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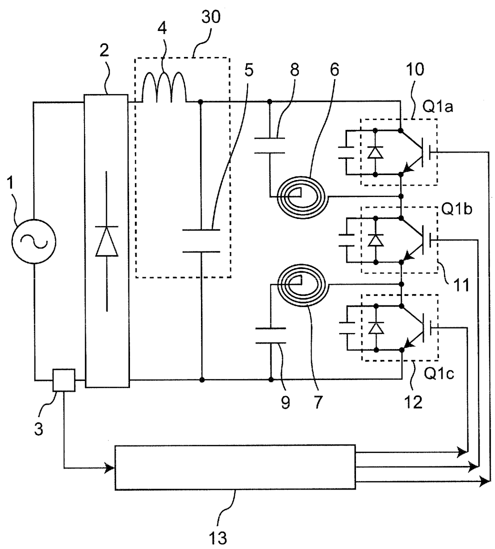
(54) INDUCTION HEATING DEVICE

(57) An induction heating device is configured that a control part controls a first semiconductor switch, a second semiconductor switch, and a third semiconductor switch to selectively drives a simultaneous heating mode supplying a high-frequency power to a first heating coil and a second heating coil at the same time, a first single heating mode supplying a high-frequency power to the second heating coil, a second single heating mode supplying a high-frequency power to the first heating coil, an alternate heating mode alternately repeating the first single heating mode and the second signal heating mode, and a step-down simultaneous heating mode supplying the high-frequency power to the first heating coil and the second heating coil at the same time.

Fig.1



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Description

Technical Field

[0001] This disclosure relates to induction heating devices including, for example, induction heating cooking devices heating an object to be heated by using induction heating with a high-frequency magnetic field.

Background Art

[0002] A conventional induction heating device will be described with preference to the drawing. Fig. 38 is a diagram showing a circuit configuration of a conventional induction heating device. The conventional induction heating device is made up of an AC power source 101 that is a commercial power source, a rectification circuit 102 rectifying the commercial power source, a smoothing circuit 130 made up of a choke coil 104 and a smoothing capacitor 105 smoothing a rectified voltage from the rectification circuit 102, a first inverter 114 converting the output of the smoothing capacitor 105 into a high-frequency power to supply the high-frequency power to a first heating coil 106, a second inverter 115 converting the output of the smoothing capacitor 105 into a high-frequency power to supply the high-frequency power to a second heating coil 107, an input current detecting part 103 detecting an input current from the AC power source 101, and a control part 113. The control part 113 is made up of a microcomputer etc., and controls an operation state of semiconductor switches in the first inverter 114 and the second inverter 115 such that a detection value of the input current detecting part 103 becomes equal to a set value.

[0003] Since the conventional induction heating device configured as described above has the rectification circuit 102, the choke coil 104, and the smoothing capacitor 105 shared by the two inverters 114 and 115, a circuit can be miniaturized.

[0004] An operation of the conventional induction heating device configured as described above will be described. The control part 113 controls a conduction time of the semiconductor switches in the first inverter 114 and the second inverter 115 such that an input current value of an input current from the AC power source 101 detected by the input current detecting part 103 made up of a current transformer etc. becomes equal to a preset current value. As a result of the control by the control part 113 as described above, a necessary high-frequency current is supplied to the first heating coil 106 and the second heating coil 107 connected to the first inverter 114 and the second inverter 115.

[0005] The high-frequency current supplied to the first heating coil 106 and the second heating coil 107 causes the first heating coil 106 and the second heating coil 107 to generate a high-frequency magnetic field, and the high-frequency magnetic field is applied to a load such as a pot magnetically coupled to the heating coils 106, 107.

[0006] The high-frequency magnetic field applied to the load such as a pot as described above generates an eddy current in the load, and the pot itself generates heat due to the eddy current and a skin resistance of the pot itself.

[0007] To adjust a heating amount of the load such as a pot, the control part 113 changes an input current to the first inverter 114 and the second inverter 115 to control the operation frequency and the conduction ratio of the semiconductor switches of the first inverter 114 and the second inverter 115 such that the detection value of the input current detecting part 103 attains a target value (see, e.g., Patent Literatures 1, 2).

[0008] Additionally, for the conventional induction heating device, a configuration using a plurality of heating coils is proposed so as to efficiently heat loads of various shapes when a load such as a pot or a pan is placed and heated on an upper surface made of crystallized glass etc. Proposed shapes of heating coils include a configuration with a plurality of heating coils concentrically arranged, a configuration with a plurality of auxiliary coils having a different center position arranged around a heating coil, or a configuration with a plurality of small-shaped heating coils arranged in a matrix shape.

[0009] On the other hand, if respective different powers are supplied to a plurality of heating coils, a configuration with an inverter provided for each of the heating coils increases a mounting area of the inverters, resulting in a problem that a device shape becomes larger. A configuration using a plurality of heating coils generates an interference sound due to an operation frequency difference because a plurality of inverters operates at different operation frequencies.

Citation List

Patent Literature

[0010]

Patent Literature 1: US 2007/0135037 A1
Patent Literature 2: JP H09-251888 A

Summary of Invention

Technical Problem

[0011] A conventional induction heating device needs a semiconductor switch in an inverter driving each of a first heating coil and a second heating coil. Therefore, the conventional induction heating device needs a semiconductor switch and a driving circuit thereof for each inverter and needs a mounting area corresponding to the driving circuits, having a problem that it is difficult to further miniaturize the device.

[0012] For the case of operating the first heating coil and the second heating coil at the same time, a method of driving the respective heating coils at the same frequency or with a frequency difference equal to or greater than an audible range is proposed so as to suppress occurrence of an interference sound due to a difference in operation frequencies. However, the operation frequency may not be the same depending on a type of a load and the interference sound may occur. The method as described above also has a problem of complicated control of semiconductor switches making a circuit design difficult.

[0013] For the purpose of solving these problems, in a proposed controlled method, three semiconductor switches described in JP H09-251888A are connected in series and two heating coils are controlled by the three semiconductor switches in a time-division manner to switch the heating operations of the respective coils at constant time intervals.

[0014] However, if a material of a heated load is different, inductance and impedance such as a resistance value of a heating coil coupled to the load vary due to a difference in electric characteristics of the load even in such a conventional induction heating device and, therefore, a resonance characteristic varies that is determined by a value of a resonance capacitor connected to the heating coil. Thus, some conventional induction heating devices utilize a method of adjusting a supply power to a load by changing an operation frequency depending on a resonance characteristic.

[0015] However, if the supply power is adjusted in such a method and loads of different materials are heated at the same time, a difference in operation frequencies is generated between the respective loads and an interference sound occurs due to the difference in operation frequencies, resulting in a problem such as that a noise during operation becomes louder.

[0016] The control method of two heating coils alternately heating in a time division manner only for a constant time as described in JP H09-251888A has problems that a feeling of boiling is periodically lost in a resting period at the time of switchover and that a cooked object easily burns and sticks because one of the heating coils is supplied with a large electric power in a heating operation period in a method of alternately switching at constant time intervals.

[0017] In a conventional induction heating device with a plurality of small-shaped heating coils arranged in a matrix shape, a plurality of small heating coils is driven in accordance with a shape of a load to be heated and, therefore, the impedance of the heating coils significantly varies depending on the number of the driven heating coils. As a result, it is very difficult to adjust the supply power to the load at the same operation frequency. If a load is heated by adjacent heating coils at the same time, different operation frequencies generate an interference sound due to a difference in the operation frequencies, resulting in a problem such as that a noise becomes louder.

[0018] The present disclosure solves various conventional problems and it is an object of this disclosure to provide an induction heating device generating no interference sound even when a high-frequency power is supplied to a plurality of heating coils, having an excellent cooking performance corresponding to a state of a load, and having the reduced number of components, a small circuit mounting area, and a low production cost.

Solution to Problem

[0019] An induction heating device of a first aspect according to the present disclosure comprises:

a series connection body, which is connected to a power source, including a first semiconductor switch, a second semiconductor switch, and a third semiconductor switch;
a series connection body, which is connected in parallel to the first semiconductor switch, including a first resonance capacitor and a first heating coil magnetically coupled to a load;
a series connection body, which is connected in parallel to the third semiconductor switch, including a second resonance capacitor and a second heating coil magnetically coupled to a load; and
a control part controlling the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch, wherein
the control part selectively drives the following modes depending on a load:

a first single heating mode in which the second semiconductor switch and the third semiconductor switch are alternately made conductive while the first semiconductor switch is made always conductive so as to supply a high-frequency power to the second heating coil,
a second single heating mode in which the first semiconductor switch and the second semiconductor switch are alternately made conductive while the third semiconductor switch is made always conductive so as to supply a high-frequency power to the first heating coil, and
a simultaneous heating mode in which the first semiconductor switch and the third semiconductor switch are alternately made conductive while the second semiconductor switch is made always conductive so as to supply a high-frequency power to the first heating coil and the second heating coil at the same time.

Advantageous Effects of Invention

[0020] The induction heating device of the present disclosure can provide an induction heating device generating no interference sound even when a high-frequency power is supplied to a plurality of heating coils, having an excellent cooking performance corresponding to a state of a load, and having the reduced number of components, a small circuit mounting area, and a low production cost.

Brief Description of Drawings

[0021]

Fig. 1 is a diagram showing a circuit configuration of an induction heating device of a first embodiment according to the present disclosure.
Fig. 2A is a waveform diagram showing a first single heating mode in the induction heating device of the first embodiment.
Fig. 2B is a waveform diagram showing a second single heating mode in the induction heating device of the first embodiment.
Fig. 3 is a waveform diagram showing a simultaneous heating mode in the induction heating device of the first embodiment.
Fig. 4 is a waveform diagram showing an alternate heating mode in the induction heating device of the first embodiment.
Fig. 5 is diagrams showing a configuration of the induction heating device of the first embodiment.
Fig. 6 is diagrams showing another configuration example of the induction heating device of the first embodiment.
Fig. 7 is a diagram showing a circuit configuration of an induction heating device of a second embodiment according to the present disclosure.
Fig. 8A is a waveform diagram showing a first single heating mode in the induction heating device of the second embodiment.
Fig. 8B is a waveform diagram showing a second single heating mode in the induction heating device of the second embodiment.
Fig. 9 is a waveform diagram showing an alternate heating mode in the induction heating device of the second embodiment.
Fig. 10 is a waveform diagram at a time of a switchover operation between the first single heating mode and the second single heating mode in the alternate heating mode of the induction heating device of the second embodiment.
Fig. 11A is a diagram for explaining power characteristics in the induction heating device of the second embodiment.
Fig. 11B is a diagram for explaining power characteristics in the induction heating device of the second embodiment.
Fig. 12 is a diagram showing power characteristics of the alternate heating mode in the induction heating device of the second embodiment.
Fig. 13 is diagrams showing a configuration of the induction heating device of the second embodiment.
Fig. 14 is a diagrams showing another configuration example of the induction heating device of the second embodiment.
Fig. 15 is a diagram showing a circuit configuration of a third embodiment according to the present disclosure.
Fig. 16 is diagrams showing a configuration of an induction heating device of the third embodiment.
Fig. 17 is diagrams showing a configuration of the induction heating device of the third embodiment.
Fig. 18 is a diagram showing a configuration of the induction heating device of the third embodiment.
Fig. 19 is a waveform diagram showing a simultaneous heating mode in the induction heating device of the third embodiment.
Fig. 20A is a waveform diagram showing a first single heating mode in the induction heating device of the third embodiment.
Fig. 20B is a waveform diagram showing a second single heating mode in the induction heating device of the third embodiment.
Fig. 21 is a waveform diagram showing an alternate heating mode in the induction heating device of the third embodiment.
Fig. 22 is a diagram showing a relationship between a conduction time of a semiconductor switch and a resonance voltage generated in resonance capacitor depending on a difference of a load, in the induction heating device of the third embodiment.
Fig. 23 is a diagram showing a change of an input power generated in the conduction time depending on a difference of a load, in the induction heating device of the third embodiment.
Fig. 24 is a waveform diagram showing a step-down simultaneous heating mode in an induction heating device of a fourth embodiment according to the present disclosure.
Fig. 25 is a diagram showing a circuit configuration of an induction heating device of a fifth embodiment according to the present disclosure.
Fig. 26 is a diagram showing characteristics of input power in a respective heating modes to a conduction time, in the induction heating device of the fifth embodiment.
Fig. 27 is a diagram showing a circuit configuration of an induction heating device of a sixth embodiment according to the present disclosure.
Fig. 28 is a plane view showing a configuration in which a plurality of heating coil elements making up heating coil groups is arranged in a matrix shape, in an induction heating device of the sixth embodiment.
Fig. 29 is a plane view showing a configuration in which a plurality of heating coil elements making up heating coil groups is arranged in a matrix shape, in an induction heating device of the sixth embodiment.
Fig. 30 is a diagram showing a relationship between a conduction time of a semiconductor switch and a resonance voltage generated in a resonance capacitor depending on a material of a load, in an induction heating device of the sixth embodiment.

Fig. 31 is a waveform diagram showing a simultaneous heating mode in the induction heating device of the sixth embodiment. a diagram showing a first operation mode of the first embodiment according to the present disclosure.

Fig. 32A is a waveform diagram showing a first single heating mode in the induction heating device of the sixth embodiment.

Fig. 32B is a waveform diagram showing a second single heating mode in the induction heating device of the sixth embodiment.

Fig. 33 is a waveform diagram showing an alternate heating mode in the induction heating device of the sixth embodiment.

Fig. 34 is a diagram showing characteristics of input power in a respective heating modes to a conduction time, in the induction heating device of the sixth embodiment.

Fig. 35 is a waveform diagram showing a step-down simultaneous heating mode in an induction heating device of a seventh embodiment according to the present disclosure.

Fig. 36 is a diagram showing characteristics of input power in a respective heating modes to a conduction time, in the induction heating device of the seventh embodiment.

Fig. 37 is a plane view showing a configuration in which a plurality of heating coil elements making up heating coil groups is arranged in a matrix shape, in an induction heating device of an eighth embodiment according to the present disclosure.

Fig. 38 is the diagram showing the circuit configuration of the conventional induction heating device.

Description of Embodiments

[0022] A specific configuration example of an induction heating device according to this disclosure will be described in detail in first to eighth embodiments described later, and the induction heating device according to this disclosure has a configuration having the following aspects.

[0023] An induction heating device of a first aspect according to the present disclosure comprises:

a series connection body, which is connected to a power source, including a first semiconductor switch, a second semiconductor switch, and a third semiconductor switch;

a series connection body, which is connected in parallel to the first semiconductor switch, including a first resonance capacitor and a first heating coil magnetically coupled to a load;

a series connection body, which is connected in parallel to the third semiconductor switch, including a second resonance capacitor and a second heating coil magnetically coupled to a load; and

a control part controlling the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch, wherein

the control part selectively drives the following modes depending on a load:

a first single heating mode in which the second semiconductor switch and the third semiconductor switch are alternately made conductive while the first semiconductor switch is made always conductive so as to supply a high-frequency power to the second heating coil,

a second single heating mode in which the first semiconductor switch and the second semiconductor switch are alternately made conductive while the third semiconductor switch is made always conductive so as to supply a high-frequency power to the first heating coil, and

a simultaneous heating mode in which the first semiconductor switch and the third semiconductor switch are alternately made conductive while the second semiconductor switch is made always conductive so as to supply a high-frequency power to the first heating coil and the second heating coil at the same time.

[0024] The induction heating device of the first aspect configured as described above can supply the high-frequency power to a plurality of the heating coils at the same time, generates no interference sound even when the high-frequency power is supplied to a plurality of the heating coils, has an excellent cooking performance as well as the reduced number of components, and therefore can provide an inexpensive induction heating device with a small circuit mounting area.

[0025] An induction heating device of a second aspect according the present disclosure is configured that in the first aspect, a resonance frequency generated by a first resonance circuit made up of the first heating coil and the first resonance capacitor becomes the same as a resonance frequency generated by a second resonance circuit made up of the second heating coil and the second resonance capacitor.

[0026] The induction heating device of the second aspect configured as described above can substantially uniformly supply the high-frequency power from the heating coils to the load when the same load is heated by a plurality of the heating coils. Therefore, the induction heating device of the second aspect can uniformly finish an object to be heated such as a cooked object and acts as an induction heating device with improved usability.

[0027] An induction heating device of a third aspect according to the present disclosure is configured that in the first aspect or the second aspect, when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part controls the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch such that an average power supplied to both the first heating coil and the second heating coil attains a target value by changing a ratio between a period in the simultaneous heating mode and a period in the first single heating mode or the second single heating mode.

[0028] The induction heating device of the third aspect configured as described above can supply different high-frequency powers to the load on the heating coils to enable fine power adjustment, and can achieve an induction heating device with improved usability.

[0029] An induction heating device of a fourth aspect according to the present disclosure is configured that in the first aspect, when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part performs an alternate heating mode in which each of the first single heating mode and the second single heating mode is repeated in a short period within one second, so as to supply the high-frequency power uniformly to both the first heating coil and the second heating coil.

[0030] The induction heating device of the fourth aspect configured as described above generates no interference sound even when the high-frequency power is supplied to a plurality of the heating coils, has an excellent cooking performance as well as the reduced number of components, and therefore can achieve an inexpensive induction heating device with a small circuit mounting area.

[0031] An induction heating device of a fifth aspect according to the present disclosure is configured that in the fourth aspect, a state transition between the first single heating mode and the second single heating mode is performed in the alternate heating mode when the second semiconductor switch is in a non-conductive state.

[0032] The induction heating device of the fifth aspect configured as described above does not particularly require a resting period provided at the time of switchover between the first single heating mode and the second single heating mode and can switch the heating coil supplying the high-frequency power at high speed. As a result, a device user can feel a cooking status equivalent to when each of multiple loads is continuously heated and the induction heating device of this disclosure can achieve a cooking performance with improved usability.

[0033] An induction heating device of a sixth aspect according to the present disclosure is configured that in the fourth aspect or the fifth aspect, when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part controls a continuous operation time of the first single heating mode and a continuous operation time of the second single heating mode in the alternate heating mode to be the same ratio and changes operation frequencies or conduction times of two semiconductor switches out of the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch supplying the high-frequency power to the first heating coil and the second heating coil in the first single heating mode and the second single heating mode, so as to control an input power.

[0034] The induction heating device of the sixth aspect configured as described above can finely perform the power adjustment and therefore can achieve an induction heating device with improved usability.

[0035] An induction heating device of a seventh aspect according the present disclosure is configured that in the fourth aspect or the fifth aspect, when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part sets operation frequencies or conduction times of two semiconductor switches constant out of the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch supplying the high-frequency power to the first heating coil and the second heating coil in the first single heating mode and the second single heating mode in the alternate heating mode and changes a ratio of a continuous operation time of the first single heating mode and a continuous operation time of the second single heating mode, so as to control an input power.

[0036] The induction heating device of the seventh aspect configured as described above can perform the power adjustment in a larger range and therefore can achieve an induction heating device with improved usability.

[0037] An induction heating device of an eighth aspect according to the present disclosure is configured that in the first aspect, the first heating coil is made up of a plurality of first heating coil elements while the first resonance capacitor is made up of a plurality of first resonance capacitor elements such that the plurality of the first heating coil elements is respectively connected to the plurality of the first resonance capacitor elements to form a plurality of series connection bodies connected in parallel to the first semiconductor switch, wherein

the second heating coil is made up of a plurality of second heating coil elements while the second resonance capacitor is made up of a plurality of second resonance capacitor elements such that the plurality of the second heating coil elements is respectively connected to the plurality of the second resonance capacitor elements to form a plurality of series connection bodies connected in parallel to the third semiconductor switch, and wherein

the control part controls the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch so as to switch between an alternate heating mode in which the first single heating mode and the second signal heating mode are alternately repeated and the simultaneous heating mode depending on a material of a load.

[0038] When the same load is heated by using a plurality of the heating coils, the induction heating device of the eighth aspect configured as described above can operate the first to third semiconductor switches in the simultaneous heating mode in the case of a material making the impedance of the load coupled to the heating coils lager and can operate the first to third semiconductor switches in the alternate heating mode in the case of a material making the impedance of the load coupled to the heating coils smaller, thereby bringing the impedances close to each other even when the materials are different. Therefore, the induction heating device of this disclosure can achieve an induction heating device that can apply necessary input power to a load at a constant frequency even if the material of the load is changed, that generates no interference sound, and that is excellent in controllability.

[0039] An induction heating device of a ninth aspect according to the present disclosure is configured that in the eighth aspect, the control part has a step-down simultaneous heating mode in which the first semiconductor switch and the third semiconductor switch are caused to perform the same on/off operation while the on/off operation of the first semiconductor switch and the third semiconductor switch are performed alternately with an on/off operation of the second semiconductor switch so as to supply the high-frequency power to the first heating coil and the second heating coil at the same time, and wherein

the control unit can selectively switch the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on a material of a load.

[0040] When the same load is heated by using a plurality of the heating coils, the induction heating device of the ninth aspect configured as described above can operate the first to third semiconductor switches in the simultaneous heating mode in the case of a material making the impedance of the load coupled to the heating coils lager and can operate the first to third semiconductor switches in the step-down simultaneous heating mode in the case of a material making the impedance of the load coupled to the heating coils smaller, thereby bringing the impedances close to each other even when the materials are different. Therefore, the induction heating device of this disclosure can achieve an induction heating device that can supply necessary input power at a constant frequency to a load even if the material of the load is changed, that generates no interference sound, and that is excellent in controllability.

[0041] An induction heating device of a tenth aspect according to the present disclosure is configured that in the eighth aspect or the ninth aspect, the induction heating device further comprises a load detecting part detecting the presence of a heatable load in the vicinity of each of the first heating coli elements and the second heating coil elements, a plurality of first opening/closing part elements detaching the respective series connection bodies of the first heating coil elements and the first resonance capacitor elements from an energizing path for parallel connection to the first semiconductor switch, and a plurality of second opening/closing part elements detaching the respective series connection bodies of the second heating coil elements and the second resonance capacitor elements from an energizing path for parallel connection to the third semiconductor switch, wherein

the control part puts into a connected state the first opening/closing part elements and/or the second opening/closing part elements corresponding to the first heating coil elements and/or the second heating coil elements having a load detected in the vicinity thereof by the load detecting part.

[0042] Since the first heating coil and the second heating coil are made up only of the heating coil elements with the load present in the vicinity thereof, the induction heating device of the tenth aspect configured as described above can supply a desired high-frequency power to the load from the appropriate heating coils in accordance with the shape of the load. As a result, the induction heating device of this disclosure can achieve a heating device heating the load with uniform heating distribution and having a high heating efficiency.

[0043] An induction heating device of an eleventh aspect according to the present disclosure is configured that in the eighth aspect or the ninth aspect, the induction heating device further comprises a load detecting part detecting the presence of a heatable load in the vicinity of each of the first heating coli elements and the second heating coil elements, a plurality of first opening/closing part elements detaching the respective series connection bodies of the first heating coil elements and the first resonance capacitor elements from an energizing path for parallel connection to the first semiconductor switch, and a plurality of second opening/closing part elements detaching the respective series connection bodies of the second heating coil elements and the second resonance capacitor elements from an energizing path for parallel connection to the third semiconductor switch, wherein

the control part controls into a connected state the first opening/closing part elements and/or the second opening/closing part elements corresponding to the first heating coil elements and/or the second heating coil elements having a load detected in the vicinity thereof by the load detecting part and selectively switches the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on the number of the first heating coil elements and/or the second heating coil elements having a load detected in the vicinity thereof by the load detecting part.

[0044] The induction heating device of the eleventh aspect configured as described above can achieve an induction heating device that can supply a predetermined input power at a constant frequency to the load even when the number of the heating coils is changed, that generates no interference sound, and that is excellent in controllability. The induction heating device of the eleventh aspect can change impedance and applied voltage of a heating coil group depending on the number of the heating coil elements making up the first heating coil and the second heating coil and therefore can perform the power adjustment with the operation frequency kept constant. The induction heating device of the eleventh aspect can perform the simultaneous heating mode if the number of the heating coil elements is small and the impedance is made larger, and can perform the alternate heating mode if the number of the heating coil elements is large and the impedance is made smaller, so as to supply a predetermined input power at a constant frequency to the load even when the number of the connected heating coil elements is changed, and can achieve an induction heating device that generates no interference sound and that is excellent in controllability.

[0045] An induction heating device of a twelfth aspect according to the present disclosure is configured that in the eighth aspect or the ninth aspect, the first heating coil elements making up the first heating coil and the second heating coil elements making up the second heating coil are arranged in a staggered manner in a planar heating region.

[0046] The induction heating device of the twelfth aspect configured as described above can uniformly supply the high-frequency power from the element heating coils to the load and therefore can achieve an induction heating device that forms favorable heating distribution for the load.

[0047] An induction heating device of embodiments according to the present disclosure will now be described with reference to the accompanying drawings.

[0048] An induction heating cooker will hereinafter be described as embodiments according to the induction heating device of this disclosure with reference to the accompanying drawings. The induction heating device of the present disclosure is not limited to the configuration of the induction heating cooker described in the following embodiments and include a device configured based on technical ideas equivalent to technical ideas described in the following embodiments.

(First Embodiment)

[0049] An induction heating device acting as an induction heating cooker of a first embodiment according to the present disclosure will be described with reference to the drawings.

[0050] Fig. 1 is a diagram of a circuit configuration of the induction heating device of the first embodiment. As depicted in Fig. 1, the induction heating device of the first embodiment is made up of an AC power source 1; a rectification circuit 2 rectifying the AC power source 1; a smoothing circuit 30 having a choke coil 4 and a smoothing capacitor 5 smoothing the current/voltage of the rectification circuit 2; a series connection body of a first semiconductor switch 10, a second semiconductor switch 11, and a third semiconductor switch 12 connected in parallel to the smoothing capacitor 5 operating as a DC power source; a series connection body of a first heating coil 6 and a first resonance capacitor 8 connected in parallel to the first semiconductor switch 10; a series connection body of a second heating coil 7 and a second resonance capacitor 9 connected in parallel to the third semiconductor switch 12; an input current detecting part 3 detecting a current flowing from the AC power source 1 to the rectification circuit 2 with a current transformer etc.; and a control part 13 controlling the first to third semiconductor switches 10, 11, and 12 such that a detection value of the input current detecting part 3 becomes equal to a set value.

[0051] A target value of the control part 13 in the induction heating device of this disclosure can be implemented by using the currents and/or voltages of the heating coils 6 and 7 besides the input current and is not particularly limited in this disclosure.

[0052] The semiconductor switches in the induction heating device of this disclosure are often made up of power semiconductors (semiconductor switch elements), such as IGBTs or MOSFETs, and diodes connected in parallel to the respective power semiconductors in the opposite direction, and each of the first to third semiconductor switches 10, 11, and 12 of the first embodiment is made up of a power semiconductor of IGBT and a diode connected in parallel to the power semiconductor in the opposite direction. A snubber capacitor suppressing a rapid voltage rise at the time of shift from the on-state to the off-state is often connected in parallel between a collector and an emitter of the first to third semiconductor switches 10, 11, and 12, and the configuration of the first embodiment is described as an example of connecting a snubber capacitor in parallel to the first semiconductor switch 10 and the third semiconductor switch 10, 12.

<Alternate Heating Mode>

[0053] The induction heating device of the first embodiment configured as described above will hereinafter be described in terms of operation and action thereof. Figs. 2A and 2B are waveform diagrams of an operation (an alternate heating mode) in the induction heating device of the first embodiment according to this disclosure. The alternate heating mode is a heating mode alternately repeating a first single heating mode and a second single heating mode described later in a short cycle. Fig. 2A is a waveform diagram of the first single heating mode in which a high-frequency power is supplied to the second heating coil 7, and depicts gate voltage waveforms (a) to (c) of the first to third semiconductor switches 10, 11, 12 and a current waveform (d) of the second heating coil 7. Fig. 2B is a waveform diagram of the second single heating mode in which a high-frequency power is supplied to the first heating coil 6, and depicts gate voltage waveforms (a) to (c) of the first to third semiconductor switches 10, 11, 12 and a current waveform (d) of the first heating coil 6.

<First Single Heating Mode>

[0054] The first single heating mode of supplying a high-frequency power to the second heating coil 7 depicted in Fig. 2A will first be described.

[0055] To supply the high-frequency power to the second heating coil 7 in the first single heating mode, the control part 13 puts the first semiconductor switch (Q1a) 10 into a constantly conductive state and controls a conductive state/non-conductive state (on-state/off-state) of the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12. In a section A depicted in Fig. 2A, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (on-state) and the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state). As a result, a path is formed from the smoothing capacitor 5 → the first semiconductor switch (Q1a) 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 → the second resonance capacitor 9, and the power is supplied to the second heating coil 7.

[0056] In the section A of Fig. 2A, the control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates a predetermined current value (termination of the section A). After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, a path is formed from the second resonance capacitor 9 → the second heating coil 7 → the third semiconductor switch (Q1c) 12, and the power is supplied to the second heating coil 7. Subsequently, the control part 13 puts the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (section B) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0057] After a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue via the transmission time (X or Y) as depicted in Fig. 2A.

[0058] As described above, in the first single heating mode, the control part 13 can put the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the first semiconductor switch (Q1a) 10 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the second heating coil 7. The high-frequency current supplied in this way causes the second heating coil 7 to generate a high-frequency magnetic field and the high-frequency magnetic field is supplied to a load such as a pot that is an object to be heated. The high-frequency magnetic field supplied to the load such as a pot in this way generates an eddy current on a surface of the pot etc., and the load such as the pot is inductively heated due to the eddy current and a high-frequency resistance of the load such as a pot itself, which leads to heat generation.

<Second Single Heating Mode>

[0059] The second single heating mode of supplying a high-frequency power to the first heating coil 6 will be described with reference to Fig. 2B.

[0060] To supply the high-frequency power to the first heating coil 6 in the second single heating mode, the control part 13 puts the third semiconductor switch (Q1c) 12 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11. When the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state in the section A depicted in Fig. 2B, a path is formed from the smoothing capacitor 5 → the first resonance capacitor 8 → the first heating coil 6 → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12, and the power is supplied to the first heating coil 6.

[0061] In the section A of Fig. 2B, the control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After the predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state. As a result, the power is supplied to the first heating coil 6 through a path from the first resonance capacitor 8 → the first semiconductor switch (Q1a) 10 → the first heating coil 6 (section B). Subsequently, the control part 13 puts the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0062] Subsequently, after the predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue via the transmission time (X or Y) as depicted in Fig. 2B.

[0063] As described above, in the second single heating mode, the control part 13 can put the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11 alternately into the conductive state while keeping the third semiconductor switch (Q1c) 12 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the first heating coil 6. The high-frequency current supplied in this way causes the first heating coil 6 to generate a high-frequency magnetic field and the high-frequency magnetic field is supplied to a load such as a pot that is an object to be heated. Because of the high-frequency magnetic field supplied to the load such as a pot in this way, the load such as the pot is inductively heated, which leads to heat generation.

<Simultaneous Heating Mode>

[0064] Fig. 3 is a waveform diagram of an operation of the simultaneous heating mode in the induction heating device of the first embodiment of this disclosure. Fig. 3 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the first heating coil 6, and (e) as a current waveform of the second heating coil 7.

[0065] To simultaneously supply the high-frequency power to the first heating coil 6 and the second heating coil 7 in the simultaneous heating mode, the control part 13 puts the second semiconductor switch (Q1b) 11 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12.

[0066] In the section A depicted in Fig. 3, the control of putting the first semiconductor switch (Q1a) 10 into the conductive state (on-state) and putting the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state) simultaneously generates the mode of supplying a power to the second heating coil 7 through the path from the smoothing capacitor 5 → the first semiconductor switch (Q1a) 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 → the second resonance capacitor 9, and the mode of supplying a power to the first heating coil 6 through the path from the first resonance capacitor 8 → the first semiconductor switch (Q1a) 10 → the first heating coil 6.

[0067] The control part 13 puts only the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A of Fig. 3).

[0068] After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, this simultaneously generates the operation of supplying a power to the first heating coil 6 through the path from the smoothing capacitor 5 → the first resonance capacitor 8 → the first heating coil 6 → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12, and the operation of supplying a power to the second heating coil 7 through the path from the second resonance capacitor 9 → the second heating coil 7 → the third semiconductor switch (Q1c) 12.

[0069] The control part 13 puts only the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (section B) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B of Fig. 3). Subsequently, after the predetermined transition time (section Y) has elapsed, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state again.

[0070] As described above, in the simultaneous heating mode, the control part 13 can put the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the second semiconductor switch (Q1b) 11 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to both the first heating coil 6 and the second heating coil 7 at the same time. As a result, in the induction heating device of the first embodiment, the high-frequency magnetic field generated from the heating coils supplied with the high-frequency current is supplied to the load such as a pot.

[0071] By properly using the heating modes of the first single heating mode, the second single heating mode, and the simultaneous heating mode depending on a state (such as a material) of a load, the induction heating device of the first embodiment can supply the power independently to, or simultaneously without an interference sound to, the loads present respectively on the first heating coil 6 and the second heating coil 7. In this case, by making the resonance frequency configured by the first heating coil 6 and the first resonance capacitor 8 substantially the same as the resonance frequency configured by the second heating coil 7 and the second resonance capacitor 9, advantages can be acquired, including that a load can uniformly be heated when the same load is heated by the two heating coils 6, 7 at the same time.

[0072] Fig. 4 is a waveform diagram of an operation using a plurality of heating modes in the induction heating device of the first embodiment according to this disclosure. Fig. 4 depicts the operation when the high-frequency power is simultaneously supplied to the first heating coil 6 and the second heating coil 7 and different powers are supplied to the respective heating coils 6, 7. In the induction heating device of the first embodiment, the first heating coil 6 has a supply power set larger than the second heating coil 7.

[0073] First, the control part 13 provides the control such that the device operates in the simultaneous heating mode (see Fig. 3) in which the power is supplied to the first heating coil 6 and the second heating coil 7 at a set value of the first heating coil 6 having a larger supply power between the first heating coil 6 and the second heating coil 7.

[0074] The control part 13 shifts the operation to the second signal heating mode (see Fig. 2B) in which the power is supplied only to the first heating coil 6 without supplying a power to the second heating coil 7 having a smaller supply power. Subsequently, when a non-conduction time has elapsed that is determined by an average power supplied to the second heating coil 7, the control part 13 makes a shift from the second signal heating mode to the simultaneous heating mode again.

[0075] By making a switchover time short between the heating modes, the loads present on the two heating coils

6, 7 can be heated at a desired power without generating an interference sound while a user is prevented from having a strong feeling of difference.

[0076] Although the supply power of the first heating coil 6 is larger than the supply power of the second heating coil 7 in the configuration described in the first embodiment, if the supply power of the second heating coil 7 is configured to be larger than the supply power of the first heating coil 6, the simultaneous heating mode and the first single heating mode can alternately be repeated to properly supply the desired power to the first heating coil 6 and the second heating coil 7 so as to acquire the same effect as the configuration described above.

[0077] Fig. 5 is diagrams of an appearance configuration of the induction heating device of the first embodiment according to this disclosure and (a) on the upper side is a plane view while (b) on the lower side is a vertical cross-sectional view taken in the substantially center portion of the first heating coil 6 disposed closer to a user. As depicted in Fig. 5, the induction heating device of the first embodiment has the first heating coil 6 and the second heating coil 7 arranged under a top plate 18 made of crystallized glass etc. Respective loads such as pots containing a cooked object are placed on the first heating coil 6 and the second heating coil 7, and the plurality of the heating modes (the first single heating mode, the second single heating mode, and the simultaneous heating mode) described above are appropriately used in accordance with an operation from an operation/display part 17 so as to properly supply necessary powers to the respective heating coils 6, 7.

[0078] The induction heating device of the first embodiment can operate in the plurality of the heating modes (the first single heating mode, the second single heating mode, and the simultaneous heating mode) described above so as to perform cooking with a power corresponding to each type of cooking.

[0079] Fig. 6 is diagrams of another configuration example of the induction heating device of the first embodiment according to this disclosure. The induction heating device depicted in Fig. 6 has the first heating coil 6 and the second heating coil 7 in an oval shape arranged under one heating region H indicated on the top plate 18 made of crystallized glass etc., and is configured such that one load such as a pot can be heated by the two heating coils 6, 7 at the same time. In the induction heating device depicted in Fig. 6, the oval heating coils 6, 7 are arranged in parallel such that the major axes are located on lines extending from the user side toward a back surface of the device. In Fig. 6, (a) on the upper side is a plane view and (b) on the lower side is a vertical cross-sectional view taken in the substantially center portions of the first heating coil 6 and the second heating coil 7. The induction heating device depicted in Fig. 6 can perform heating and cooking with uniform heating distribution without an interference sound when a plurality of the heating coils is used for heating a single load.

[0080] As described above, in the first embodiment, a plurality of resonance circuits made up of heating coils inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches and, while one semiconductor switch of the three semiconductor switches is in the constantly conductive state (on-state) as a semiconductor switch determining a heating coil supplied with power, the operation in the single heating mode is used in which the remaining semiconductor switches are used as semiconductor switches controlled to the conductive state/non-conductive state (on/off-state) for supplying the high-frequency power to the heating coils, along with the simultaneous heating mode in which the second semiconductor switch is put into the constantly conductive state. By using the single heating mode and the simultaneous heating mode in this way, the induction heating device of the first embodiment can supply power to a plurality of the heating coils at the same time, generates no interference sound even when supplying the high-frequency power to a plurality of the heating coils, and has excellent cooking performance. The configuration of the first embedment has the reduced number of components and therefore leads to an inexpensive induction heating device with a small circuit mounting area.

(Second Embodiment)

[0081] An induction heating device acting as an induction heating cooker of a second embodiment according to the present disclosure will be described with reference to the drawings. The induction heating device of the second embodiment is useful when two heating coils have different operation frequencies due to a difference in material etc. of a load such as a pot, or when impedance of a load is small. The induction heating device of the second embodiment has a configuration preventing the interference sound in an alternate heating mode in which the first single heating mode and the second single heating mode described in the first embodiment are properly alternately switched in a short period of time. In the description of the second embodiment, elements having substantially the same functions and configurations as those of the first embodiment described above will be denoted by the same reference numerals and will not be described.

[0082] Fig. 7 is a diagram of a circuit configuration of the induction heating device of the second embodiment according to this disclosure. As depicted in Fig. 7, the induction heating device of the second embodiment has the similar circuit configuration as the induction heating device of the first embodiment described above, and is made up of the AC power source 1; the rectification circuit 2; the smoothing circuit 30; the series connection body of the first to third semiconductor switches 10, 11, 12; a series connection body of the first heating coil 6 and the first resonance capacitor 8; a series connection body of the second heating coil 7 and the second resonance capacitor 9; the input current detecting part 3; and the control part 13.

[0083] Also in the induction heating device of the second embodiment, the first to third semiconductor switches 10, 11, and 12 are made up of power semiconductors (semiconductor switch elements), such as IGBTs or MOSFETs, and diodes connected in parallel to the respective power semiconductors in the opposite direction. A snubber capacitor suppressing a rapid voltage rise at the time of shift from the on-state to the off-state may be connected in parallel between a collector and an emitter of the first to third semiconductor switches 10, 11, and 12. In the second embodiment, a snubber capacitor is connected in parallel between the collector and the emitter of the first semiconductor switch 10 and the third semiconductor switch 12.

[0084] The induction heating device of the second embodiment configured as described above will hereinafter be described in terms of operation and action thereof. Figs. 8A and 8B are waveform diagrams of an operation (the alternate heating mode) in the induction heating device of the second embodiment according to this disclosure. Fig. 8A is a waveform diagram of the first single heating mode in which the high-frequency power is supplied to the second heating coil 7, and depicts gate voltage waveforms (a) to (c) of the first to third semiconductor switches 10, 11, 12 and a current waveform (d) of the second heating coil 7. Fig. 8B is a waveform diagram of the second single heating mode in which the high-frequency power is supplied to the first heating coil 6, and depicts gate voltage waveforms (a) to (c) of the first to third semiconductor switches 10, 11, 12 and a current waveform (d) of the first heating coil 6.

[0085] To supply the high-frequency power to the second heating coil 7, the control part 13 puts the first semiconductor switch (Q1a) 10 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12. In a section A depicted in Fig. 8A, the control part 13 puts the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11 into the conductive state (on-state) and the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state). As a result, a path is formed from the smoothing capacitor 5 → the first semiconductor switch (Q1a) 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 → the second resonance capacitor 9, and the power is supplied to the second heating coil 7.

[0086] The control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time (Tb) when the current value detected by the input current detecting part 3 indicates the predetermined current value. After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, a path is formed from the second resonance capacitor 9 → the second heating coil 7 → the third semiconductor switch (Q1c) 12, and the power is supplied to the second heating coil 7. Subsequently, the control part 13 puts the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (Tc) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0087] Subsequently, after a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue alternately via the transmission time (X or Y).

[0088] As described above, the control part 13 can put the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the first semiconductor switch (Q1a) 10 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the second heating coil 7. The high-frequency magnetic field generated from the second heating coil 7 due to the high-frequency current supplied in this way is supplied to the load such as a pot.

[0089] The high-frequency magnetic field supplied to the load such as a pot in this way generates an eddy current on a surface of the load such as a pot, and the load such as a pot is inductively heated due to the eddy current and a high-frequency resistance of the load such as a pot itself, which leads to heat generation.

[0090] The second single heating mode of supplying a high-frequency power to the first heating coil 6 will be described with reference to Fig. 8B.

[0091] To supply the high-frequency power to the first heating coil 6 in the second single heating mode, the control part 13 puts the third semiconductor switch (Q1c) 12 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11. When the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state in the section A depicted in Fig. 8B, a path is formed from the smoothing capacitor 5 → the first resonance capacitor 8 → the first heating coil 6 → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12, and the power is supplied to the first heating coil 6.

[0092] In the section A of Fig. 8B, the control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time (Tb) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A of Fig. 8B). After the predetermined transition time (section X) has elapsed, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state.

[0093] As a result, a path is formed from the first resonance capacitor 8 → the first semiconductor switch

(Q1a) 10 → the first heating coil 6, and the power is supplied to the first heating coil 6. Subsequently, the control part 13 puts the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time (Ta) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B of Fig. 8B).

[0094] Subsequently, after a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue via the transmission time (X or Y). As described above, in the second single heating mode, the control part 13 can put the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11 alternately into the conductive state while keeping the third semiconductor switch (Q1c) 12 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the first heating coil 6. The high-frequency magnetic field generated from the heating coil due to the high-frequency current supplied in this way is supplied to the load such as a pot.

[0095] Fig. 9 is a waveform diagram of an operation of the alternate heating mode in the induction heating device of the second embodiment. The alternate heating mode is the operation when the first single heating mode and the second single heating mode described above are alternately used for heating a plurality of loads. Fig. 9 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the second heating coil 7, and (e) as a current waveform of the first heating coil 6. In the alternate heating mode of the induction heating device of the second embodiment, an operation time of the first single heating mode is T2 and an operation time of the second single heating mode is T1. Therefore, in the second embodiment, the operation time T1 and the operation time T2 are set to a very short cycle. Each of the operation time T1 and the operation time T2 is set to, for example, one second or less, and one cycle (T1+T2) of the alternate heating mode is set to a very short cycle within two seconds.

[0096] As depicted in Fig. 9, in the alternate heating mode, the device can be operated in the first single heating mode and the second single heating mode alternately in a short cycle so as to perform the heating operation for a load placed on the second heating coil 7 and a load placed on the first heating coil substantially at the same time.

[0097] This is because the control part 13 can change the heating coil supplied with power simply by changing the operation states of the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c).

[0098] The switchover operation between the first single heating mode and the second single heating mode in the alternate heating mode can switch the heating modes within approximately one second to maintain a continuously boiling state when boiling water. Therefore, as compared to the case of simultaneous heating using a plurality of the heating coils, an equivalent performance can be acquired.

[0099] Fig. 10 is a waveform diagram at the time of the switchover operation between the first single heating mode and the second single heating mode in the alternate heating mode of the induction heating device of the second embodiment. Fig. 10 depicts the operation state at the time of switching the heating coil supplied with power from the first single heating mode to the second single heating mode at a high speed.

[0100] As depicted in the waveform diagram of Fig. 10, at the time of switching from the first single heating mode to the second single heating mode, when the third semiconductor switch (Q1c) 12 enters the conductive state and the second semiconductor switch (Q1b) is in the non-conductive state, the control part 13 puts the first semiconductor switch (Q1a) into the non-conductive state for switching to the second single heating mode.

[0101] When the switchover is performed in the state described above, an overvoltage etc. are not applied to the second semiconductor switch (Q1b) 11. Therefore, the switchover from the first single heating mode to the second single heating mode can smoothly be performed without applying a stress to the semiconductor switches.

[0102] On the other hand, at the time of switching from the second single heating mode to the first single heating mode, when the first semiconductor switch (Q1a) 10 enters the conductive state and the second semiconductor switch (Q1b) 11 is in the non-conductive state, the control part 13 puts the third semiconductor switch (Q1c) 12 into the non-conductive state for switching to the first single heating mode.

[0103] As described above, by switching from the second single heating mode to the first single heating mode in the non-conductive period of the second semiconductor switch (Q1b) 11, the heating coil to be supplied with power can smoothly be switched in a short time.

[0104] Since the heating is performed alternately between the first heating coil 6 and the second heating coil 7, the alternate heating mode can eliminate the occurrence of interference sound due to a difference in operation frequencies.

[0105] Figs. 11A and 11B are diagrams for explaining the power characteristics in the induction heating device of the second embodiment and depict the characteristics when amounts of power supplied to the first heating coil 6 and the second heating coil 7 are changed. Fig. 11A is a characteristic diagram showing characteristics of a conduction time [μsec] and an input power [W] of a semiconductor switch (at a constant operation frequency). Fig. 11B is a characteristic diagram of characteristics of an operation frequency [kHz] and an input power [W] of a semiconductor switch (at a constant on-time ratio).

[0106] If control is provided such that power is supplied to the first heating coil 6 and the second heating coil 7 substantially at the same time, a transition time between the heating modes must be made short so as to perform the heating in a continuous manner.

[0107] Therefore, it is desirable to change the conduction time (see the characteristic diagram of Fig. 11A) or the operation frequency (see the characteristic diagram of Fig. 11B) of the semiconductor switches with the transition time fixed to a constant time.

[0108] With regard to the conduction time of the semiconductor switches, the supply power becomes the largest when the conduction times of two semiconductor switches performing the high-frequency operation are the same (Ta=Tb, Tb=Tc). As the conduction time of one of the semiconductor switches decreases and the conduction time of the other semiconductor switch increases, i.e., as a duty ratio deteriorates from 1:1, the supply power is reduced.

[0109] In the case of changing the operation frequency, since the operation is normally performed at a frequency higher than the resonance frequency of a series resonance circuit made up of a heating coil and a resonance capacitor coupled to a load, the input power decreases as the frequency becomes higher as depicted in Fig. 11B.

[0110] Fig. 12 is a diagram of electric characteristics of the alternate heating mode in the induction heating device of the second embodiment. Fig. 12 depicts changes in amounts of power supplied to the first heating coil 6 and the second heating coil 7 when a conduction time ratio (T1/TL) of the second single heating mode in one cycle (TL) is changed in the alternate heating mode.

[0111] As depicted in Fig. 12, when the heating is performed with the first heating coil 6 and the second heating coil 7 at substantially the same time in the alternate heating mode, the powers supplied to the first heating coil 6 and the second heating coil 7 are determined by a conduction time ratio during the power supply to the respecting heating coils 6, 7. Therefore, if the supply power to one of the heating coils is increased, the conduction time ratio for the power supply to the heating coils must be changed. In this case, to prevent a user from having a feeling of difference from actual simultaneous heating in the alternate heating mode, it is desirable to change only the conduction time ratio with a cycle period kept constant when the alternate heating mode is performed.

[0112] Fig. 13 is diagrams of an appearance configuration of the induction heating device of the second embodiment according to this disclosure and (a) on the upper side is a plane view while (b) on the lower side is a vertical cross-sectional view taken in the substantially center portion of the first heating coil 6 disposed closer to a user. As depicted in Fig. 13, the induction heating device of the second embodiment has the first heating coil 6 and the second heating coil 7 arranged under the top plate 18 made of crystallized glass etc. Loads of different materials and shapes are placed on the first heating coil 6 and the second heating coil 7, and necessary powers are supplied to the respective heating coils 6, 7 in accordance with an operation from the operation/display part 17 in this configuration.

[0113] The induction heating device of the second embodiment generates no interference sound even when being operated by the control part 13 at an optimum operation frequency depending on a material of a load and a necessary power set by a user. As a result, a loss is reduced in the first to third semiconductor switches 10, 11, 12 in the induction heating device of the second embodiment and this configuration has advantages such as that cooling components including a radiation fin can be miniaturized.

[0114] Fig. 14 is diagrams of another configuration example of the induction heating device of the second embodiment according to this disclosure. The induction heating device depicted in Fig. 14 has the first heating coil 6 and the second heating coil 7 in an oval shape arranged under the one heating region H indicated on the top plate 18 made of crystallized glass etc., and is configured such that one load such as a pot can be heated by the two heating coils 6, 7 at the same time. In the induction heating device depicted in Fig. 14, the oval heating coils 6, 7 are arranged in parallel such that the major axes are located on lines extending from the user side toward a back surface of the device. In Fig. 14, (a) on the upper side is a plane view and (b) on the lower side is a vertical cross-sectional view taken in the substantially center portions of the first heating coil 6 and the second heating coil 7.

[0115] When a plurality of the heating coils is used for heating a single load, the induction heating device depicted in Fig. 14 can perform the heating without the interference sound regardless of the placement state of the pot. In this case, only the necessary heating coil can be energized depending on a shape, an amount, etc. of the load and, therefore, the heating can efficiently be performed in this configuration.

[0116] As described above, in the second embodiment, a plurality of resonance circuits made up of heating coils inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches and, while one semiconductor switch of the three semiconductor switches is in the constantly conductive state (on-state) as a semiconductor switch determining a heating coil supplied with power, the alternate heating mode is used in which the remaining semiconductor switches are used as semiconductor switches controlled to the conductive state/non-conductive state (on/off-state) for supplying the high-frequency power to the heating coils. By using the alternate heating mode in this way, the induction heating device of the second embodiment generates no interference sound even when supplying the high-frequency power to a plurality of the heating coils by switching the heating coils supplied with the power at high speed, and has excellent cooking performance. The configuration of the second embedment has the reduced number of components and therefore can achieve an inexpensive induction heating device with a small circuit mounting area.

(Third Embodiment)

[0117] An induction heating device acting as an induction heating cooker of a third embodiment according to the present disclosure will be described with reference to the drawings. In the description of the third embodiment, elements having substantially the same functions and configurations as those of the first and second embodiments described above will be denoted by the same reference numerals and will not be described.

[0118] Fig. 15 is a diagram of a circuit configuration of the induction heating device of the third embodiment. As depicted in Fig. 15, the induction heating device of the third embodiment has the similar circuit configuration as the induction heating device of the first embodiment described above, and is made up of the AC power source 1; the rectification circuit 2; the smoothing circuit 30; the series connection body of the first to third semiconductor switches 10, 11, 12; a series connection body of the first heating coil 6 and the first resonance capacitor 8; a series connection body of the second heating coil 7 and the second resonance capacitor 9; the input current detecting part 3; and the control part 13.

[0119] Also in the induction heating device of the third embodiment, the first to third semiconductor switches 10, 11, and 12 are made up of power semiconductors (semiconductor switch elements), such as IGBTs or MOSFETs, and diodes connected in parallel to the respective power semiconductors in the opposite direction. A snubber capacitor suppressing a rapid voltage rise at the time of shift from the on-state to the off-state may be connected in parallel between a collector and an emitter of the first to third semiconductor switches 10, 11, and 12. In the third embodiment, a snubber capacitor is connected in parallel between the collector and the emitter of the first semiconductor switch 10 and the third semiconductor switch 12.

[0120] The induction heating device of the third embodiment configured as described above is configured such that a plurality of heating coils heats loads of substantially the same material, and is particularly used when a single load is heated by a plurality of heating coils.

[0121] In the induction heating device of the third embodiment, as depicted in Fig. 16, in the case of configuration of the two heating coils 6 and 7, the two heating coils 6 and 7 are arranged substantially concentrically in one heating region. In another configuration in the induction heating device of the third embodiment, as depicted in Fig. 17, the two heating coils 6 and 7 having an oval shape as a planar shape are arranged adjacently in one heating region. The configuration of the induction heating device of the third embodiment includes a configuration of heating one load by using a plurality of heating coils having respective different centers of circles. Therefore, as depicted in Fig. 18, the configuration of the induction heating device of the third embodiment includes a configuration in which a plurality of the heating coils 6, 7 is arranged on an almost entire area of the top plate in a matrix shape to heat one load with a plurality of the heating coils 6, 7.

[0122] When a plurality of loads (denoted by reference numeral 25 in Figs. 16 to 18) is simultaneously heated in the induction heating device of the third embodiment, the operation frequencies of the high-frequency powers supplied to the loads 25 are respectively different in most cases. When a difference in the operation frequencies is in the audible range in such case, an interference sound attributable to the operation frequency difference is generated and a user feels that a noise is loud. Therefore, a configuration must be achieved that enables the heating operation performed with the operation frequency kept in a constant state even when the material of the load 25 is changed, so as not to generate the interference sound.

[0123] The inductance values of the first heating coil 6 and the second heating coil 7 for heating the one load 25 depicted in Figs. 16 to 18 are desirably set to substantially the same value so that the electric power amounts are hardly biased.

[0124] The operation of the induction heating device of the third embodiment will be described. Fig. 19 is a waveform diagram of an operation state of the simultaneous heating mode in the induction heating device of the third embodiment. Fig. 19 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the first heating coil 6, and (e) as a current waveform of the second heating coil 7.

[0125] To simultaneously supply the high-frequency power to the first heating coil 6 and the second heating coil 7 in the simultaneous heating mode, the control part 13 puts the second semiconductor switch (Q1b) 11 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12.

[0126] In the section A depicted in Fig. 19, the control of putting the first semiconductor switch (Q1a) 10 into the conductive state (on-state) and putting the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state) simultaneously generates the mode of supplying a power to the second heating coil 7 through the path from the smoothing capacitor 5 → the first semiconductor switch (Q1a) 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 → the second resonance capacitor 9, and the mode of supplying a power to the first heating coil 6 through the path from the first resonance capacitor 8 → the first semiconductor switch (Q1a) 10 → the first heating coil 6.

[0127] The control part 13 puts only the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, this simultaneously generates the operation of supplying a power to the first heating coil 6 through the path from the smoothing capacitor 5 → the first resonance capacitor 8 → the first heating coil 6 → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12, and the operation of supplying a power to the second heating coil 7 through the path from the second resonance capacitor 9 → the second heating coil 7 → the third semiconductor switch (Q1c) 12.

[0128] The control part 13 puts only the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (section B) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B). After the termination of the section B, when the predetermined transition time (section Y) has elapsed, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state again.

[0129] As described above, in the simultaneous heating mode, the control part 13 can put the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the second semiconductor switch (Q1b) 11 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to both the first heating coil 6 and the second heating coil 7 at the same time. As a result, in the induction heating device of the third embodiment, a desired high-frequency magnetic field generated from the heating coils supplied with the high-frequency current is supplied to the load such as a pot.

[0130] The induction heating device of the third embodiment is configured such that the alternate heating mode can be performed.

[0131] Fig. 20A is a waveform diagram of the first single heating mode in which high-frequency power is supplied to the second heating coil 7. Fig. 20A includes (a) to (c) depicting gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, and (d) depicting a current waveform of the second heating coil 7.

[0132] To supply the high-frequency power to the second heating coil 7 in the first single heating mode depicted in Fig. 20A, the control part 13 puts the first semiconductor switch (Q1a) 10 into a constantly conductive state and controls a conductive state/non-conductive state (on-state/off-state) of the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12. In a section A depicted in Fig. 20A, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (on-state) and the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state). As a result, the power is supplied to the second heating coil 7 through the path from the smoothing capacitor 5 → the first semiconductor switch (Q1a) 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 → the second resonance capacitor 9.

[0133] The control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time (Tb) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, the power is supplied to the second heating coil 7 through the path from the second resonance capacitor 9 → the second heating coil 7 → the third semiconductor switch 12. Subsequently, the control part 13 puts the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (Tc) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0134] Subsequently, after a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue alternately via the transmission time (X or Y).

[0135] As described above, the control part 13 can put the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the first semiconductor switch (Q1a) 10 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the second heating coil 7. The high-frequency magnetic field generated from the second heating coil 7 due to the high-frequency current supplied in this way is supplied to the load such as a pot.

[0136] The high-frequency magnetic field supplied to the load such as a pot in this way generates an eddy current on a surface of the load such as a pot, and the load such as the pot is inductively heated due to the eddy current and a high-frequency resistance of the load such as a pot itself, which leads to heat generation.

[0137] The second single heating mode of supplying high-frequency power to the first heating coil 6 will be described with reference to Fig. 20B.

[0138] To supply the high-frequency power to the first heating coil 6 in the second single heating mode, the control part 13 puts the third semiconductor switch (Q1c) 12 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11. When the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state in the section A depicted in Fig. 20B, the power is supplied to the first heating coil 6 through the path from the smoothing capacitor 5 → the first resonance capacitor 8 → the first heating coil 6 → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12.

[0139] In the section A of Fig. 20B, the control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time (Tb) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After the predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state. As a result, the power is supplied to the first heating coil 6 through the path from the first resonance capacitor 8 → the first semiconductor switch (Q1a) → the first heating coil 6. Subsequently, the control part 13 puts the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time (Ta) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0140] Subsequently, after a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue via the transmission time (X or Y). As described above, in the second single heating mode, the control part 13 can put the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11 alternately into the conductive state while keeping the third semiconductor switch (Q1c) 12 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the first heating coil 6. The high-frequency magnetic field generated from the heating coil due to the high-frequency current supplied in this way is supplied to the load such as a pot.

[0141] Fig. 21 is a waveform diagram of an operation of the alternate heating mode in the induction heating device of the third embodiment. The alternate heating mode is the operation when the first single heating mode depicted in Fig. 20A and the second single heating mode depicted in Fig. 20B are alternately used for heating a plurality of loads. Fig. 21 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the second heating coil 7, and (e) as a current waveform of the first heating coil 6. In the alternate heating mode of the induction heating device of the third embodiment, an operation time of the first single heating mode is T2 and an operation time of the second single heating mode is T1. Therefore, in the third embodiment, each of the operation time T1 and the operation time T2 is set to a very short time within one second and one cycle (T1+T2) of the alternate heating mode is set to two seconds or less.

[0142] For the switchover operation between the first single heating mode and the second single heating mode in the alternate heating mode of the induction heating device of the third embodiment, the same control is provided as the control described with reference to Fig. 10 in the second embodiment and the highly efficient switchover operation is performed in a short time.

[0143] As depicted in Fig. 21, in the alternate heating mode, the loads can simultaneously be heated without deteriorating the heating distribution for the loads by periodically operating the first single heating mode and the second single heating mode alternately in a short period of time. Particularly, the induction heating device of the third embodiment can reduce heating unevenness for the loads without lowering the average power by setting a short switchover time equal to or less than two seconds between the first single heating mode and the second single heating mode.

[0144] Fig. 22 is a diagram of a relationship between the conduction time of the semiconductor switch and the resonance voltage generated in the resonance capacitor depending on a material of a load. The resonance frequency varies depending on a material of a load in the resonance circuit made up of the first resonance capacitor 8 and the first heating coil 6 magnetically coupled to the load, or the resonance circuit made up of the second resonance capacitor 9 and the second heating coil 7 magnetically coupled to the load.

[0145] While no load exists, the inductance is the largest and the resonance frequency becomes lower. On the other hand, when a load is disposed in the vicinity of the heating coil and the load is magnetically coupled to the heating coil, the inductance is reduced and the resonance frequency becomes higher.

[0146] When a load is disposed in the vicinity of the heating coil, the inductance is reduced in the load 25B made of non-magnetic stainless steel etc., as compared to the load 25A made of iron, stainless steel, etc., and therefore, the resonance frequency is increased. If a load has intermediate characteristics between magnetic stainless steel and non-magnetic stainless steel, the resonance frequency is between those of the both stainless steels.

[0147] Therefore, the control part 13 can determine a type of a load by detecting a resonance voltage generated at predetermined operation frequency and conduction time. A load 25B having a low inductance and an operation frequency close to the resonance frequency makes the resonance voltage higher, while a load 25A having characteristics of a high inductance and an operation frequency far from the resonance frequency makes the resonance voltage lower. In the case of no load, the resonance voltage becomes lower in the order of the load 25B, the load 25A, and no load. Therefore, a type of a load and the presence/absence of a load can be determined by detecting the resonance voltage generated at predetermined operation frequency and conduction time.

[0148] If the operation frequency is kept constant for preventing the inference sound with an adjacent load in the configuration of the third embodiment, a large difference is generated in the input power generated during the conduction time depending on a material of a load as depicted in Fig. 23. Therefore, since the input power cannot sufficiently be reduced for some loads and a control width of power control must be increased, the heating device may have poor usability.

[0149] Therefore, in the case of a load having characteristics of a high inductance and an operation frequency sufficiently far from the resonance frequency, for example, in the case of the load 25A made of a magnetic material, the device is operated in the simultaneous heating mode (see Fig. 19) that is the operation in which the first heating coil 6 and the second heating coil 7 are connected in parallel. On the other hand, in the case of a load having characteristics of a low inductance and an operation frequency close to the resonance frequency so that the input power is easily introduced, for example, in the case of the load 25B made of a non-magnetic material, the device is operated in the alternate heating mode (see Figs. 20A and 20B) that is the operation in which the first heating coil 6 and the second heating coil 7 are connected separately from each other. If the device is activated in the simultaneous heating mode also for the load 25B as is the case with the load 25A, the input power is more easily introduced since the resonance frequency is closer to the operation frequency. Therefore, as indicated by an arrow of Fig. 23, a shift to the alternate heating mode is made in the case of the load 25B to increase the impedance of the circuit, thereby achieving a circuit configuration in which the input power is hardly introduced.

[0150] Since the number of the parallelly-connected heating coils reduced by half in the alternate heating mode as compared to the simultaneous heating mode, the impedance of the heating coils connected to the semiconductor switches is doubled and, as a result, the current to the heating coils can be suppressed to reduce the input power.

[0151] As described above, in the induction heating device of the third embodiment, a plurality of resonance circuits made up of heating coils inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches in the induction heating device configured to use a plurality of the heating coils to heat the same load and, in the case of a load of a load material making an equivalent resistance value larger, the device is operated in the simultaneous heating mode (see Fig. 19) in which the first and third semiconductor switches are alternately made conductive while the second semiconductor switch is made always conductive so as to supply power to the first heating coil and the second heating coil at the same time.

[0152] On the other hand, in the case of the load 25B of a material making an equivalent resistance value smaller, the device is operated in the alternate heating mode (see Figs. 20A and 20B) by alternately repeating the operations in a short cycle between the first single heating mode in which the second and third semiconductor switches are alternately made conductive while the first semiconductor switch is made always conductive so as to supply high-frequency power to the second heating coil and the second single heating mode in which the first and second semiconductor switches are alternately made conductive while the third semiconductor switch is made always conductive so as to supply high-frequency power to the first heating coil.

[0153] Since the heating control is provided as described above in the induction heating device of the third embodiment, a predetermined input power can be applied at a constant frequency to a load even when a type of the load is changed, and the induction heating device generating no interference sound and excellent in controllability can be achieved.

(Fourth Embodiment)

[0154] An induction heating device acting as an induction heating cooker of a fourth embodiment according to the present disclosure will be described with reference to the drawings. In the description of the fourth embodiment, elements having substantially the same functions and configurations as those of the first to third embodiments described above will be denoted by the same reference numerals and will not be described.

[0155] The configuration of the induction heating device of the fourth embodiment has the same configuration as the induction heating devices of the first to third embodiments and is different in a method of controlling the heating operation for the heating coils. The induction heating device of the fourth embodiment has a mode of heating a plurality of heating coils in the simultaneous heating mode and this simultaneous heating mode is the same operation as the simultaneous heating mode described with reference to Fig. 19 in the third embodiment described above. The induction heating device of the fourth embodiment has a step-down simultaneous heating mode described later in addition to the simultaneous heating mode.

[0156] The operation of the induction heating device of the fourth embodiment will be described. Fig. 24 is a waveform diagram of an operation state of the step-down simultaneous heating mode in the induction heating device of the fourth embodiment. Fig. 24 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the first heating coil 6, and (e) as a current waveform of the second heating coil 7.

<Step-Down Simultaneous Heating Mode>

[0157] To simultaneously supply the high-frequency power to the first heating coil 6 and the second heating coil 7 in the step-down simultaneous heating mode, the control part 13 controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10, the second semiconductor switch (Q1b) 11, and the third semiconductor switch (Q1c) 12.

[0158] For example, in the section B depicted in Fig. 24, when the control part 13 puts the first semiconductor switch (Q1a) 10 into the non-conductive state (off-state), the second semiconductor switch (Q1b) 11 into the conductive state (on-state), and the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state), the power is supplied to the first heating coil 6 and the second heating coil 7 through the path from the smoothing capacitor 5 → the first resonance capacitor 8 → the first heating coil 6 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 → the second resonance capacitor 9.

[0159] In this case, the series circuit of the first heating coil 6 and the first resonance capacitor 8 and the series circuit of the second heating coil 7 and the second resonance capacitor 9 are connected to the smoothing capacitor 5 in series. Therefore, a divided voltage is applied to each of the series circuits and, particularly when each of the series circuits has substantially the same circuit constant, an approximately 1/2 voltage is applied.

[0160] The control part 13 puts the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B). After the predetermined transition time (section Y) has elapsed from the termination of the section B, the control part 13 puts the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 into the conductive state (section A). As a result, this simultaneously generates the operation of supplying a power to the first heating coil 6 through the path from the first resonance capacitor 8 → the first semiconductor switch (Q1a) 10 → the first heating coil 6, and the operation of supplying a power to the second heating coil 7 through the path from the second resonance capacitor 9 → the second heating coil 7 → the third semiconductor switch (Q1c) 12.

[0161] The control part 13 puts the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (section A) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After the predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state again (section B).

[0162] As described above, in the step-down simultaneous heating mode, the control part 13 can put the second semiconductor switch (Q1b) 11 and a set of the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 alternately into the conductive state/non-conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to both the first heating coil 6 and the second heating coil 7 at the same time. As a result, in the induction heating device of the forth embodiment, a desired high-frequency magnetic field generated from the heating coils supplied with the high-frequency current is supplied to the load such as a pot.

[0163] As described in the third embodiment, the control part 13 in the induction heating device of the fourth embodiment also has a configuration capable of determining a type of a load coupled to the heating coils and the presence/absence of the load by detecting a resonance voltage generated at predetermined operation frequency and conduction time.

[0164] If the operation frequency is kept constant for preventing the inference sound with an adjacent load in the configuration of the fourth embodiment, a large difference is generated in the input power generated during the conduction time depending on a material of a load as is the case with the third embodiment (see Fig. 23). Therefore, the input power cannot sufficiently be reduced for some loads and the heating device may have poor usability because of an increased control width of power control etc.

[0165] Therefore, in the case of the load 25A having characteristics of a high inductance and an operation frequency sufficiently far from the resonance frequency, the device is operated in the simultaneous heating mode that is the operation in which the first heating coil 6 and the second heating coil 7 are connected in parallel. On the other hand, in the case of the load 25B having characteristics of a low inductance and an operation frequency close to the resonance frequency so that the input power is easily introduced, the device is operated in the step-down simultaneous heating mode in which the voltage applied to each of the first heating coil 6 and the second heating coil 7 is reduced (by 1/2 under the same conditions). When the device is operated in the step-down simultaneous heating mode, the input power can sufficiently be reduced. If the voltage applied to each of the heating coils is reduced by 1/2, the power becomes 1/4 under the same operation conditions (the operation frequency and the conduction time).

[0166] The induction heating device of the fourth embodiment may be in a configuration having the alternate heating mode (Figs. 20A and 20B) described in the third embodiment. If a load is inductively heated under the same operation conditions (the operation frequency and the conduction time) in the configuration having the simultaneous heating mode, the step-down simultaneous heating mode, and the alternate heating mode, the magnitude of the input power often becomes smaller in the order of the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode. Therefore, in the configuration having the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode, a method of selecting a suitable heating mode for a load can be implemented by sequentially switching the three heating modes in the order of the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on a condition such as a material of the load.

[0167] As described above, in the induction heating device of the fourth embodiment, a plurality of resonance circuits made up of heating coils inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches in the induction heating device configured to use a plurality of the heating coils to heat the same load and, in the case of a load of a load material making an equivalent resistance value larger, the device is operated in the simultaneous heating mode in which the first and third semiconductor switches are alternately made conductive while the second semiconductor switch is made always conductive so as to supply power to the first heating coil and the second heating coil at the same time.

[0168] On the other hand, in the case of a load of a material making an equivalent resistance value smaller, the device is operated in the step-down simultaneous heating mode in which the second semiconductor switch and a set of the first semiconductor switch and the third semiconductor switch are alternately made conductive to supply the high-frequency power to the first heating coil and the second heating coil at the same time while the voltage applied to the heating coils can be reduced.

[0169] Since the heating control is provided as described above in the induction heating device of the fourth embodiment, a predetermined input power can be applied at a constant frequency to a load even when a type of the load is changed, and the induction heating device generating no interference sound and excellent in controllability can be achieved.

(Fifth Embodiment)

[0170] An induction heating device acting as an induction heating cooker of a fifth embodiment according to the present disclosure will be described with reference to the drawings. In the description of the fifth embodiment, elements having substantially the same functions and configurations as those of the first to fourth embodiments described above will be denoted by the same reference numerals and will not be described.

[0171] Fig. 25 is a diagram of a circuit configuration of the induction heating cooker of the fifth embodiment according to this disclosure. The induction heating device of the fifth embodiment is different from the induction heating devices of the third embodiment and the fourth embodiment described above in that the first heating coil 6 is made up of a heating coil group of first heating coil elements 6a, 6b, 6c and that the second heating coil 7 is made up of a heating coil group of second heating coil elements 7a, 7b, 7c. The respective heating coil elements 6a, 6b, 6c are connected to first resonance capacitor elements 8a, 8b, 8c making up the first resonance capacitor 8 and first opening/closing part elements 20a, 20b, 20c making up a first opening/closing part 20 in series. Similarly, the respective heating coil elements 7a, 7b, 7c are connected to second resonance capacitor elements 9a, 9b, 9c making up the second resonance capacitor 9 and second opening/closing part elements 21a, 21b, 21c making up a second opening/closing part 21 in series. The induction heating device of the fifth embodiment is disposed with a load detecting part 22 detecting the presence of a load in the vicinity of the heating coil elements 6a, 6b, 6c and the heating coil elements 7a, 7b, 7c, which is another difference from the induction heating devices of the third embodiment and the fourth embodiment described above.

[0172] Although the induction heating device of the fifth embodiment is described by using an example in which the first heating coil and the second heating coil are the heating coil groups each made up of three heating coil elements, each heating coil may be made up of two or more heating coil elements and the number of heating coil elements is not particularly limited in this disclosure.

[0173] The first opening/closing part elements 20a to 20c making up the first opening/closing part 20 and the second opening/closing part elements 21a to 21c making up the second opening/ closing part 21 may have any configurations, such as those of electromagnetic relays and semiconductor switches, capable of operations for connecting/disconnecting the heating coil elements to/from a power source circuit, and the configurations of the opening/closing part elements are not particularly limited in this disclosure.

[0174] The operation of the induction heating device of the fifth embodiment according to this disclosure will be described.

[0175] When receiving a command for an operation start from an operation part not depicted, the control part 13 first puts the first opening/closing part elements 20a to 20c and the second opening/ closing part elements 21a to 21c into a closed state and applies to the heating coils a predetermined high-frequency current smaller than a high-frequency current during the heating operation to detect whether a load is present in the vicinity of the heating coils with the load detecting part 22.

[0176] In this detection operation, the load detecting part 22 determines the presence of a load and a material of a load from control values such as a conduction time and an operation frequency from the control part 13 as well as voltage values of the resonance capacitors, current values of the heating coil elements, a current value detected by the input current detecting part 3, etc.

[0177] For the heating coil element determined as having no load in the vicinity thereof by the load detecting part 22, the control part 13 puts the opening/closing part element connected to the heating coil element into an opened state to open the connection state to the first semiconductor switch 10 or the third semiconductor switch 12.

[0178] On the other hand, for the heating coil element determined as having a load in the vicinity thereof by the load detecting part 22, the control part 13 puts the opening/closing part element connected to the heating coil element into a closed state to achieve the connection state to the first semiconductor switch 10 or the third semiconductor switch 12. The control part 13 selects an appropriate heating mode from the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on the number of the heating coil elements having the opening/closing part elements connected and operates the semiconductor switches in accordance with the selected heating mode. The number of the connected heating coil elements depends on a shape of the load and, therefore, when the load has a larger shape, the heating operation is performed by using a larger number of the heating coils. As a result, the induction heating device of the fifth embodiment can achieve favorable heating distribution and can improve the cooking performance.

[0179] Fig. 26 is a diagram of characteristics of input power in the heating modes to the conduction time. As depicted in Fig. 26, the induction heating device of the fifth embodiment is operated in the simultaneous heating mode when a load of a single material is heated by two heating coil elements.

[0180] On the other hand, if a load of substantially the same material having a larger shape is heated, for example, if a load is heated by four heating coil elements, and the device is operated in the simultaneous heating mode, the impedance of the heating coil elements connected in parallel and coupled to the load is reduced by approximately 1/2 as compared to when the load is heated by two heating coils. Therefore, when the load is heated by four heating coil elements, this results in an increase in input power for the same conduction time as compared to when the load is heated by two heating coils.

[0181] Therefore, the case of heating by four heating coil elements causes problems such as that the control part 13 cannot reduce the power to the necessary input power or cannot provide proper power control under the condition of a constant operation frequency because of deterioration in resolving power. Therefore, for example, in the case of heating by four heating coil elements, the alternate heating mode is used for reducing the number of the heating coil elements connected in parallel to the load when being operated at the same time. As described above, the induction heating device of the fifth embodiment is configured to be operated depending on the number of the connected heating coil elements supplied with the high-frequency power so as not to reduce the impedance of the heating coils parallel to the load, such that the characteristics of the input power to the conduction time are not changed.

[0182] The characteristics of the input power to the conduction time can be changed depending on the number of the connections of the heating coil elements by using the step-down simultaneous heating mode. In this case, it is desirable to sequentially select the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on a material of the load and the number of the connections of the heating coil elements so as to perform the appropriate heating mode.

[0183] As described above, the induction heating device of the fifth embodiment can be operated by selecting any heating mode of the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on the number of the connections of the heating coil elements forming the first heating coil and the second heating coil supplied with the high-frequency power so as to apply a predetermined input power to the load at a constant frequency even when the number of the heating coil elements to be driven is changed, and the induction heating device generating no interference sound and excellent in controllability can be achieved.

(Sixth Embodiment)

[0184] An induction heating device acting as an induction heating cooker of a sixth embodiment according to the present disclosure will be described with reference to the drawings. In the description of the sixth embodiment, elements having substantially the same functions and configurations as those of the first to fifth embodiments described above will be denoted by the same reference numerals and will not be described.

[0185] Fig. 27 is a diagram of a circuit configuration of the induction heating device of the sixth embodiment according to this disclosure. As is the case with the induction heating devices of the first to fifth embodiments described above, the induction heating device of the sixth embodiment is made up of the AC power source 1; the rectification circuit 2; the smoothing circuit 30 made up of the choke coil 4 and the smoothing capacitor 5; and the series connection body of the first semiconductor switch 10, the second semiconductor switch 11, and the third semiconductor switch 12 connected in parallel to the smoothing capacitor 5. As is the case with the induction heating device of the fifth embodiment depicted in Fig. 25, the induction heating device of the sixth embodiment has a series connection body of the first heating coil 6, the first resonance capacitor 8, and the first opening/closing part 20 connected in parallel to the first semiconductor switch 10, and a series connection body of the second heating coil 7, the second resonance capacitor 9, and the second opening/closing part 21 connected in parallel to the third semiconductor switch 12.

[0186] In the induction heating device of the sixth embodiment, the first heating coil 6 is made up of a heating coil group of a plurality of first heating coil elements 6a, 6b, 6c, 6d, and the second heating coil 7 is made up of a heating coil group of a plurality of second heating coil elements 7a, 7b, 7c, 7d. The respective heating coil elements 6a, 6b, 6c, 6d are connected to first resonance capacitor elements 8a, 8b, 8c, 8d making up the first resonance capacitor 8 and first opening/closing part elements 20a, 20b, 20c, 20d making up a first opening/closing part 20 in series. Similarly, the respective heating coil elements 7a, 7b, 7c, 7d are connected to second resonance capacitor elements 9a, 9b, 9c, 9d making up the second resonance capacitor 9 and second opening/closing part elements 21a, 21b, 21c, 21d making up a second opening/closing part 21 in series.

[0187] The induction heating device of the sixth embodiment further has the load detecting part 22 detecting whether a heatable load is present in the vicinity of each of the heating coil elements, the input current detecting part 3 detecting a current flowing from the AC power source 1 to the rectification circuit 2 with a current transformer etc., and the control part 13 controlling the first to third semiconductor switches 10, 11, and 12 such that a detection value of the input current detecting part 3 becomes equal to a set value, and controlling the opened/closed states of the first opening/closing part 20 and the second opening/closing part 21 in accordance with a detection value of the load detecting part 22.

[0188] Although the induction heating device of the sixth embodiment is described by using an example in which the first heating coil and the second heating coil are the heating coil groups each made up of four heating coil elements (see Fig. 27), each heating coil may be made up of two or more heating coil elements and the number of heating coil elements is not particularly limited in this disclosure.

[0189] The target values of the control part 13 include the current and voltage of the heating coils in addition to the input current, and are not particularly limited in the configuration of the sixth embodiment.

[0190] Also in the induction heating device of the sixth embodiment, the first to third semiconductor switches 10, 11, and 12 are made up of power semiconductors (semiconductor switch elements), such as IGBTs or MOSFETs, and diodes connected in parallel to the respective power semiconductors in the opposite direction. A snubber capacitor suppressing a rapid voltage rise at the time of shift from the on-state to the off-state may be connected in parallel between a collector and an emitter of the first to third semiconductor switches 10, 11, and 12. In the sixth embodiment, a snubber capacitor is connected in parallel between the collector and the emitter of the first semiconductor switch 10 and the third semiconductor switch 12.

[0191] Figs. 28 and 29 are plane views of configurations in which a plurality of the heating coil elements making up the heating coil groups is arranged in a matrix shape. In the configuration depicted in Fig. 28, a plurality of the heating coil elements is arranged longitudinally and laterally in lattice in a region except an operation/display part 16 disposed closer to a user in a region under a top plate 15 on which a load is placed.

[0192] In the induction heating device of the sixth embodiment configured as described above, for example, when a small load 14a with a pot bottom in a circular shape is placed on the top plate 15 as depicted in Fig. 28, the first heating coil 6 is formed by the two heating coil elements 6b, 6c while the second heating coil 7 is formed by the two heating coil elements 7b, 7c, and the high-frequency current is supplied only to each of the heating coil elements 6b, 6c, 7b, 7c,. For example, when a large load 14b with a pot bottom in a rectangular shape is placed, the high-frequency current is supplied to more corresponding heating coil elements.

[0193] By selecting the heating coil elements to be driven depending on a shape of a load as described above, the load can efficiently be heated with favorable heating distribution. With regard to the planar shape of the heating coil elements, considering that a load with a pot bottom diameter of ø160 to ø240 mm is heated by a plurality of heating coil elements, it is desirable that the diameter of the circle of the planar shape is about ø30 to ø120 mm. However, in this disclosure, the planar shape of the heating coil elements is not particularly limited to the shape described above.

[0194] In the configuration of arranging a plurality of the heating coil elements in a matrix shape in a region under the top plate 15, the heating coil elements are arranged to form a staggered grid so as to arrange the heating coil elements as dense as possible. Therefore, in an arrangement configuration depicted in Fig. 29, a plurality of the heating coil elements are arranged on longitudinal lines extended from the side closer to a user (closer to the operation/display part) toward the back surface and the heating coil elements on the adjacent longitudinal lines are staggered. In the case of this arrangement configuration, a gap between the heating coil elements decreases although the number of the heating coil elements increases. Therefore, more favorable heating distribution can be acquired as compared to the arrangement configuration depicted in Fig. 28.

[0195] The heating coil elements are desirably have the inductance values set to substantially the same value and the same shape so as to avoid a bias in the electric power amount.

[0196] When the load 14a and the load 14b having different pot bottom shapes are placed on the top plate 15 as depicted in Fig. 28, for example, it is desirable that four heating coil elements are driven in the case of the load 14a while eight heating coil elements are driven in the case of the load 14b.

[0197] If a large number of heating coil elements are put together into one heating group and integrated into a small number of heating coils, the number of parallel connections increases and the impedance is made smaller in one heating coil. As a result, a current more easily flows through each heating coil and a more power is generated for a conduction time of each semiconductor switch. This results in problems such as that the input power cannot be reduced or that an element loss of the semiconductor switches increases.

[0198] To improve the power control performance, it is conceivable that the operation frequency is made higher in the case of heating the load 14b heated by a large number of the heating coil elements so as to reduce the input power. However, if the load 14a heated by a small number of the heating coil elements is heated along with the load 14b heated by a large number of the heating coil elements at the same time, a frequency difference occurs between the respective operation frequencies, and the interference sound occurs.

[0199] Therefore, the control part 13 in the induction heating device of the sixth embodiment changes the heating mode depending on the number of the connections of the heating coil elements used in the case of heating the load. In particular, the control part 13 controls the conduction states of the first semiconductor switch 10, the second conductive switch 11, and the third conductive switch 12 to the states adapted to the respective heating modes. The control part 13 can change the conduction states of the semiconductor switches 10, 11, 12 depending on the number of the connected heating coils so as to change the voltage applied to the first heating coil 6 and the second heating coil 7.

[0200] As a result, even when the number of the heating coil elements used is changed, the power control can be provided with the operation frequency kept constant.

[0201] The operation of the induction heating device of the sixth embodiment will be described.

[0202] When a signal for a heating start is input from the operation/display part 16, the control part 13 detects whether a load is present on the top plate 15 with the load detecting part 22.

[0203] In this case, to determine the presence/absence of a load, a type of a load, and the number of loads for each of the heating coil elements, the load detecting part 22 operates the semiconductor switches and uses the current and voltage generated in the heating coil elements and the detection values of the input current detecting part 3.

[0204] Fig. 30 depicts an example of a load detection method and is a diagram of a relationship between a conduction time of a semiconductor switch and a resonance voltage generated in a resonance capacitor depending on a material of a load. The resonance frequency varies depending on a material of a load in the resonance circuit made up of the heating coil elements magnetically coupled to a load and the resonance capacitor. While no load exists, the inductance is the largest and the resonance frequency becomes lower.

[0205] On the other hand, when a load is disposed in the vicinity of the heating coil and the load is magnetically coupled to the heating coil, the inductance is reduced and the resonance frequency becomes higher. When a load is disposed in the vicinity of the heating coil, the inductance is reduced in the load 14b made of non-magnetic stainless steel etc., as compared to the load 14a made of magnetic stainless steel, etc., and therefore, the resonance frequency is increased.

[0206] Therefore, the control part 13 can determine a type of a load by detecting a resonance voltage generated at predetermined operation frequency and conduction time. The load 14b having an operation frequency close to the resonance frequency makes the resonance voltage higher, while the load 14a having a lower operation frequency far from the resonance frequency makes the resonance voltage lower. In the case of no load, the detection value of the resonance voltage becomes lower in the order of the load 14b, the load 14a, and no load. Therefore, a material of a load can be determined by detecting the resonance voltage generated at predetermined operation frequency and conduction time.

[0207] In the induction heating device of the sixth embodiment, among the heating coil elements having a detected load, the heating coil elements put together by a load placed thereon at substantially the same time are determined as having the same load placed thereon, and the corresponding first and second opening/closing part elements are put into the closed state to connect the respective heating coil elements having a detected load to the first semiconductor switch 10 and the third semiconductor switch 12. The control part 13 performs the operation of the simultaneous heating mode or the alternate heating mode depending on the number of connections of the heating coil elements.

[0208] Fig. 31 is a waveform diagram of an operation state of the simultaneous heating mode in the induction heating device of the sixth embodiment. Fig. 31 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the heating coil elements in the first heating coil 6, and (e) as a current waveform of the heating coil elements of the second heating coil 7.

[0209] To simultaneously supply the high-frequency power to the first heating coil 6 having a plurality of the heating coil elements and the second heating coil 7 having a plurality of the heating coil elements in the simultaneous heating mode, the control part 13 puts the second semiconductor switch (Q1b) 11 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12.

[0210] In the section A depicted in Fig. 31, the control of putting the first semiconductor switch (Q1a) 10 into the conductive state (on-state) and putting the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state) simultaneously generates the operation of supplying a power to the second heating coil 7 (the corresponding second heating coil elements) through the path from the smoothing capacitor 5 → the first semiconductor switch 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 (the corresponding second heating coil elements) → the second resonance capacitor 9 (the corresponding second resonance capacitor elements) → the second opening/closing part 21 (the corresponding second opening/closing part elements), and the operation of supplying a power to the first heating coil 6 (the corresponding first heating coil elements) through the path from the first resonance capacitor 8 (the corresponding first resonance capacitor elements) → the first opening/closing part 20 (the corresponding first opening/closing part elements) → the first semiconductor switch (Q1a) 10 → the first heating coil 6 (the corresponding first heating coil elements).

[0211] The control part 13 puts only the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, this simultaneously generates the operation of supplying a power to the first heating coil 6 (the corresponding first heating coil elements) through the path from the smoothing capacitor 5 → the first opening/closing part 20 (the corresponding first opening/closing part elements) → the first resonance capacitor 8 (the corresponding first resonance capacitor elements) → the first heating coil 6 (the corresponding first heating coil elements) → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12, and the operation of supplying a power to the second heating coil 7 (the corresponding second heating coil elements) through the path from the second resonance capacitor 9 (the corresponding second resonance capacitor elements) → the second heating coil 7 (the corresponding second heating coil elements) → the third semiconductor switch (Q1c) 12 → the second opening/closing part 21 (the corresponding second opening/closing part elements).

[0212] The control part 13 puts only the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (section B) when the current value detected by the input current detecting part 3 indicates the predetermined current value. After the termination of the section B, when the predetermined transition time (section Y) has elapsed, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state again.

[0213] As described above, in the simultaneous heating mode, the control part 13 puts the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the second semiconductor switch (Q1b) 11 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the corresponding heating coil elements in the first heating coil 6 and the second heating coil 7 at the same time, and the high-frequency magnetic field generated from the corresponding heating coil elements due to the high-frequency current is supplied to the load such as a pot.

[0214] The induction heating device of the sixth embodiment is configured such that the alternate heating mode can be performed.

[0215] Fig. 32A is a waveform diagram of the first single heating mode in which high-frequency power is supplied to the corresponding second heating coil elements in the second heating coil 7. Fig. 32A includes (a) to (c) depicting gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, and (d) depicting a current waveform of the second heating coil 7.

[0216] To supply the high-frequency power to the corresponding second heating coil elements in the second heating coil 7 in the first single heating mode depicted in Fig. 32A, the control part 13 puts the first semiconductor switch (Q1a) 10 into the constantly conductive state and controls a conductive state/non-conductive state (on-state/off-state) of the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12. In a section A depicted in Fig. 32A, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (on-state) and the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state). As a result, the power is supplied to the second heating coil 7 (the corresponding second heating coil elements) through the path from the smoothing capacitor 5 → the first semiconductor switch (Q1a) 10 → the second semiconductor switch (Q1b) 11 → the second heating coil 7 (the corresponding second heating coil elements) → the second resonance capacitor 9 (the corresponding second resonance capacitor elements) → the second opening/ closing part 21 (the corresponding second opening/closing part elements).

[0217] The control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time (Tb) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After a predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the third semiconductor switch (Q1c) 12 into the conductive state. As a result, the power is supplied to the second heating coil 7 (the corresponding second heating coil elements) through the path from the second resonance capacitor 9 (the corresponding second resonance capacitor elements) → the second heating coil 7 (the corresponding second heating coil elements) → the third semiconductor switch (Q1c) 12 → the second opening/closing part 21 (the corresponding second opening/closing part elements). Subsequently, the control part 13 puts the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time (Tc) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0218] Subsequently, after a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue alternately via the transmission time (X or Y).

[0219] As described above, the control part 13 puts the second semiconductor switch (Q1b) 11 and the third semiconductor switch (Q1c) 12 alternately into the conductive state while keeping the first semiconductor switch (Q1a) 10 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the corresponding second heating coil elements in the second heating coil 7 and supplying the high-frequency magnetic field generated from the corresponding second heating coil elements in the second heating coil 7 due to the high-frequency current to the load such as a pot.

[0220] The high-frequency magnetic field supplied to the load such as a pot in this way generates an eddy current on a surface of the load such as a pot, and the load such as the pot is inductively heated due to the eddy current and a high-frequency resistance of the load such as a pot itself, which leads to heat generation.

[0221] The second single heating mode of supplying high-frequency power to the corresponding heating coil elements in the first heating coil 6 will be described with reference to Fig. 32B.

[0222] To supply the high-frequency power to the first heating coil elements in the first heating coil 6 in the second single heating mode, the control part 13 puts the third semiconductor switch (Q1c) 12 into the constantly conductive state and controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11. When the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state in the section A depicted in Fig. 32B, the power is supplied to the first heating coil 6 (the corresponding first heating coil elements) through the path from the smoothing capacitor 5 → the first opening/closing part 20 (the corresponding first opening/closing part elements) → the first resonance capacitor 8 (the corresponding first resonance capacitor elements) → the first heating coil 6 (the corresponding first heating coil elements) → the second semiconductor switch (Q1b) 11 → the third semiconductor switch (Q1c) 12.

[0223] In the section A of Fig. 32B, the control part 13 puts only the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time (Tb) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section A). After the predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the first semiconductor switch (Q1a) 10 into the conductive state. As a result, the power is supplied to the first heating coil 6 (the corresponding first heating coil elements) through the path from the first resonance capacitor 8 (the corresponding first resonance capacitor elements) → the first opening/closing part 20 (the corresponding first opening/closing part elements) → the first semiconductor switch (Q1a) → the first heating coil 6 (the corresponding first heating coil elements). Subsequently, the control part 13 puts the first semiconductor switch (Q1a) 10 into the non-conductive state at the conduction time (Ta) when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B).

[0224] Subsequently, after a predetermined transition time (section Y) has elapsed, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state (section A). As described above, the control part 13 allows the operations of the section A and the section B to continue via the transmission time (X or Y).

[0225] As described above, the control part 13 can put the first semiconductor switch (Q1a) 10 and the second semiconductor switch (Q1b) 11 alternately into the conductive state while keeping the third semiconductor switch (Q1c) 12 in the conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to the corresponding first heating coil elements in the first heating coil 6. The high-frequency magnetic field generated from the corresponding second heating coil elements in the first heating coil due to the high-frequency current supplied in this way is supplied to the load such as a pot.

[0226] Fig. 33 is a waveform diagram of an operation of the alternate heating mode in the induction heating device of the sixth embodiment. The alternate heating mode is the operation when the first single heating mode depicted in Fig. 32A and the second single heating mode depicted in Fig. 32B are alternately used for heating a plurality of loads. Fig. 33 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the second heating coil 7, and (e) as a current waveform of the first heating coil 6. In the alternate heating mode of the induction heating device of the sixth embodiment, an operation time of the first single heating mode is T2 and an operation time of the second single heating mode is T1. Therefore, in the sixth embodiment, each of the operation time T1 and the operation time T2 is set to a very short period within one second and one cycle (T1+T2) of the alternate heating mode is set to two seconds or less.

[0227] For the switchover operation between the first single heating mode and the second single heating mode in the alternate heating mode of the induction heating device of the sixth embodiment, the same control is provided as the control described with reference to Fig. 10 in the second embodiment and the highly efficient switchover operation is performed in a short time.

[0228] As depicted in Fig. 33, in the alternate heating mode, loads can simultaneously be heated without deteriorating the heating distribution for the loads by periodically operating the first single heating mode and the second single heating mode alternately in a short period of time. Particularly, the induction heating device of the sixth embodiment can reduce heating unevenness for the loads without lowering the average power by setting a short switchover time generally equal to or less than two seconds between the first single heating mode and the second single heating mode. When the alternate heating mode is used in the induction heating device of the sixth embodiment, the control is provided without any feeling of difference given to a user at the time of alternate heating of a plurality of loads, which is a problem of a conventional induction heating device.

[0229] If the operation frequency is kept constant for preventing the inference sound with an adjacent load in the configuration of the sixth embodiment, a large difference may be generated in the input power generated during the conduction time depending on the number of heating coil elements supplied with the high-frequency power as depicted in Fig. 34. Therefore, the input power cannot sufficiently be lowered for some shapes (sizes) of loads and the heating device may have poor usability because of an increased control width of power control etc.

[0230] Therefore, in the case of a load associated with a small number of the connected heating coil elements and making the impedance larger, for example, in the case of the first load 14a (the four heating coil elements), the device is operated in the simultaneous heating mode that is the operation in which the first heating coil 6 and the second heating coil 7 are connected in parallel. On the other hand, in the case of a load associated with a large number of the connected heating coil elements and making the impedance smaller, for example, in the case of the second load 14b (the eight heating coil elements), the device is operated in the alternate heating mode with the number of the connected heating coil elements reduced by 1/2.

[0231] As a result, since the number of the parallelly-connected heating coil elements is reduced by half in the alternate heating mode as compared to the simultaneous heating mode, the impedance of the heating coils connected to the semiconductor switches is doubled. The current to the heating coils can consequently be suppressed and the input power can be lowered.

[0232] As described above, in the induction heating device of the sixth embodiment configured to heat the same load by using a plurality of the heating coil elements, a plurality of resonance circuits made up of heating coil elements inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches and, in the case of a load associated with a small number of connections of the heating coil elements and making the impedance larger, the device is operated in the simultaneous heating mode in which the first and third semiconductor switches 10, 12 are alternately made conductive while the second semiconductor switch 11 is made always conductive so as to supply power to the first heating coil and the second heating coil at the same time.

[0233] On the other hand, in the case of a load associated with a large number of connections of the heating coil elements and making the impedance smaller, the device is operated in the alternate heating mode by alternately repeating the operations at short constant intervals between the first single heating mode in which the second and third semiconductor switches 11, 12 are alternately made conductive while the first semiconductor switch 10 is made always conductive so as to supply high-frequency power to the second heating coil 7, and the second single heating mode in which the first and second semiconductor switches 10, 11 are alternately made conductive while the third semiconductor switch 12 is made always conductive so as to supply high-frequency power to the first heating coil 6. Since the power is supplied to the first heating coil 6 and the second heating coil 7 in this way, a predetermined input power can be applied at a constant operation frequency to a load even when the number of the heating coil elements used is changed, and the induction heating device generating no interference sound and excellent in controllability can be achieved.

(Seventh Embodiment)

[0234] An induction heating device acting as an induction heating cooker of a seventh embodiment according to the present disclosure will be described with reference to the drawings. In the description of the seventh embodiment, elements having substantially the same functions and configurations as those of the first to sixth embodiments described above will be denoted by the same reference numerals and will not be described.

[0235] The configuration of the induction heating device of the seventh embodiment has the same configuration as the induction heating device of the sixth embodiment depicted in Fig. 27 and is different in a method of controlling the heating operation for the heating coils. The induction heating device of the seventh embodiment has a mode of heating a plurality of heating coils in the simultaneous heating mode and this simultaneous heating mode is the same operation as the simultaneous heating mode described with reference to Fig. 31 in the sixth embodiment described above. The induction heating device of the seventh embodiment has the step-down simultaneous heating mode in addition to the simultaneous heating mode.

[0236] The operation of the induction heating device of the seventh embodiment will be described. Fig. 35 is a waveform diagram of an operation state of the step-down simultaneous heating mode in the seventh embodiment. Fig. 35 includes (a) to (c) as gate voltage waveforms of the first to third semiconductor switches 10, 11, and 12, (d) as a current waveform of the first heating coil 6, and (e) as a current waveform of the second heating coil 7.

[0237] To simultaneously supply the high-frequency power to the first heating coil 6 and the second heating coil 7 that are the heating coil groups made up of pluralities of the heating coil elements in the step-down simultaneous heating mode, the control part 13 controls the conductive state/non-conductive state (on-state/off-state) of the first semiconductor switch (Q1a) 10, the second semiconductor switch (Q1b) 11, and the third semiconductor switch (Q1c) 12.

[0238] For example, in the section B depicted in Fig. 35, when the control part 13 puts the first semiconductor switch (Q1a) 10 into the non-conductive state (off-state), the second semiconductor switch (Q1b) 11 into the conductive state (on-state), and the third semiconductor switch (Q1c) 12 into the non-conductive state (off-state), the power is supplied to the first heating coil 6 and the second heating coil 7 that are the heating coil groups at the same time through the path from the smoothing capacitor 5 → the first opening/closing part 20 (the corresponding first opening/closing part elements) → the first resonance capacitor 8 (the corresponding first resonance capacitor elements) → the first heating coil 6 (the corresponding first heating coil elements) → the second semiconductor switch (Q1b) 11 → the second heating coil 7 (the corresponding second heating coil elements) → the second resonance capacitor 9 (the corresponding second resonance capacitor elements) → the second opening/closing part 21 (the corresponding second opening/closing part elements).

[0239] In this case, the series circuit of the first heating coil 6 and the first resonance capacitor 8 and the series circuit of the second heating coil 7 and the second resonance capacitor 9 are connected to the smoothing capacitor 5 in series. Therefore, a divided voltage is applied to each of the series circuits and, particularly when each of the series circuits has substantially the same circuit constant, an approximately 1/2 voltage is applied.

[0240] The control part 13 puts the second semiconductor switch (Q1b) 11 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value (termination of the section B). After the predetermined transition time (section Y) has elapsed from the termination of the section B, the control part 13 puts the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 into the conductive state (section A). As a result, this simultaneously generates the operation of supplying a power to the first heating coil 6 that is the heating coil group through the path from the first resonance capacitor 8 (the corresponding first resonance capacitor elements) → the first opening/closing part 20 (the corresponding first opening/closing part elements) → the first semiconductor switch (Q1a) 10 → the first heating coil 6 (the corresponding first heating coil elements), and the operation of supplying a power to the second heating coil 7 that is the heating coil group through the path from the second resonance capacitor 9 (the corresponding second resonance capacitor elements) → the second heating coil 7 (the corresponding second heating coil elements) → the third semiconductor switch (Q1c) 12 → the second opening/ closing part 21 (the corresponding second opening/closing part elements).

[0241] The control part 13 puts the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 into the non-conductive state at the conduction time when the current value detected by the input current detecting part 3 indicates the predetermined current value. After the predetermined transition time (section X) has elapsed from the termination of the section A, the control part 13 puts the second semiconductor switch (Q1b) 11 into the conductive state again.

[0242] As described above, in the step-down simultaneous heating mode, the control part 13 can put the second semiconductor switch (Q1b) 11 and a set of the first semiconductor switch (Q1a) 10 and the third semiconductor switch (Q1c) 12 alternately into the conductive state/non-conductive state, thereby supplying a high-frequency current of about 20 kHz to 60 kHz to both the first heating coil 6 and the second heating coil 7 that are the heating coil elements at the same time. As a result, in the induction heating device of the forth embodiment, a desired high-frequency magnetic field generated from the heating coils supplied with the high-frequency current is supplied to the load such as a pot.

[0243] With regard to the presence/absence and material of a load coupled to the heating coils, as is the case with the sixth embodiment described above, the control part 13 can determine the presence/absence of the load and/or the type of the load by detecting a resonance voltage generated at predetermined operation frequency and conduction time.

[0244] If the operation frequency is kept constant for preventing the inference sound with an adjacent load in the configuration of the seventh embodiment, a large difference may be generated in the input power generated during the conduction time depending on the number of the connected heating coil elements supplied with the high-frequency power as depicted in Fig. 36. Therefore, the input power cannot sufficiently be lowered for some shapes (sizes) of loads and the heating device may have poor usability because of an increased control width of power control etc.

[0245] Therefore, as depicted in Fig. 36, in the case of a load having a small load shape and associated with a small number of the connected heating coil elements, for example, if the number of the connected heating coil elements is four (if two heating coil elements are connected in each of the first heating coil 6 and the second heating coil 7), the device is operated in the simultaneous heating mode that is the operation in which the first heating coil 6 and the second heating coil 7 are connected in parallel.

[0246] On the other hand, in the case of a load having a large load shape and associated with a large number of the connected heating coil elements, for example, if the number of the connected heating coil elements is ten (if five heating coil elements are connected in each of the first heating coil 6 and the second heating coil 7), i.e., if a load is associated with a large number of the parallelly-connected heating coil elements and has a small impedance, the operation in the simultaneous heating mode makes the impedance of the load too small, resulting in a situation in which a current easily flows through the connected heating coil elements and a situation in which the input current is excessively supplied during the conduction time. In Fig. 36, as indicated by a characteristic example when ten heating coil elements are operated in the simultaneous heating mode, the input power is set to an upper line.

[0247] Therefore, in the case of a load having a large shape and associated with a large number of the connected heating coil elements, the device is operated in the step-down simultaneous heating mode. Since the step-down simultaneous heating mode reduces the input voltage applied to the first heating coil and the second heating coil that are the heating coil groups, the step-down simultaneous heating mode can create a situation in which the input current hardly flows even if the impedance is reduced. For example, the first heating coil 6 and the second heating coil have the same number of the heating coil elements, the input voltage is reduced by half. In Fig. 36, as indicated by a characteristic example when ten heating coil elements are operated in the step-down simultaneous heating mode, the input power is set to a lower line.

[0248] For example, if the voltage applied to each of the heating coils is reduced by 1/2, the power becomes 1/4 under the same operation conditions (the operation frequency and the conduction time).

[0249] The configuration of the seventh embodiment may be the configuration having the alternate heating mode described with reference to Figs. 32A and 32B in the sixth embodiment in addition to the simultaneous heating mode and the step-down simultaneous heating mode. The input power for the conduction time becomes smaller in the order of the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode under the same conditions depending on the impedance in the load. Therefore, the configuration of the seventh embodiment also enables a method in which the heating modes are sequentially switched depending on a condition such as the number of connections of the heating coil elements.

[0250] As described above, in the induction heating device of the seventh embodiment configured to heat the same load by using a plurality of the heating coil elements, a plurality of resonance circuits made up of heating coil elements inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches and, in the case of a load associated with a small number of connections of the heating coil elements and making the impedance larger, the device is operated in the simultaneous heating mode in which the first and third semiconductor switches 10, 12 are alternately made conductive while the second semiconductor switch 11 is made always conductive so as to supply power to the first heating coil 6 and the second heating coil 7 at the same time.

[0251] On the other hand, in the case of a load associated with a large number of connections of the heating coil elements and making the impedance smaller, the device is operated in the step-down simultaneous heating mode in which the second semiconductor switch and a set of the first semiconductor switch and the third semiconductor switch are alternately made conductive to supply the high-frequency power to the first heating coil 6 and the second heating coil 7 at the same time to reduce the voltage applied to the heating coils. Since the power is supplied to the first heating coil 6 and the second heating coil 7 in this way, a predetermined input power can be applied at a constant operation frequency to a load even when the number of the heating coil elements used is changed, and the induction heating device generating no interference sound and excellent in controllability can be achieved.

(Eighth Embodiment)

[0252] An induction heating device acting as an induction heating cooker of an eighth embodiment according to the present disclosure will be described with reference to the drawings. In the description of the eighth embodiment, elements having substantially the same functions and configurations as those of the first to seventh embodiments described above will be denoted by the same reference numerals and will not be described.

[0253] Fig. 37 is a plane view of heating coil groups having pluralities of heating coil elements disposed direct under the top plate 15 in the configuration of the induction heating device of the eighth embodiment according to this disclosure. The induction heating device of the eighth embodiment is different from the sixth embodiment and the seventh embodiment described above in that the heating coil elements making up the first heating coil 6 defined as the heating coil group are alternately arranged with the heating coil elements making up the second heating coil 7 defined as the heating coil group on the same plane.

[0254] In the induction heating device of the eighth embodiment depicted in Fig. 37, the first heating coil 6 is made up of 12 heating coil elements 6a to 61 and the second heating coil 7 is made up of 12 heating coil elements 7a to 71. In an arrangement example depicted in Fig. 37, the 24 heating coil elements 6a to 61, 7a to 71 are arranged in 4 rows × 6 columns in zigzags. In rows and columns adjacent to the rows and columns in which the heating coil elements 6a to 61 of the first heating coil 6 are arranged, the heating coil elements 7a to 71 of the second heating coil 7 are respectively arranged.

[0255] When a plurality of the heating coil elements is arranged as described above, a large difference is not generated between the number of connections of the heating coil elements in the first heating coil 6 and the number of connections of the heating coil elements in the second heating coil 7 regardless of a position where a load is placed in the heating region on the top plate 15. Therefore, the control part 13 can symmetrically operate the semiconductor switches in each of the heating modes and therefore can provide reliable and simple control and can create favorable heating distribution for the load.

[0256] As described above, in the configuration of the induction heating device of the eighth embodiment, since the heating coil elements are alternately arranged to reduce a difference between the number of connections of the heating coil elements forming the first heating coil 6 and the number of connections of the heating coil elements forming the second heating coil 7 in all the heating modes, the power can uniformly be supplied from the heating coil elements to the load. Therefore, the configuration of the induction heating device of the eighth embodiment can achieve a heating device capable of forming favorable heating distribution for the load.

[0257] The induction heating device of this disclosure is configured such that the control part controls the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch depending on a state of a load when the load is placed on the heating region, for example, a material, a size, etc., of the load, so as to select and perform an appropriate heating mode. The heating modes performed in the induction heating device of this disclosure include the simultaneous heating mode in which the high-frequency power is supplied to the first heating coil and the second heating coil at the same time, the first single heating mode in which the high-frequency power is supplied to the second heating coil, the second single heating mode in which the high-frequency power is supplied to the first heating coil, the alternate heating mode in which the first single heating mode and the second single heating mode are alternately performed, and the step-down simultaneous heating mode in which the high-frequency power can be supplied to the first heating coil and the second heating coil in a step-down state at the same time. The induction heating device of this disclosure is configured to select an appropriate heating mode for a detected load out of these heating modes so as to inductively heat the load. The induction heating device of this disclosure may be configured such that when the heating mode selected for the detected load is performed and an inconvenient state occurs such as an excessively high input power etc., the heating mode is sequentially switched to those suppressing the input power.

[0258] One embodiment of the induction heating device of the present disclosure includes a series connection body of a first semiconductor switch, a second semiconductor switch, and a third semiconductor switch connected to a power source; a series connection body of a first resonance capacitor and a first heating coil connected in parallel to the first semiconductor switch and magnetically coupled to a load; a series connection body of a second resonance capacitor and a second heating coil connected in parallel to the third semiconductor switch and magnetically coupled to a load; and a control part controlling the first to third semiconductor switches. The control part includes the first single heating mode of performing an operation in which the second and third semiconductor switches are alternately made conductive while the first semiconductor switch is made always conductive so as to supply the high-frequency power to the second heating coil and the second single heating mode of performing an operation in which the first and second semiconductor switches are alternately made conductive while the third semiconductor switch is made always conductive so as to supply the high-frequency power to the first heating coil. In this disclosure, the first to third semiconductor switches respectively include a first diode, a second diode, and a third diode connected in reversely parallel to the respective semiconductor switches.

[0259] The control part configured as described above can perform the alternate heating mode in which the first single heating mode and the second single heating mode are repeated in a short cycle when supplying a power from both the first heating coil and the second heating coil to a load, thereby supplying an average high-frequency power uniformly to both the first heating coil and the second heating coil at the same time.

[0260] As described above, when a plurality of resonance circuits made up of heating coils inductively heating a load and resonance capacitors are connected to three serially-connected semiconductor switches; one semiconductor switch of the three semiconductor switches is put into the conductive state as a semiconductor switch determining a heating coil to be supplied with the high-frequency power; the remaining semiconductor switches are used as semiconductor switches driven to ON/OFF for supplying the high-frequency power to the heating coils; and the semiconductor switch determining the heating coil to be supplied with the high-frequency power is switched, a configuration is achieved that supplies the high-frequency power to a plurality of the heating coils substantially at the same time. Even in the configuration supplying the high-frequency power to a plurality of the heating coils substantially at the same time as described above, the inexpensive induction heating device can be provided that generates no interference sound, that is excellent in cooking performance, and that even has a reduced number of components and a smaller circuit mounting area.

[0261] Another embodiment of the induction heating device of the present disclosure includes a series connection body of first to third semiconductor switches connected to a smoothing capacitor operating as an AC power source; a series connection body of a first resonance capacitor and a first heating coil connected in parallel to the first semiconductor switch and having at least one heating coil element magnetically coupled to a load; a series connection body of a second resonance capacitor and a second heating coil connected in parallel to the third semiconductor switch and having at least one heating coil element magnetically coupled to a load; and a control part controlling the first to third semiconductor switches. The control part includes the simultaneous heating mode in which the first and third semiconductor switches are alternately made conductive while the second semiconductor switch is conductive so as to supply the high-frequency power to the first heating coil and the second heating coil. The control part also includes an alternate operation mode of alternately repeating a first operation (the first single heating mode) in which the second semiconductor switch and the third semiconductor switch are alternately made conductive while the first semiconductor switch is conductive so as to supply the high-frequency power to the second heating coil and a second operation (the second single heating mode) in which the first semiconductor switch and the second semiconductor switch are alternately made conductive while the third semiconductor switch is conductive so as to supply the high-frequency power to the first heating coil. The control part including the simultaneous heating mode and the alternate heating mode in this way controls the first to third semiconductor switches such that the heating modes are switched depending on a material of a load.

[0262] According to another embodiment configured as described above, the induction heating device using a plurality of heating coils to heat the same load is configured such that the simultaneous heating mode is performed in the case of a material making the impedance larger in the load coupled to the heating coils while the alternate heating mode is performed in the case of a material making the impedance smaller in the load so as to bring the impedances close to each other even when the materials are different. Therefore, the necessary input power can be applied to a load at a constant frequency even if the material of the load is changed, and the induction heating device generating no interference sound and excellent in controllability can be provided.

[0263] A further embodiment of the induction heating device of the present disclosure includes a series connection body of first to third semiconductor switches connected to a smoothing capacitor operating as an AC power source; a plurality of first heating coil elements arranged in a matrix shape and connected in parallel to the first semiconductor switch; a plurality of second heating coil elements connected in parallel to the third semiconductor switch; a plurality of first resonance capacitor elements connected in series respectively to the plurality of the first heating coil elements; a plurality of second resonance capacitor elements connected in series respectively to the plurality of the second heating coil elements; and a load detecting part detecting the presence of a heatable load in the vicinity of each of the pluralities of the first and second heating coil elements. The induction heating device of the further embodiment includes an opening/closing part having a plurality of first opening/closing part elements interrupting the supply of the high-frequency power to each of the plurality of the first heating coil elements (a first heating coil) and a plurality of second opening/closing part elements interrupting the supply of the high-frequency power to each of the plurality of the second heating coil elements (a second heating coil). The induction heating device of the further embodiment configured in this way is configured such that if the same load is heated, the control is provided to supply the high-frequency power by using the first and second opening/closing part elements to the heating coil elements having a load detected in the vicinity thereof by the load detecting part so as to select the appropriate heating mode and control the operation of the first to third semiconductor switches depending on the number of connections of the heating coil elements supplied with the high-frequency power.

[0264] The induction heating device of the further embodiment configured as described above can switch the operations of the first to third semiconductor switches depending on the number of connections of the heating coil elements in the first heating coil and the second heating coil made up of heating coil groups, thereby changing the respective impedances and applied voltages of the first heating coil and the second heating coil. Therefore, the induction heating device of the further embodiment can adjust power even when the operation frequency is kept constant.

[0265] As a result, the inexpensive induction heating device can be provided that generates no interference sound even when the high-frequency power is supplied to a plurality of the heating coil elements, that is excellent in cooking performance, and that even has a reduced number of components and a smaller circuit mounting area.

[0266] Although the induction heating device of the present disclosure is described by taking as an example an inductive heating cooker inductively heating a load such as a pot for heating and cooking foodstuffs, the induction heating device is applicable to a normal induction heating device as well as a power feeding device to non-contact power feeding equipment including a power-receiving coil other than the inductive heating cooker.

[0267] Although this disclosure has been described in some detail in terms of the embodiments, these contents of disclosure of the embodiments may obviously be changed in detail of configurations, and changes in combinations and orders of elements in the embodiments may be achieved without departing from the scope and the idea of the claimed disclosure.

Industrial Applicability

[0268] An induction heating device according to this disclosure generates no interference sound even when high-frequency power is applied to a plurality of heating coil elements, has excellent cooking performance, even has a reduced number of components and a smaller circuit mounting area, can inexpensively be achieved, and therefore is useful in various uses of induction heating equipment.

Reference Signs List

[0269]

1	AC power source
2	Rectification circuit
3	Input current detecting part
4	Choke coil
5	Smoothing capacitor
6	First heating coil
7	Second heating coil
8	First resonance capacitor
9	Second resonance capacitor
10	First semiconductor switch
11	Second semiconductor switch
12	Third semiconductor switch
13	Control part
14a, 14b	Load
15	Top plate
16	Operation/display part

17	Operation/display part
18	Top plate
20	First opening/closing part
21	Second opening/closing part
22	Load detecting part
25A, 25B	Load

Claims

1. An induction heating device comprising:

a series connection body, which is connected to a power source, including a first semiconductor switch, a second semiconductor switch, and a third semiconductor switch;
a series connection body, which is connected in parallel to the first semiconductor switch, including a first resonance capacitor and a first heating coil magnetically coupled to a load;
a series connection body, which is connected in parallel to the third semiconductor switch, including a second resonance capacitor and a second heating coil magnetically coupled to a load; and
a control part controlling the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch, wherein
the control part selectively drives the following modes depending on a load:

a first single heating mode in which the second semiconductor switch and the third semiconductor switch are alternately made conductive while the first semiconductor switch is made always conductive so as to supply a high-frequency power to the second heating coil,
a second single heating mode in which the first semiconductor switch and the second semiconductor switch are alternately made conductive while the third semiconductor switch is made always conductive so as to supply a high-frequency power to the first heating coil, and
a simultaneous heating mode in which the first semiconductor switch and the third semiconductor switch are alternately made conductive while the second semiconductor switch is made always conductive so as to supply a high-frequency power to the first heating coil and the second heating coil at the same time.

2. The induction heating device of claim 1, wherein a resonance frequency generated by a first resonance circuit made up of the first heating coil and the first resonance capacitor becomes the same as a resonance frequency generated by a second resonance circuit made up of the second heating coil and the second resonance capacitor.

3. The induction heating device of claim 1 or 2, wherein when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part controls the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch such that an average power supplied to both the first heating coil and the second heating coil attains a target value by changing a ratio between a period in the simultaneous heating mode and a period in the first single heating mode or the second single heating mode.

4. The induction heating device of claim 1, wherein when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part performs an alternate heating mode in which each of the first single heating mode and the second single heating mode is repeated in a short period within one second, so as to supply the high-frequency power uniformly to both the first heating coil and the second heating coil.

5. The induction heating device of claim 4, wherein a state transition between the first single heating mode and the second single heating mode is performed in the alternate heating mode when the second semiconductor switch is in a non-conductive state.

6. The induction heating device of claim 4 or 5, wherein when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part controls a continuous operation time of the first single heating mode and a continuous operation time of the second single heating mode in the alternate heating mode to be the same ratio and changes operation frequencies or conduction times of two semiconductor switches out of the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch supplying the high-frequency power to the first heating coil and the second heating coil in the first single heating mode and the second single heating mode, so as to control an input power.

7. The induction heating device of claim 4 or 5, wherein when the high-frequency power is supplied to both the first heating coil and the second heating coil, the control part sets operation frequencies or conduction times of two semiconductor switches constant out of the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch supplying the high-frequency power to the first heating coil and the second heating coil in the first single heating mode and the second single heating mode in the alternate heating mode and changes a ratio of a continuous operation time of the first single heating mode and a continuous operation time of the second single heating mode, so as to control an input power.

8. The induction heating device of claim 1, wherein
the first heating coil is made up of a plurality of first heating coil elements while the first resonance capacitor is made up of a plurality of first resonance capacitor elements such that the plurality of the first heating coil elements is respectively connected to the plurality of the first resonance capacitor elements to form a plurality of series connection bodies connected in parallel to the first semiconductor switch, wherein
the second heating coil is made up of a plurality of second heating coil elements while the second resonance capacitor is made up of a plurality of second resonance capacitor elements such that the plurality of the second heating coil elements is respectively connected to the plurality of the second resonance capacitor elements to form a plurality of series connection bodies connected in parallel to the third semiconductor switch, and wherein
the control part controls the first semiconductor switch, the second semiconductor switch, and the third semiconductor switch so as to switch between an alternate heating mode in which the first single heating mode and the second signal heating mode are alternately repeated and the simultaneous heating mode depending on a material of a load.

9. The induction heating device of claim 8, wherein
the control part has a step-down simultaneous heating mode in which the first semiconductor switch and the third semiconductor switch are caused to perform the same on/off operation while the on/off operation of the first semiconductor switch and the third semiconductor switch are performed alternately with an on/off operation of the second semiconductor switch so as to supply the high-frequency power to the first heating coil and the second heating coil at the same time, and wherein
the control unit can selectively switch the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on a material of a load.

10. The induction heating device of claim 8 or 9, further comprising a load detecting part detecting the presence of a heatable load in the vicinity of each of the first heating coli elements and the second heating coil elements, a plurality of first opening/closing part elements detaching the respective series connection bodies of the first heating coil elements and the first resonance capacitor elements from an energizing path for parallel connection to the first semiconductor switch, and a plurality of second opening/closing part elements detaching the respective series connection bodies of the second heating coil elements and the second resonance capacitor elements from an energizing path for parallel connection to the third semiconductor switch, wherein
the control part puts into a connected state the first opening/closing part elements and/or the second opening/closing part elements corresponding to the first heating coil elements and/or the second heating coil elements having a load detected in the vicinity thereof by the load detecting part.

11. The induction heating device of claim 8 or 9, further comprising a load detecting part detecting the presence of a heatable load in the vicinity of each of the first heating coli elements and the second heating coil elements, a plurality of first opening/closing part elements detaching the respective series connection bodies of the first heating coil elements and the first resonance capacitor elements from an energizing path for parallel connection to the first semiconductor switch, and a plurality of second opening/closing part elements detaching the respective series connection bodies of the second heating coil elements and the second resonance capacitor elements from an energizing path for parallel connection to the third semiconductor switch, wherein
the control part controls into a connected state the first opening/closing part elements and/or the second opening/closing part elements corresponding to the first heating coil elements and/or the second heating coil elements having a load detected in the vicinity thereof by the load detecting part and selectively switches the simultaneous heating mode, the alternate heating mode, and the step-down simultaneous heating mode depending on the number of the first heating coil elements and/or the second heating coil elements having a load detected in the vicinity thereof by the load detecting part.

12. The induction heating device of claim 8 or 9, wherein the first heating coil elements making up the first heating coil and the second heating coil elements making up the second heating coil are arranged in a staggered manner in a planar heating region.

Fig.1

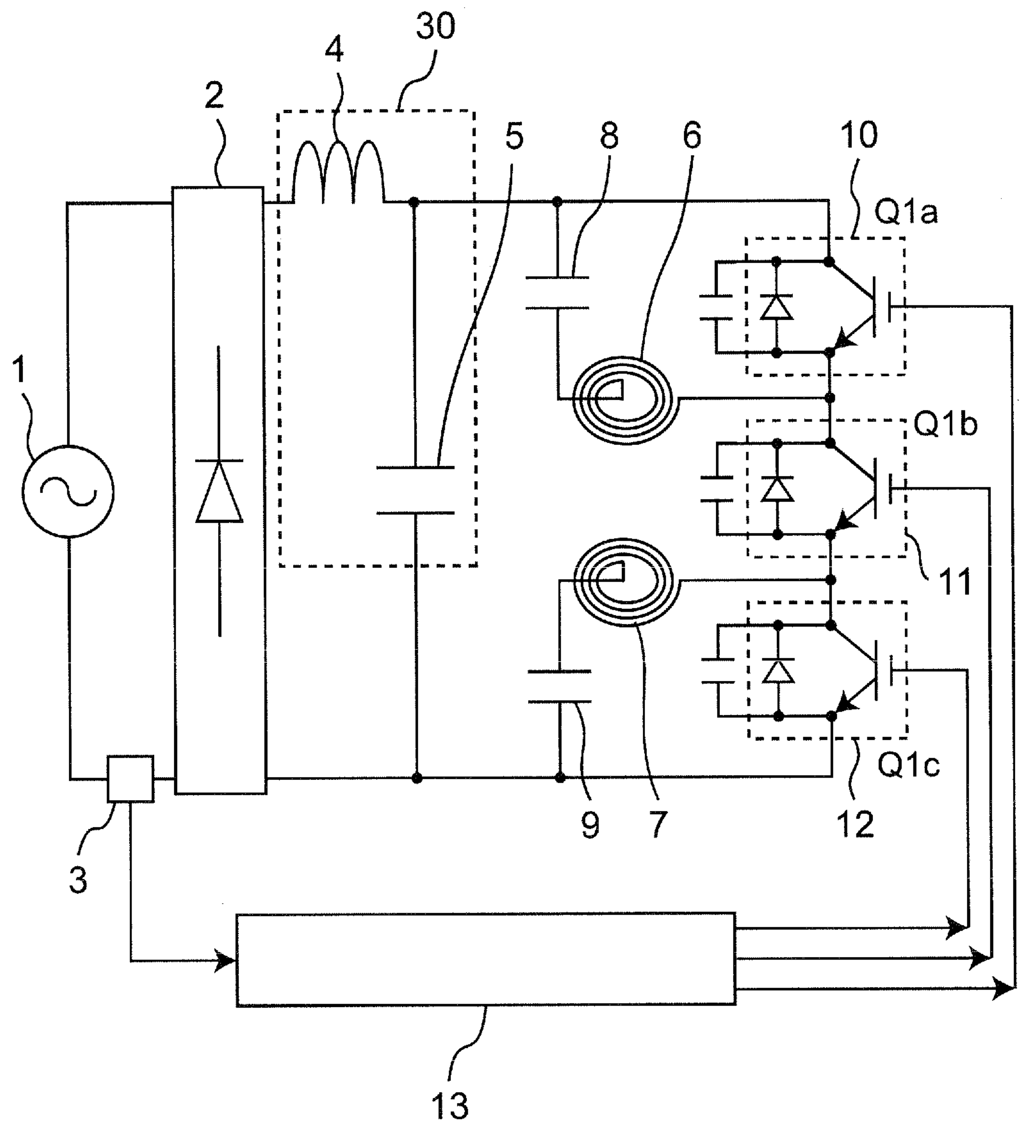
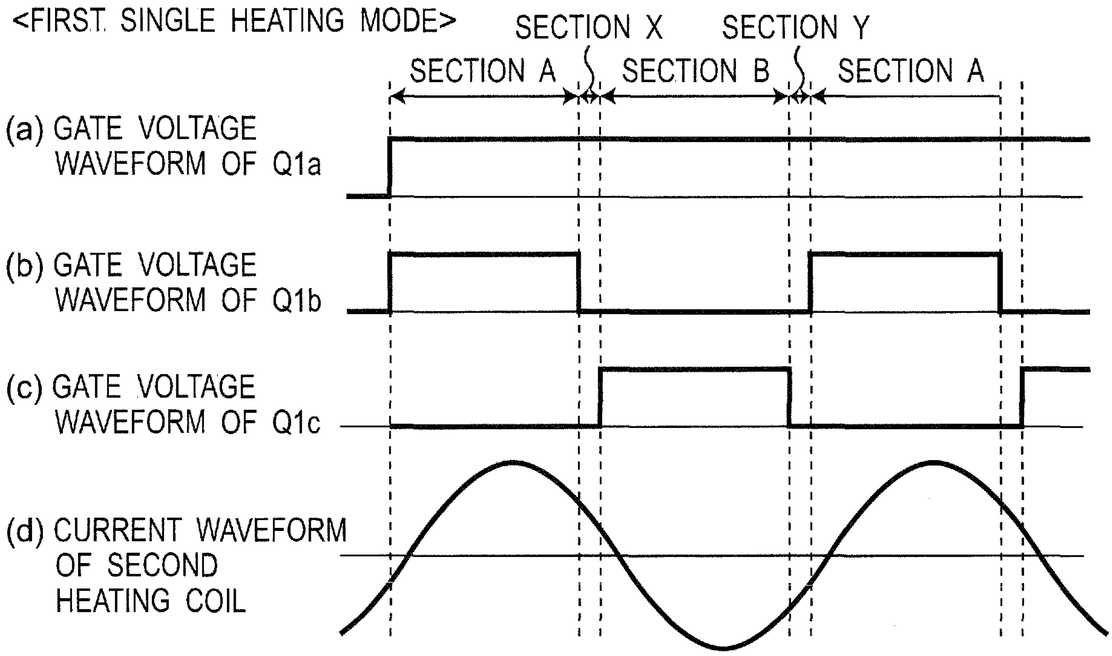


Fig.2A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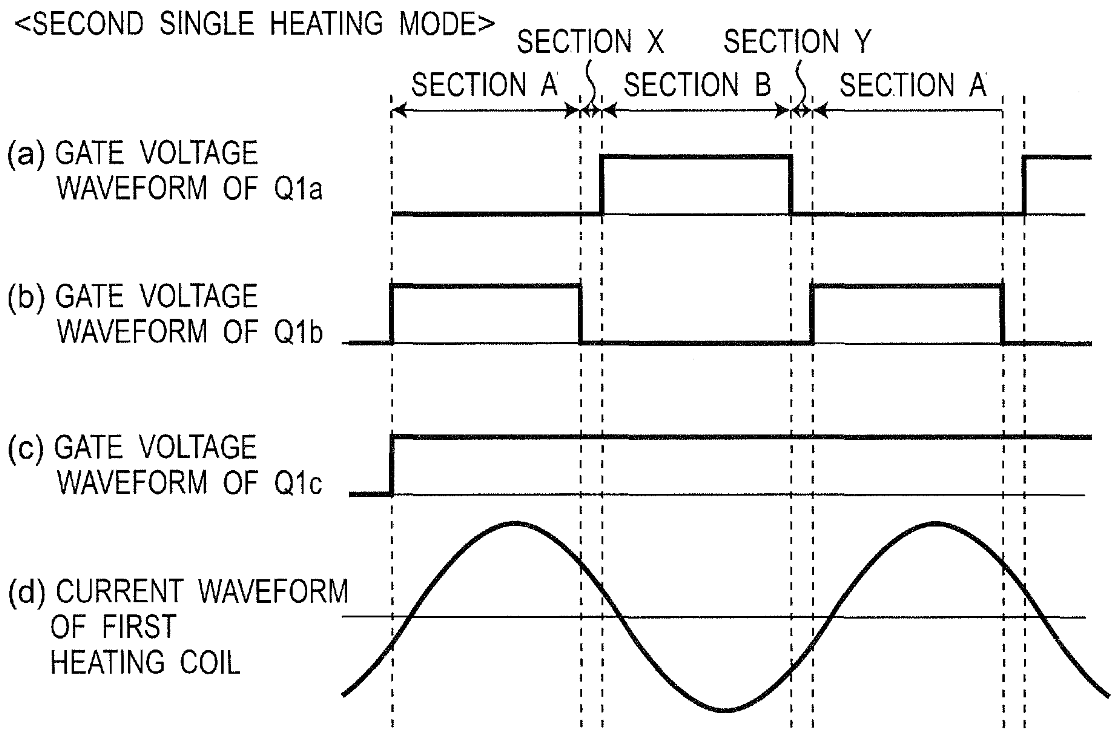
SECTION Y
SECTION A
SECTION B
SECTION A
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.2B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SECTION X
SECTION Y
SECTION A'
SECTION B
SECTION A'
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL

Fig.3

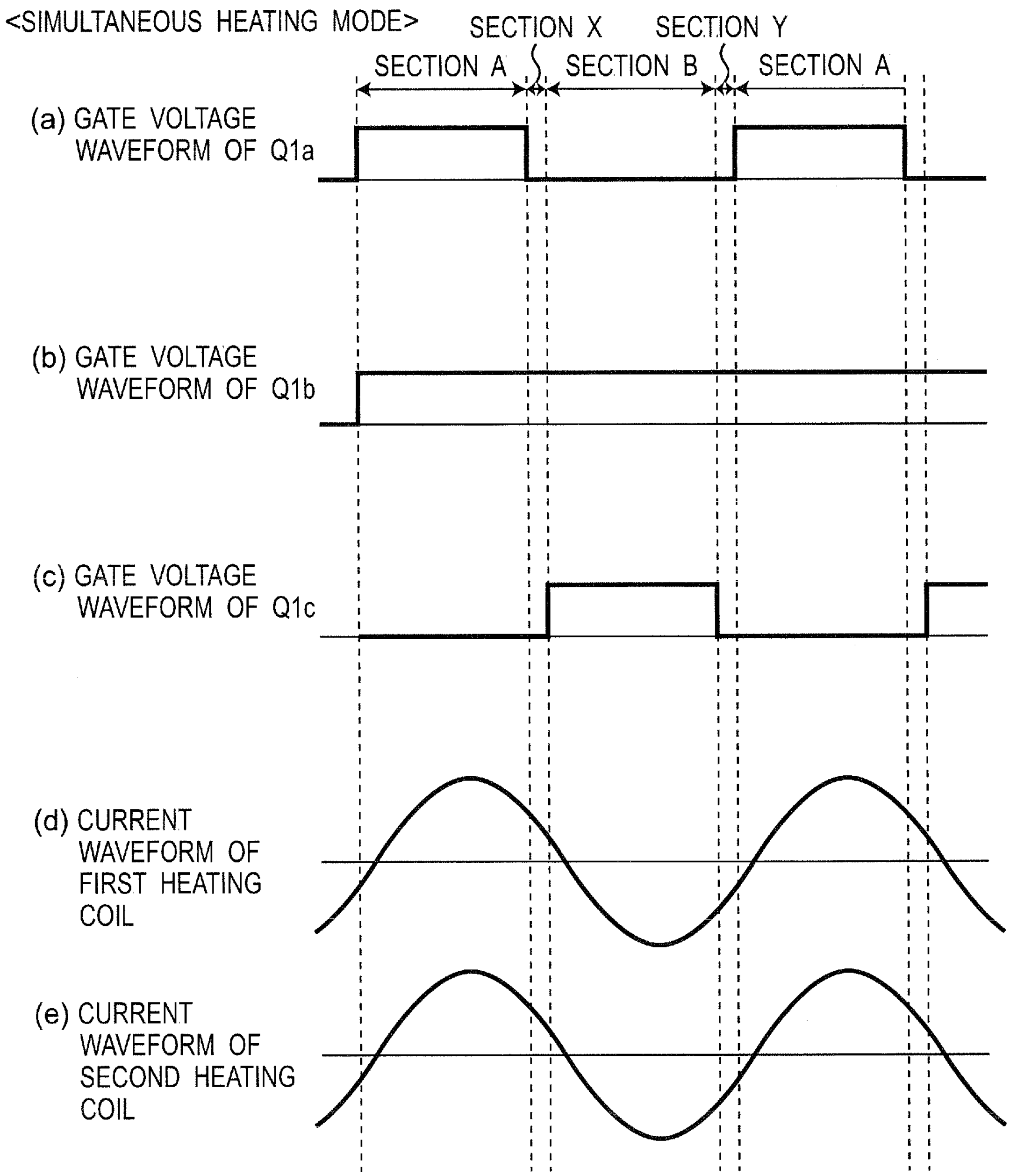

<SIMULTANEOUS HEATING MODE>
SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL
(e) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.4

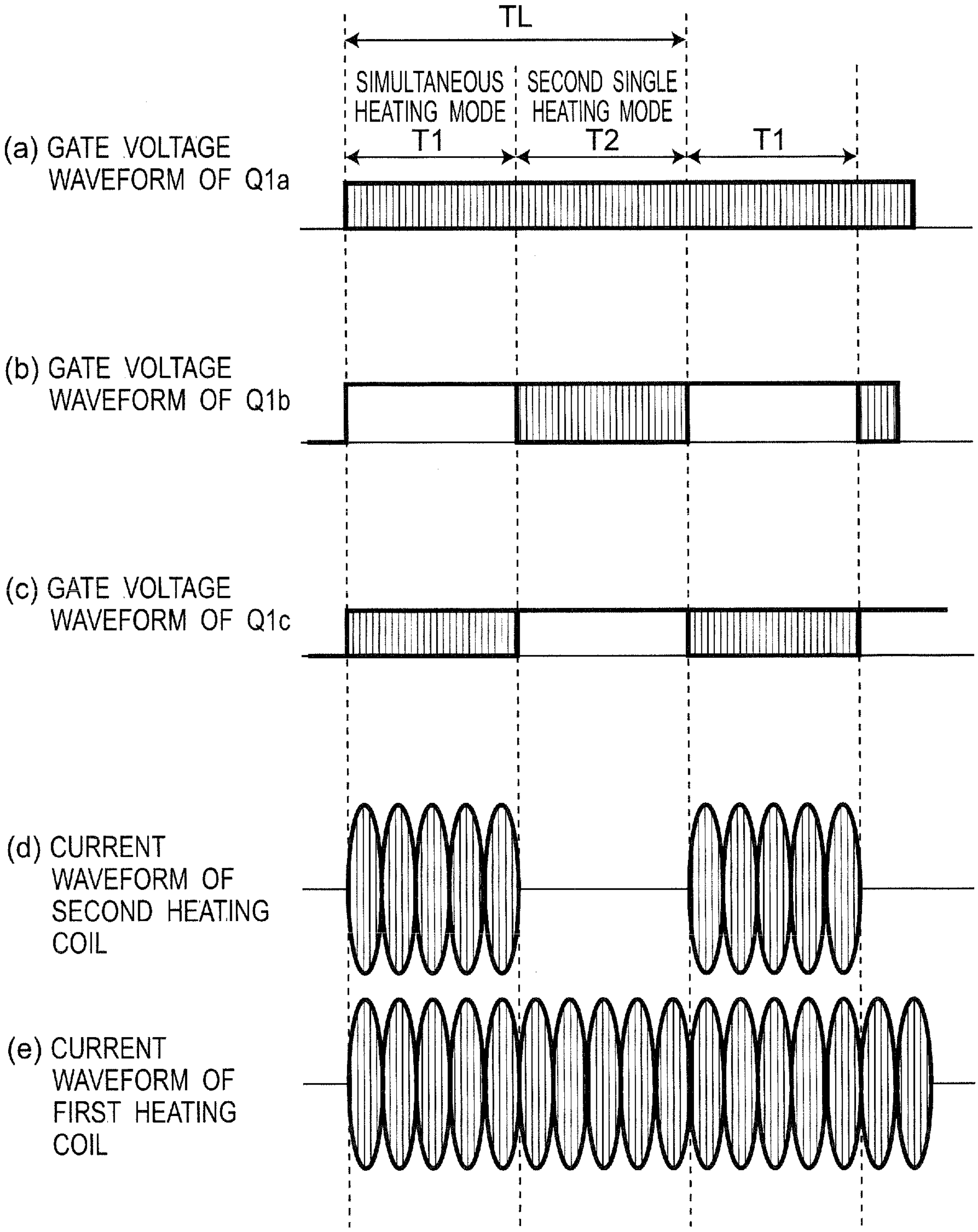

TL
SIMULTANEOUS HEATING MODE
SECOND SINGLE HEATING MODE
T1
T2
T1
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF SECOND HEATING COIL
(e) CURRENT WAVEFORM OF FIRST HEATING COIL

Fig.5

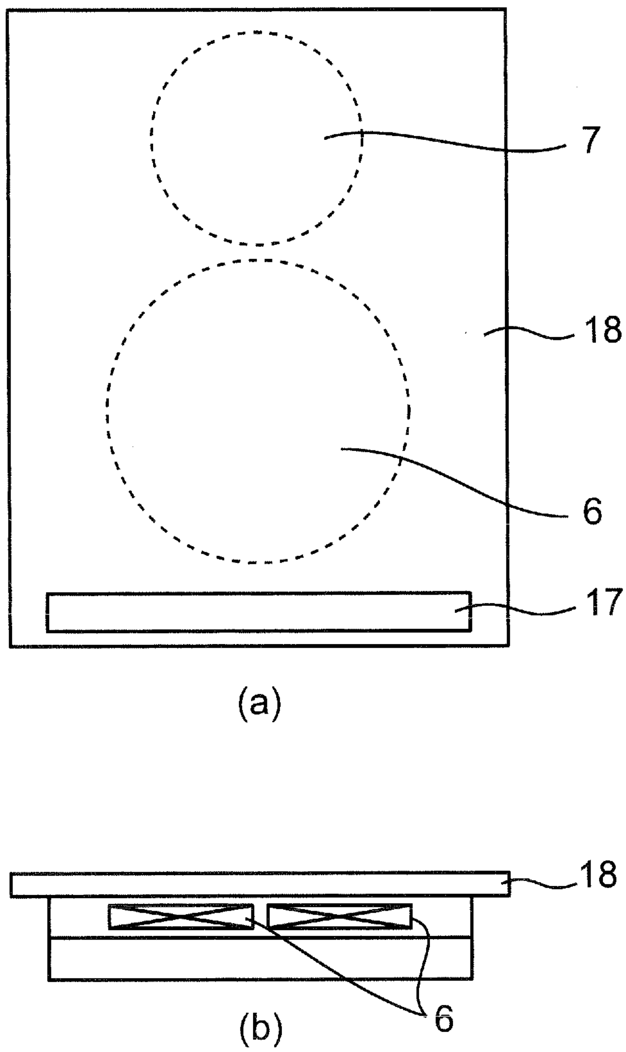


Fig.6

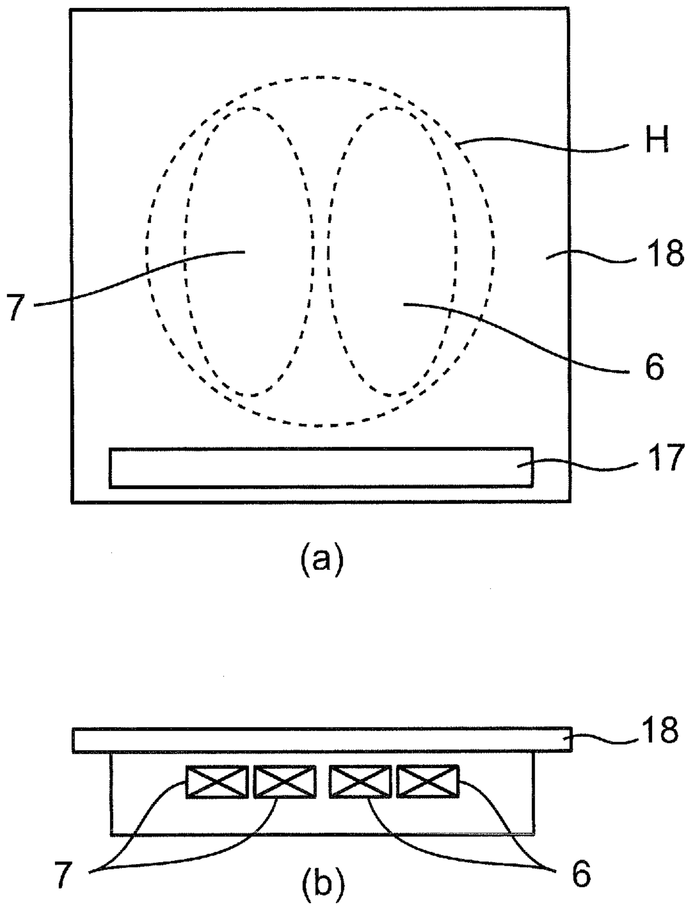


Fig.7

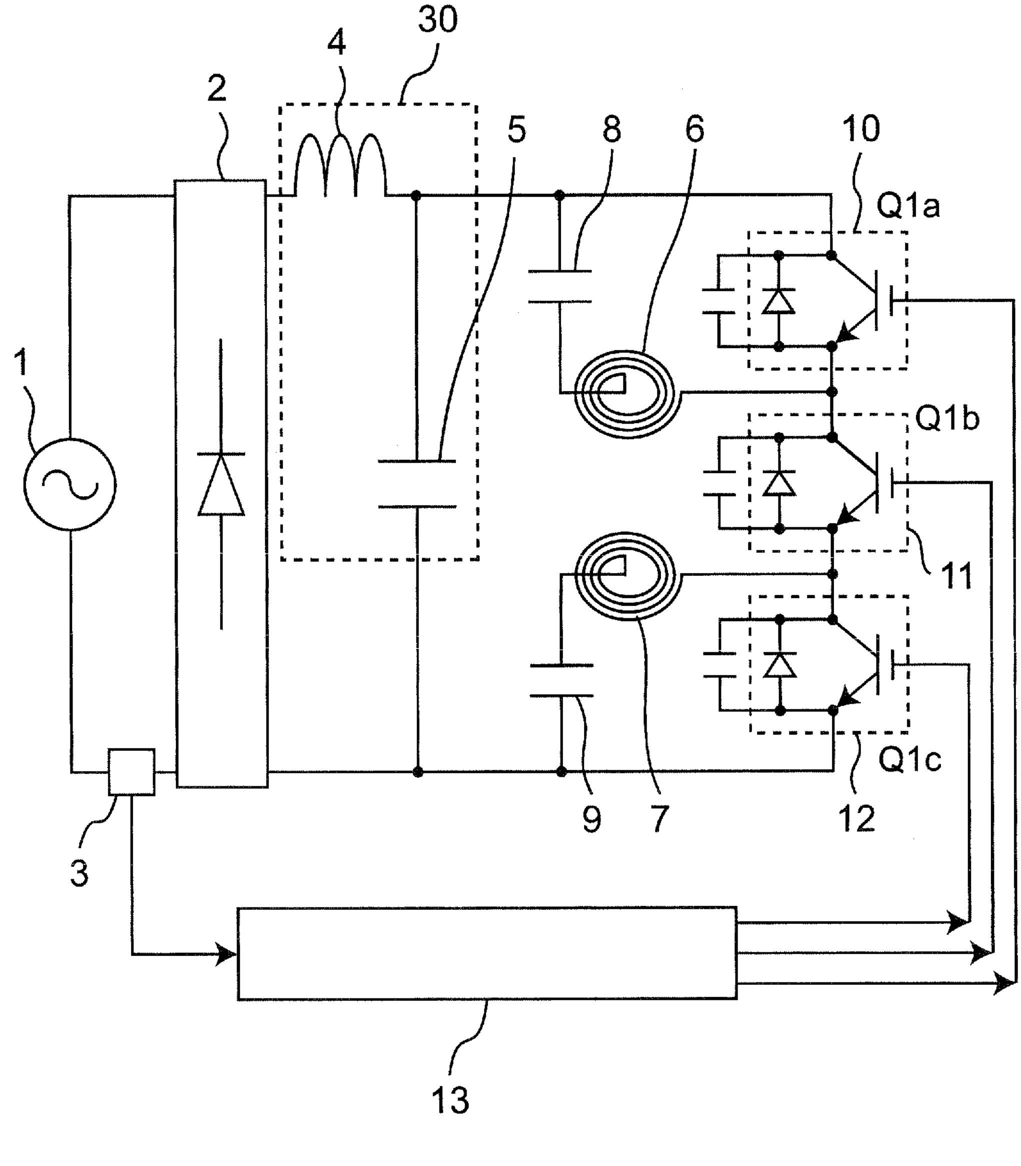
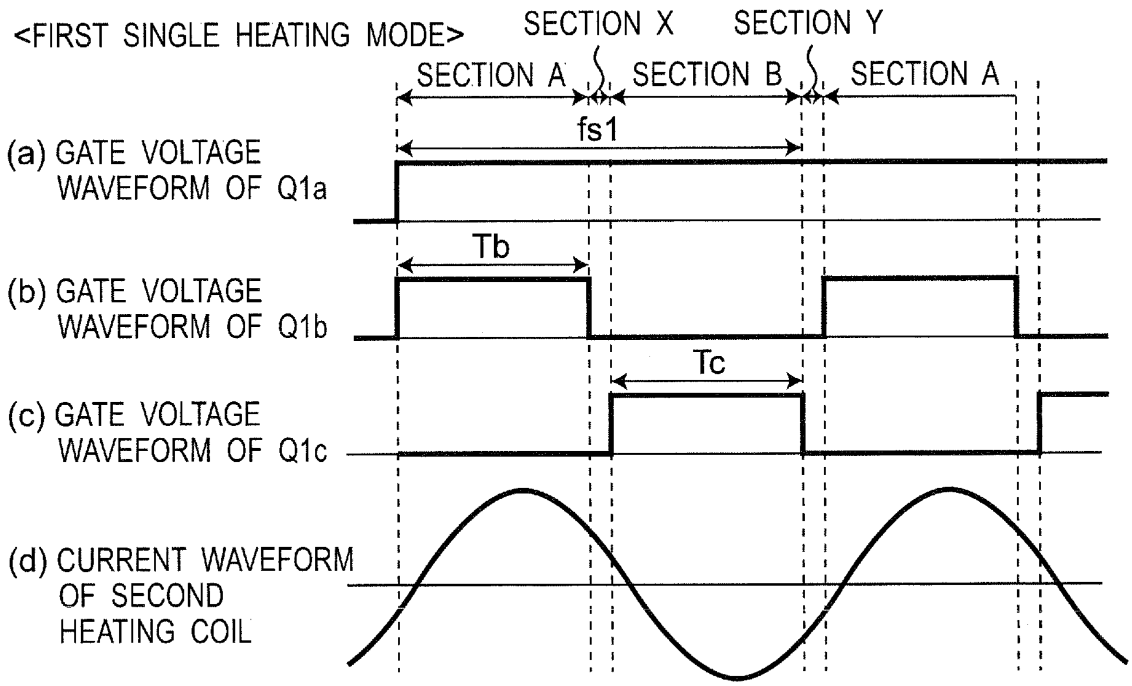


Fig.8A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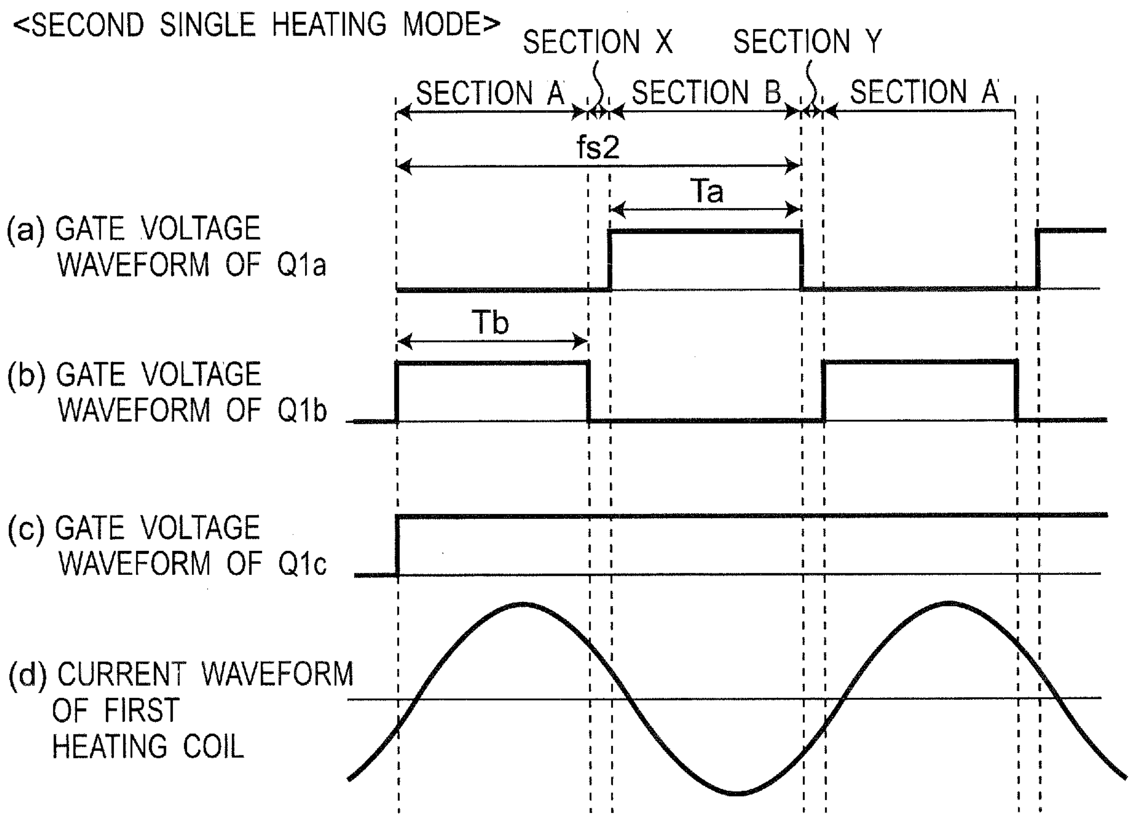
SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
fs1
(a) GATE VOLTAGE WAVEFORM OF Q1a
Tb
(b) GATE VOLTAGE WAVEFORM OF Q1b
Tc
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.8B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SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
fs2
Ta
(a) GATE VOLTAGE WAVEFORM OF Q1a
Tb
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL

Fig.9

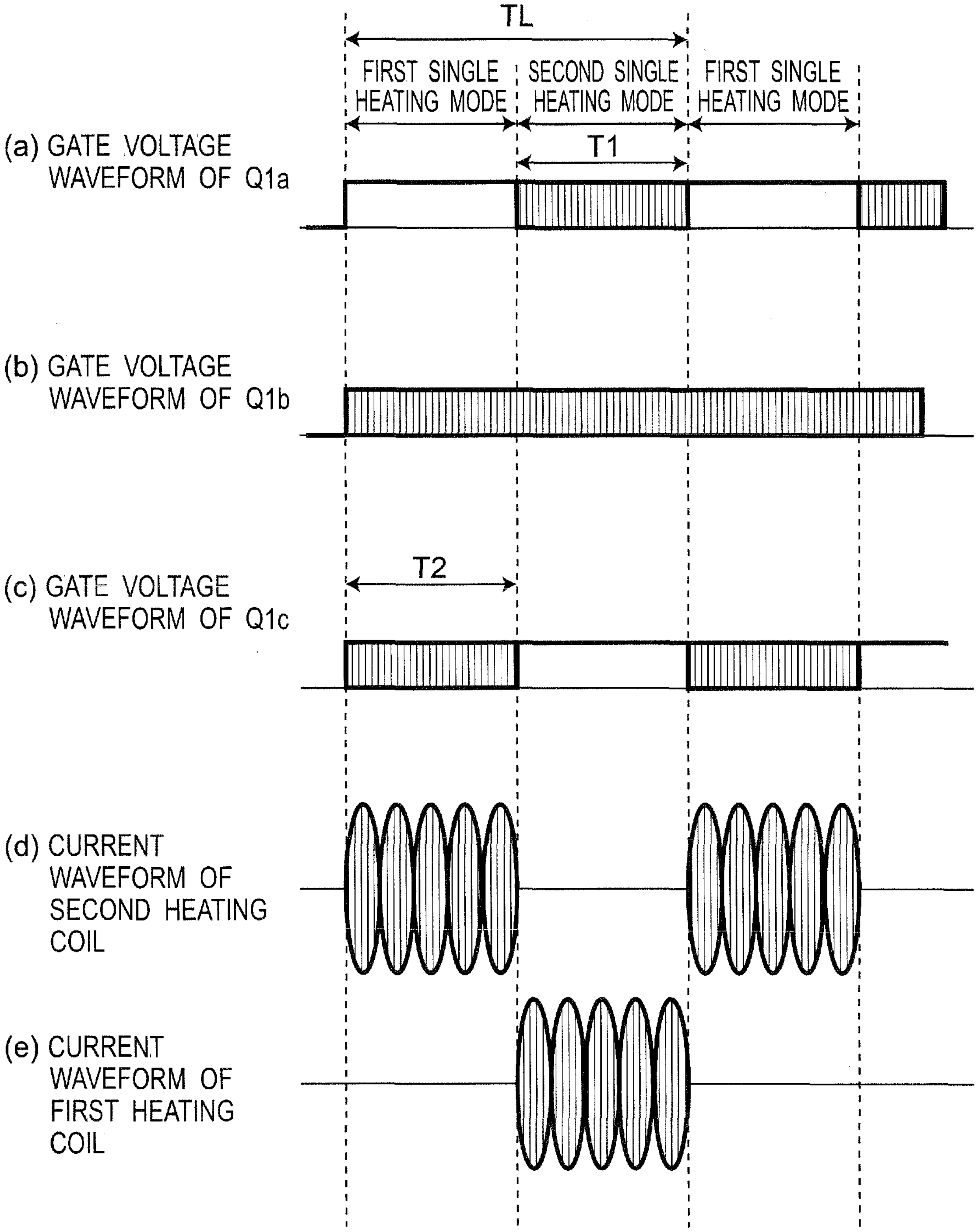

TL
FIRST SINGLE HEATING MODE
SECOND SINGLE HEATING MODE
FIRST SINGLE HEATING MODE
T1
T2
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF SECOND HEATING COIL
(e) CURRENT WAVEFORM OF FIRST HEATING COIL

Fig.10

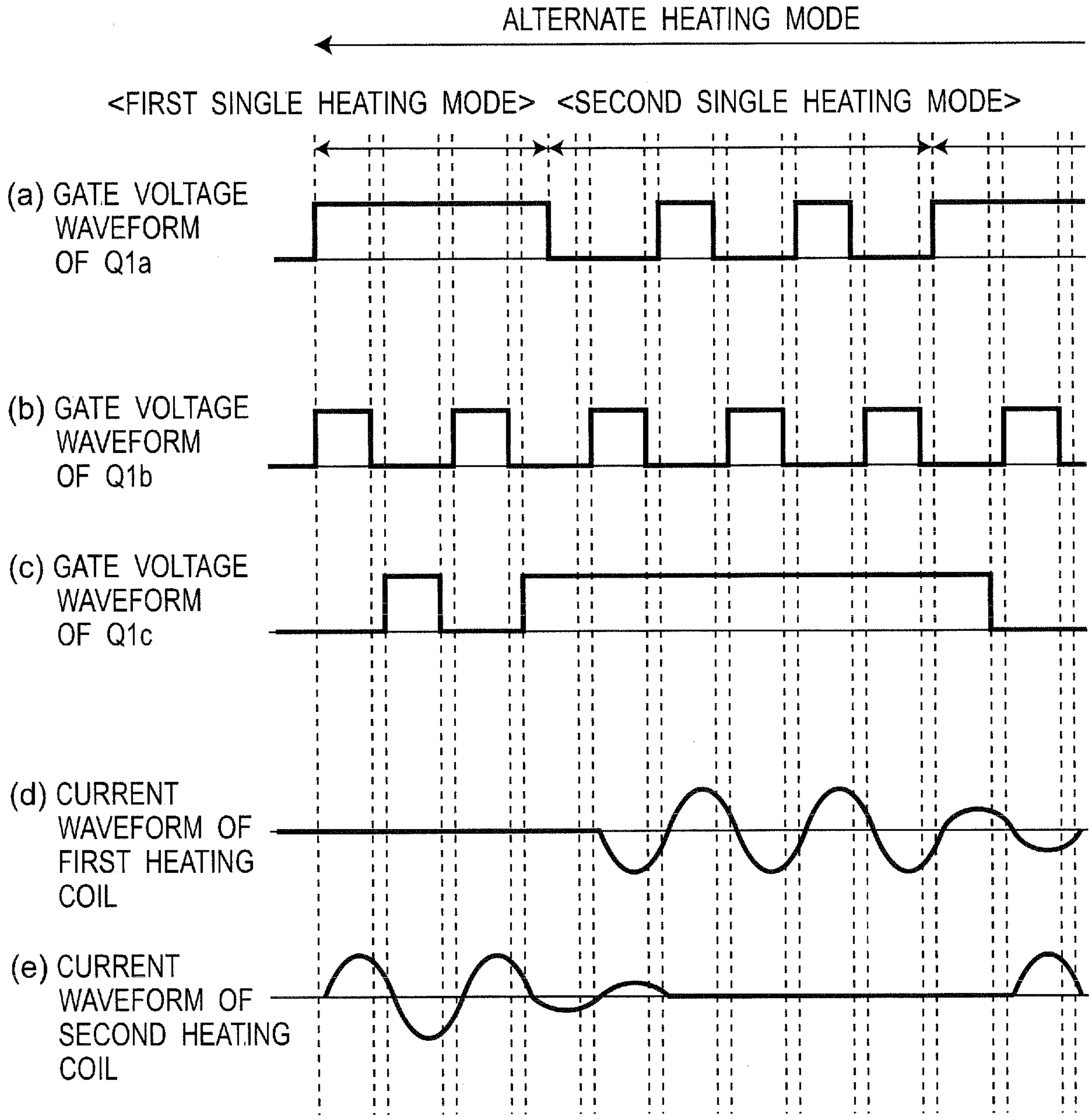

ALTERNATE HEATING MODE
<FIRST SINGLE HEATING MODE>
<SECOND SINGLE HEATING MODE>
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL
(e) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.11A

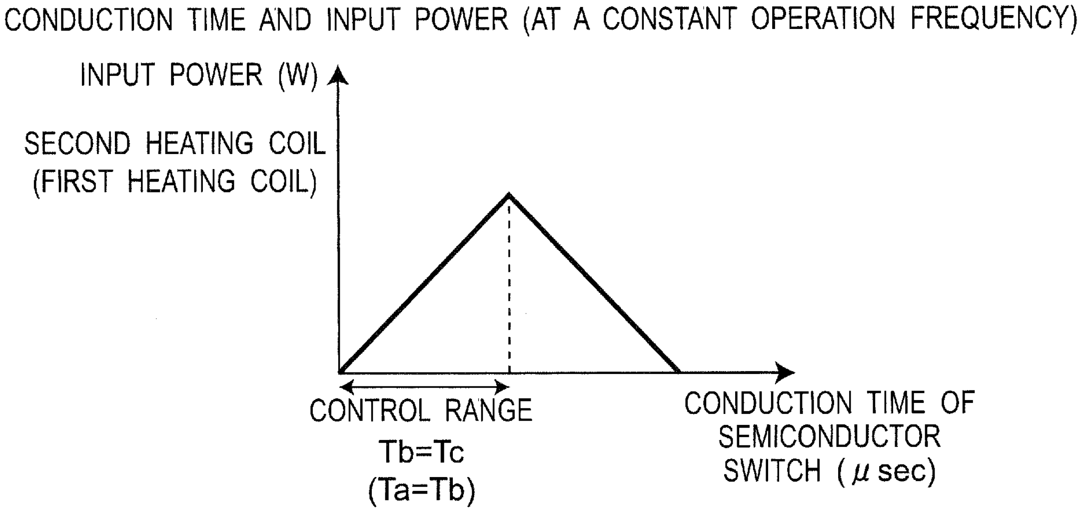


Fig.11B

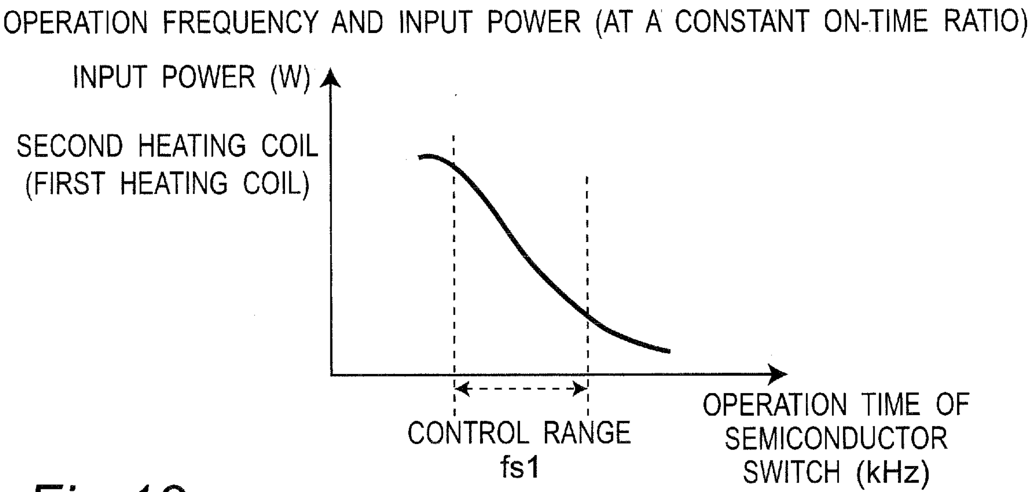


Fig.12

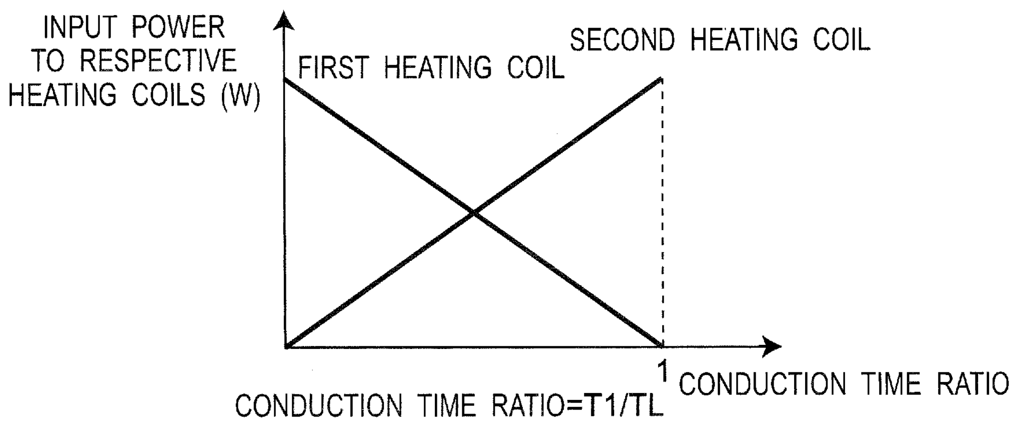


Fig.13

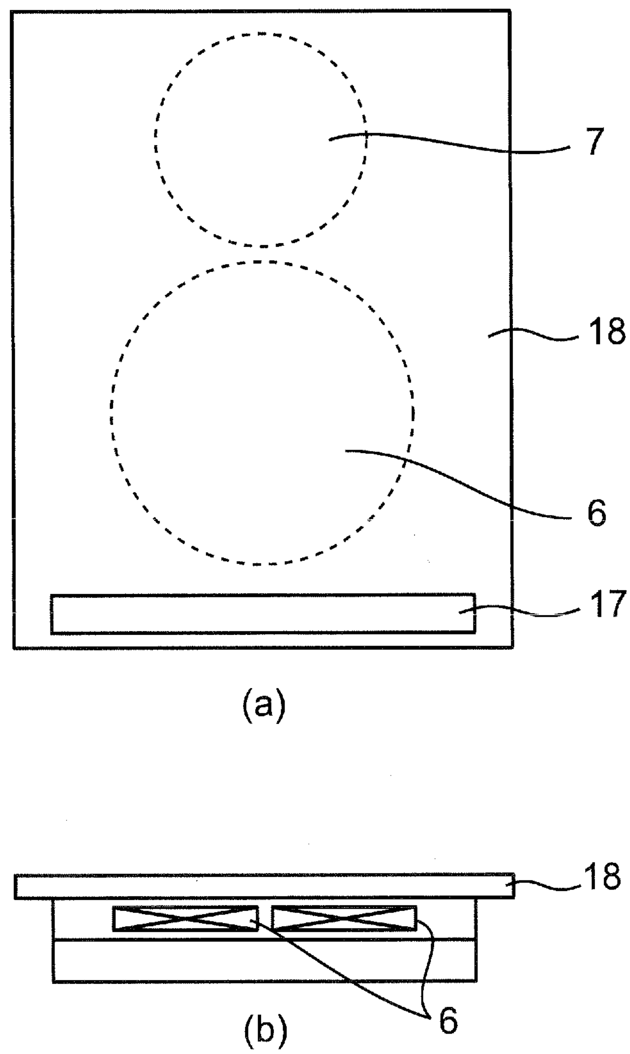


Fig.14

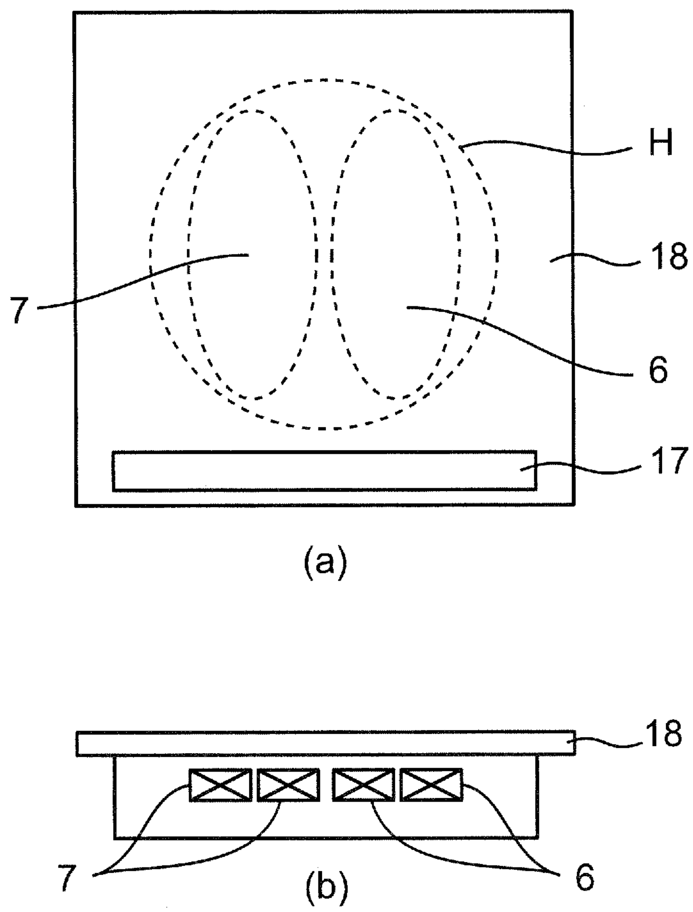


Fig.15

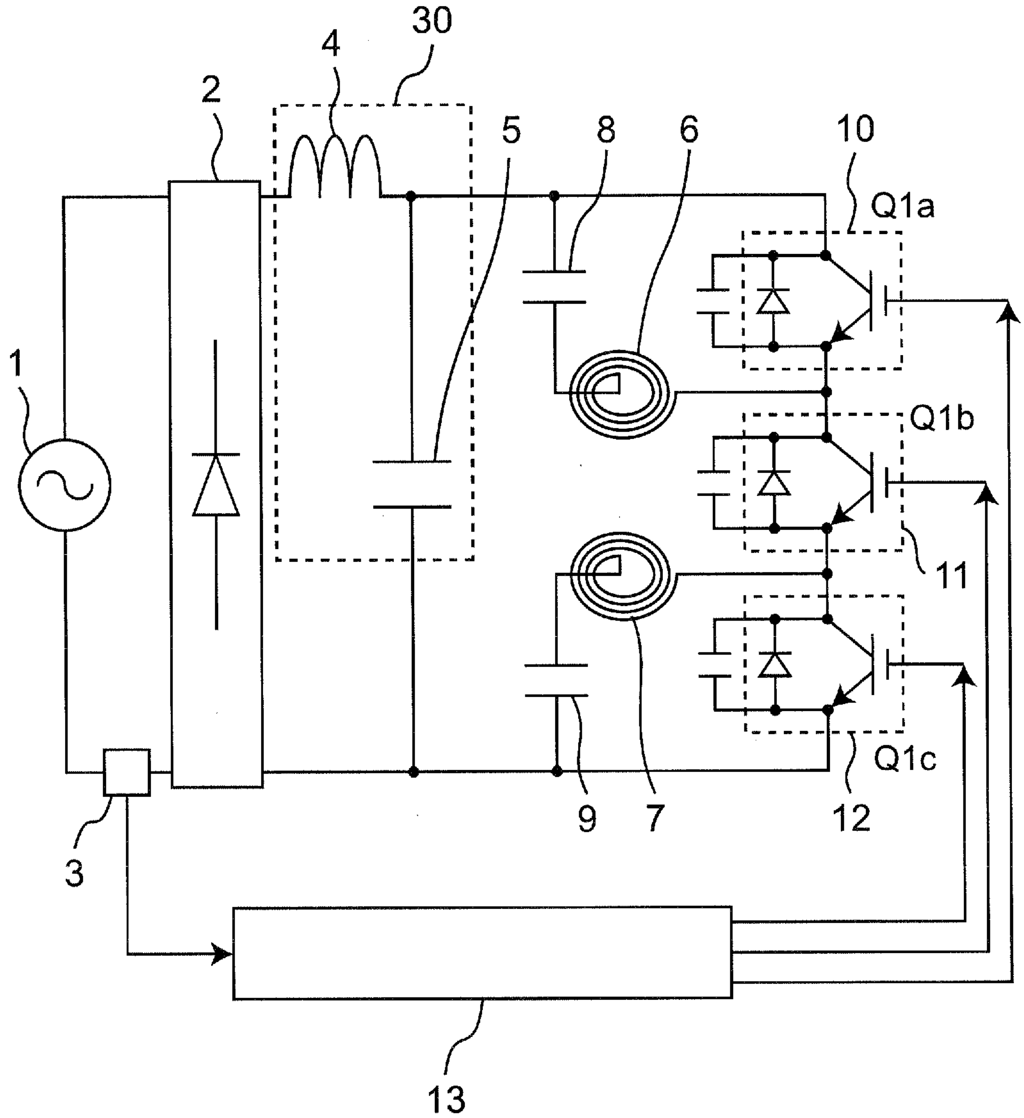


Fig.16

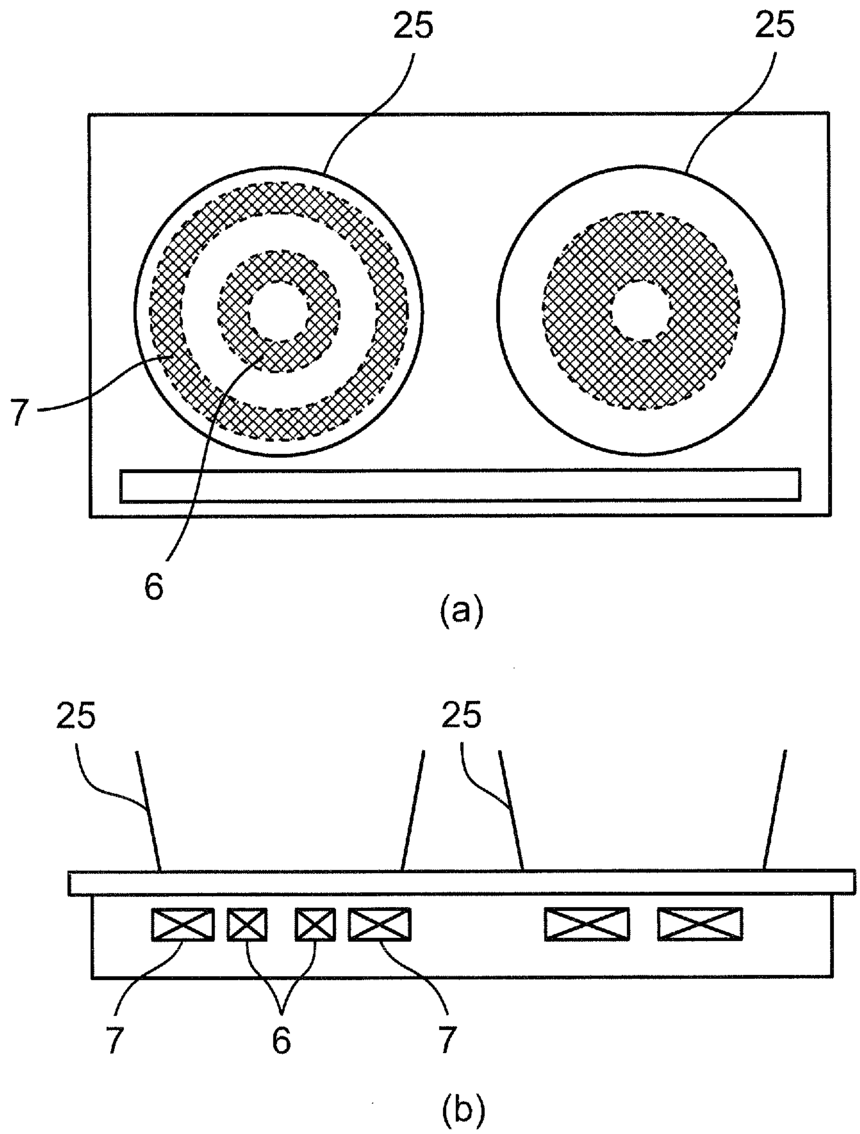
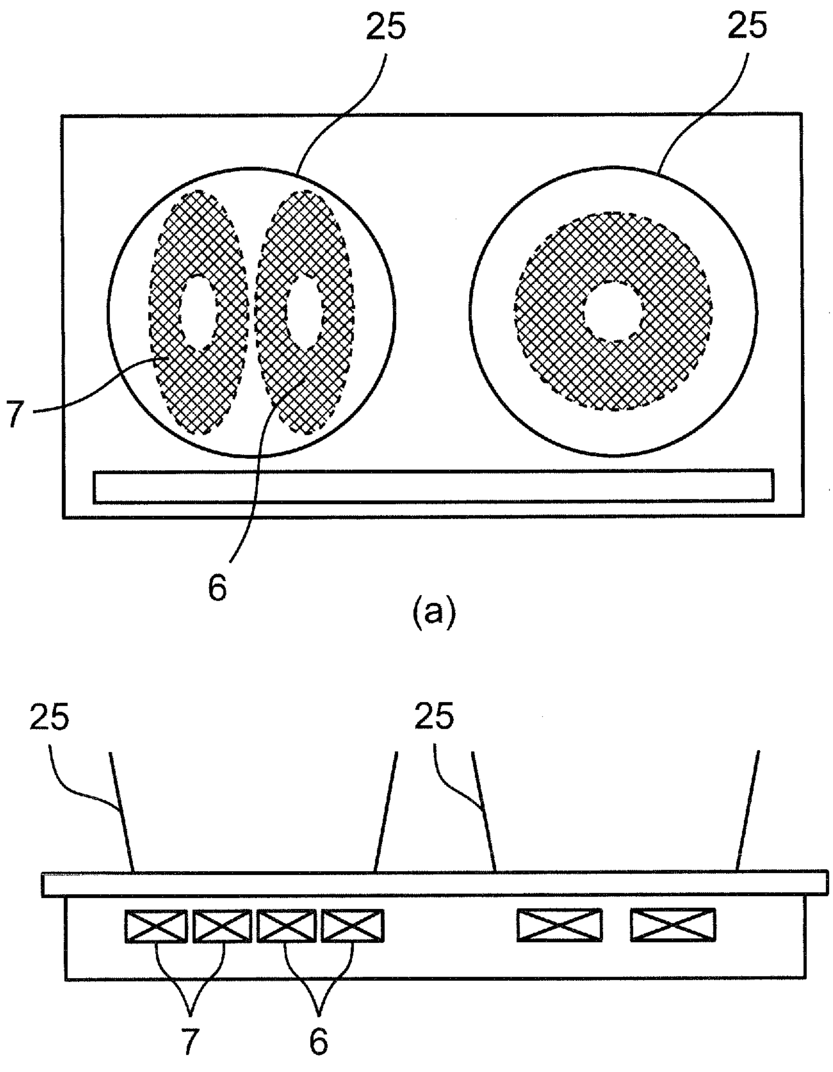


Fig.17



(a)

(b)

Fig.18

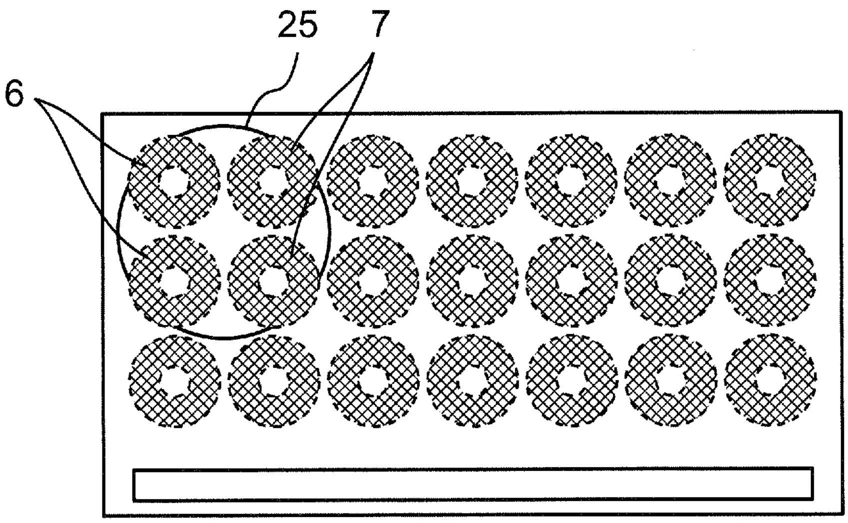
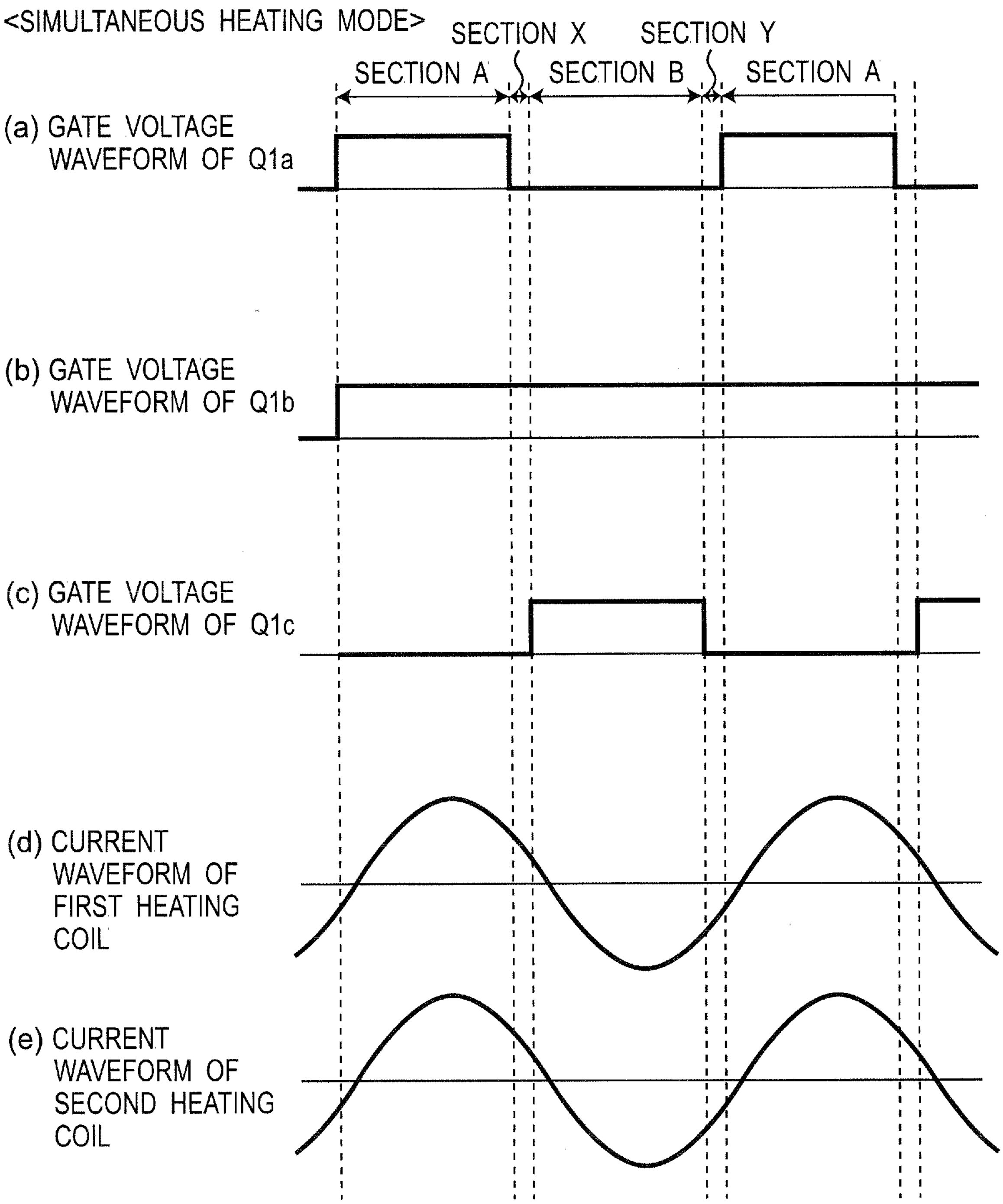


Fig.19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SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL
(e) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.20A

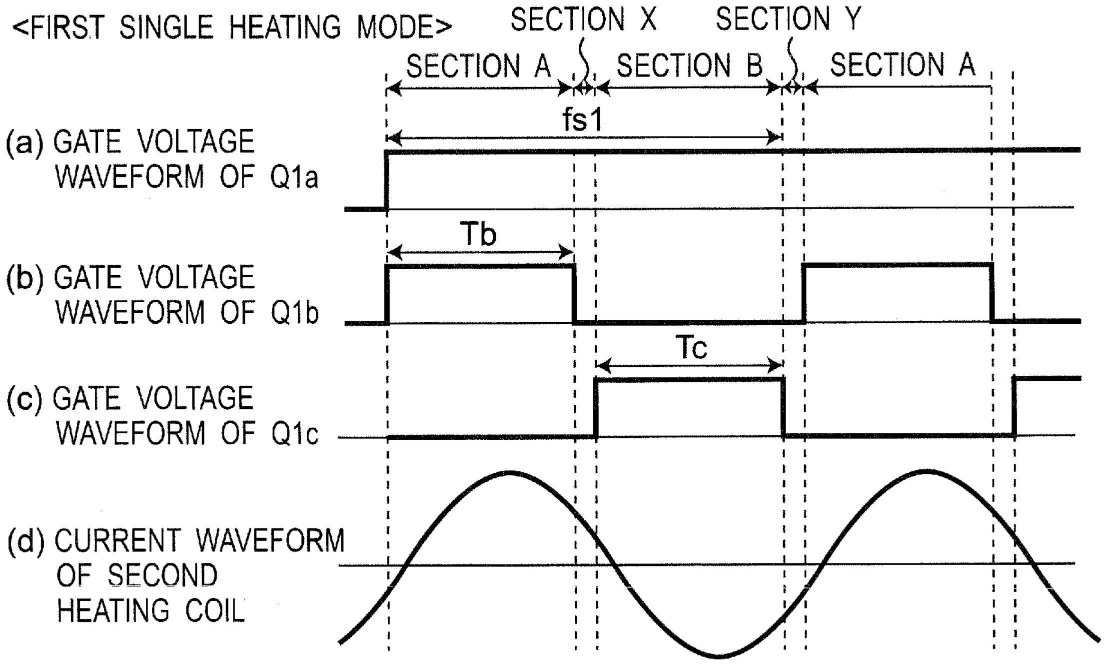


Fig.20B

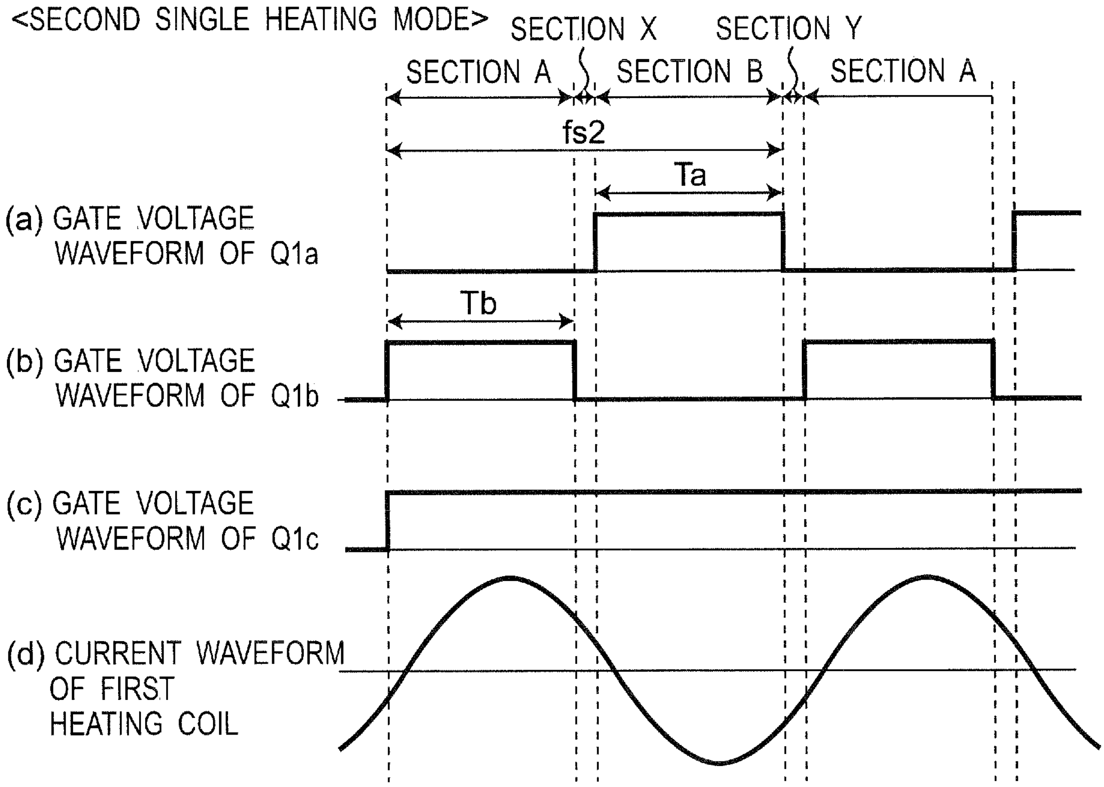


Fig.21

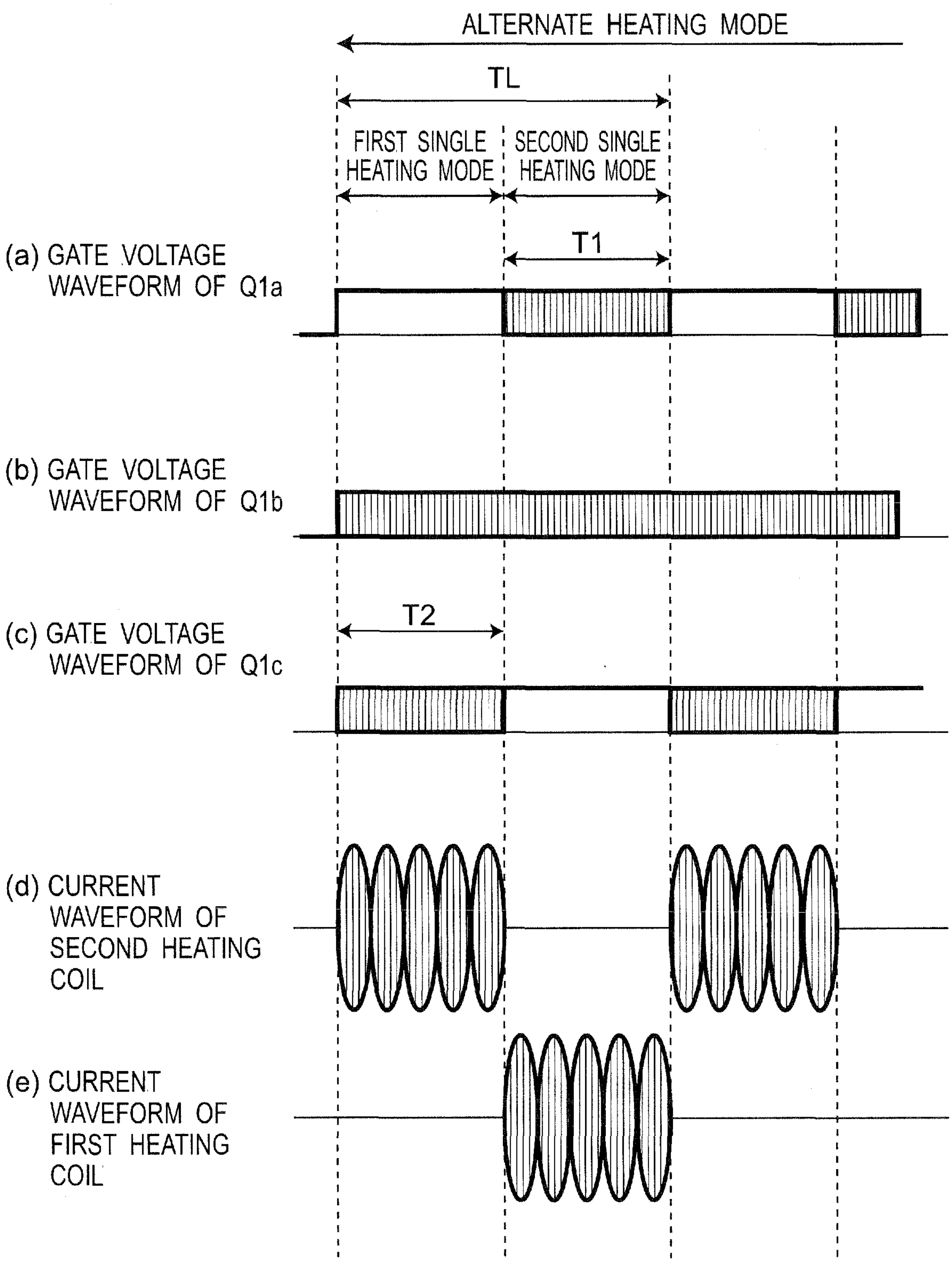

ALTERNATE HEATING MODE
TL
FIRST SINGLE HEATING MODE
SECOND SINGLE HEATING MODE
T1
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
T2
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF SECOND HEATING COIL
(e) CURRENT WAVEFORM OF FIRST HEATING COIL

Fig.22

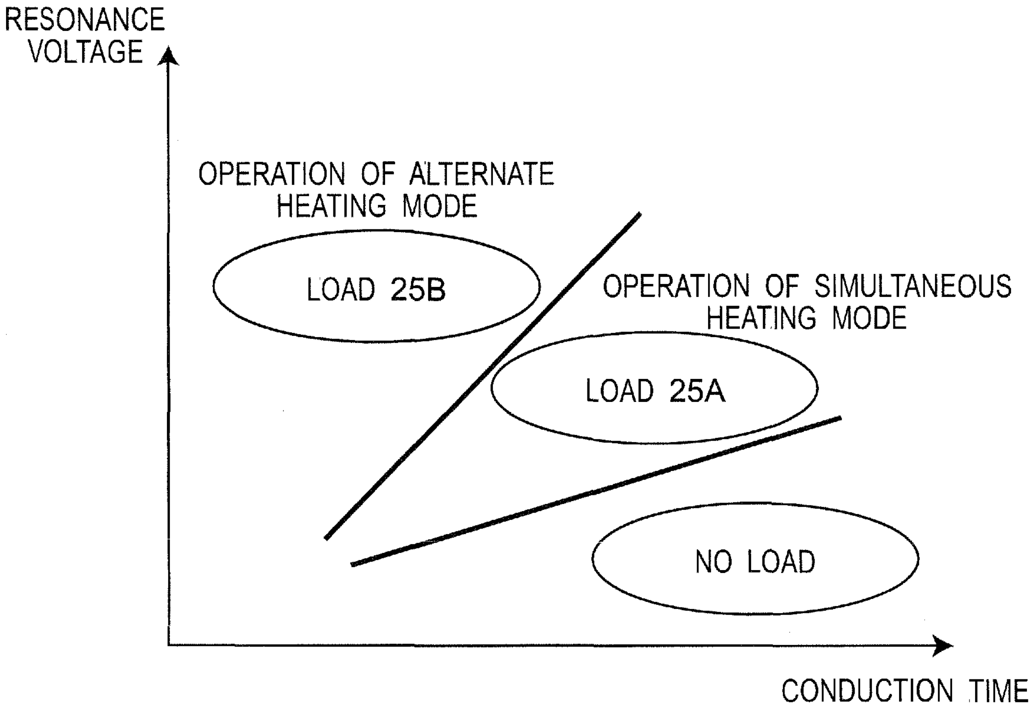

RESONANCE VOLTAGE
OPERATION OF ALTERNATE HEATING MODE
LOAD 25B
OPERATION OF SIMULTANEOUS HEATING MODE
LOAD 25A
NO LOAD
CONDUCTION TIME

Fig.23

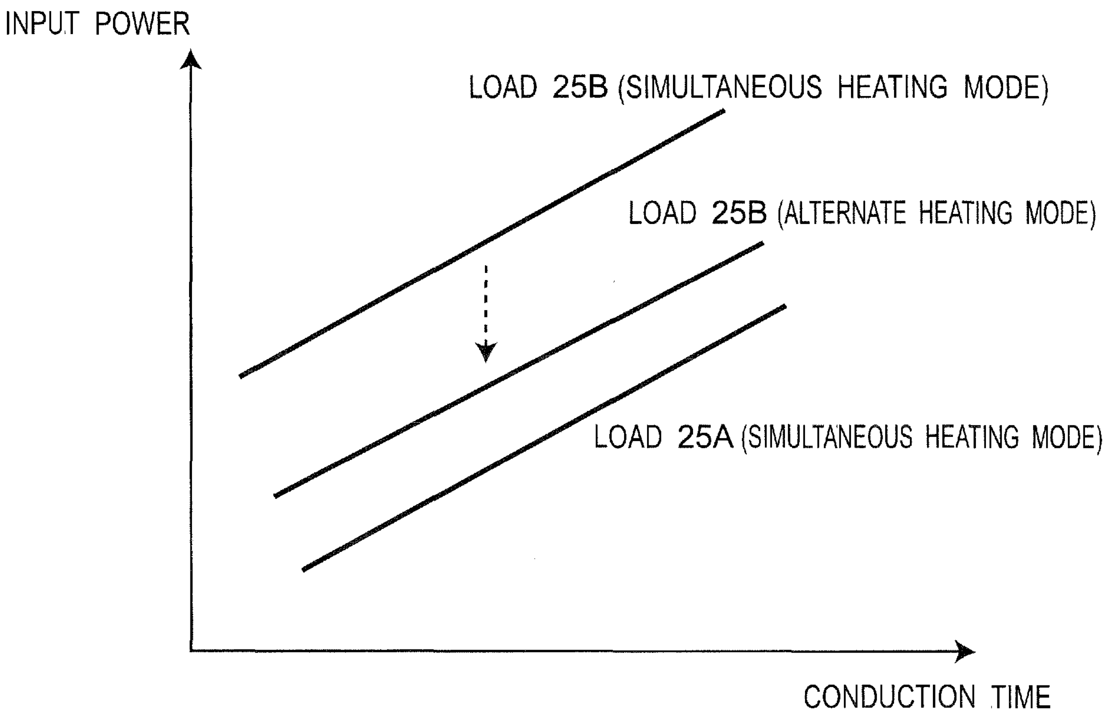
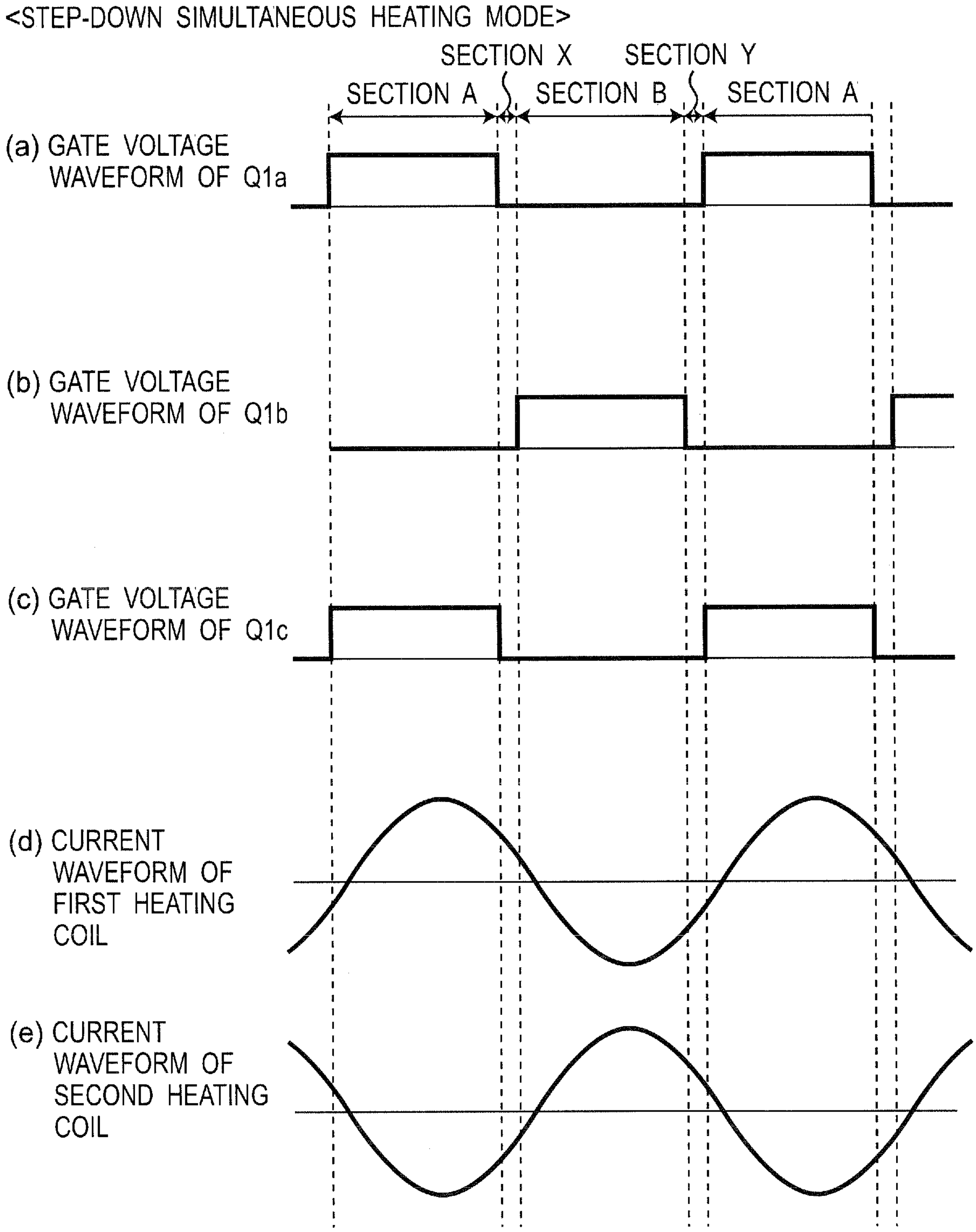

INPUT POWER
LOAD 25B (SIMULTANEOUS HEATING MODE)
LOAD 25B (ALTERNATE HEATING MODE)
LOAD 25A (SIMULTANEOUS HEATING MODE)
CONDUCTION TIME

Fig.24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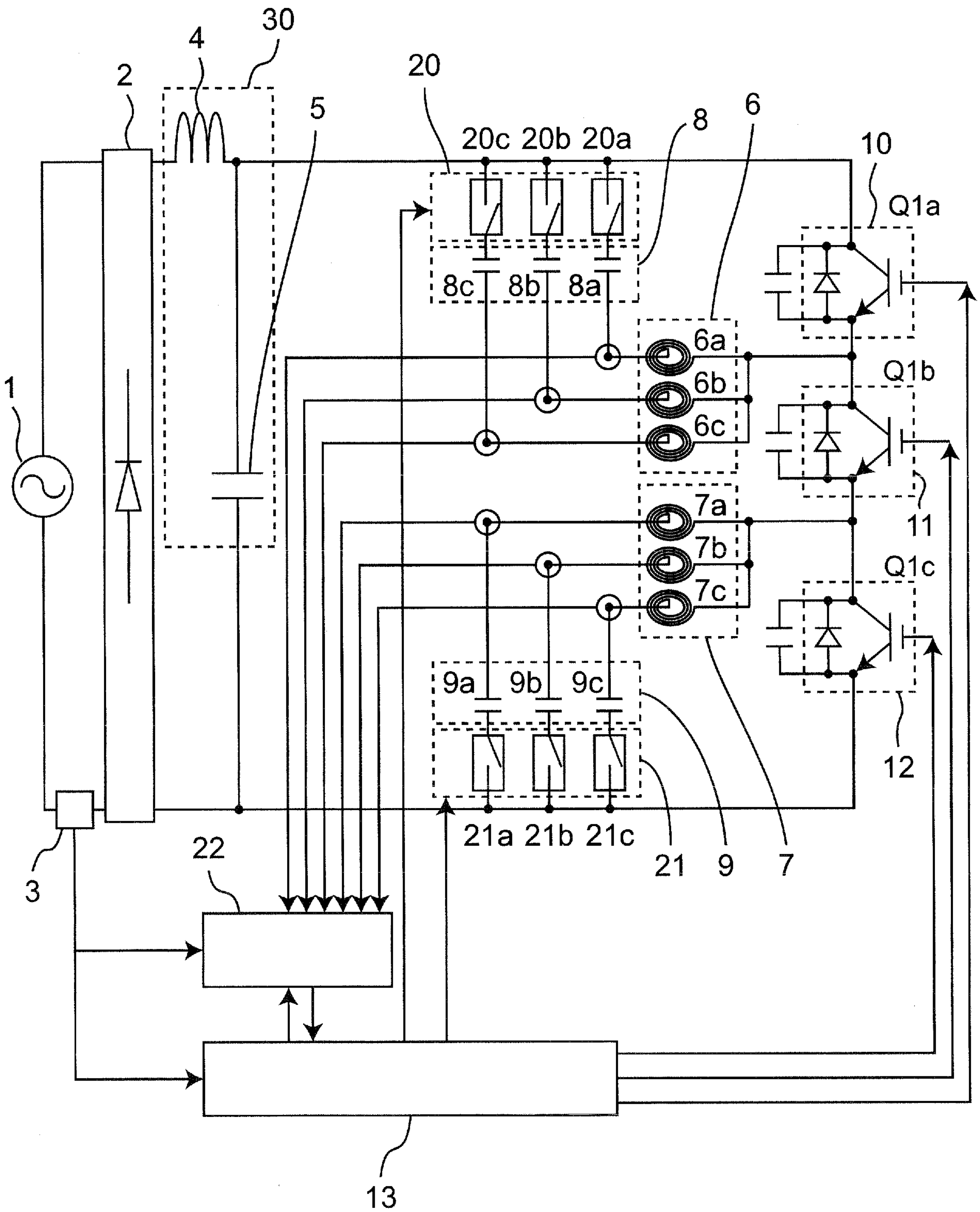
SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL
(e) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.25



30
4
2
20
5
20c 20b 20a
8
6
10
Q1a
8c 8b 8a
6a
6b
6c
Q1b
1
11
7a
7b
7c
Q1c
9a 9b 9c
12
3
21a 21b 21c
21
9
7
22
13

Fig.26

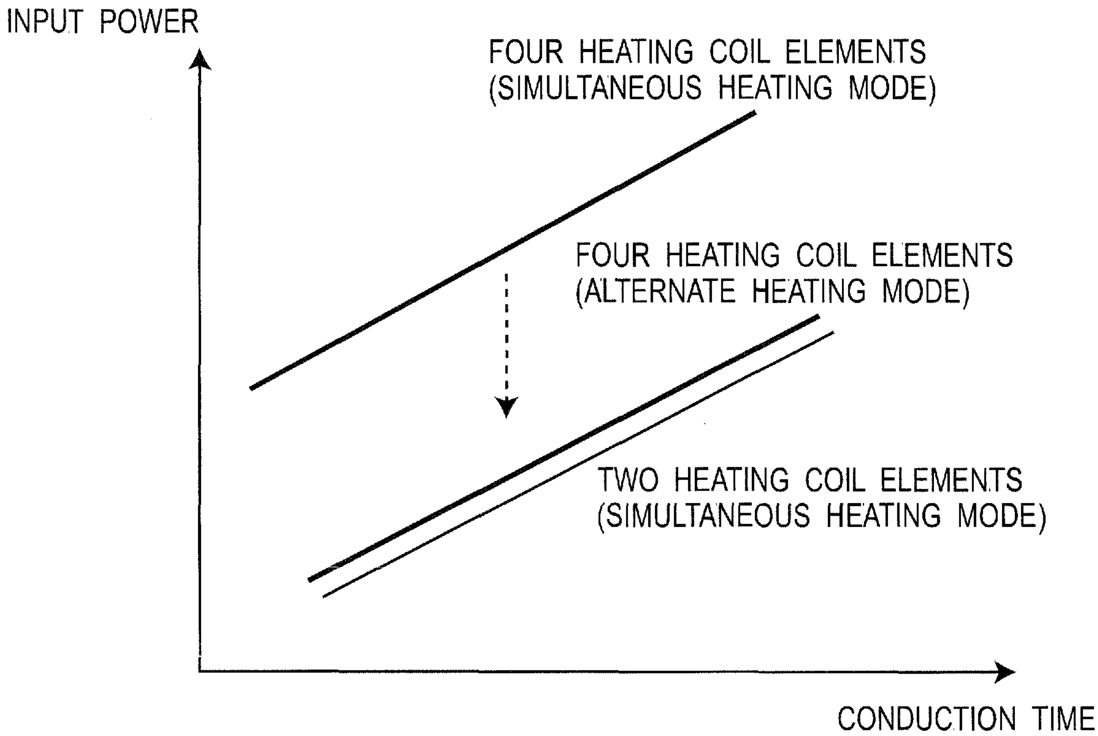
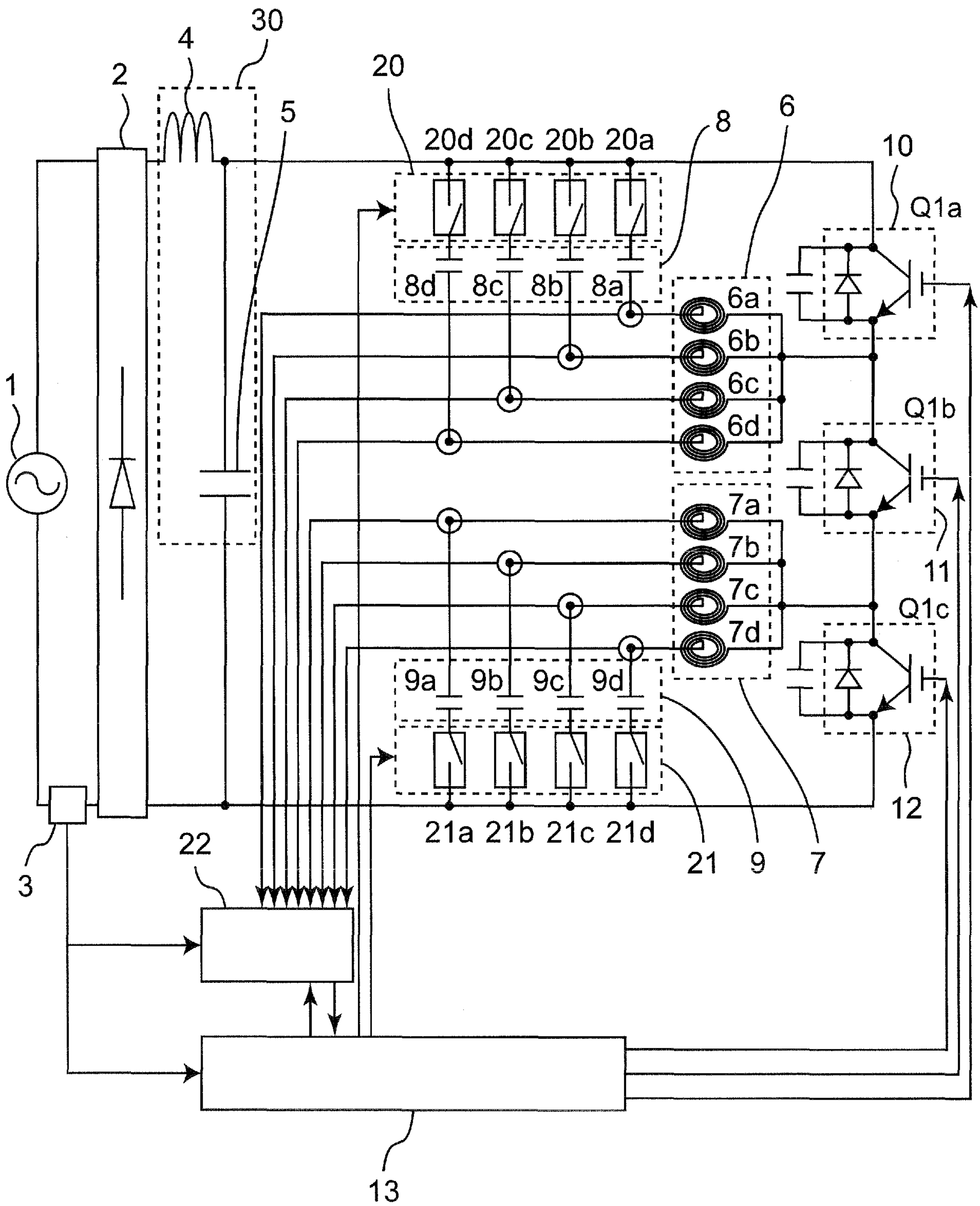

INPUT POWER
FOUR HEATING COIL ELEMENTS (SIMULTANEOUS HEATING MODE)
FOUR HEATING COIL ELEMENTS (ALTERNATE HEATING MODE)
TWO HEATING COIL ELEMENTS (SIMULTANEOUS HEATING MODE)
CONDUCTION TIME

Fig.27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20d 20c 20b 20a
8
8d 8c 8b 8a
6
6a
6b
6c
6d
7a
7b
7c
7d
9a 9b 9c 9d
21a 21b 21c 21d
21 9 7
10
Q1a
Q1b
11
Q1c
12
22
13

Fig.28

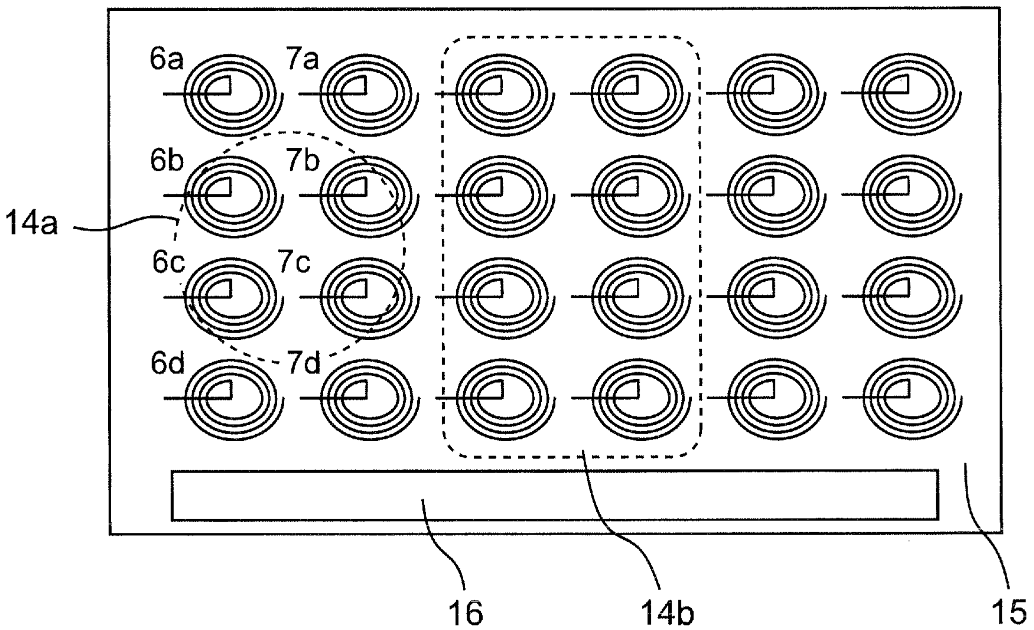
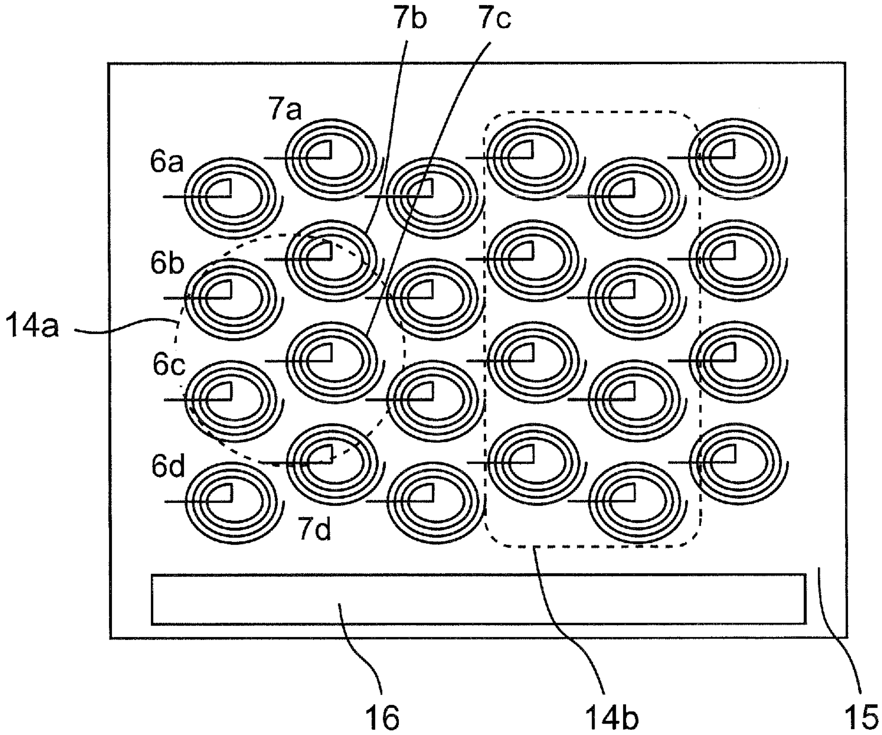

6a
7a
6b
7b
14a
6c
7c
6d
7d
16
14b
15

Fig.29


7b
7c
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6a
6b
14a
6c
6d
7d
16
14b
15

Fig.30

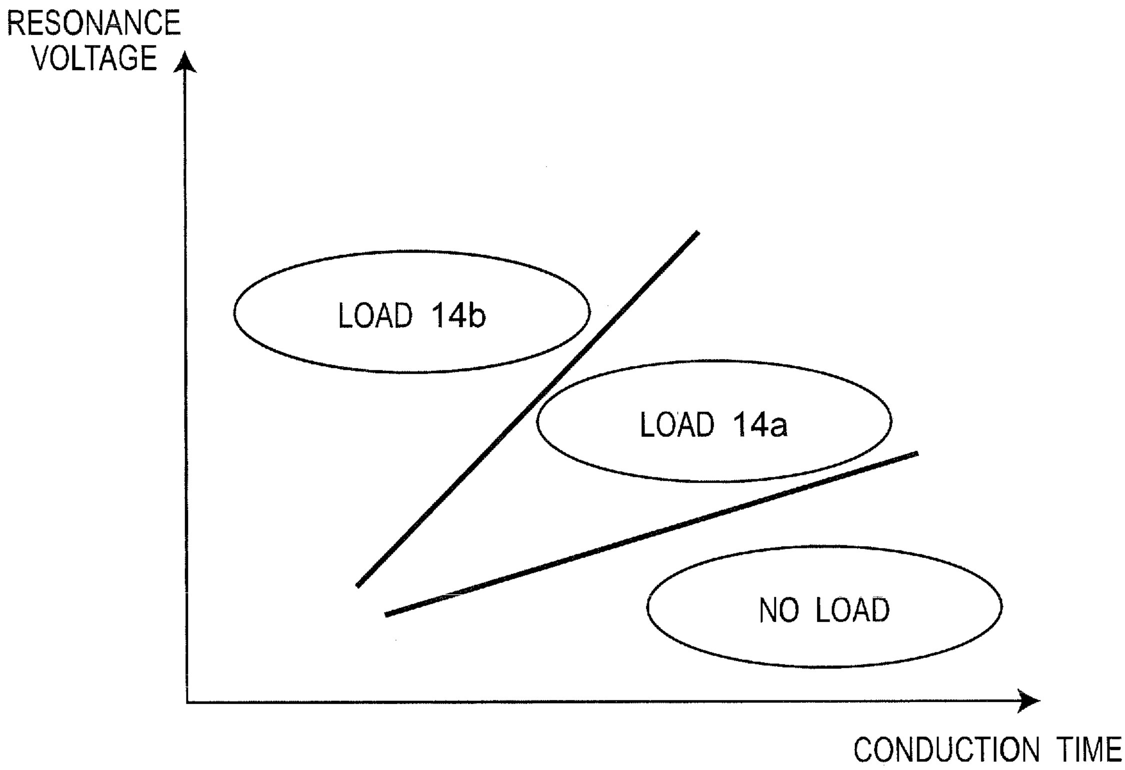
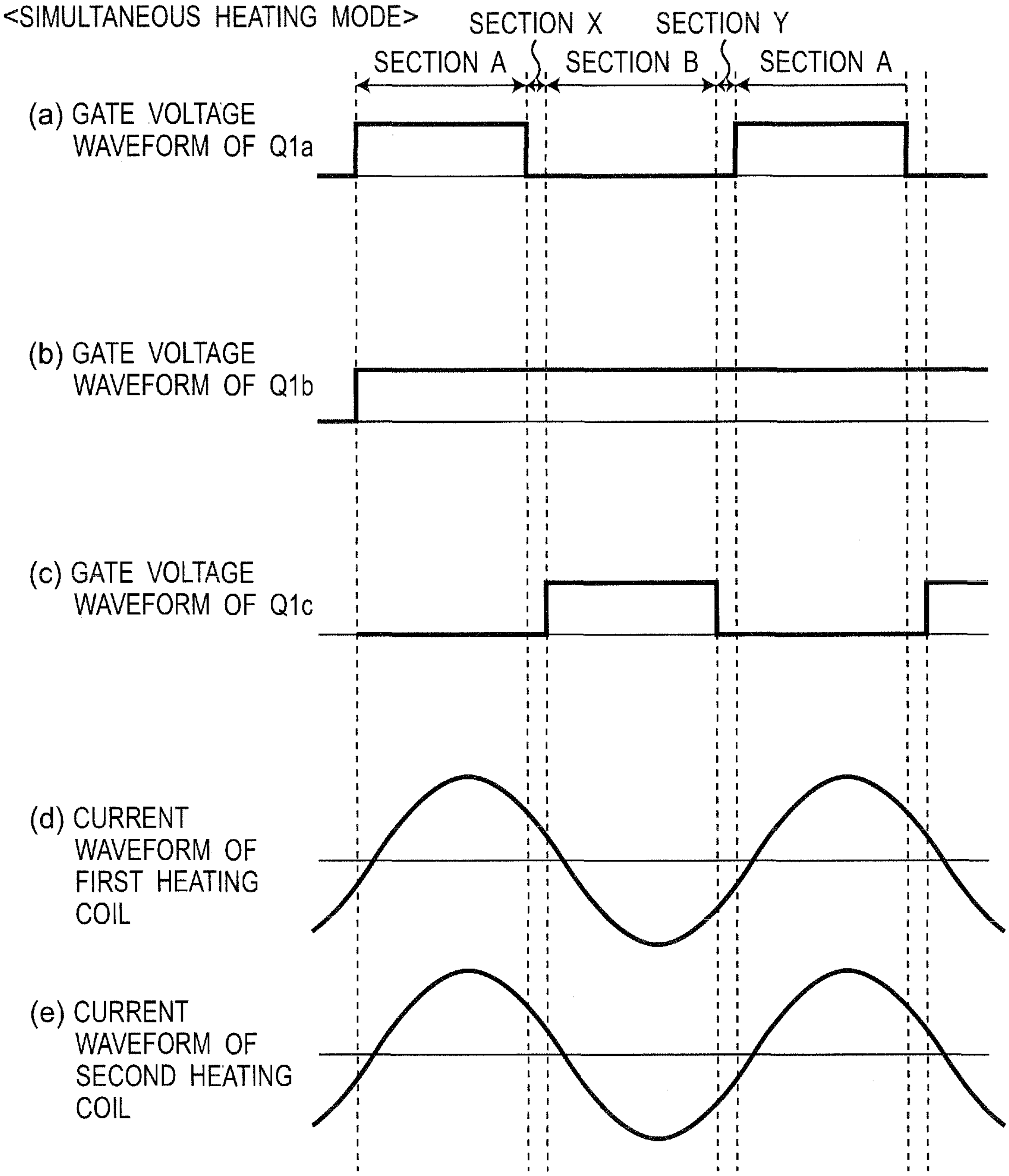

RESONANCE VOLTAGE
LOAD 14b
LOAD 14a
NO LOAD
CONDUCTION TIME

Fig.31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SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL
(e) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.32A

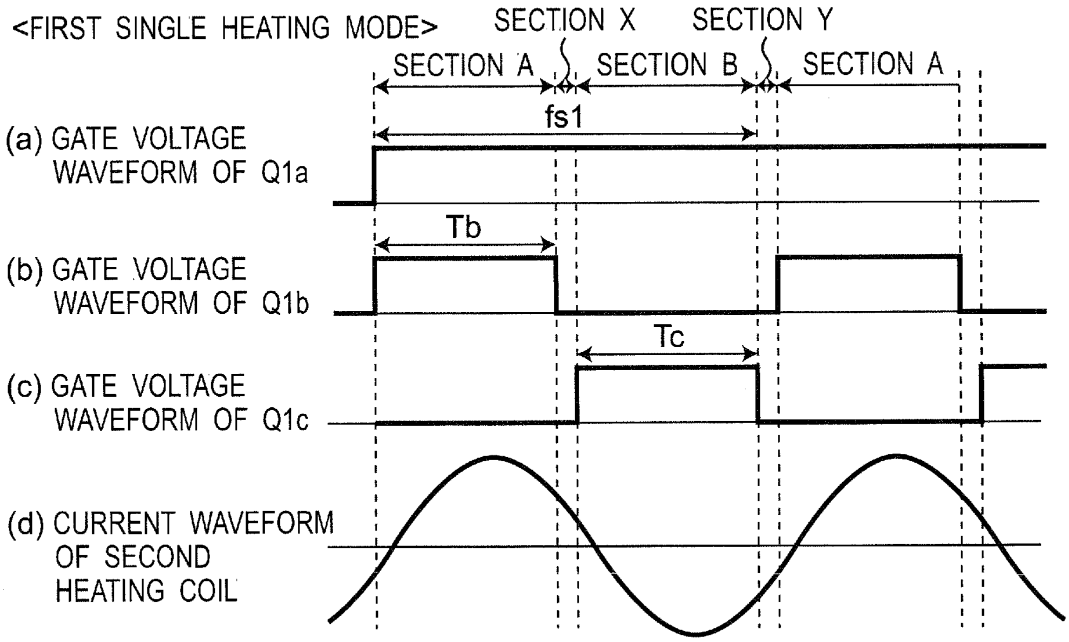


Fig.32B

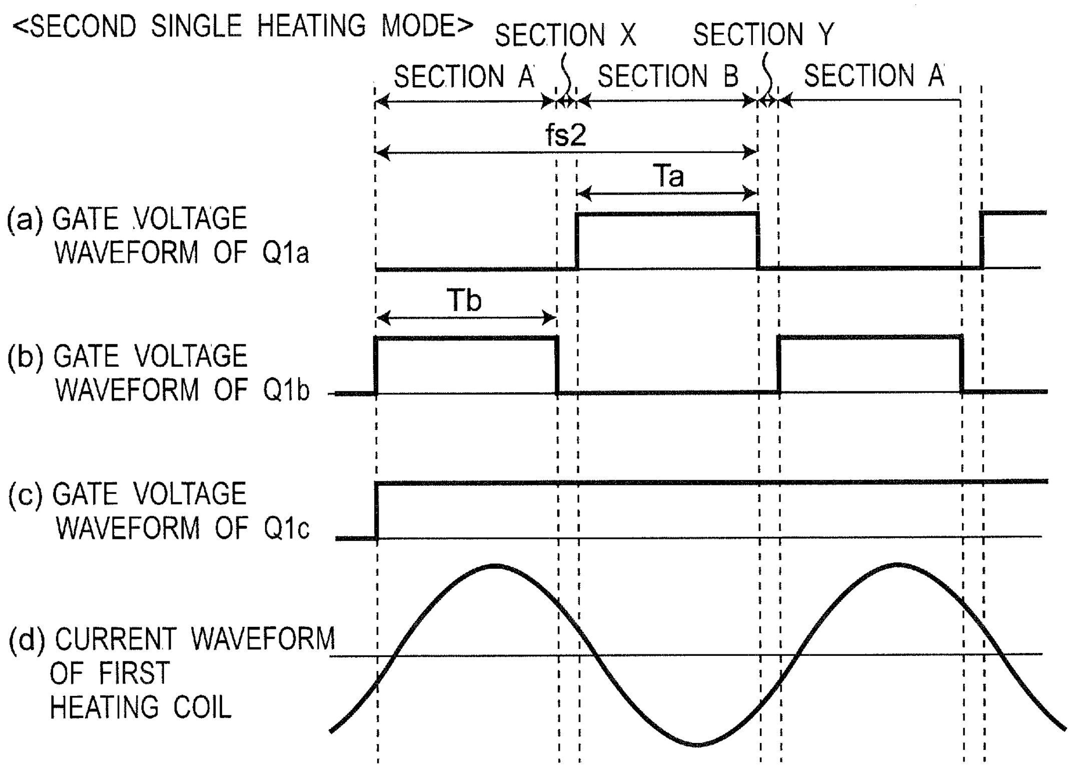


Fig.33

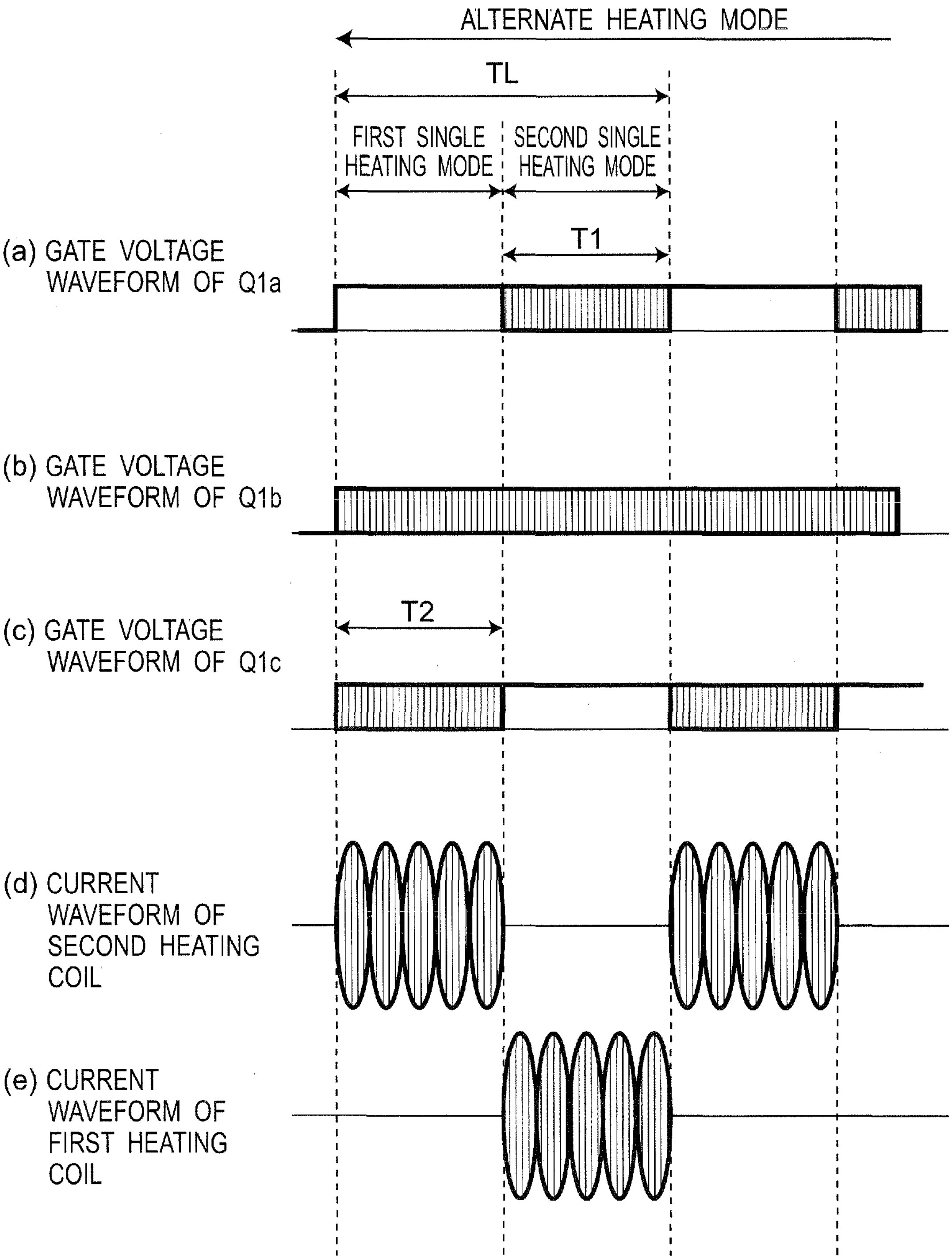

ALTERNATE HEATING MODE
TL
FIRST SINGLE HEATING MODE
SECOND SINGLE HEATING MODE
T1
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
T2
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF SECOND HEATING COIL
(e) CURRENT WAVEFORM OF FIRST HEATING COIL

Fig.34

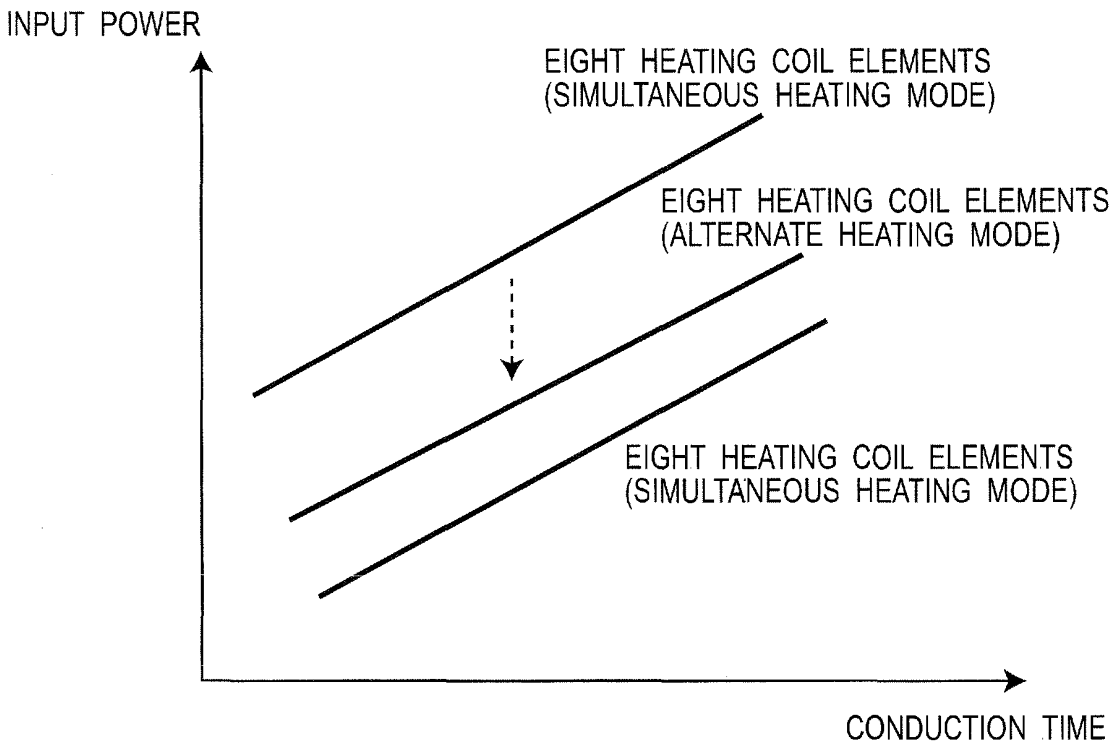
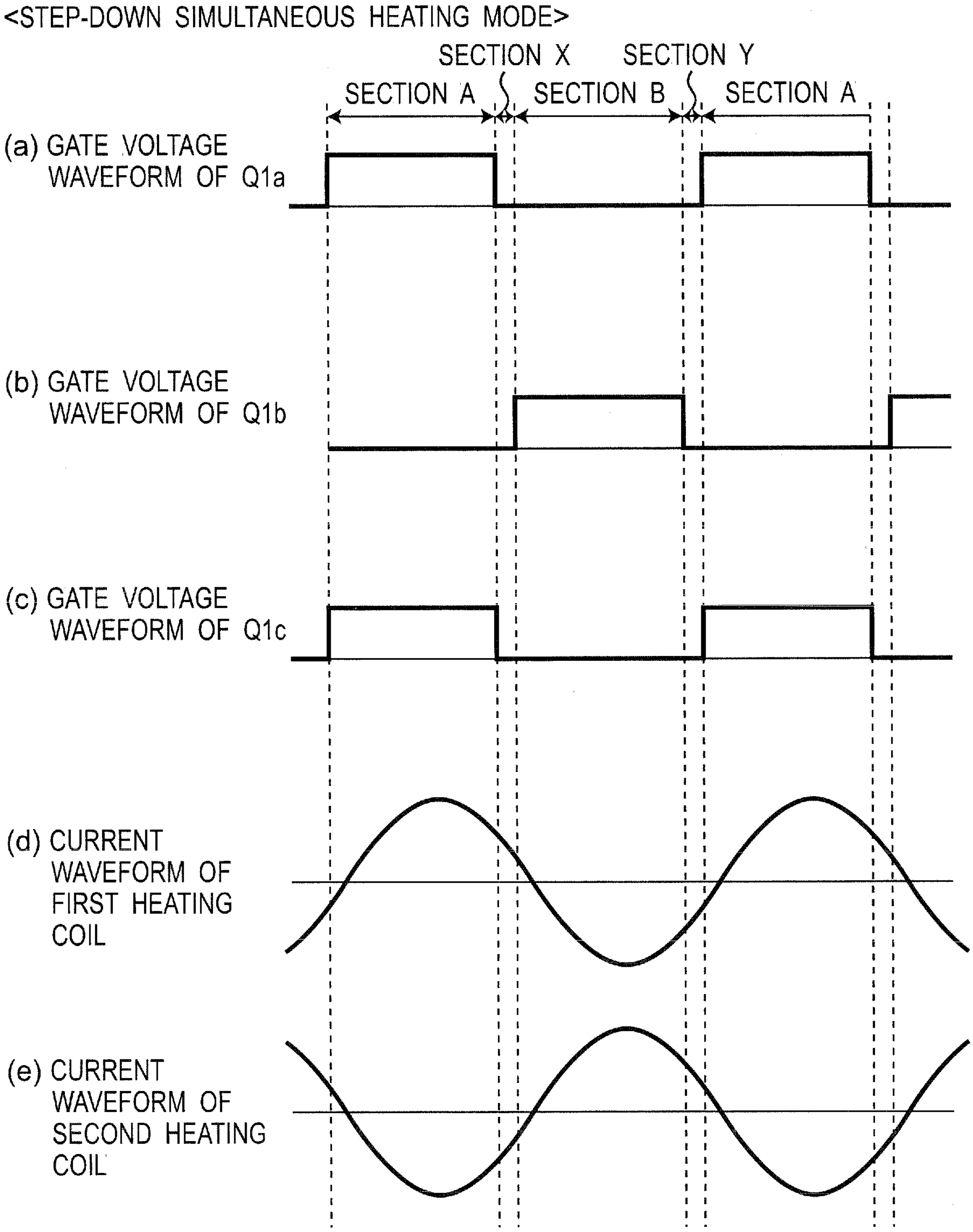

INPUT POWER
EIGHT HEATING COIL ELEMENTS
(SIMULTANEOUS HEATING MODE)
EIGHT HEATING COIL ELEMENTS
(ALTERNATE HEATING MODE)
EIGHT HEATING COIL ELEMENTS
(SIMULTANEOUS HEATING MODE)
CONDUCTION TIME

Fig.35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SECTION X
SECTION Y
SECTION A
SECTION B
SECTION A
(a) GATE VOLTAGE WAVEFORM OF Q1a
(b) GATE VOLTAGE WAVEFORM OF Q1b
(c) GATE VOLTAGE WAVEFORM OF Q1c
(d) CURRENT WAVEFORM OF FIRST HEATING COIL
(e) CURRENT WAVEFORM OF SECOND HEATING COIL

Fig.36

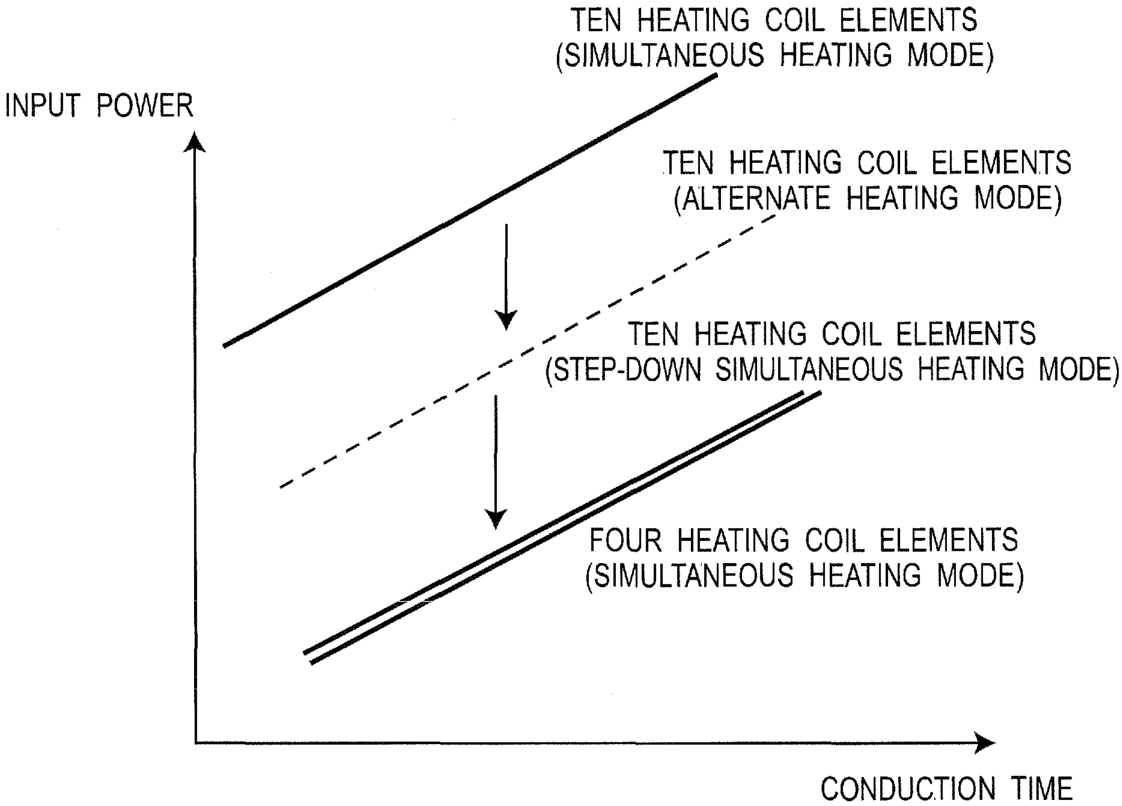
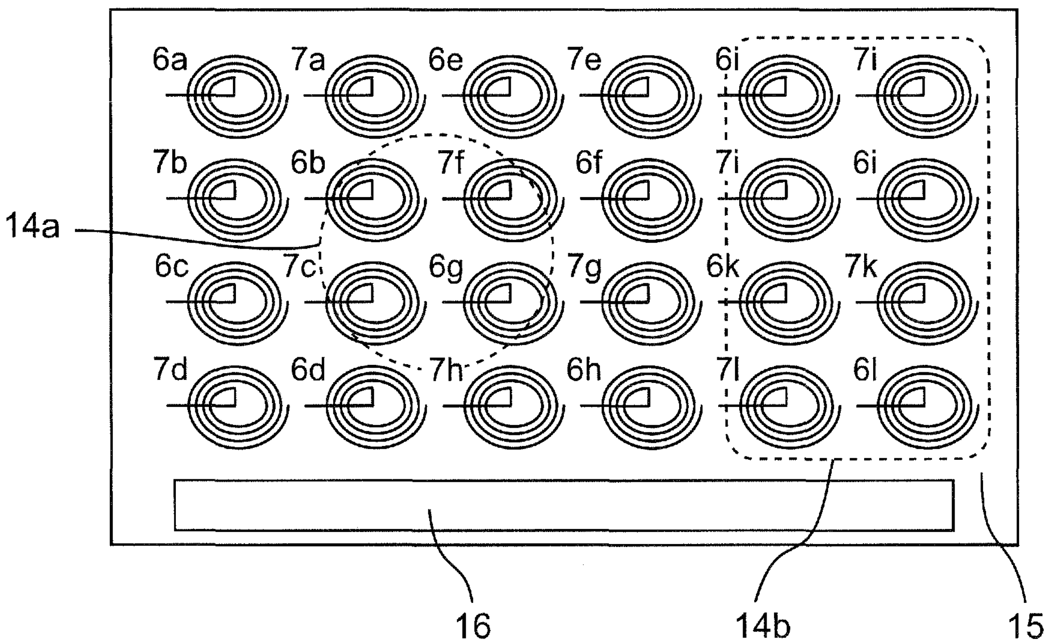

TEN HEATING COIL ELEMENTS
(SIMULTANEOUS HEATING MODE)
INPUT POWER
TEN HEATING COIL ELEMENTS
(ALTERNATE HEATING MODE)
TEN HEATING COIL ELEMENTS
(STEP-DOWN SIMULTANEOUS HEATING MODE)
FOUR HEATING COIL ELEMENTS
(SIMULTANEOUS HEATING MODE)
CONDUCTION TIME

Fig.37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6l
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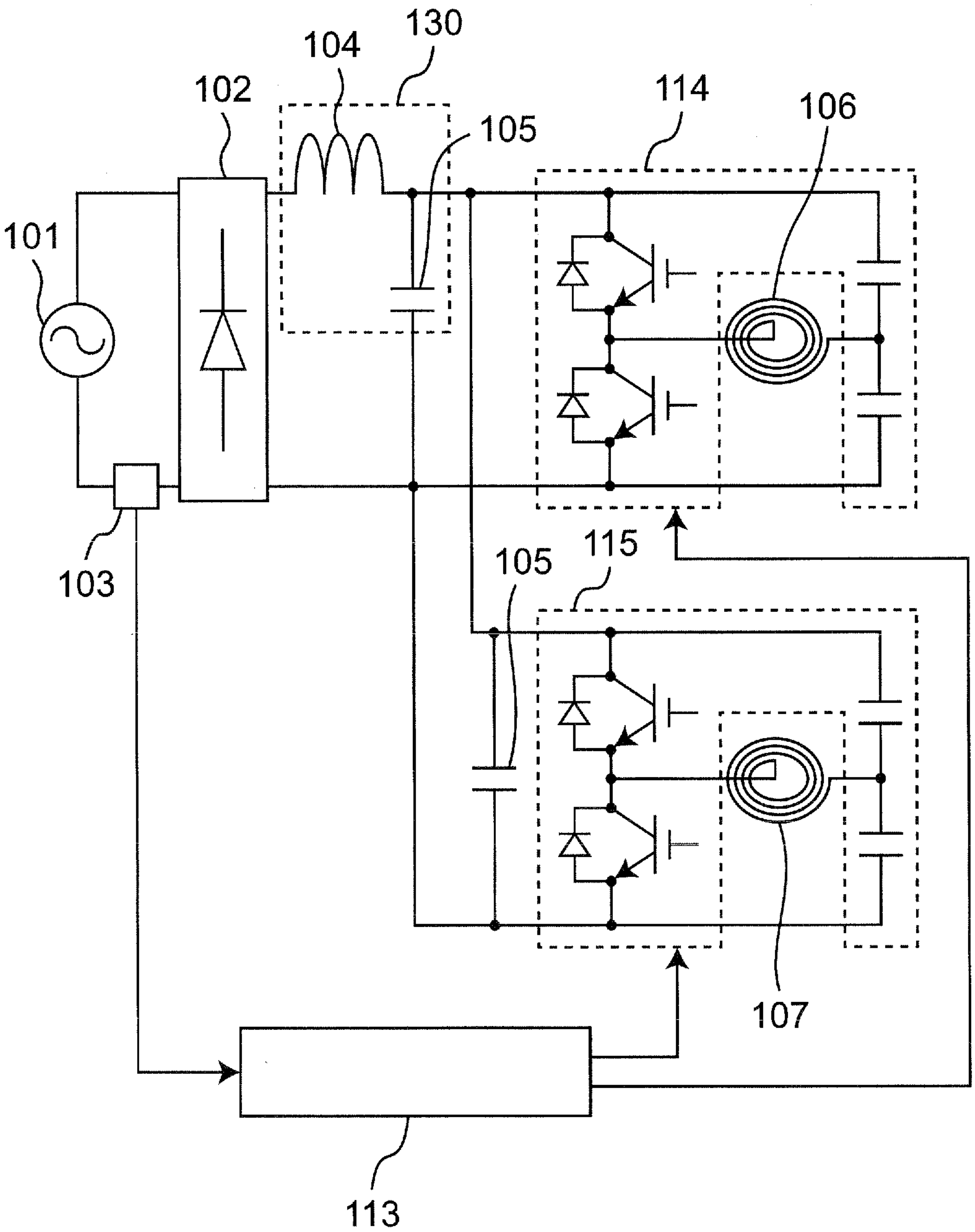
14b
15

Fig.38



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/006265

A. CLASSIFICATION OF SUBJECT MATTER
H05B6/12(2006.01)i, *H05B6/04*(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)
H05B6/12, H05B6/04

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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.
A	JP 9-199265 A (LG Electronics Inc.), 31 July 1997 (31.07.1997), fig. 2, 3 & US 5951904 A & DE 19654269 A & KR 10-0179535 B1	1-12
A	JP 9-251888 A (LG Electronics Inc.), 22 September 1997 (22.09.1997), fig. 2, 3 & DE 19654268 A & KR 10-0179529 B1	1-12

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Date of the actual completion of the international search	Date of mailing of the international search report
04 December, 2013 (04.12.13)	17 December, 2013 (17.12.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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Patent documents cited in the description

- US 20070135037 A1 **[0010]**
- JP H09251888 A **[0010] [0013] [0016]**