a time-divisional manner, the bottom surface temperature of the heating target 5 is further uniformized, which is preferable. Alternatively, the controller 45 may operate in a mode in which the controller 45 opens the first switcher unit 61 to put the inner coil 111 into the conduction state and also opens the second switcher unit 62 to put the outer coil 112 into the conduction state, for a short time in a time-divisional manner, thereby further uniformizing the bottom surface temperature of the heating target 5.

[Normal Heating Mode]

[0078] The normal heating mode in the composite heating operation is a heating mode in which the whole of the heating target 5 is heated in a state where a cooking material and the like are put into the heating target 5. In the normal heating mode, the controller 45 heats both of the center part and the outer circumferential part of the composite heating target 5.

[0079] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 opens the first switcher unit 61 to put the inner coil 111 into the conduction state and closes the second switcher unit 62 to put the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 closes the first switcher unit 61 to put the inner coil 111 into the non-conduction state and opens the second switcher unit 62 to put the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to the outer coil 112.

[0080] Further, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to the inner coil 111, to a first frequency, and sets the frequency of the high-frequency current supplied from the driver circuit 50 to the outer coil 112, to a second frequency higher than the first frequency. For example, the controller 45 sets the first frequency to a preset frequency corresponding to the magnetic material, for example, near 25 kHz. Further, for example, the controller 45 sets the second frequency to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz.

[0081] The controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 25 kHz or near 90 kHz. As a result, the whole of the composite heating target 5 placed on the top plate 4 is induction-heated. In other words, the normal heating mode is a heating mode in which a power amount supplied to the inner coil 111

is increased as compared with the preheating mode.

[0082] The reason why the second frequency of the high-frequency current supplied from the driver circuit 50 to the outer coil 112 is set higher than the first frequency of the high-frequency current supplied to the inner coil 111 is as follows.

[0083] To perform induction heating of the nonmagnetic material such as aluminum, it is necessary to reduce a skin depth and a penetration volume of an eddy current generated in the heating target 5, to increase impedance of the current. Therefore, when the high-frequency current (for example, 80 kHz or more and 100 kHz or less) is supplied to the outer coil 112 above which the nonmagnetic material is placed, to generate the high-frequency eddy current in the nonmagnetic material, the heating target 5 can be heated by Joule heat.

[0084] On the other hand, in the magnetic material such as iron, impedance to the eddy current is large. Therefore, even when the high-frequency current of the frequency (for example, 20 kHz or more and 35 kHz or less) lower than the frequency of the high-frequency current supplied to the outer coil 112 is supplied to the inner coil 111 above which the magnetic material is placed, the heating target 5 can be sufficiently heated by Joule heat of the eddy current.

[0085] When a plurality of induction heating units are simultaneously driven at the plurality of heating ports, interference sound corresponding to a difference among the driving frequencies may occur. To suppress such interference sound, the controller 45 may make the second frequency higher than the first frequency by an audible frequency or more (about 20 kHz or more). Even when the heating operation is simultaneously performed at the plurality of heating ports, it is possible to suppress occurrence of the interference sound.

[0086] In the configuration in which the high-frequency current is supplied from one driver circuit 50 to each of the inner coil 111 and the outer coil 112, such composite heating operation enables induction heating suitable for the material of the composite heating target 5. Further, it is possible to suppress nonuniformity of the heating temperature when the composite heating target 5 is heated.

(Small-Diameter Heating Operation)

[0087] Fig. 10 is a diagram to explain the operation state of the first switcher unit and the operation state of the second switcher unit in the small-diameter heating operation of the induction heating cooker according to Embodiment 1.

[0088] In a case where the heating target 5 is present above the inner coil 111 and no heating target 5 is present above the outer coil 112, the controller 45 performs the small-diameter heating operation.

[0089] As illustrated in Fig. 10, the controller 45 opens the first switcher unit 61 to put the inner coil 111 into the conduction state, and closes the second switcher unit 62

to put the outer coil 112 into the non-conduction state. In other words, the controller 45 supplies the high-frequency current from the driver circuit 50 to the inner coil 111, but stops supply of the high-frequency current from the driver circuit 50 to the outer coil 112. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to the inner coil 111, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0090] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 20 kHz. As a result, the whole of the heating target 5 having the small diameter placed on the top plate 4 is induction-heated.

[0091] In the small-diameter heating operation, no high-frequency current is supplied to the outer coil 112 above which no heating target 5 is placed. This enables effective use of energy. Further, it is possible to prevent unnecessary magnetic field from being radiated from the outer coil 112.

(Large-Diameter Heating Operation)

[0092] Fig. 11 is a diagram to explain the operation state of the first switcher unit and the operation state of the second switcher unit in the large-diameter heating operation of the induction heating cooker according to Embodiment 1.

[0093] In a case where the heating target 5 is present above the inner coil 111 and the outer coil 112, the controller 45 performs the following operation.

[Normal Heating Mode]

[0094] The normal heating mode in the large-diameter heating operation is a heating mode in which the whole of the heating target 5 having the large diameter is heated. In the normal heating mode, the controller 45 heats both of the center part and the outer circumferential part of the heating target 5 having the large diameter.

[0095] As illustrated in Fig. 11, the controller 45 opens the first switcher unit 61 and the second switcher unit 62 to put the inner coil 111 and the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the inner coil 111 and the outer coil 112. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the inner coil 111 and the outer coil 112, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0096] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 20 kHz. As a result, the whole of the heating target 5 having the large diameter placed on the top plate 4 is induction-heated.

[0097] Such a large-diameter heating operation in the

normal heating mode enables induction heating suitable for the size and the material of the heating target 5.

[Convection Mode]

[0098] The convection mode is a cooking mode in which convection is generated in a liquid cooking material contained in the heating target 5 in cooking such as stewing and noodle boiling.

[0099] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 into the conduction state and puts the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 puts the inner coil 111 into the non-conduction state and puts the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to the outer coil 112. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the coils, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0100] In such a large-diameter heating operation in the convection mode, heating of the center part of the heating target 5 by the inner coil 111 and heating of the outer circumferential part of the heating target 5 by the outer coil 112 are alternately repeated. As a result, convection is generated in the liquid cooking material such as soup contained in the heating target 5, which makes it possible to diffuse the liquid cooking material. In other words, in the configuration in which the inner coil 111 and the outer coil 112 are driven by one driver circuit 50, it is possible to generate convection in the liquid cooking material contained in the heating target 5.

[0101] As described above, in Embodiment 1, the plurality of heating coils, one driver circuit 50 supplying the high-frequency current to each of the plurality of heating coils, and the switcher unit 60 switching each of the plurality of heating coils into one of the conduction state in which the high-frequency current is supplied from the driver circuit 50 and the non-conduction state in which no high-frequency current is supplied from the driver circuit 50, are provided. Therefore, as compared with a configuration in which the driver circuit 50 is provided for each of the plurality of heating coils, it is possible to simplify the circuit configuration. This makes it possible to reduce a manufacturing cost of the induction heating cooker 100. Further, in the configuration in which the plurality of heating coils are driven by one driver circuit 50, it is possible to switch each of the plurality of heating coils into one of the conduction state and the non-conduction state.

[0102] Further, in Embodiment 1, the controller 45 determines whether the heating target 5 is present above the inner coil 111 while the inner coil 111 is in the conduction state and the outer coil 112 is in the non-conduction state. In a case where no heating target 5 is present

above the inner coil 111, the controller 45 stops the operation of the driver circuit 50. Therefore, in the configuration in which the plurality of heating coils are driven by one driver circuit 50, it is possible to rapidly stop the load determination operation in the no-load state.

[0103] Further, the composite heating operation, the small-diameter heating operation, or the large-diameter heating operation is performed depending on the determination result of the material of the heating target 5 above the inner coil 111 and the determination result of the material of the heating target 5 above the outer coil 112. Therefore, in the configuration in which the plurality of heating coils are driven by one driver circuit 50, it is possible to perform induction heating suitable for the size and the material of the heating target 5.

[0104] Note that, in the above-described heating operation (Fig. 5), the following operation may be performed after step S7. The controller 45 opens both of the first switcher unit 61 and the second switcher unit 62 to put both of the inner coil 111 and the outer coil 112 into the conduction state. In this state, the load determination unit 46 determines presence/absence and the material of the heating target 5 above each of the inner coil 111 and the outer coil 112. Adding such an operation makes it possible to grasp characteristics of the whole of the heating target 5.

(Modification 1)

[0105] The switcher unit 60 may include only one of the first switcher unit 61 and the second switcher unit 62. A specific example is described below.

[0106] Fig. 12 is a diagram illustrating a configuration of a switcher unit in Modification 1 of the induction heating cooker according to Embodiment 1.

[0107] As illustrated in Fig. 12, the first switcher unit 61 may be omitted and only the second switcher unit 62 may be provided. In the case where the heating target 5 has the small diameter, such a configuration enables the controller 45 to perform the above-described small-diameter heating operation.

[0108] Fig. 13 is a diagram illustrating another configuration of the switcher unit in Modification 1 of the induction heating cooker according to Embodiment 1.

[0109] As illustrated in Fig. 13, the second switcher unit 62 may be omitted and only the first switcher unit 61 may be provided. In the case where the heating target 5 is the composite, such a configuration enables the controller 45 to perform the composite heating operation of the preheating mode described above.

(Modification 2)

[0110] The inner coil 111 and the outer coil 112 are not limited to the circular coils concentrically arranged, and may have optional shapes. Further, each of the inner coil 111 and the outer coil 112 is not limited to one integrated coil, and may include a plurality of coils arranged in se-

ries. A specific example is described below.

[0111] Fig. 14 is a plan view illustrating a first induction heating unit in Modification 2 of the induction heating cooker according to Embodiment 1.

[0112] As illustrated in Fig. 14, the first induction heating unit 11 includes the inner coil 111 disposed at the center of the first induction heating port 1 and the outer coil 112 disposed on the outer circumference of the inner coil 111.

[0113] The inner coil 111 includes a circular coil 111a and a circular coil 111b that are concentrically arranged. The circular coils 111a and 111b are connected in series. The first switcher unit 61 is connected in parallel with a serial circuit of the circular coils 111a and 111b. The first switcher unit 61 switches each of the circular coils 111a and 111b into one of the conduction state and the non-conduction state.

[0114] The outer coil 112 includes an elliptical coil 112a, an elliptical coil 112b, an elliptical coil 112c, and an elliptical coil 112d. The elliptical coils 112a to 112d each have a substantially 1/4-arc (banana-shaped or cucumber-shaped) flat shape, and are arranged on the outside of the inner coil 111 substantially along the outer circumference of the inner coil 111. The elliptical coils 112a to 112d are connected in series. The second switcher unit 62 is connected in parallel with a serial circuit of the elliptical coils 112a to 112d. The second switcher unit 62 switches each of the elliptical coils 112a to 112d into one of the conduction state and the non-conduction state. In such a configuration, the above-described heating operation is performable and similar effects are achievable.

[0115] The inner coil 111 and the outer coil 112 may be configured by three or more circular heating coils that are concentrically arranged. In other words, the three or more circular heating coils are classified into the heating coils disposed on the inner circumferential side and the other heating coils disposed on the outer circumferential side. The first switcher unit 61 is connected in parallel with the heating coils on the inner circumferential side among the plurality of heating coils, and switches each of the heating coils into one of the conduction state and the non-conduction state. The second switcher unit 62 is connected in parallel with the other heating coils on the outer circumferential side among the plurality of heating coils, and switches each of the coils into one of the conduction state and the non-conduction state. In such a configuration, the above-described heating operation is performable and similar effects are achievable.

Embodiment 2.

[0116] A configuration and an operation of an induction heating cooker according to Embodiment 2 are described below while focusing on differences with Embodiment 1 described above. Note that the components same as the components in Embodiment 1 described above are denoted by the same reference numerals, and descriptions of the components are omitted.

[0117] Fig. 15 is a plan view illustrating a first induction heating unit of the induction heating cooker according to Embodiment 2.

[0118] As illustrated in Fig. 15, the first induction heating unit 11 includes an intermediate coil 113 disposed between the inner coil 111 and the outer coil 112. The intermediate coil 113 is configured by winding a conductive wire made of an insulation-coated metal. As a material of the conductive wire, for example, an optional metal such as copper and aluminum is usable. Further, each of the inner coil 111, the intermediate coil 113, and the outer coil 112 is configured by independently winding the conductive wire.

[0119] Fig. 16 is a block diagram illustrating the configuration of the induction heating cooker according to Embodiment 2.

[0120] As illustrated in Fig. 16, the inner coil 111, the intermediate coil 113, and the outer coil 112 are electrically connected in series. The inner coil 111, the intermediate coil 113, and the outer coil 112 are driven and controlled by one driver circuit 50.

[0121] The switcher unit 60 includes the first switcher unit 61 connected in parallel with the inner coil 111, the second switcher unit 62 connected in parallel with the outer coil 112, and a third switcher unit 63 connected in parallel with the intermediate coil 113. The third switcher unit 63 switches the intermediate coil 113 into one of the conduction state in which the high-frequency current is supplied from the driver circuit 50 and the non-conduction state in which no high-frequency current is supplied from the driver circuit 50. The third switcher unit 63 includes, for example, a relay in which a contact switch is switched by an electric signal, or a switching element made of a semiconductor material. When the high-frequency current is supplied from the driver circuit 50 to the intermediate coil 113 while the intermediate coil 113 is in the conduction state, a high-frequency magnetic field is generated from the intermediate coil 113.

[0122] Fig. 17 is a diagram illustrating a circuit configuration of the induction heating cooker according to Embodiment 2.

[0123] As illustrated in Fig. 17, a resonance circuit that includes the inner coil 111, the intermediate coil 113, the outer coil 112, and the resonance capacitor 24 is connected to the terminal A and the terminal B that are contact points with the driver circuit 50. The resonance circuit that includes the inner coil 111, the intermediate coil 113, the outer coil 112, and the resonance capacitor 24 has a resonance frequency corresponding to inductance of the inner coil 111, the intermediate coil 113, and the outer coil 112, and a capacitance of the resonance capacitor 24. The inductance of the inner coil 111, the intermediate coil 113, and the outer coil 112 is varied based on characteristics of a metal load when the heating target 5 as the metal load is magnetically coupled, and the resonance frequency of the resonance circuit is varied based on the variation of the inductance.

[0124] With such a configuration, the high-frequency

current of about several tens A flows through the inner coil 111 in the conduction state. The heating target 5 placed on the top plate 4 just above the inner coil 111 is induction-heated by a high-frequency magnetic flux generated by the high-frequency current flowing through the inner coil 111.

[0125] Further, the high-frequency current of about several tens A flows through the intermediate coil 113 in the conduction state. The heating target 5 placed on the top plate 4 just above the intermediate coil 113 is induction-heated by a high-frequency magnetic flux generated by the high-frequency current flowing through the intermediate coil 113.

[0126] Furthermore, the high-frequency current of about several tens A flows through the outer coil 112 in the conduction state. The heating target 5 placed on the top plate 4 just above the outer coil 112 is induction-heated by a high-frequency magnetic flux generated by the high-frequency current flowing through the outer coil 112.

(Operation)

[0127] Next, an operation of the induction heating cooker according to Embodiment 2 is described.

[0128] Fig. 18 and Fig. 19 are flowcharts illustrating a heating operation of the induction heating cooker according to Embodiment 2.

[0129] In the following, the heating operation of the induction heating cooker 100 is described based on steps in Fig. 18 and Fig. 19 while focusing on differences with Embodiment 1 described above.

[0130] The controller 45 opens the first switcher unit 61 to put the inner coil 111 into the conduction state, closes the third switcher unit 63 to put the intermediate coil 113 into the non-conduction state, and closes the second switcher unit 62 to put the outer coil 112 into the non-conduction state (step S21). The load determination unit 46 determines presence/absence and the material of the heating target 5 above the inner coil 111 while the inner coil 111 is in the conduction state and the intermediate coil 113 and the outer coil 112 are in the non-conduction state (step S22).

[0131] Next, the controller 45 determines whether the heating target 5 is present above the inner coil 111 based on the determination result of the load determination unit 46 (step S23). In a case where no heating target 5 is present above the inner coil 111, the controller 45 stops the operation of the driver circuit 50 (step S24). In other words, in the case where no heating target 5 is present above the inner coil 111, the controller 45 ends the load determination operation without determining presence/absence and the material of the heating target 5 above each of the intermediate coil 113 and the outer coil 112.

[0132] In a case where the heating target 5 is present above the inner coil 111, the controller 45 determines the material of the heating target 5 above the inner coil 111

based on the determination result of the load determination unit 46 (step S25). In a case where the material of the heating target 5 above the inner coil 111 is the non-magnetic material, the controller 45 stops the operation of the driver circuit 50 (step S24).

[0133] In contrast, in a case where the material of the heating target 5 above the inner coil 111 is the magnetic material, the controller 45 closes the first switcher unit 61 to put the inner coil 111 into the non-conduction state. In addition, the controller 45 opens the third switcher unit 63 to put the intermediate coil 113 into the conduction state, and closes the second switcher unit 62 to put the outer coil 112 into the non-conduction state (step S26). The load determination unit 46 determines presence/absence and the material of the heating target 5 above the intermediate coil 113 while the inner coil 111 and the outer coil 112 are in the non-conduction state and the intermediate coil 113 is in the conduction state (step S27).

[0134] Next, the controller 45 closes the third switcher unit 63 to put the intermediate coil 113 into the non-conduction state, and opens the second switcher unit 62 to put the outer coil 112 into the conduction state (step S28). The load determination unit 46 determines presence/absence and the material of the heating target 5 above the outer coil 112 while the inner coil 111 and the intermediate coil 113 are in the non-conduction state and the outer coil 112 is in the conduction state (step S29).

[0135] The controller 45 determines whether the heating target 5 is present above the intermediate coil 113 and determines whether the material of the heating target 5 is the magnetic material or a material containing the nonmagnetic material, based on the determination result of the load determination unit 46 (step S30).

[0136] In a case where the material of the heating target 5 above the intermediate coil 113 contains the non-magnetic material in step S30, the controller 45 determines whether the heating target 5 is present above the outer coil 112 and determines whether the material of the heating target 5 is the magnetic material or a material containing the nonmagnetic material, based on the determination result of the load determination unit 46 (step S31).

[0137] In a case where the material of the heating target 5 above the outer coil 112 contains the nonmagnetic material in step S31, the controller 45 determines that the heating target 5 is a composite having a large diameter, and performs the heating operation of the heating target 5 by a large-diameter composite heating operation described below (step S32).

[0138] In a case where no heating target 5 is present above the outer coil 112 in step S31, the controller 45 determines that the heating target 5 is a composite having a middle diameter, and performs the heating operation of the heating target 5 by a middle-diameter composite heating operation described below (step S33).

[0139] In a case where the material of the heating target 5 above the intermediate coil 113 is the magnetic material in step S30, the controller 45 determines whether

the heating target 5 is present above the outer coil 112 and determines whether the material of the heating target 5 is the magnetic material or a material containing the nonmagnetic material, based on the determination result of the load determination unit 46 (step S34).

[0140] In a case where the material of the heating target 5 above the outer coil 112 is the magnetic material in step S34, the controller 45 determines that the heating target 5 is a magnetic material having a large diameter, and performs the heating operation of the heating target 5 by a large-diameter magnetic-material heating operation described below (step S35).

[0141] In a case where no heating target 5 is present above the outer coil 112 in step S34, the controller 45 determines that the heating target 5 is a magnetic material having a middle diameter, and performs the heating operation of the heating target 5 by a middle-diameter magnetic-material heating operation described below (step S36).

[0142] In a case where no heating target 5 is present above the intermediate coil 113 in step S30, the controller 45 determines that the heating target 5 is a magnetic material having a small diameter, and performs the heating operation of the heating target 5 by a small-diameter magnetic-material heating operation described below (step S37).

[0143] Each heating operation is described in detail below.

(Large-Diameter Composite Heating Operation)

[0144] In the large-diameter composite heating operation, the controller 45 operates in the preheating mode in which heating is performed by attaching importance to the outer circumferential part of the composite heating target 5, and in the normal heating mode in which the whole of the heating target 5 is heated.

[Preheating Mode]

[0145] The controller 45 puts the inner coil 111 into the non-conduction state and puts the intermediate coil 113 and the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the intermediate coil 113 and the outer coil 112. Further, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the intermediate coil 113 and the outer coil 112, to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz.

[0146] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 90 kHz. As a result, the outer circumferential part of the composite heating target 5 placed on the top plate 4 is induction-heated.

[0147] The controller 45 may operate in a mode in which the controller 45 opens the first switcher unit 61 to

put the inner coil 111 into the conduction state and closes the second switcher unit 62 and the third switcher unit 63 to put the outer coil 112 and the intermediate coil 113 into the non-conduction state, for a short time in a time-divisional manner. Alternatively, the controller 45 may operate in a mode in which the controller 45 opens all of the first switcher unit 61, the second switcher unit 62, and the third switcher unit 63 to put all of the inner coil 111, the intermediate coil 113, and the outer coil 112 into the conduction state, for a short time in a time-divisional manner. This operation makes it possible to further uniformize the temperature of the heating target 5.

[Normal Heating Mode]

[0148] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 into the conduction state and puts the intermediate coil 113 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current of a first frequency from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 puts the inner coil 111 into the non-conduction state and puts the intermediate coil 113 and the outer coil 112 into the conduction state, and supplies the high-frequency current of a second frequency higher than the first frequency, from the driver circuit 50 to each of the intermediate coil 113 and the outer coil 112.

[0149] The controller 45 sets the first frequency to a preset frequency corresponding to the magnetic material, for example, near 25 kHz. Further, the controller 45 sets the second frequency to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz. The controller 45 may make the second frequency higher than the first frequency by an audible frequency or more (about 20 kHz or more).

[0150] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 25 kHz or near 90 kHz. As a result, the whole of the composite heating target 5 placed on the top plate 4 is induction-heated.

[0151] In the configuration in which the high-frequency current is supplied from one driver circuit 50 to each of the inner coil 111, the intermediate coil 113, and the outer coil 112, such a composite heating operation enables induction heating suitable for the material and the size of the composite heating target 5. Further, it is possible to suppress nonuniformity of the heating temperature when the composite heating target 5 is heated.

(Middle-Diameter Composite Heating Operation)

[0152] In the middle-diameter composite heating operation, the controller 45 operates in the preheating mode in which heating is performed by attaching importance to the outer circumferential part of the composite heating

target 5, and in the normal heating mode in which the whole of the heating target 5 is heated.

[Preheating Mode]

[0153] The controller 45 puts the inner coil 111 and the outer coil 112 into the non-conduction state and puts the intermediate coil 113 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to the intermediate coil 113. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to the intermediate coil 113, to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz.

[0154] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 90 kHz. As a result, the outer circumferential part of the composite heating target 5 placed on the top plate 4 is induction-heated.

[Normal Heating Mode]

[0155] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 into the conduction state and puts the intermediate coil 113 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current of a first frequency from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 puts the inner coil 111 and the outer coil 112 into the non-conduction state and puts the intermediate coil 113 into the conduction state, and supplies the high-frequency current of a second frequency higher than the first frequency, from the driver circuit 50 to the intermediate coil 113.

[0156] The controller 45 sets the first frequency to a preset frequency corresponding to the magnetic material, for example, near 25 kHz. Further, the controller 45 sets the second frequency to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz. The controller 45 may make the second frequency higher than the first frequency by an audible frequency or more (about 20 kHz or more).

[0157] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 25 kHz or near 90 kHz. As a result, the whole of the composite heating target 5 placed on the top plate 4 is induction-heated.

[0158] In the configuration in which the high-frequency current is supplied from one driver circuit 50 to each of the inner coil 111, the intermediate coil 113, and the outer coil 112, such a composite heating operation enables induction heating suitable for the material and the size of the composite heating target 5. Further, it is possible to suppress nonuniformity of the heating temperature when the composite heating target 5 is heated.

(Large-Diameter Magnetic-Material Heating Operation)

[0159] In the large-diameter magnetic-material heating operation, the controller 45 operates in the normal heating mode in which the whole of the heating target 5 having a large diameter is heated, and in the convection mode in which convection is generated in a liquid cooking material contained in the heating target 5.

[Normal Heating Mode]

[0160] The controller 45 puts the inner coil 111, the intermediate coil 113, and the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the inner coil 111, the intermediate coil 113, and the outer coil 112. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the coils, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0161] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 20 kHz. As a result, the whole of the heating target 5 having a large diameter placed on the top plate 4 is induction-heated.

[0162] Such a large-diameter magnetic-material heating operation in the normal heating mode enables induction heating suitable for the size and the material of the heating target 5.

[Convection Mode]

[0163] The controller 45 puts some of the heating coils among the inner coil 111, the intermediate coil 113, and the outer coil 112 into the conduction state, supplies the high-frequency current from the driver circuit 50, and switches the heating coil to be put into the conduction state with lapse of time, thereby sequentially changing the heating coil to be supplied with the high-frequency current. In the following, specific examples of patterns 1 to 4 are described.

<Pattern 1>

[0164] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 and the outer coil 112 into the conduction state and puts the intermediate coil 113 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the inner coil 111 and the outer coil 112. In the second operation, the controller 45 puts the inner coil 111 into the non-conduction state and puts the intermediate coil 113 and the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the intermediate coil 113 and the outer coil 112.

<Pattern 2>

[0165] The controller 45 sequentially performs a first operation, a second operation, and a third operation described below. In the first operation, the controller 45 puts the inner coil 111 into the conduction state and puts the intermediate coil 113 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 puts the intermediate coil 113 into the conduction state and puts the inner coil 111 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the intermediate coil 113. In the third operation, the controller 45 puts the outer coil 112 into the conduction state and puts the inner coil 111 and the intermediate coil 113 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the outer coil 112.

<Pattern 3>

[0166] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 into the conduction state and puts the intermediate coil 113 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 puts the inner coil 111 into the non-conduction state and puts the intermediate coil 113 and the outer coil 112 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the intermediate coil 113 and the outer coil 112.

<Pattern 4>

[0167] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 and the outer coil 112 into the non-conduction state and puts the intermediate coil 113 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to the intermediate coil 113. In the second operation, the controller 45 puts the inner coil 111 and the outer coil 112 into the conduction state and puts the intermediate coil 113 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the inner coil 111 and the outer coil 112.

[0168] In any of the patterns 1 to 4, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the coils, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0169] Such a large-diameter magnetic-material heating operation in the convection mode causes convection in the liquid cooking material such as soup contained in the heating target 5, which makes it possible to diffuse

the liquid cooking material. In other words, in the configuration in which the inner coil 111, the intermediate coil 113, and the outer coil 112 are driven by one driver circuit 50, it is possible to generate convection in the liquid cooking material contained in the heating target 5.

(Middle-Diameter Magnetic-Material Heating Operation)

[0170] In the middle-diameter magnetic-material heating operation, the controller 45 operates in the normal heating mode in which the whole of the heating target 5 having a middle diameter is heated, and in the convection mode in which convection is generated in a liquid cooking material contained in the heating target 5.

[Normal Heating Mode]

[0171] The controller 45 puts the inner coil 111 and the intermediate coil 113 into the conduction state and puts the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to each of the inner coil 111 and the intermediate coil 113. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the coils, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0172] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 20 kHz. As a result, the whole of the heating target 5 having the large diameter placed on the top plate 4 is induction-heated.

[0173] Such a middle-diameter magnetic-material heating operation in the normal heating mode enables induction heating suitable for the size and the material of the heating target 5.

[Convection Mode]

[0174] The controller 45 alternately repeats a first operation and a second operation described below. In the first operation, the controller 45 puts the inner coil 111 into the conduction state and puts the intermediate coil 113 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the inner coil 111. In the second operation, the controller 45 puts the inner coil 111 and the outer coil 112 into the non-conduction state and puts the intermediate coil 113 into the conduction state, and supplies the high-frequency current from the driver circuit 50 to the intermediate coil 113. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to each of the coils, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0175] Such a middle-diameter large-diameter heating operation in the convection mode causes convection in the liquid cooking material such as soup contained in the

heating target 5, which makes it possible to diffuse the liquid cooking material. In other words, in the configuration in which the inner coil 111, the intermediate coil 113, and the outer coil 112 are driven by one driver circuit 50, it is possible to generate convection in the liquid cooking material contained in the heating target 5.

(Small-Diameter Magnetic-Material Heating Operation)

[0176] The controller 45 puts the inner coil 111 into the conduction state and puts the intermediate coil 113 and the outer coil 112 into the non-conduction state, and supplies the high-frequency current from the driver circuit 50 to the inner coil 111. The controller 45 supplies the high-frequency current from the driver circuit 50 to the inner coil 111, and stops supply of the high-frequency current from the driver circuit 50 to each of the intermediate coil 113 and the outer coil 112. In addition, the controller 45 sets the frequency of the high-frequency current supplied from the driver circuit 50 to the inner coil 111, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0177] Further, the controller 45 controls heating power (power) by varying the driving frequency of each of the switching elements of the inverter circuit 23 near 20 kHz. As a result, the whole of the heating target 5 made of the magnetic material and having the small diameter placed on the top plate 4 is induction-heated.

[0178] In such a small-diameter magnetic-material heating operation, no high-frequency current is supplied to each of the intermediate coil 113 and the outer coil 112 above which no heating target 5 is placed. This enables effective use of energy. Further, it is possible to prevent unnecessary magnetic field from being radiated from the intermediate coil 113 and the outer coil 112.

[0179] As described above, in Embodiment 2, the controller 45 determines whether the heating target 5 is present above the inner coil 111 while the inner coil 111 is in the conduction state and the intermediate coil 113 and the outer coil 112 are in the non-conduction state. In the case where no heating target 5 is present above the inner coil 111, the controller 45 stops the operation of the driver circuit 50. Accordingly, in the configuration in which the plurality of heating coils are driven by one driver circuit 50, it is possible to rapidly stop the load detection operation in the no-load state.

[0180] Further, the heating operation is performed based on the determination result of presence/absence and the material of the heating target 5 above each of the inner coil 111, the intermediate coil 113, and the outer coil 112. Accordingly, in the configuration in which the plurality of heating coils are driven by one driver circuit 50, it is possible to perform induction heating suitable for the size and the material of the heating target 5.

(Modification 1)

[0181] The switcher unit 60 may have a configuration

in which any one of the first switcher unit 61, the third switcher unit 63, and the second switcher unit 62 is omitted. A specific example is described below.

[0182] Fig. 20 is a diagram illustrating a configuration of a switcher unit in Modification 1 of the induction heating cooker according to Embodiment 2.

[0183] As illustrated in Fig. 20, the first switcher unit 61 may be omitted, and the third switcher unit 63 and the second switcher unit 62 may be provided. In the case where the heating target 5 is made of the magnetic material, such a configuration enables the controller 45 to perform the small-diameter magnetic-material heating operation, the middle-diameter magnetic-material heating operation, or the large-diameter magnetic-material heating operation each described above based on the size of the heating target 5. Further, in the case where the heating target 5 has the middle diameter, the controller 45 can perform the above-described middle-diameter magnetic-material heating operation. Furthermore, in the middle-diameter magnetic-material heating operation or the large-diameter magnetic-material heating operation, the controller 45 can operate in the above-described convection mode.

[0184] Fig. 21 is a diagram illustrating another configuration of the switcher unit in Modification 1 of the induction heating cooker according to Embodiment 2.

[0185] As illustrated in Fig. 21, the second switcher unit 62 may be omitted, and the first switcher unit 61 and the third switcher unit 63 may be provided. In the case where the heating target 5 is made of the composite and has the large diameter, such a configuration enables the controller 45 to perform the above-described large-diameter composite heating operation.

(Modification 2)

[0186] The inner coil 111, the intermediate coil 113, and the outer coil 112 are not limited to the circular coils concentrically arranged, and may have optional shapes. Further, each of the inner coil 111, the intermediate coil 113, and the outer coil 112 is not limited to one integrated coil, and may include a plurality of coils arranged in series.

[0187] For example, the inner coil 111, the intermediate coil 113, and the outer coil 112 may be configured by four or more circular heating coils that are concentrically arranged. In other words, the four or more circular heating coils are classified into three heating coil groups disposed on the inner circumferential side, the intermediate side, and the outer circumferential side. The first switcher unit 61 is connected in parallel with the heating coil group on the inner circumferential side among the plurality of heating coils, and switches each of the heating coils of the connected heating coil group into one of the conduction state and the non-conduction state. The third switcher unit 63 is connected in parallel with the heating coil group on the intermediate side among the plurality of heating coils, and switches each of the heating coils

of the connected heating coil group into one of the conduction state and the non-conduction state. The second switcher unit 62 is connected in parallel with the heating coil group on the outer circumferential side among the plurality of heating coils, and switches each of the heating coils of the connected heating coil group into one of the conduction state and the non-conduction state. In such a configuration, the above-described heating operation is performable and similar effects are achievable.

Embodiment 3.

[0188] A configuration and an operation of an induction heating cooker according to Embodiment 3 are described below while focusing on differences with Embodiments 1 and 2 described above. Note that the components same as the components in Embodiments 1 and 2 described above are denoted by the same reference numerals, and descriptions of the components are omitted.

[0189] Fig. 22 is a diagram illustrating a circuit configuration of the induction heating cooker according to Embodiment 3.

[0190] As illustrated in Fig. 22, the driver circuit 50 is connected to a resonance circuit that includes the inner coil 111, the outer coil 112, a resonance capacitor 24a, and a resonance capacitor 24b.

[0191] The resonance capacitor 24a is connected in series with the inner coil 111 and the outer coil 112. The resonance capacitor 24b is connected in parallel with the resonance capacitor 24a through a selector switch 70.

[0192] The selector switch 70 includes, for example, a relay in which a contact switch is switched by an electric signal, or a switching element made of a semiconductor material. When the selector switch 70 is closed, the resonance capacitor 24b is connected in parallel with the resonance capacitor 24a. When the selector switch 70 is opened, the resonance capacitor 24b is disconnected. In other words, when the selector switch 70 is closed, a capacitance of the resonance capacitor configuring the resonance circuit together with the inner coil 111 and the outer coil 112 is increased. In contrast, when the selector switch 70 is opened, the capacitance of the resonance capacitor configuring the resonance circuit together with the inner coil 111 and the outer coil 112 is decreased.

(Operation)

[0193] The controller 45 switches the selector switch 70 to vary the capacitance of the resonance capacitor based on at least one of switching of each of the plurality of heating coils into one of the conduction state and the non-conduction state and the frequency of the high-frequency current. In other words, the controller 45 decreases the capacitance of the resonance capacitor as the number of heating coils in the conduction state increases among the plurality of heating coils. Further, the controller 45 decreases the capacitance of the resonance capacitor as the frequency of the high-frequency current increases.

[0194] Specific examples for the composite heating operation, the small-diameter heating operation, and the large-diameter heating operation in Embodiment 1 described above are individually described below.

(Composite Heating Operation)

[Preheating Mode]

[0195] In the preheating mode of the composite heating operation, the controller 45 puts the outer coil 112 into the conduction state, and performs heating attaching importance to the outer circumferential part of the heating target 5. In addition, the controller 45 sets the frequency of the high-frequency current supplied to the outer coil 112 to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz.

[0196] In this operation, the controller 45 opens the selector switch 70 to decrease the capacitance of the resonance capacitor configuring the resonance circuit together with the outer coil 112. As a result, the resonance frequency of the resonance circuit is increased and the resonance frequency and the driving frequency of the driver circuit 50 can be brought close to each other, which makes it possible to improve heating efficiency to the outer coil 112.

[Normal Heating Mode]

[0197] In the normal heating mode of the composite heating operation, the controller 45 alternately repeats a first operation in which the controller 45 puts only the inner coil 111 into the conduction state, and a second operation in which the controller 45 puts only the outer coil 112 into the conduction state. In the first operation, the controller 45 sets the frequency of the high-frequency current supplied to the inner coil 111, to a frequency corresponding to the magnetic material, for example, near 25 kHz. In the second operation, the controller 45 sets the frequency of the high-frequency current supplied to the outer coil 112, to a frequency corresponding to the nonmagnetic material, for example, near 90 kHz.

[0198] In the first operation, the controller 45 closes the selector switch 70 to increase the capacitance of the resonance capacitor configuring the resonance circuit together with the inner coil 111. In the second operation, the controller 45 opens the selector switch 70 to decrease the capacitance of the resonance capacitor configuring the resonance circuit together with the outer coil 112. As a result, in any of the first operation and the second operation, the resonance frequency and the driving frequency of the driver circuit 50 can be brought close to each other, which makes it possible to improve heating efficiency to each of the inner coil 111 and the outer coil 112.

(Small-Diameter Heating Operation)

[0199] In the small-diameter heating operation, the controller 45 puts only the inner coil 111 into the conduction state. In addition, the controller 45 sets the frequency of the high-frequency current supplied to the inner coil 111, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0200] In this operation, the controller 45 closes the selector switch 70 to increase the capacitance of the resonance capacitor configuring the resonance circuit together with the inner coil 111. Since only the inner coil 111 is in the conduction state and the inductance of the resonance circuit is decreased, the capacitance of the resonance capacitor is increased to prevent the resonance frequency of the resonance circuit from being largely varied by the load. This makes it possible to bring the resonance frequency and the driving frequency of the driver circuit 50 close to each other, and to improve heating efficiency to the inner coil 111.

(Large-Diameter Heating Operation)

[Normal Heating Mode]

[0201] In the normal heating mode of the large-diameter heating operation, the controller 45 puts the inner coil 111 and the outer coil 112 into the conduction state. In addition, the controller 45 sets the frequency of the high-frequency current supplied to each of the inner coil 111 and the outer coil 112, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0202] In this operation, the controller 45 opens the selector switch 70 to decrease the capacitance of the resonance capacitor configuring the resonance circuit together with the inner coil 111 and the outer coil 112. Since the inner coil 111 and the outer coil 112 are in the conduction state and the inductance of the resonance circuit is increased, the capacitance of the resonance capacitor is decreased to prevent the resonance frequency of the resonance circuit from being largely varied by the load. This makes it possible to bring the resonance frequency and the driving frequency of the driver circuit 50 close to each other, and to improve heating efficiency to each of the inner coil 111 and the outer coil 112.

[Convection Mode]

[0203] In the convection mode of the large-diameter heating operation, the controller 45 alternately repeats a first operation in which the controller 45 puts only the inner coil 111 into the conduction state, and a second operation in which the controller 45 puts only the outer coil 112 into the conduction state. In addition, the controller 45 sets the frequency of the high-frequency current supplied to each of the inner coil 111 and the outer coil 112, to a frequency corresponding to the magnetic material, for example, near 20 kHz.

[0204] In any of the first operation and the second operation, the controller 45 closes the selector switch 70 to increase the capacitance of the resonance capacitor configuring the resonance circuit together with the inner coil 111 or the outer coil 112. Since only one of the inner coil 111 and the outer coil 112 is in the conduction state and the inductance of the resonance circuit is decreased, the capacitance of the resonance capacitor is increased to prevent the resonance frequency of the resonance circuit from being largely varied by the load. This makes it possible to bring the resonance frequency and the driving frequency of the driver circuit 50 close to each other, and to improve heating efficiency to each of the inner coil 111 and the outer coil 112.

[0205] Note that, in Embodiment 3, the configuration in which two resonance capacitors are provided in the resonance circuit is described; however, three or more resonance capacitors may be provided. A plurality of resonance capacitors are connected in series, and a switcher unit short-circuiting at least one or more resonance capacitors may be provided to vary the capacitance of the resonance capacitors. Alternatively, some of the plurality of resonance capacitors may be connected in series, and may be connected in parallel with the other resonance capacitors.

[0206] In Embodiment 3, the configuration in which the two heating coils that are the inner coil 111 and the outer coil 112 are provided is described; however, the number of heating coils is not limited thereto. For example, the configuration of the resonance capacitors of Embodiment 3 may be applied to the configuration of Embodiment 2 described above.

Reference Signs List

[0207] 1: first induction heating port, 2: second induction heating port, 3: third induction heating port, 4: top plate, 5: heating target, 6: magnetic material, 11: first induction heating unit, 12: second induction heating unit, 13: third induction heating unit, 21: alternating-current power supply, 22: direct-current power supply circuit, 22a: diode bridge, 22b: reactor, 22c: smoothing capacitor, 23: inverter circuit, 23a: IGBT, 23b: IGBT, 23c: diode, 23d: diode, 24: resonance capacitor, 24a: resonance capacitor, 24b: resonance capacitor, 25a: input current detection unit, 25b: coil current detection unit, 40: operation unit, 40a: operation unit, 40b: operation unit, 40c: operation unit, 41: display unit, 41a: display unit, 41b: display unit, 41c: display unit, 43: operation display unit, 45: controller, 46: load determination unit, 48: memory, 50: driver circuit, 60: switcher unit, 61: first switcher unit, 62: second switcher unit, 63: third switcher unit, 70: selector switch, 100: induction heating cooker, 111: inner coil, 111a: circular coil, 111b: circular coil, 112: outer coil, 112a: elliptical coil, 112b: elliptical coil, 112c: elliptical coil, 112d: elliptical coil, 113: intermediate coil

Claims

1. An induction heating cooker, comprising:

5 a plurality of heating coils including an inner coil disposed on an innermost circumference and an outer coil disposed on an outermost circumference;
10 a driver circuit configured to supply a high-frequency current to each of the plurality of heating coils;
a switcher unit configured to switch each of the plurality of heating coils into one of a conduction state in which the high-frequency current is supplied from the driver circuit and a non-conduction state in which no high-frequency current is supplied from the driver circuit; and
20 a controller configured to control an operation of the driver circuit and an operation of the switcher unit,
the controller being configured to,
when the inner coil is in the conduction state and the outer coil is in the non-conduction state, determine whether a heating target is present
25 above the inner coil, and
when the controller determines that no heating target is present above the inner coil, stop an operation of the driver circuit.

30 2. The induction heating cooker of claim 1, wherein

when the inner coil is in the conduction state and the outer coil is in the non-conduction state, the controller determines whether the heating target is present above the inner coil and determines
35 a material of the heating target, and
when the controller determines that the heating target is present above the inner coil, the controller determines whether the heating target is present above the outer coil and determines a material of the heating target while the inner coil is in the non-conduction state and the outer coil is in the conduction state.

45 3. The induction heating cooker of claim 2, wherein, when the controller determines that the material of the heating target above the inner coil is a magnetic material and the material of the heating target above the outer coil contains a nonmagnetic material, the controller puts the inner coil into the non-conduction state and puts the outer coil into the conduction state, and supplies the high-frequency current from the driver circuit to the outer coil.

50 4. The induction heating cooker of claim 2, wherein, when the controller determines that the material of the heating target above the inner coil is a magnetic material and the material of the heating target above

the outer coil contains a nonmagnetic material, the controller alternately repeats an operation in which the controller puts the inner coil into the conduction state and puts the outer coil into the non-conduction state, and supplies the high-frequency current of a first frequency from the driver circuit to the inner coil, and an operation in which the controller puts the inner coil into the non-conduction state and puts the outer coil into the conduction state, and supplies the high-frequency current of a second frequency higher than the first frequency, from the driver circuit to the outer coil.

5. The induction heating cooker of claim 2, wherein, when the controller determines that the heating target is present above the inner coil and no heating target is present above the outer coil, the controller puts the inner coil into the conduction state and puts the outer coil into the non-conduction state, and supplies the high-frequency current from the driver circuit to the inner coil.
6. The induction heating cooker of claim 2, wherein, when the controller determines that the heating target is present above the inner coil and the outer coil, the controller puts the inner coil and the outer coil into the conduction state, and supplies the high-frequency current from the driver circuit to each of the inner coil and the outer coil.
7. The induction heating cooker of claim 2, wherein, when the controller determines that the heating target is present above the inner coil and the outer coil, the controller alternately repeats an operation in which the controller puts the inner coil into the conduction state and puts the outer coil into the non-conduction state, and supplies the high-frequency current from the driver circuit to the inner coil, and an operation in which the controller puts the inner coil into the non-conduction state and puts the outer coil into the conduction state, and supplies the high-frequency current from the driver circuit to the outer coil.
8. The induction heating cooker of any one of claims 1 to 7, wherein

the controller is configured to determine a material of the heating target above the inner coil while the inner coil is in the conduction state and the outer coil is in the non-conduction state, and when the controller is configured to determine that the material of the heating target above the inner coil is a nonmagnetic material, the controller stops an operation of the driver circuit.

9. The induction heating cooker of claim 1, wherein

the plurality of heating coils include an intermediate coil disposed between the inner coil and the outer coil, the controller is configured to determine whether the heating target is present above the inner coil while the inner coil is in the conduction state and the intermediate coil and the outer coil are in the non-conduction state, and when the controller determines that no heating target is present above the inner coil, the controller stops an operation of the driver circuit.

10. The induction heating cooker of claim 9, wherein

the controller is configured to determine whether the heating target is present above the inner coil and determines a material of the heating target while the inner coil is in the conduction state and the intermediate coil and the outer coil are in the non-conduction state, and when the controller determines that the heating target is present above the inner coil, the controller determines whether the heating target is present above the intermediate coil and determines a material of the heating target while the inner coil and the outer coil are in the non-conduction state and the intermediate coil is in the conduction state, and the controller is configured to determine whether the heating target is present above the outer coil and determines a material of the heating target while the inner coil and the intermediate coil are in the non-conduction state and the outer coil is in the conduction state.

11. The induction heating cooker of claim 10, wherein, when the controller determines that the material of the heating target above the inner coil is a magnetic material and the material of the heating target above each of the intermediate coil and the outer coil contains a nonmagnetic material, the controller puts the inner coil into the non-conduction state and puts the intermediate coil and the outer coil into the conduction state, and supplies the high-frequency current from the driver circuit to each of the intermediate coil and the outer coil.

12. The induction heating cooker of claim 10, wherein, when the controller determines that the material of the heating target above the inner coil is a magnetic material and the material of the heating target above each of the intermediate coil and the outer coil contains a non-magnetic material, the controller alternately repeats an operation in which the controller puts the inner coil into the conduction state and puts the intermediate coil and the outer coil into the non-conduction state, and supplies the high-frequency current of a first frequency from the driver circuit to

the inner coil, and an operation in which the controller puts the inner coil into the non-conduction state and puts the intermediate coil and the outer coil into the conduction state, and supplies the high-frequency current of a second frequency higher than the first frequency from the driver circuit to each of the intermediate coil and the outer coil.

13. The induction heating cooker of claim 10, wherein, when the controller determines that the material of the heating target above the inner coil is a magnetic material, the material of the heating target above the intermediate coil contains a nonmagnetic material, and no heating target is present above the outer coil, the controller puts the inner coil and the outer coil into the non-conduction state and puts the intermediate coil into the conduction state, and supplies the high-frequency current from the driver circuit to the intermediate coil.

14. The induction heating cooker of claim 10, wherein, when the controller determines that the heating target is present above the inner coil and no heating target is present above the intermediate coil and the outer coil, the controller puts the inner coil into the conduction state and puts the intermediate coil and the outer coil into the non-conduction state, and supplies the high-frequency current from the driver circuit to the inner coil.

15. The induction heating cooker of claim 10, wherein, when the controller determines that the heating target is present above the inner coil, the intermediate coil, and the outer coil, the controller puts the inner coil, the intermediate coil, and the outer coil into the conduction state, and supplies the high-frequency current from the driver circuit to each of the inner coil, the intermediate coil, and the outer coil.

16. The induction heating cooker of claim 10, wherein, when the controller determines that the heating target is present above the inner coil, the intermediate coil, and the outer coil, the controller puts some of the heating coils among the inner coil, the intermediate coil, and the outer coil into the conduction state, and supplies the high-frequency current from the driver circuit, and switches the heating coil to be put into the conduction state with lapse of time to sequentially change the heating coil to be supplied with the high-frequency current.

17. The induction heating cooker of claim 10, wherein, when the controller determines that the heating target is present above the inner coil and the intermediate coil and no heating target is present above the outer coil, the controller puts the inner coil and the intermediate coil into the conduction state and puts the outer coil into the non-conduction state, and sup-

plies the high-frequency current from the driver circuit to each of the inner coil and the intermediate coil.

18. The induction heating cooker of claim 10, wherein, when the controller determines that the heating target is present above the inner coil and the intermediate coil and no heating target is present above the outer coil, the controller alternately repeats an operation in which the controller puts the inner coil into the conduction state and puts the intermediate coil and the outer coil into the non-conduction state, and supplies the high-frequency current from the driver circuit to the inner coil, and an operation in which the controller puts the inner coil and the outer coil into the non-conduction state and puts the intermediate coil into the conduction state, and supplies the high-frequency current from the driver circuit to the intermediate coil.

19. The induction heating cooker of any one of claims 1 to 18, wherein

the driver circuit includes a resonance capacitor that configures a resonance circuit together with the plurality of heating coils and has a variable capacitance, and

the controller varies the capacitance of the resonance capacitor based on at least one of switching of each of the plurality of heating coils into one of the conduction state and the non-conduction state and the frequency of the high-frequency current.

20. The induction heating cooker of claim 19, wherein the controller decreases the capacitance of the resonance capacitor as number of heating coils in the conduction state increases among the plurality of heating coils.

21. The induction heating cooker of claim 19 or 20, wherein the controller decreases the capacitance of the resonance capacitor as the frequency of the high-frequency current increases.

22. The induction heating cooker of any one of claims 1 to 21, further comprising:

an input current detection unit configured to detect a current input to the driver circuit; and a coil current detection unit configured to detect a coil current flowing through each of the plurality of heating coils, wherein the controller determines whether the heating target is present above the plurality of heating coils and a material of the heating target, based on correlation between the input current and the coil current.

23. The induction heating cooker of any one of claims 1 to 22, wherein the driver circuit includes an inverter circuit including at least one arm in which two switching elements are connected in series.

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24. The induction heating cooker of claim 23, wherein each of the switching elements is made of a wide band gap semiconductor material.

25. The induction heating cooker of any one of claims 1 to 24, wherein the switcher unit is made of a semiconductor material.

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FIG. 1

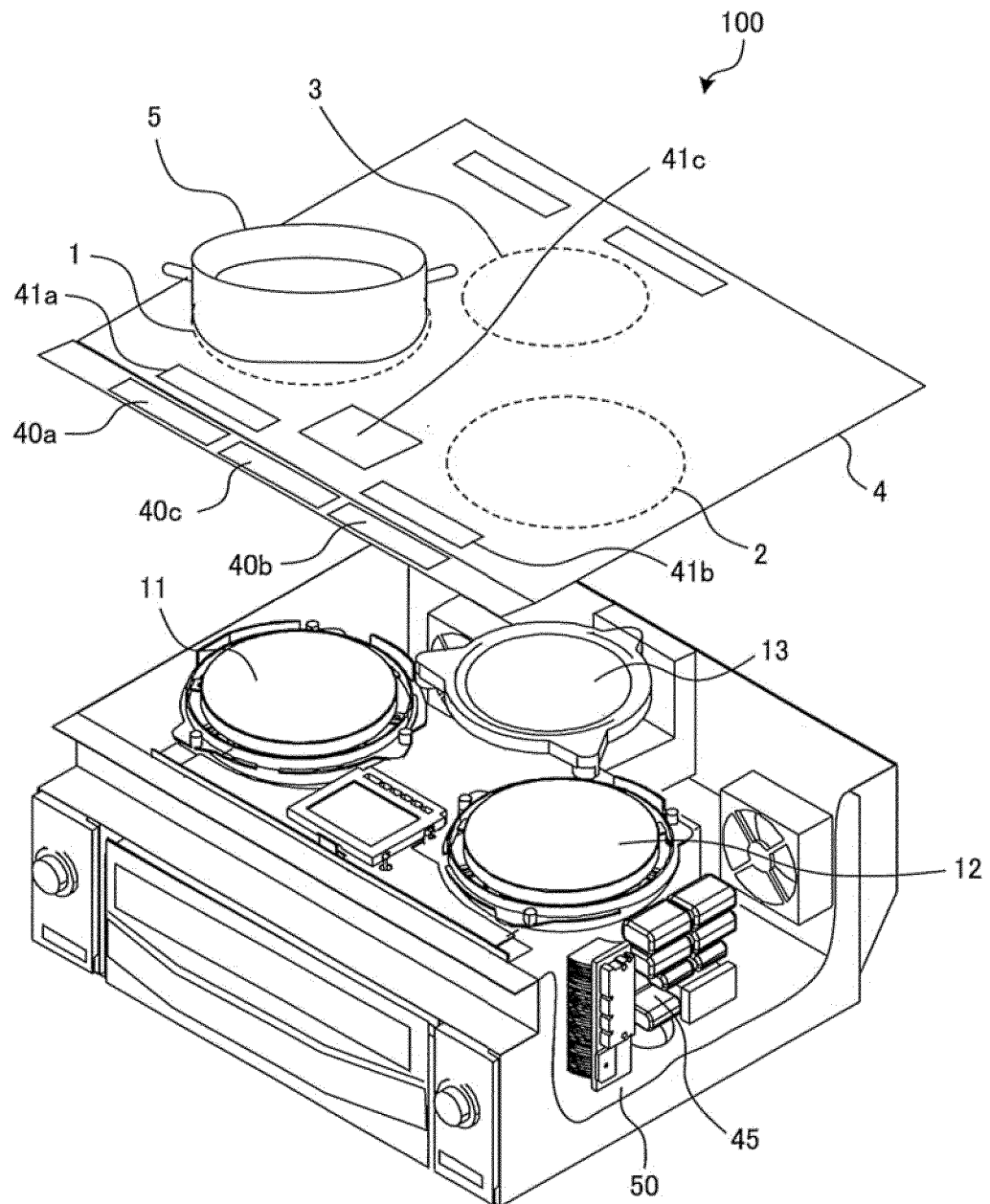


FIG. 2

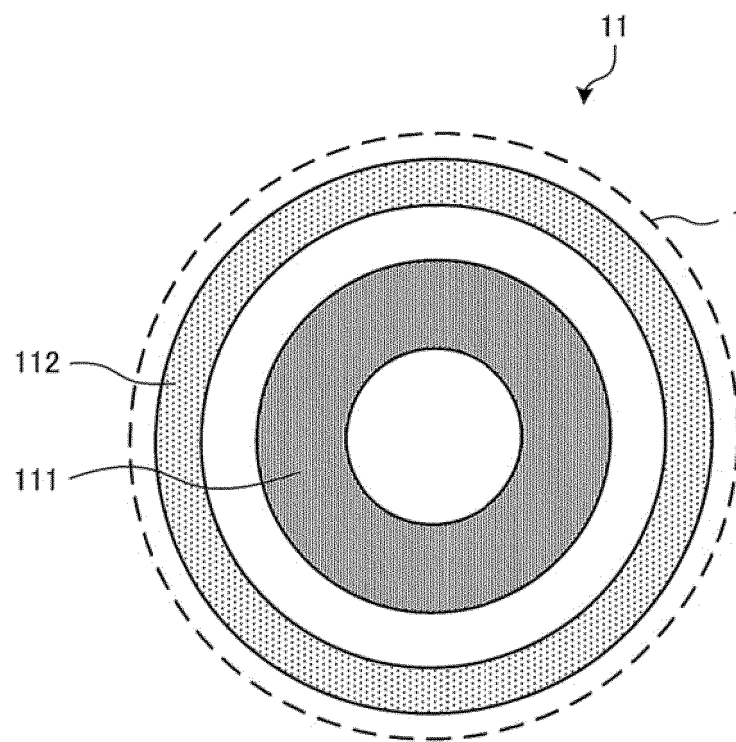


FIG. 3

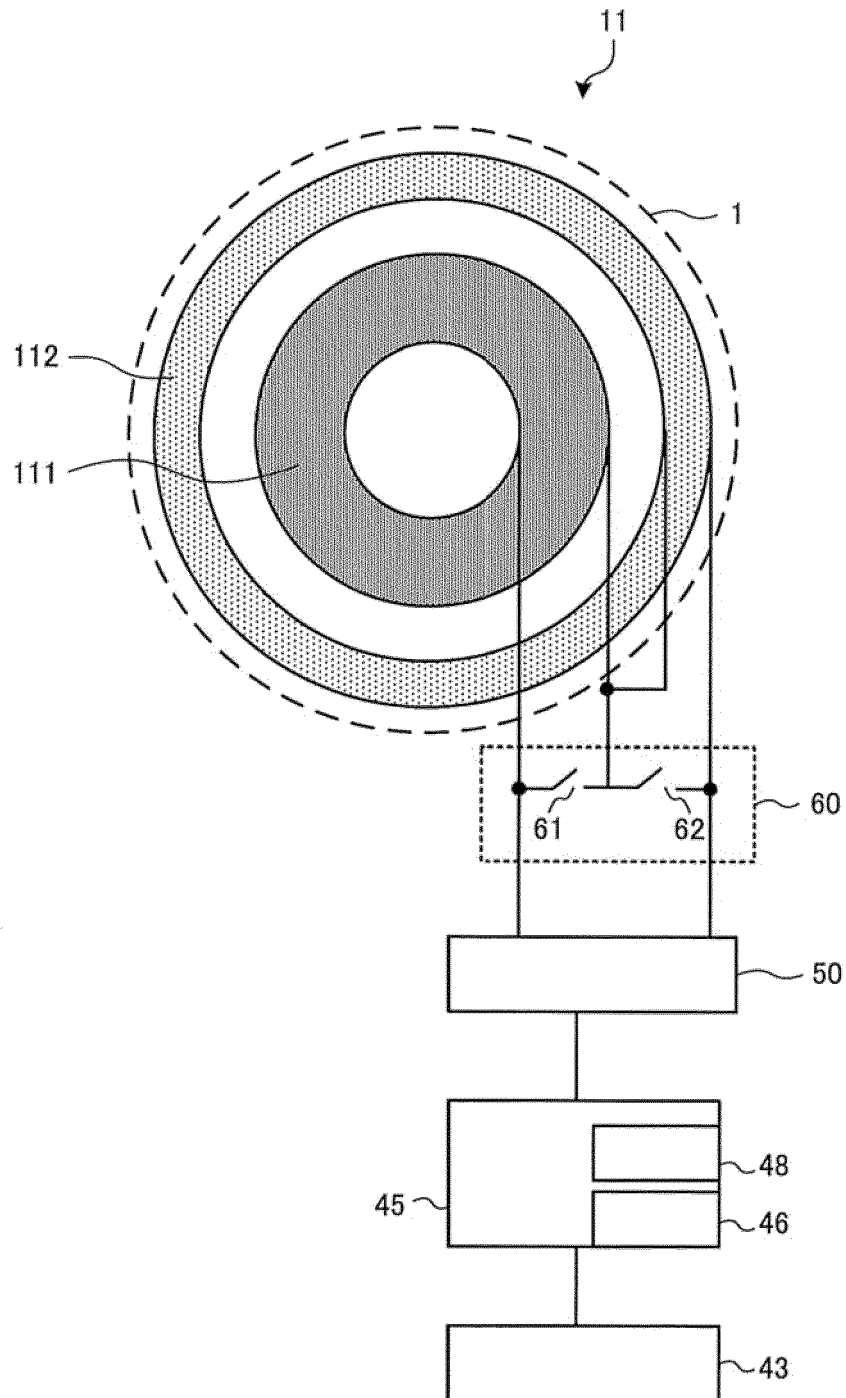


FIG. 4

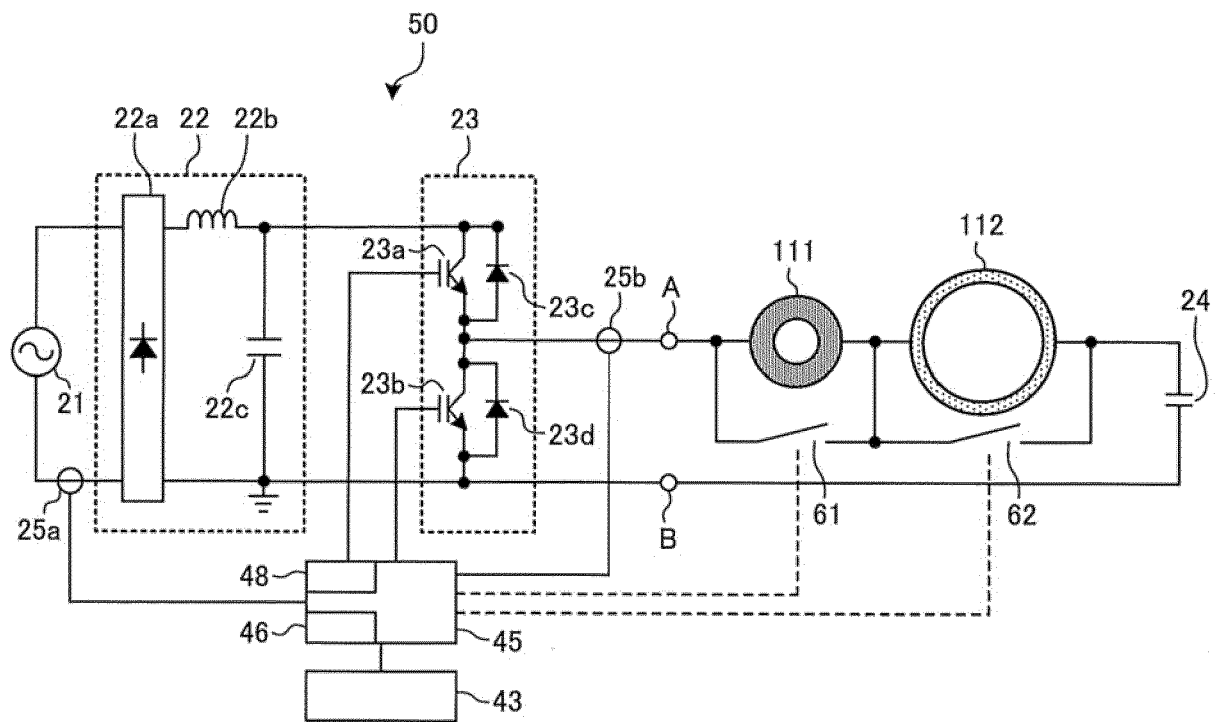


FIG. 5

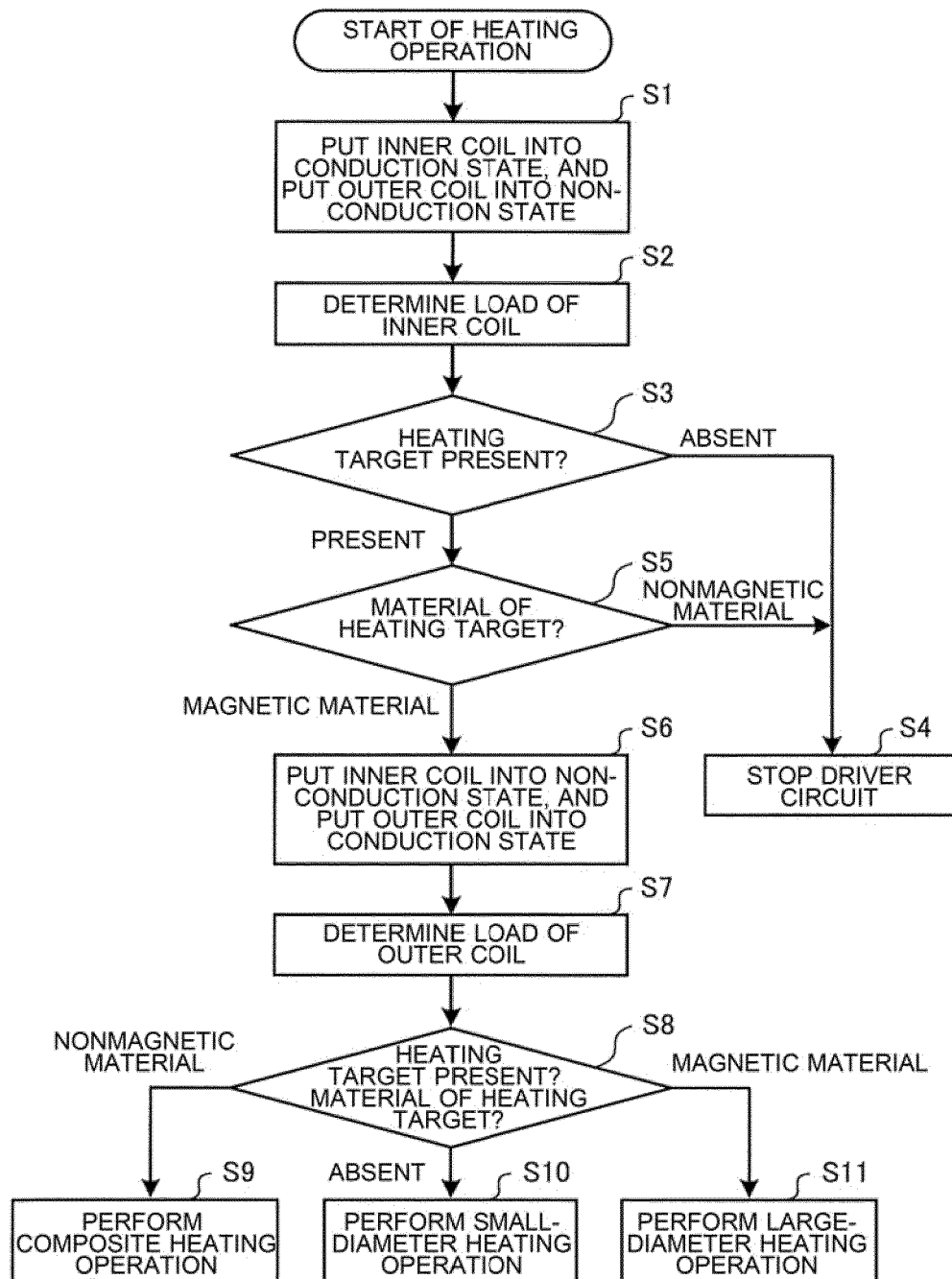


FIG. 6

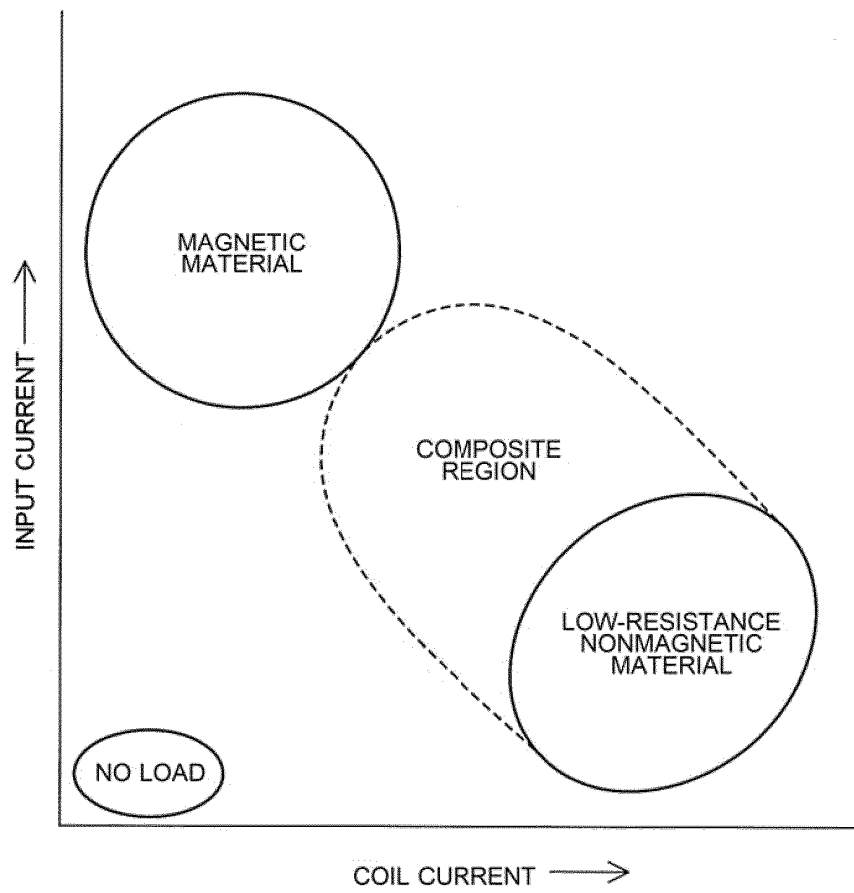


FIG. 7

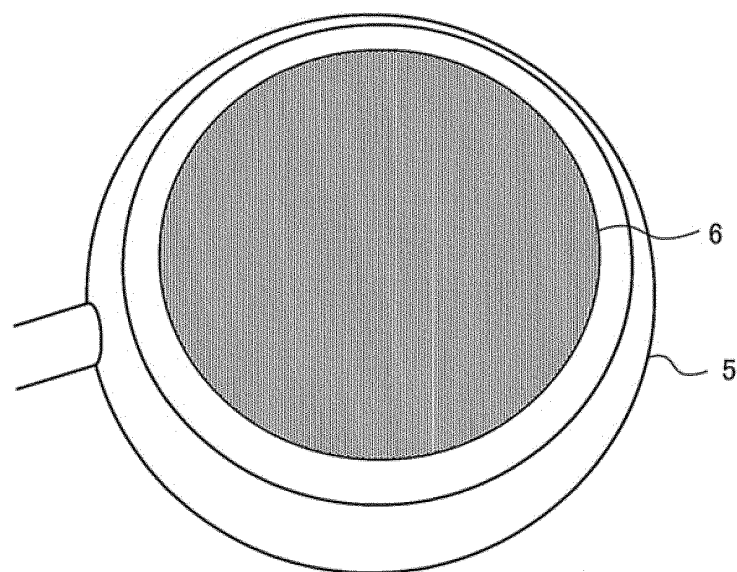


FIG. 8

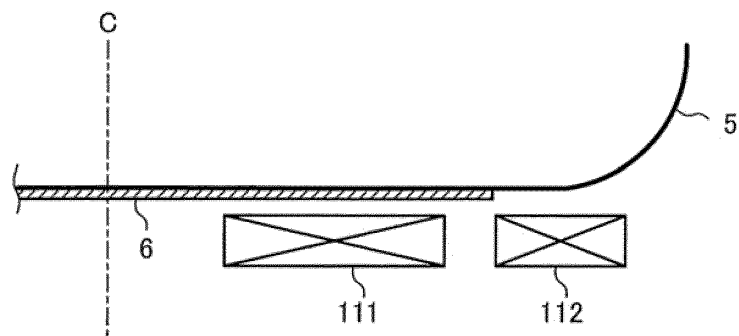


FIG. 9

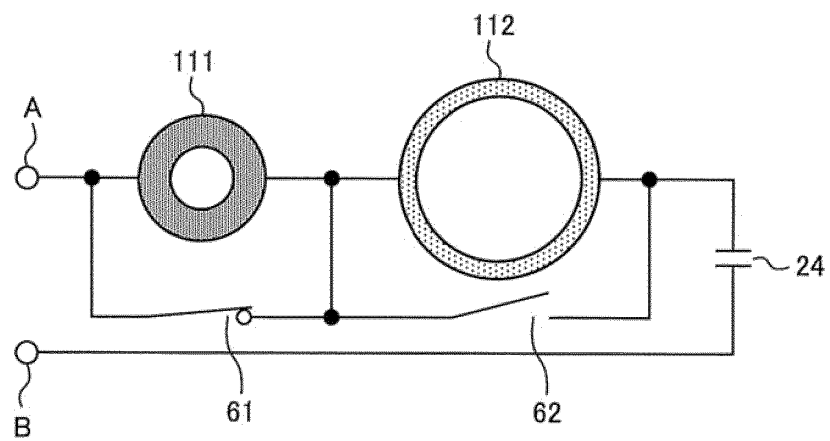


FIG. 10

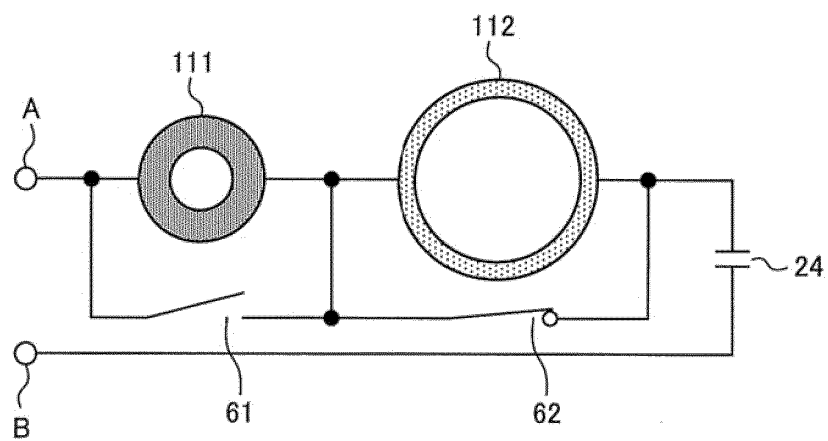


FIG. 11

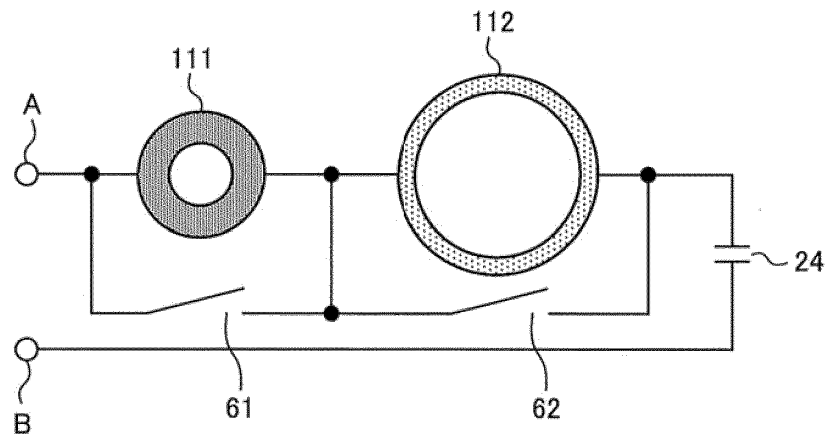


FIG. 12

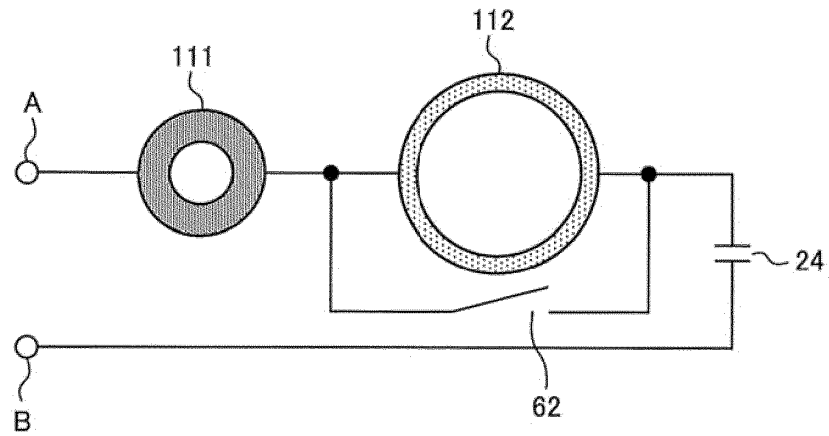


FIG. 13

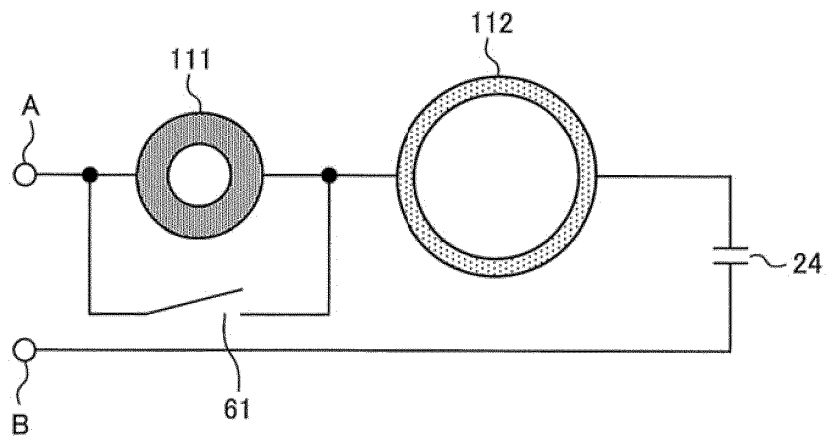


FIG. 14

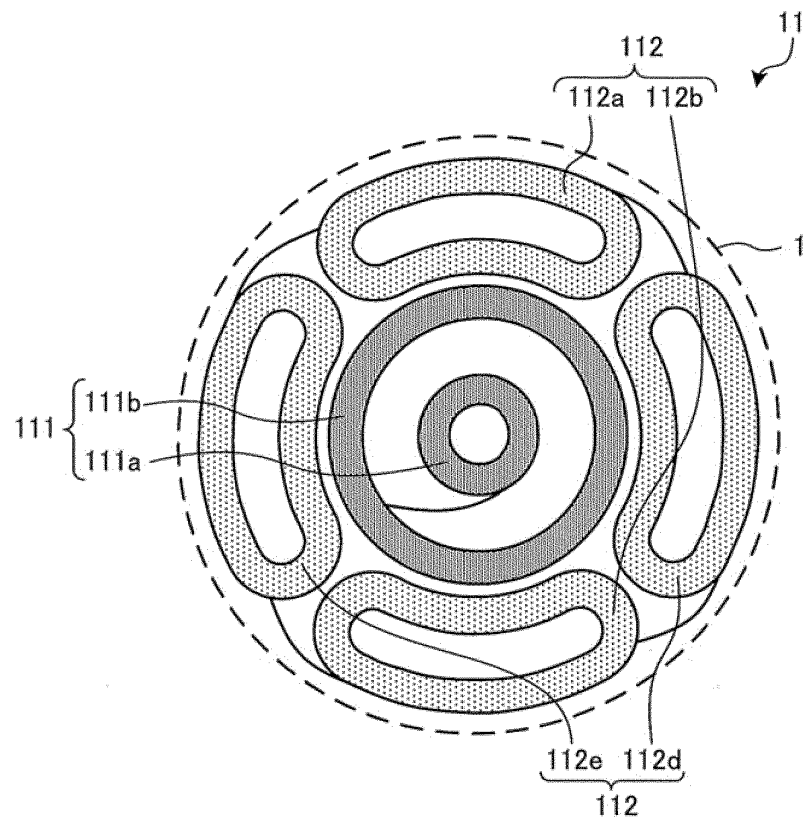


FIG. 15

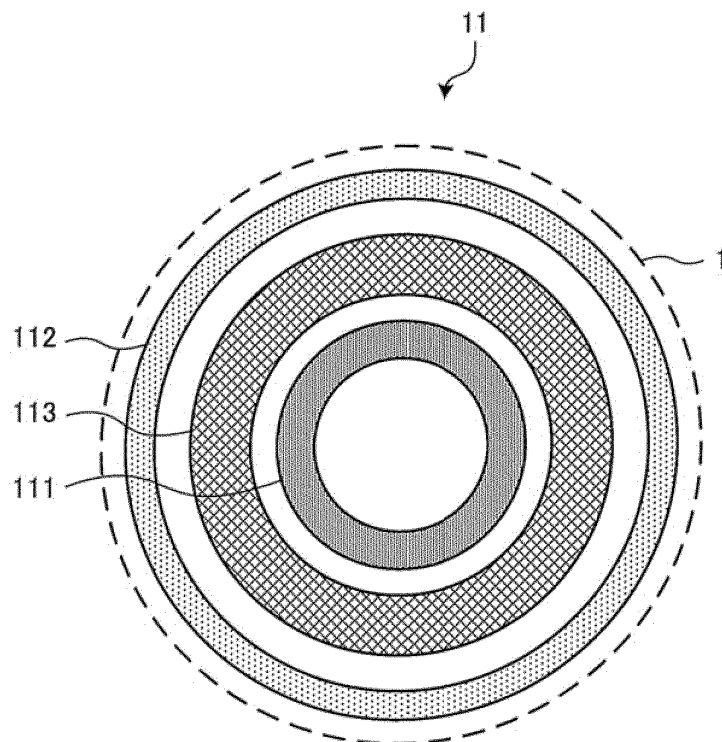


FIG. 16

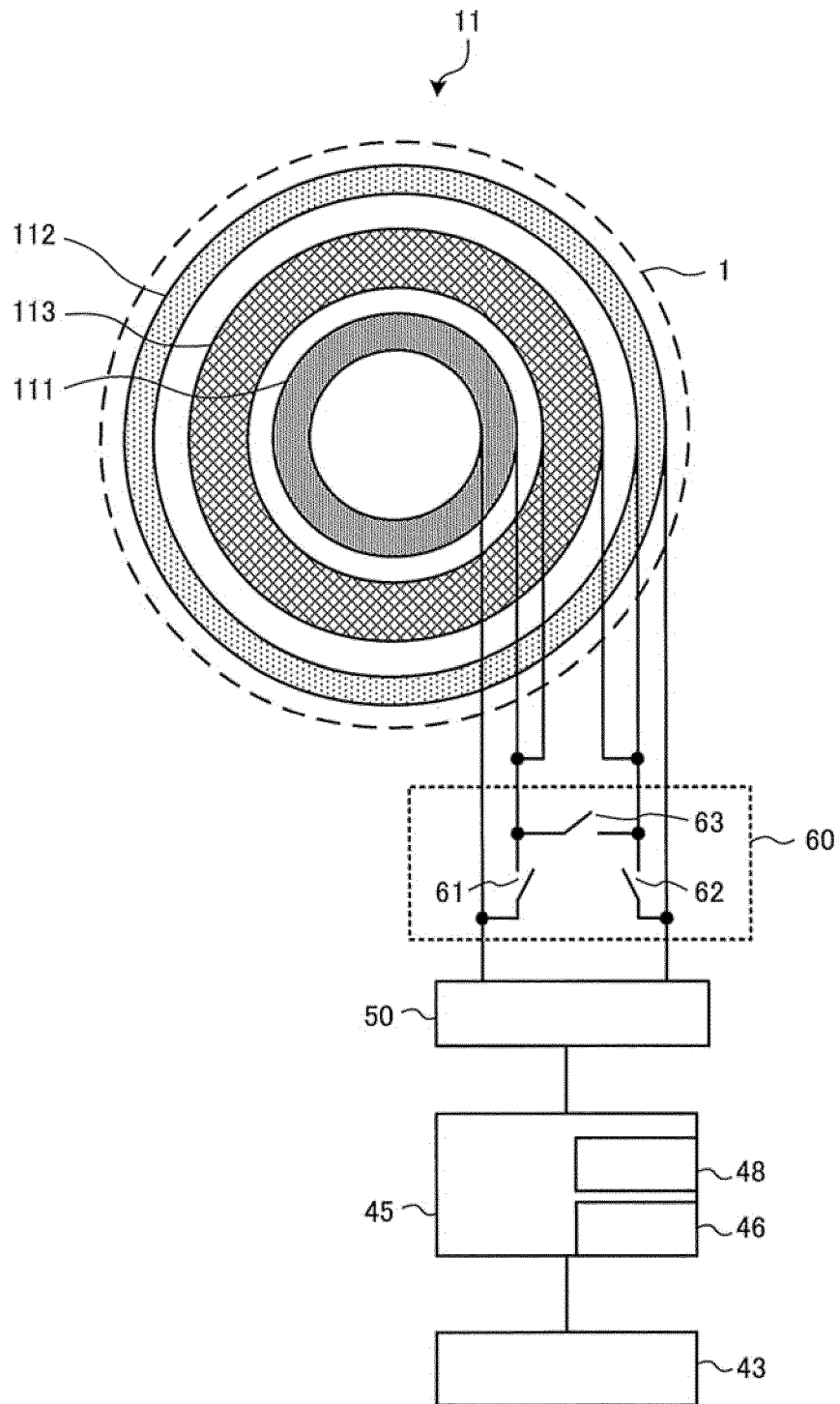


FIG. 17

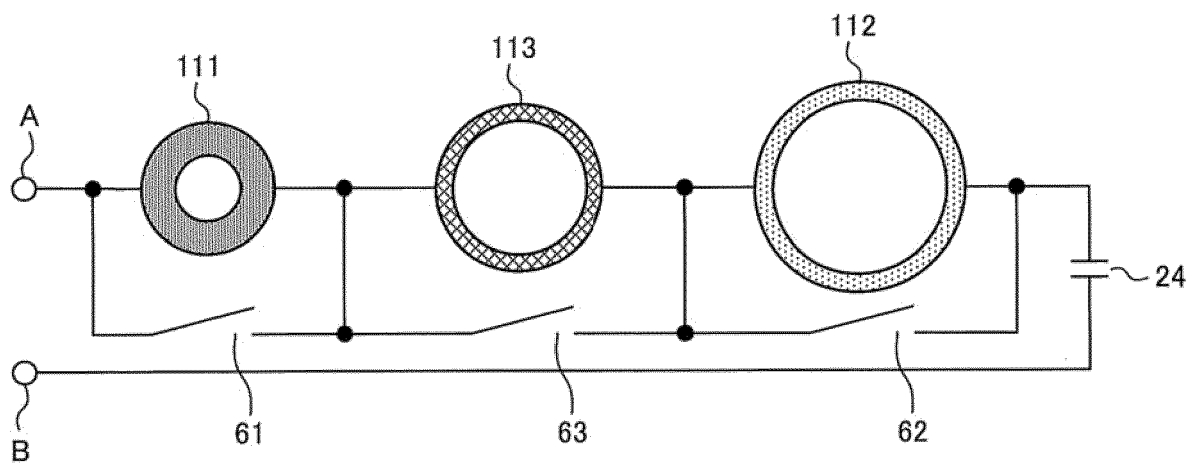


FIG. 18

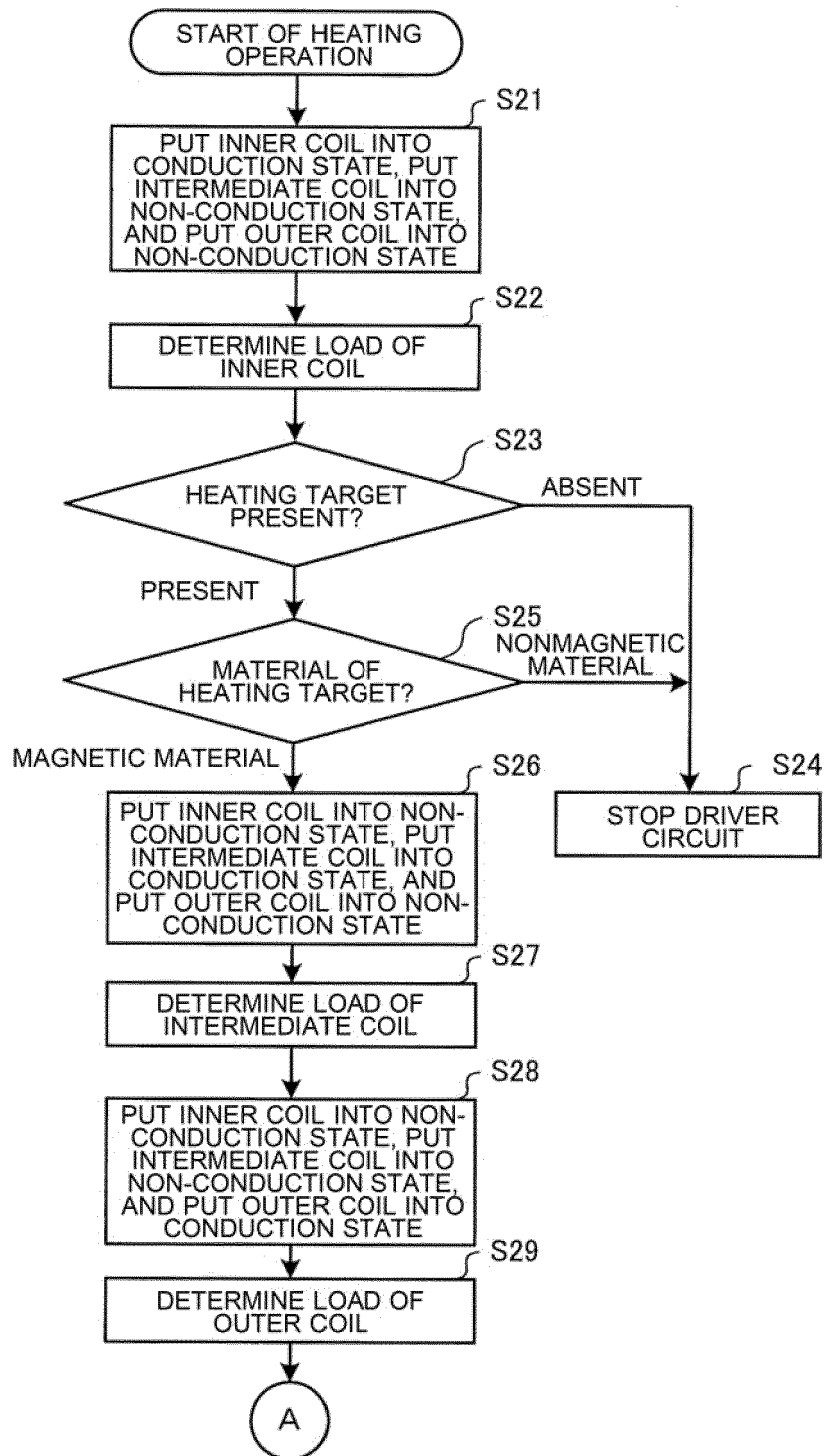


FIG. 19

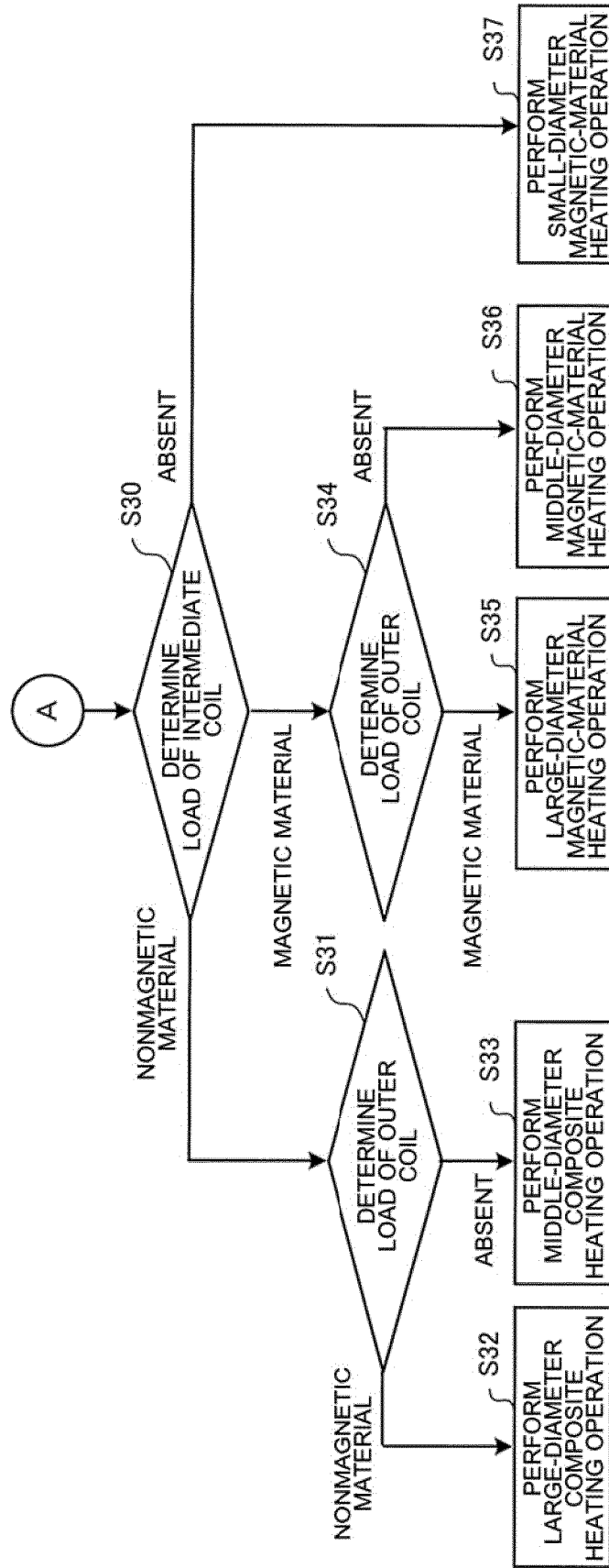


FIG. 20

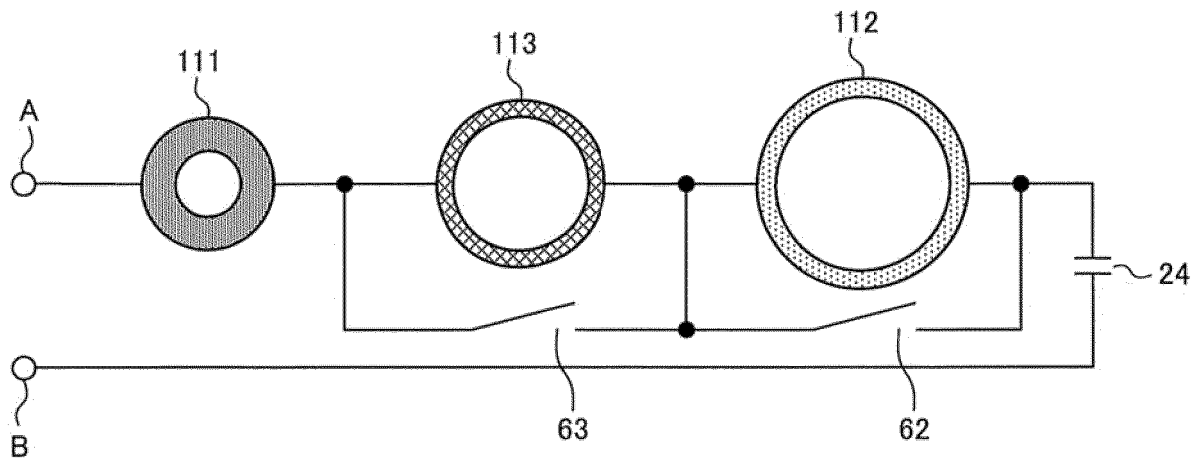


FIG. 21

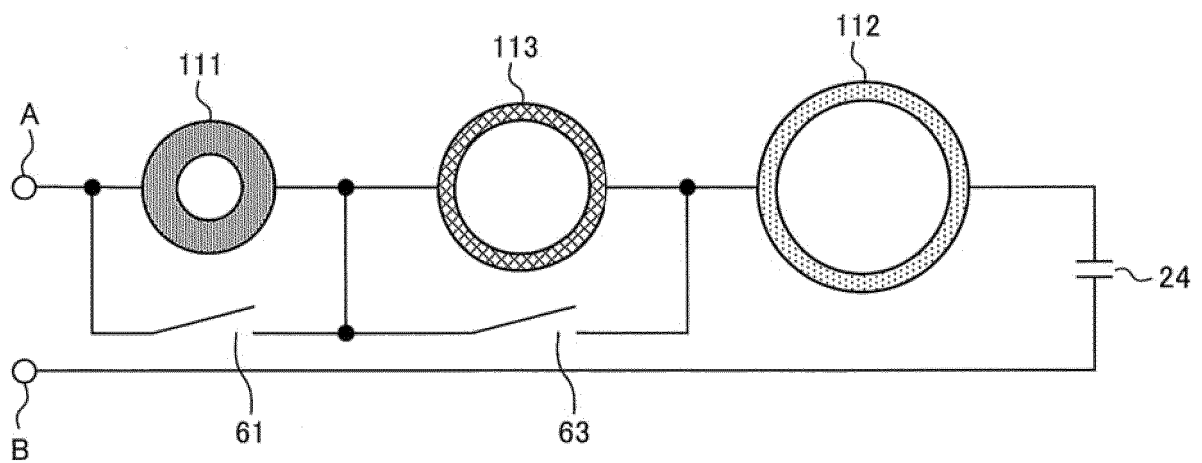
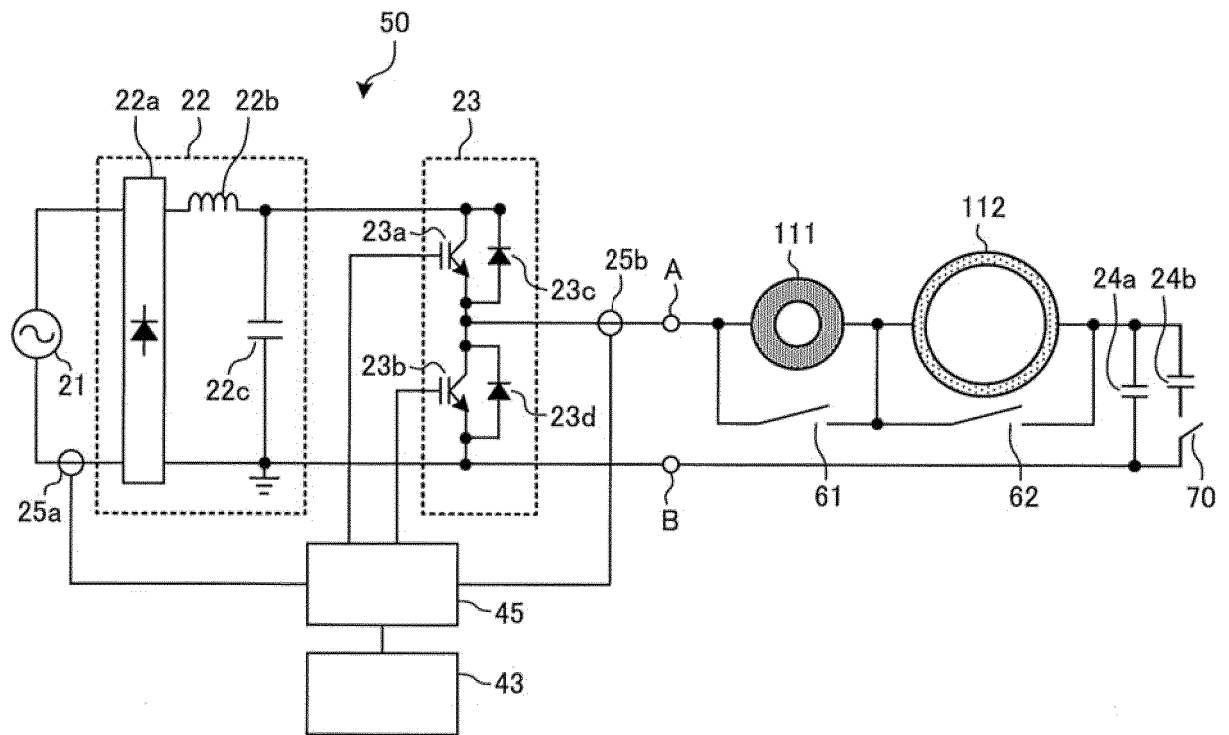


FIG. 22



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/005547

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. H05B6/12 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. H05B6/12

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2011-34712 A (MITSUBISHI ELECTRIC CORPORATION)	1-2, 5-6
Y	17 February 2011, paragraphs [0011]-[0022], [0025], fig. 1 (Family: none)	3-4, 7-25
Y	JP 2013-157162 A (MITSUBISHI ELECTRIC CORPORATION) 15 August 2013, paragraphs [0039]-[0055] (Family: none)	3-4, 7-25
Y	JP 2016-207544 A (MITSUBISHI ELECTRIC CORPORATION) 08 December 2016, paragraphs [0035]-[0039] (Family: none)	3-4, 7-25
Y	JP 2010-277761 A (THE TOKYO ELECTRIC POWER CO., INC.) 09 December 2010, paragraph [0034] (Family: none)	3-4, 7-25



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
19.03.2019Date of mailing of the international search report
26.03.2019Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/005547
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2016-213201 A (MITSUBISHI ELECTRIC CORPORATION) 15 December 2016, paragraphs [0064], [0069], [0077], [0099], [0099], fig. 6, 7 (Family: none)	3-4, 7-25
Y	JP 2003-151751 A (MITSUBISHI ELECTRIC CORPORATION) 23 May 2003, paragraphs [0017], [0018] (Family: none)	19-25

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2006310006 A [0003]