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# (54) AIR CONDITIONING DEVICE

(57) To provide an air conditioning apparatus capable of performing control taking into account the heat quantity applied to a refrigerant drawn into a compression mechanism in superheating degree control of the refrigerant drawn thereinto, even when the refrigerant in the intake side of the compression mechanism is heated. An air conditioning apparatus (1) that performs a refrigeration cycle includes at least a compressor (21), an indoor heat exchanger (41), an indoor fan (42), an outdoor electric expansion valve (24), and an outdoor heat exchanger (23), and the air conditioning apparatus comprises a coil (68), an electromagnetic induction thermistor (14), and a control part (11). The coil (68) creates a magnetic field in order to induction-heat a magnetic tube (F2), with the objective of heating the refrigerant flowing through an accumulation tube (F). The electromagnetic induction thermistor (14) senses the temperature of the magnetic tube (F2) which generates heat by being induction-heated by the coil (68). The control part (11) performs control for increasing the opening degree of the electric expansion valve (24) in the case of a high rate of increase in the temperature sensed by the electromagnetic induction thermistor (14).

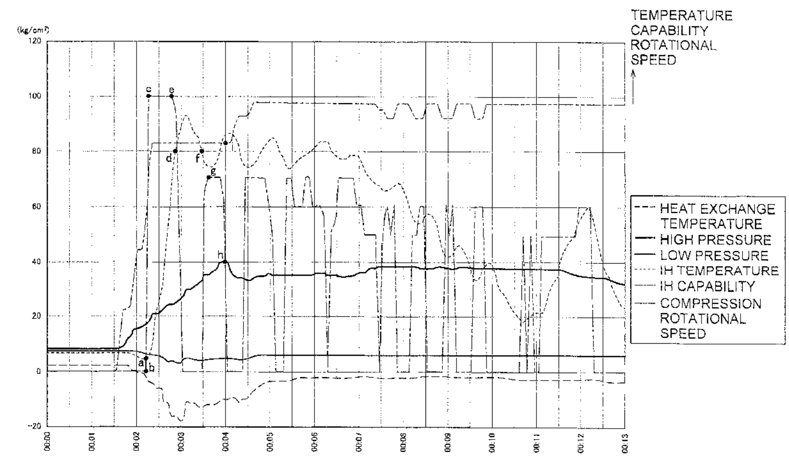


FIG. 9

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## Description

## TECHNICAL FIELD

**[0001]** The present invention relates to an air conditioning apparatus.

## BACKGROUND ART

**[0002]** In conventional practice, there are known air conditioning apparatuses in which the refrigerant circulation quantity or the like is controlled in order to control the degree of superheating of refrigerant drawn into the compressor.

**[0003]** For example, in the air conditioning apparatus disclosed in Patent Literature 1 (Japanese Laid-open Patent Publication No. 7-120083), the refrigerant circulation quantity can be increased and the degree of superheating of refrigerant drawn into the compressor can be controlled by performing a control so that the opening degree of an electric expansion valve is increased in accordance with the temperature of the refrigerant drawn into the compressor.

## SUMMARY OF THE INVENTION

<Technical Problem>

**[0004]** There are cases in which, in the intake side of the compressor, the refrigerant drawn into the compressor is indirectly warmed by using an external heating apparatus to heat a refrigerant tube or the like in thermal contact with the refrigerant.

**[0005]** In cases of using such an external heating device, when an intake refrigerant temperature sensor of the compressor is disposed between the portion to be heated by the external heating device and the intake side of the compressor, for example, the heat applied to the heated portion by the external heating device is thermally transmitted to the vicinity where the downstream intake refrigerant temperature sensor is attached, making an accurate sensing of the intake refrigerant temperature difficult. With valve opening degree control of the electric expansion valve, which is based on the sensed value of the intake refrigerant temperature sensor of the compressor disposed between the portion heated by the external heating device and the intake side of the compressor, there is a risk that the valve opening degree will be over-increased and the refrigerant circulation quantity will increase by too much, and not only will the excessive increase in the degree of superheating of the refrigerant drawn into the compressor be minimized, but liquid compression will occur.

**[0006]** When the portion heated by the external heating device is provided so as to be downstream of the sensing position of the intake refrigerant temperature sensor of the compressor and upstream of the intake side of the compressor, for example, it is not possible to perceive the temperature of the intake refrigerant which is heated by passing through the heated portion. With valve opening degree control of the electric expansion valve, which is based on the sensed value of the intake refrigerant temperature sensor disposed upstream of the portion heated by the external heating device, there is a risk that the valve opening degree will be over-reduced and the refrigerant circulation quantity will decrease by too much, and the degree of superheating of the refrigerant drawn into the compressor will increase excessively.

**[0007]** The present invention was devised in view of the circumstances described above, and an object thereof is to provide an air conditioning apparatus capable of performing control taking into account the heat quantity applied to the intake refrigerant in superheating degree control of the refrigerant drawn into the compression mechanism, even when the refrigerant in the intake side of the compression mechanism is heated.

<Solution to Problem>

**[0008]** An air conditioning apparatus according to a first aspect is an air conditioning apparatus which includes at least a compression mechanism, a refrigerant cooler, an expansion mechanism, and a refrigerant heater; the air conditioning apparatus comprising a magnetic field generator, a generated heat temperature sensor, and a control part. The magnetic field generator generates a magnetic field in order to induction-heat a refrigerant tube for circulating refrigerant to the compression mechanism, the refrigerant cooler, the expansion mechanism, and the refrigerant heater, and/or a member in thermal contact with the refrigerant flowing through the refrigerant tube. The generated heat temperature sensor senses the temperature of a portion that generates heat due to the induction heating performed by the magnetic field generator. The control part performs superheating protection control for increasing the opening degree of the expansion mechanism either when the temperature sensed by the generated heat temperature sensor reaches or exceeds a predetermined generated heat temperature, or when the rate of increase of the temperature sensed by the generated heat temperature sensor reaches or exceeds a predetermined rate of increase.

**[0009]** In this air conditioning apparatus, since a generated heat temperature sensor is provided, it is possible to perceive the temperature situation of the portion where heat is generated by the induction heating of the magnetic field generator. Due to the superheating protection control performed by the control part, the opening degree of the expansion mechanism is increased and the refrigerant quantity supplied to the intake side of the compression mechanism becomes larger when either the temperature sensed by the generated heat temperature sensor reaches or exceeds a predetermined generated heat temperature, or the rate of increase of the temperature sensed by the generated heat temperature sensor reaches or exceeds a predetermined rate of increase. Therefore, it is possible to minimize the abnormal increase in the the degree of superheating of refrigerant drawn into the compression mechanism. It is thereby possible to perform superheating degree control on the refrigerant drawn into the compression mechanism while taking into account the heat quantity applied to the drawn-in refrigerant, even when the refrigerant in the intake side of the compression mechanism is heated.

**[0010]** An air conditioning apparatus according to a second aspect is the air conditioning apparatus according to the first aspect, wherein the magnetic field generator generates a magnetic field for induction-heating an intake refrigerant tube within the refrigerant tube in the intake side of the compression mechanism and/or a member in thermal contact with the refrigerant flowing through the intake refrigerant tube.

**[0011]** In this air conditioning apparatus, refrigerant immediately before being drawn into the compression mechanism is rapidly heated, and not refrigerant flowing through the refrigerant tube some distance away from the compression mechanism. The refrigerant flowing through the intake side of the compression mechanism is either very dry or superheated, and compared with cases in which there is a change in the latent heat of gas-liquid two-phase refrigerant flowing further upstream, it is easy to induce a change in sensible heat and the temperature therefore increases readily.

**[0012]** In this air conditioning apparatus, since superheating protection control is performed either when the temperature sensed by the generated heat temperature sensor reaches or exceeds the predetermined generated heat temperature or when the rate of increase of the temperature sensed by the generated heat temperature sensor exceeds the predetermined rate of increase, it is possible to prevent excessive induction heating of the refrigerant passing through the intake side of the compression mechanism. Thereby, even in a case of heating being performed on the refrigerant passing through the intake side of the compression mechanism with a rise in temperature readily occurring, it is possible to suppress excessive heating of the induction-heated portion.

**[0013]** An air conditioning apparatus according to a third aspect is the air conditioning apparatus according to the first or second aspect, wherein the control part performs startup control and post-startup control. In startup control, the magnetic field generator is made to generate a magnetic field so that the temperature of the portion where heat is generated by the induction heating by the magnetic field generator reaches a predetermined startup target temperature while driving of the compression mechanism is initiated from a stopped state of the compression mechanism. Post-startup control is performed after the startup control has ended. When the superheating protection control is performed at the same time the post-startup control is being performed, the control part increases the opening degree of the expansion mechanism when the temperature sensed by the generated heat temperature sensor reaches or exceeds a post-startup predetermined generated heat temperature. This post-startup predetermined generated heat temperature is a temperature equal to or greater than the predetermined startup target temperature. The post-startup predetermined generated heat temperature may also be a temperature simply equal to the predetermined startup target temperature.

**[0014]** In this air conditioning apparatus, in the post-startup control, the opening degree of the expansion mechanism is increased when the temperature of the portion that generates heat by induction heating has increased to reach or exceed the post-startup predetermined generated heat temperature, whereby the temperature of the portion that generates heat by induction heating can be reduced. Therefore, in post-startup control, it is possible to suppress the abnormal temperature increase of the portion that generates heat by induction heating.

**[0015]** When the post-startup predetermined generated heat temperature is not a temperature equal to the predetermined startup target temperature but is a temperature higher than the predetermined startup target temperature, and even when a process is performed for stopping or diminishing the supply of a magnetic field from the magnetic field generator when the temperature of the portion that generates heat by induction heating has increased too much, the time duration in which a high refrigerant temperature can be maintained by induction heating can be further lengthened.

**[0016]** An air conditioning apparatus according to a fourth aspect is the air conditioning apparatus according to the third aspect, wherein when the superheating protection control is performed at the same time the startup control is being performed, the control part increases the opening degree of the expansion mechanism when the rate of increase of the temperature sensed by the generated heat temperature sensor at the time the predetermined startup target temperature is reached reaches or exceeds the predetermined rate of increase.

**[0017]** In this air conditioning apparatus, in the startup control, the opening degree of the expansion mechanism is increased when the sensed temperature of the generated heat temperature sensor increases fast enough for the temperature rate of increase to reach or exceed a predetermined rate of increase. In the post-startup control, the opening degree of the expansion mechanism is increased when the sensed temperature of the generated heat temperature sensor reaches or exceeds a predetermined generated heat temperature. Therefore, since a determination is made based on the sensed temperature in the post-startup control but a determination is made based on the temperature rate of increase in the startup control, the opening degree of the expansion mechanism is increased at the point in time when the rate of increase either reaches or exceeds the predetermined rate of increase even when a rapid temperature increase is being induced during startup; therefore, when the predetermined rate of increase is reached or exceeded before the predetermined generated heat temperature is reached, there is no need to wait for a process of increasing the opening degree of the expansion mechanism until the predetermined generated heat temperature is reached. Therefore, a large amount of refrigerant can be more reliably supplied to the portion that generates heat by induction heating. It is thereby possible to suppress the extent by which the temperature steadily increases in the portion that generates heat by induction heating.

**[0018]** An air conditioning apparatus according to a fifth aspect is the air conditioning apparatus according to the fourth aspect, wherein when the predetermined rate of increase is determined to have been reached or exceeded, the control part increases the opening degree of the expansion mechanism only when the rotational speed of the compression mechanism reaches or exceeds a predetermined rotational speed.

**[0019]** In this air conditioning apparatus, there are cases in which the temperature rate of increase of the portion that generates heat by induction heating reaches or exceeds the predetermined rate of increase when a state is ensured in which the rotational speed of the compression mechanism reaches or exceeds the predetermined rotational speed. Even in such cases, the refrigerant circulation quantity can be more reliably increased by increasing the opening degree of the compression mechanism in a state in which the drive state of the compression mechanism is ensured.

**[0020]** An air conditioning apparatus according to a sixth aspect is the air conditioning apparatus according to any of the third through fifth aspects, further comprising a cooler-side-refrigerant-state-perceiving part for perceiving the state of refrigerant passing through from the refrigerant cooler to the expansion mechanism. When the startup control has ended, the control part initiates subcooling-degree-fixing control for controlling the opening degree of the expansion mechanism so that the degree of subcooling of the refrigerant perceived using the value perceived by the cooler-side-refrigerant-state-perceiving part is kept fixed at a predetermined target degree of subcooling. Furthermore, when the superheating protection control is performed at the same time the subcooling-degree-fixing control is being performed, the control part further increases the opening degree of the expansion mechanism above the opening degree controlled by the subcooling-degree-fixing control when the temperature sensed by the generated heat temperature sensor reaches or exceeds a predetermined subcooling-degree-fixing control generated heat temperature. The predetermined subcooling-degree-fixing control generated heat temperature is a temperature equal to or greater than the predetermined startup target temperature.

**[0021]** In this air conditioning apparatus, it is possible to minimize abnormal increases in the temperature of the portion that generates heat by induction heating, even when subcooling-degree-fixing control is being performed.

<Effects of Invention>

**[0022]** In the air conditioning apparatus according to the first aspect, it is possible to perform superheating degree control on the refrigerant drawn into the compression mechanism while taking into account the heat quantity applied to the drawn-in refrigerant, even when the refrigerant in the intake side of the compression mechanism is heated.

**[0023]** In the air conditioning apparatus according to the second aspect, it is possible to minimize the excessive heating of the induction-heated portion, despite heating of the refrigerant passing through the intake side of the compression mechanism, which readily increases in temperature.

**[0024]** In the air conditioning apparatus according to the third aspect, the abnormal temperature increase of the portion that generates heat by induction heating can be suppressed in post-startup control.

**[0025]** In the air conditioning apparatus according to the fourth aspect, it is possible to suppress the extent by which the temperature steadily increases in the portion that generates heat by induction heating.

**[0026]** In the air conditioning apparatus according to the fifth aspect, the refrigerant circulation quantity can be more reliably increased.

**[0027]** In the air conditioning apparatus according to the sixth aspect, it is possible to minimize abnormal increases in the temperature of the portion that generates heat by induction heating, even when subcooling-degree-fixing control is being performed.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0028]**

FTG. 1 is a refrigerant circuit diagram of an air conditioning apparatus according to an embodiment of the present invention.

FIG. 2 is an external perspective view of an electromagnetic induction heating unit.

FIG. 3 is an external perspective view showing a state in which a shielding cover has been removed from the electromagnetic induction heating unit.

FIG. 4 is an external perspective view of an electromagnetic induction thermistor.

FIG. 5 is an external perspective view of a fuse.

FIG. 6 is a schematic cross-sectional view showing the attached state of the electromagnetic induction thermistor and the fuse.

FIG. 7 is a cross-sectional structural view of the electromagnetic induction heating unit.

FIG. 8 is a view showing the details of a magnetic flux.

FIG. 9 is a view showing the various state transitions of the superheating protection control.

FIG. 10 is a view showing a flowchart of the startup superheating protection control.

FIG. 11 is a view showing a flowchart of the regular superheating protection control.

FIG. 12 is an explanatory view of a refrigerant tube of another embodiment (E).

FIG. 13 is an explanatory view of a refrigerant tube of another embodiment (F).

FIG. 14 is a view showing an example of arranging coils and a refrigerant tube of another embodiment (G).

FIG. 15 is a view showing an example of arranging bobbin covers of another embodiment (G).

FIG. 16 is a view showing an example of arranging ferrite cases of another embodiment (G).

## DESCRIPTION OF EMBODIMENTS

**[0029]** An air conditioning apparatus 1 comprising an electromagnetic induction heating unit 6 in one embodiment of the present invention is described in an example hereinbelow with reference to the drawings.

<1-1> Air Conditioning Apparatus 1

**[0030]** FIG. 1 shows a refrigerant circuit diagram showing a refrigerant circuit 10 of the air conditioning apparatus 1.

**[0031]** In the air conditioning apparatus 1, an outdoor unit 2 as a heat source-side apparatus and an indoor unit 4 as a usage-side apparatus are connected by refrigerant tubes, and air conditioning is performed in the space where the usage-side apparatus is disposed; the air conditioning apparatus 1 comprising a compressor 21, a four-way switching valve 22, an outdoor heat exchanger 23, an outdoor electric expansion valve 24, an accumulator 25, an outdoor fan 26, an indoor heat exchanger 41, an indoor fan 42, a hot gas bypass valve 27, a capillary tube 28, an electromagnetic induction heating unit 6, and other components.

**[0032]** The compressor 21, the four-way switching valve 22, the outdoor heat exchanger 23, the outdoor electric expansion valve 24, the accumulator 25, the outdoor fans 26, the hot gas bypass valve 27, the capillary tube 28, and the electromagnetic induction heating unit 6 are housed within the outdoor unit 2. The indoor heat exchanger 41 and the indoor fan 42 are housed within the indoor unit 4.

**[0033]** The refrigerant circuit 10 has a discharge tube A, an indoor-side gas tube B, an indoor-side liquid tube C, an outdoor-side liquid tube D, an outdoor-side gas tube E, an accumulation tube F, an intake tube G, and a hot gas bypass circuit H. The indoor-side gas tube B and the outdoor-side gas tube E pass large quantities of gas-state refrigerant, but the refrigerant passing through is not limited to a gas refrigerant. The indoor-side liquid tube C and the outdoor-side liquid tube D pass large quantities of liquid-state refrigerant, but the refrigerant passing through is not limited to a liquid refrigerant.

**[0034]** The discharge tube A connects the compressor 21 and the four-way switching valve 22. The discharge tube A is provided with a discharge temperature sensor 29d for sensing the temperature of the refrigerant passing through. An electric current supply part 21e supplies an electric current to the compressor 21. The amount of electricity supplied by the electric current supply part 21e is sensed by a compressor electricity sensor 29f. The drive rotational speed of the piston of the compressor 21 is sensed by a rotational speed perceiving part 29r. The indoor-side gas tube B connects the four-way switching valve 22 and the indoor heat exchanger 41. A first pressure sensor 29a for sensing the pressure of the refrigerant passing through is provided at some point along the indoor-side gas tube B. The indoor-side liquid tube C connects the indoor heat exchanger 41 and the outdoor electric expansion valve 24. The outdoor-side liquid tube D connects the outdoor electric expansion valve 24 and the outdoor heat exchanger 23. The outdoor-side gas tube E connects the outdoor heat exchanger 23 and the four-way switching valve 22. A second pressure sensor 29g for sensing the pressure of the refrigerant passing through is provided at some point along the outdoor-side gas tube E.

**[0035]** The accumulation tube F connects the four-way switching valve 22 and the accumulator 25, and extends in a vertical direction when the outdoor unit 2 has been installed. The electromagnetic induction heating unit 6 is attached to a part of the accumulation tube F. A heat-generating portion of the accumulation tube F, whose periphery is covered at least by a coil 68 described hereinafter, is composed of a copper tube F1 through which refrigerant flows and a magnetic tube F2 provided so as to cover the periphery of the copper tube F1. This magnetic tube F2 is composed of stainless used steel (SUS) 430. This SUS 430 is a ferromagnetic material, which creates eddy currents when placed in a magnetic field and which generates heat by Joule heat created by its own electrical resistance. Aside from the magnetic tube F2, the tubes constituting the refrigerant circuit 10 are composed of copper tubes of the same material as the copper tube F1 By performing electromagnetic induction heating in this manner, the accumulation tube F can be heated by electromagnetic induction, and the refrigerant drawn into the compressor 21 via the accumulator 25 can be warmed. The warming capability of the air conditioning apparatus 1 can thereby be improved. Even in cases in which the compressor 21 is not sufficiently warmed at the start of the air-warming operation, for example, the lack of capability at startup can be compensated for by the quick heating by the electromagnetic induction heating unit 6. Furthermore, when the four-way switching valve 22 is switched to the air-cooling operation, state and a defrosting operation is performed for removing frost deposited on the outdoor heat exchanger 23 or other components, the compressor 21 can quickly compress the warmed refrigerant as a target due to the electromagnetic induction heating unit 6 quickly heating the accumulation tube F. Therefore, the temperature of the hot gas discharged from the compressor 21 can be quickly increased. The time required to thaw the frost through the defrosting operation can thereby be shortened. Thereby, even when the defrosting operation must be performed at the right time during the air-warming operation, the air-warming operation can be resumed as quickly as possible, and user comfort can be improved.

**[0036]** The intake tube G connects the accumulator 25 and the intake side of the compressor 21.

**[0037]** The hot gas bypass circuit H connects a branching point A1 provided at some point along the discharge tube A and a branching point D1 provided at some point along the outdoor-side liquid tube D. Disposed at some point in the hot gas bypass circuit H is the hot gas bypass valve 27, which can switch between a state of permitting the passage of refrigerant and a state of not permitting the passage of refrigerant. Between the hot gas bypass valve 27 and the branching point D1, the hot gas bypass circuit H is provided with a capillary tube 28 for lowering the pressure of refrigerant passing through. This capillary tube 28 makes it possible to approach the pressure that follows the refrigerant pressure decrease caused by the outdoor electric expansion valve 24 during the air-warming operation, and therefore makes it possible to suppress the rise in refrigerant pressure in the outdoor-side liquid tube D caused by the supply of hot gas through the hot gas bypass circuit H to the outdoor-side liquid tube D.

**[0038]** The four-way switching valve 22 is capable of switching between an air-cooling operation cycle and an air-warming operation cycle. In FIG. 1, the connection state during the air-warming operation is shown by solid lines, and the connection state during the air-cooling operation is shown by dotted lines. During the air-warming operation, the indoor heat exchanger 41 functions as a cooler of refrigerant and the outdoor heat exchanger 23 functions as a heater of refrigerant. During the air-cooling operation, the outdoor heat exchanger 23 functions as a cooler of refrigerant and the indoor heat exchanger 41 functions as a heater of refrigerant.

**[0039]** One end of the outdoor heat exchanger 23 is connected to the end of the outdoor-side gas tube E side of the outdoor heat exchanger 23, and the other end is connected to the end of the outdoor-side liquid tube D side of the outdoor heat exchanger 23. The outdoor heat exchanger 23 is also provided with an outdoor heat exchange temperature sensor 29c for sensing the temperature of the refrigerant flowing through the air conditioning apparatus 1. Furthermore, the upstream side of the outdoor heat exchanger 23 in the direction of air flow is provided with an outdoor temperature sensor 29b for sensing the outdoor air temperature.

**[0040]** An indoor temperature sensor 43 for sensing the indoor temperature is provided inside the indoor unit 4. The indoor heat exchanger 41 is also provided with an indoor heat exchange temperature sensor 44 for sensing the refrigerant temperature of the indoor-side liquid tube C side where the outdoor electric expansion valve 24 is connected.

**[0041]** An outdoor control part 12 for controlling the devices disposed in the outdoor unit 2 and an indoor control part 13 for controlling the devices disposed in the indoor unit 4 are connected by a communication line 11a, thereby constituting a control part 11. This control part 11 performs various controls on the air conditioning apparatus 1.

**[0042]** The outdoor control part 12 is also provided with a timer 95 for counting the elapsed times when the various controls are performed.

**[0043]** A controller 90 for receiving setting input from the user is connected to the control part 11.

<1-2> Electromagnetic Induction Heating Unit 6

**[0044]** FIG. 2 shows a schematic perspective view of the electromagnetic induction heating unit 6 attached to the accumulation tube F. FIG. 3 shows an external perspective view in which a shielding cover 75 has been removed from the electromagnetic induction heating unit 6. FIG. 4 shows a schematic structural view of an electromagnetic induction thermistor 14. FIG. 5 shows a schematic structural view of a fuse 15. FIG. 6 shows a cross-sectional view of the attached state of the electromagnetic induction thermistor 14 and the fuse 15 to the accumulation tube F. FIG. 7 shows a cross-sectional view of the electromagnetic induction heating unit 6 attached to the accumulation tube F. FIG. 8 shows an explanatory view of a state of a magnetic field generated by the coil 68.

**[0045]** The electromagnetic induction heating unit 6 is disposed so as to cover the magnetic tube F2 from the radially outer side, the magnetic tube F2 being the heat-generating portion of the accumulation tube F, and the magnetic tube F2 is made to generate heat by electromagnetic induction heating. This heat-generating portion of the accumulation tube F has a double-layered tube structure having the copper tube F1 on the inner side and the magnetic tube F2 on the outer side.

**[0046]** The electromagnetic induction heating unit 6 comprises a first hexagonal nut 61, a second hexagonal nut 66, a first bobbin cover 63, a second bobbin cover 64, a bobbin main body 65, a first ferrite case 71, a second ferrite case 72, a third ferrite case 73, a fourth ferrite case 74, a first ferrite 98, a second ferrite 99, the coil 68, the shielding cover 75, the electromagnetic induction thermistor 14, the fuse 15, and other components.

**[0047]** The first hexagonal nut 61 and the second hexagonal nut 66 are made of a resin, and are used to stabilize the fixed state between the electromagnetic induction heating unit 6 and the accumulation tube F with the aid of a C ring (not shown). The first bobbin cover 63 and the second bobbin cover 64 are made of a resin, and are used to cover the accumulation tube F from the radially outer side in the top end position and the bottom end position, respectively. The first bobbin cover 63 and the second bobbin cover 64 have four screw holes for screws 69 in order for the first through fourth ferrite cases 71 to 74 described hereinafter to be screwed in via the screws 69. Furthermore, the second bobbin cover 64 has an electromagnetic induction thermistor insertion opening 64f for inserting the electromagnetic induction thermistor 14 and attaching it to the outer surface of the magnetic tube F2. The second bobbin cover 64 has a fuse insertion opening 64e for inserting the fuse 15 and attaching it to the outer surface of the magnetic tube F2. The electromagnetic induction thermistor 14 has an electromagnetic induction thermistor sensor 14a, an outer projection 14b, a side projection 14c, and electromagnetic induction thermistor wires 14d for converting the sensing result of the electromagnetic induction thermistor sensor 14a to a signal and sending it to the control part 11, as shown in FIG. 4. The electromagnetic induction thermistor sensor 14a has a shape that conforms to the curved shape of the outer surface of the accumulation tube F, and has a substantial contact surface area. The fuse 15 has a fuse sensor 15a, an asymmetrical shape 15b, and fuse wires 15d for converting the sensing result of the fuse sensor 15a to a signal and sending it to the control part 11, as shown in FIG. 5. Having received from the fuse 15 a notification that a temperature exceeding a predetermined limit temperature has been sensed, the control part 11 performs a control for stopping the supply of electricity to the coil 68, avoiding heat damage to the equipment. The bobbin main body 65 is made of a resin, and the coil 68 is wound over the bobbin main body 65. The coil 68 is wound in a helical shape over the outer side of the bobbin main body 65, with the axial direction being the direction in which the accumulation tube F extends. The coil 68 is connected to a control print board (not shown), and the coil receives a supply of highfrequency electric current. The output of the control print board is controlled by the control part 11. The electromagnetic induction thermistor 14 and the fuse 15 are attached in a state in which the bobbin main body 65 and the second bobbin cover 64 have been joined together, as shown in FIG. 6. When the electromagnetic induction thermistor 14 has been attached, a satisfactory state of pressurized contact with the outer surface of the magnetic tube F2 is maintained by a plate spring 16 pushing radially inward on the magnetic tube F2. Similarly, in the attachment of the fuse 15, a satisfactory state of pressurized contact with the outer surface of the magnetic tube F2 is maintained by a plate spring 17 pushing radially inward on the magnetic tube F2. Thus, since the electromagnetic induction thermistor 14 and the fuse 15 stay satisfactorily in firm contact with the outer surface of the accumulation tube F, responsiveness is improved and sudden temperature changes caused by electromagnetic induction heating can be quickly detected. In the first ferrite case 71, the first bobbin cover 63 and the second bobbin cover 64 are held in from the direction in which the accumulation tube F extends and are screwed in place by the screws 69. The first ferrite case 71 through the fourth ferrite case 74 house the first ferrite 98 and the second ferrite 99, which are composed of the highly magnetically permeable material ferrite. The first ferrite 98 and the second ferrite 99 absorb the magnetic field created by the coil 68 and form a magnetic flux pathway, thereby impeding the magnetic field from leaking out to the exterior, as shown in the cross-sectional view of the accumulation tube F and electromagnetic induction heating unit 6 of FIG. 7 as well as the magnetic flux explanatory view of FIG. 8. The shielding cover 75 is disposed around the outermost periphery of the electromagnetic induction heating unit 6, and collects a magnetic flux that cannot be contained with the first ferrite 98 and the second ferrite 99 alone. The magnetic flux mostly does not leak outside of the shielding cover 75, and the location where the magnetic flux is created can be determined arbitrarily.

<1-3> Electromagnetic Induction Heating Control

**[0048]** The electromagnetic induction heating unit 6 described above performs a control for causing the magnetic tube F2 of the accumulation tube F to generate heat, during startup in which the air-warming operation is initiated when the refrigeration cycle is caused to perform the air-warming operation, during air-warming capability assistance, and during the defrosting operation.

**[0049]** The description hereinbelow pertains to the time of startup in particular. FIG. 9 shows the details of the different states transitioning.

(Initial process during startup)

**[0050]** The initial process during startup is a process performed after the air-warming operation is initiated until the pressure sensed by the first pressure sensor 29a reaches a target high pressure.

**[0051]** When an air-warming operation command is inputted to the controller 90 from the user, the control part 11 initiates the air-warming operation. When the air-warming operation is initiated, the control part 11 waits until the compressor 21 has started up and the pressure sensed by the first pressure sensor 29a has risen to the predetermined target high pressure of 39 kg/cm$^2$ (shown by point h in FIG. 9), and causes the indoor fan 42 to be driven. This prevents discomfort for the user due to unwarmed air flowing into the room in the stage at which the refrigerant passing through the indoor heat exchanger 41 has not yet warmed.

**[0052]** Electromagnetic induction heating using the electromagnetic induction heating unit 6 is performed here while the opening degree of the outdoor electric expansion valve 24 is maintained at a fixed opening degree, in order to shorten the time duration for the compressor 21 to start up and the pressure sensed by the first pressure sensor 29a to reach 39 kg/cm$^2$. The control part 11 initiates the rapid pressure-increasing process after confirming that a sufficient flow of refrigerant is ensured in the accumulation tube F after the compressor 21 has started up. In the rapid pressure-increasing process, in order to shorten the time needed for the temperature sensed by the electromagnetic induction thermistor 14 to reach the startup target accumulation tube temperature of 80°C, the control part 11 brings the supply of electric current to the coil 68 of the electromagnetic induction heating unit 6 to a predetermined maximum supplied electricity (2 kW). This output state of the electromagnetic induction heating unit 6 at the predetermined maximum supplied electricity is continued until the temperature sensed by the electromagnetic induction thermistor 14 reaches a startup target accumulation tube temperature of 80°C.

**[0053]** Thus, control is performed for maintaining the opening degree of the outdoor electric expansion valve 24 at a fixed opening degree in order to shorten the time needed to reach the predetermined target high pressure at startup, or for bringing the output of the electromagnetic induction heating unit 6 to the maximum supplied electricity in order to shorten the time needed for the temperature sensed by the electromagnetic induction thermistor 14 to reach the startup target accumulation tube temperature, but there is a risk of this induction heating causing an abnormal increase in the degree of superheating of the refrigerant drawn into the compressor 21. Therefore, to prevent such abnormal increases in the degree of superheating of the drawn-in refrigerant, startup superheating protection control (described hereinafter) is performed by the control part 11 at startup.

(Secondary process during startup)

**[0054]** The secondary process during startup is a process during startup which is performed after the pressure sensed by the first pressure sensor 29a has reached the target high pressure.

**[0055]** In this secondary process during startup, after the pressure sensed by the first pressure sensor 29a has reached the predetermined target high pressure of 39 $kg/cm^2$, steady output control is performed for increasing the refrigerant circulation quantity of the refrigeration cycle and increasing capability by further increasing the rotational speed of the compressor 21 and increasing the opening degree of the outdoor electric expansion valve 24.

**[0056]** After the air-warming operation has been initiated. and once the startup target accumulation tube temperature of 80°C has been reached and the initial action at startup has ended, the control part 11 holds the output at a steady supplied electricity (1.4 kW) which is less than the predetermined maximum supplied electricity (2 kW), and controls the output of the electromagnetic induction heating unit 6 so that the temperature sensed by the electromagnetic induction thermistor 14 is maintained at a temperature near the target temperature of 80°C, the same as the startup target accumulation tube temperature. In this control of maintaining the temperature near 80°C, the control part 11 performs a process in which induction heating by the electromagnetic induction heating unit 6 is initiated at the steady supplied electricity (1.4 kW) output when the temperature sensed by the electromagnetic induction thermistor 14 is equal to or less than 60°C, and induction heating by the electromagnetic induction heating unit 6 is stopped when the temperature sensed by the electromagnetic induction thermistor 14 reaches 80°C.

(Regular process after the process during startup has ended)

**[0057]** Due to the steady output control continuing, the rotational speed of the compressor 21 increasing, the opening degree of the outdoor electric expansion valve 24 also being increased, and the refrigerant circulation quantity of the refrigeration cycle increasing, the process during startup ends when a circulation quantity corresponding to the operation state is reached, after which the regular operation is performed. In this regular operation, subcooling-degree-fixing control whereby the control part 11 controls the opening degree of the outdoor electric expansion valve 24 is performed so that the degree of subcooling of the refrigerant passing through the outlet side of the indoor heat exchanger 41 in the air-warming operation circuit is kept fixed at a predetermined value. This degree of subcooling is obtained by the control part 11 calculating the difference between the saturation temperature corresponding to the sensed pressure of the second pressure sensor 29g and the temperature sensed by the indoor heat exchange temperature sensor 44.

(Startup superheating protection control)

**[0058]** The startup superheating protection control is a control for increasing the opening degree of the outdoor electric expansion valve 24 in order to prevent the degree of superheating of the refrigerant drawn into the compressor 21 from increasing abnormally, by induction heating by the electromagnetic induction heating unit 6 at the initial maximum supplied electricity (2 kW) during startup.

**[0059]** FIG. 10 shows a flowchart of the startup superheating protection control.

**[0060]** In step S11, the control part 11 confirms that the temperature sensed by the electromagnetic induction thermistor 14 has decreased after startup of the compressor 21 has been initiated (shown by point a in FIG. 9), and then transitions to step S12.

**[0061]** In step S12, the control part 11 switches the output of the electromagnetic induction heating unit 6 from a state of 0 to the maximum supplied electricity (2 kW) (shown in FIG. 9 as the change from point b to point c), and at the same time begins to count the elapsed time through the timer 95.

**[0062]** In step S13, the control part 11 determines whether or not the temperature sensed by the electromagnetic induction thermistor 14 has reached the startup target accumulation tube temperature of 80°C. When the startup target accumulation tube temperature of 80°C is reached (shown as point d in FIG. 9), the process transitions to step S14.

**[0063]** In step S14, the control part 11 temporarily stops the induction heating by the electromagnetic induction heating unit 6 (shown as point e in FIG. 9), and ends the count of the timer 95 initiated in step S12.

**[0064]** In step S 15, the control part 11 determines whether or not the rotational speed sensed by the rotational speed perceiving part 29r is greater than a superheat-minimizing estimated rotational speed of 82 rps (82 rotations per second). This superheat-minimizing estimated rotational speed is a rotational speed set in advance as a rotational speed at which the degree of superheating of the refrigerant drawn into the compressor 21 is not likely to increase abnormally, based on the conditions established for the refrigeration cycle. Since the intake pressure is not likely to decrease by much when this superheat-minimizing estimated rotational speed is not met, it is estimated that there is no risk of an abnormal increase in the degree of superheating of the refrigerant drawn into the compressor 21, and the startup superheating protection control is ended. When the superheat-minimizing estimated rotational speed is exceeded, the process transitions to step S16.

**[0065]** In step S16, the control part 11 determines whether or not the value of the timer 95 at the end of the count in step S14 is less than a temperature increase rate judgment time of 20 seconds. This temperature increase rate judgment time is a time duration set in advance as a time duration corresponding to the temperature increase rate at which the degree of superheating of the refrigerant drawn into the compressor 21 is not likely to increase abnormally, based on the set conditions of the refrigeration cycle. Specifically, when the time needed to reach the startup target accumulation tube temperature of 80°C after induction heating by the electromagnetic induction heating unit 6 is initiated is less than the temperature increase rate judgment time (20 seconds), the temperature increase rate of the temperature sensed by the electromagnetic induction thermistor 14 is too fast, and a transition is made to step S 17 and a protection routine is performed on the premise that there is a risk of an abnormal increase in the degree of superheating of the refrigerant drawn into the compressor 21. Conversely, when the time needed reaches or exceeds the temperature increase rate judgment time, it is estimated that there is no risk of an abnormal increase in the degree of superheating of the refrigerant drawn into the compressor 21, and the startup superheating protection control is ended.

**[0066]** In step S 17, the control part 11 performs a valve opening degree increasing process for increasing the opening degree of the outdoor electric expansion valve 24 to increase the refrigerant circulation quantity through the accumulation tube F, thereby preventing too fast of a temperature increase in the accumulation tube F caused by the induction heating by the electromagnetic induction heating unit 6. In this valve opening degree increasing process, the opening degree of the outdoor electric expansion valve 24 is increased in 20 pulse increments every 20 seconds. This process of increasing in 20 pulse increments every 20 seconds is repeated until the rate of increase in the temperature sensed by the electromagnetic induction thermistor 14 caused by induction heating is equal to or less than a predetermined rate. Specifically, simultaneous with the action of increasing the opening degree of the outdoor electric expansion valve 24, a process is performed for determining whether or not the rate of increase in the temperature sensed by the electromagnetic induction thermistor 14 has ceased to exceed the predetermined rate, and when the opening degree of the outdoor electric expansion valve 24 has increased to the point of no longer exceeding the predetermined rate, it is determined that there is no longer a risk of the temperature of the accumulation tube F increasing too much, and the valve opening degree increasing process is ended.

**[0067]** The startup superheating protection control is ended in the above manner.

**[0068]** After the pressure sensed by the first pressure sensor 29a has reached the target high pressure, the steady output control is performed as described above, whereby the frequency of the compressor 21 is increased, the opening degree of the outdoor electric expansion valve 24 is further increased, the refrigerant quantity circulating in the refrigeration cycle further increases, and the capability of the refrigeration cycle is increased.

(Regular superheating protection control)

**[0069]** The regular superheating protection control is a control for preventing the degree of superheating from increasing abnormally due to induction heating in a case where the opening degree of the outdoor electric expansion valve 24 is increased, the temporary decrease in the temperature sensed by the electromagnetic induction thermistor 14 is sensed, and induction heating is performed by the electromagnetic induction heating unit 6, when the subcooling-degree-fixing control is performed.

**[0070]** FIG. 11 shows a flowchart of the regular superheating protection control.

**[0071]** In step S21, when the temperature sensed by the electromagnetic induction thermistor 14 is 80°C or less, the control part 11 increases the output of the electromagnetic induction heating unit 6 from a state of 0 to an output (steady level) from a steady supply of electricity (1.4 kW; steady level).

**[0072]** In step S22, the control part 11 determines whether or not the temperature sensed by the electromagnetic induction thermistor 14 has reached 80°C. If it has reached 80°C, the process transitions to step S23.

**[0073]** In step S23, the control part 11 temporarily stops the induction heating by the electromagnetic induction heating unit 6.

**[0074]** In step S24, after stopping the induction heating by the electromagnetic induction heating unit 6, the control part 11 continues to sense the manner in which the temperature sensed by the electromagnetic induction thermistor 14 is increasing, and determines whether or not the temperature exceeds an abnormally increased temperature of 110°C. Specifically, the control part determines whether or not overshooting is occurring in which the temperature sensed by the electromagnetic induction thermistor 14 continues to increase above 80°C, regardless of the induction heating by the electromagnetic induction heating unit 6 having ended. The abnormally increased temperature of 110°C is a temperature set in advance, based on the design conditions of the refrigeration cycle, as a temperature at which after its value is exceeded, the degree of superheating of the refrigerant drawn into the compressor 21 increases abnormally. If it is determined that the abnormally increased temperature is exceeded, the process transitions to step S25. If it is determined that the abnormally increased temperature is not exceeded, it is estimated that there is no risk of an abnormal increase in the degree of superheating of the refrigerant drawn into the compressor 21 and the startup superheating protection control is ended.

**[0075]** In step S25, the control part 11 performs an adjustment for increasing the opening degree (valve opening degree adjustment process) in which the opening degree of the outdoor electric expansion valve 24 controlled by the subcooling-degree-fixing control is increased from its pulse value by another 50 pulses. The increase here is 50 pulses, which is greater than the single 20-pulse increase in the opening degree of the outdoor electric expansion valve 24 in the startup superheating protection control described above. It is thereby possible to more quickly prevent an abnormal temperature increase in the accumulation tube F even when it appears that an abnormal state will occur in the regular superheating protection control.

**[0076]** The regular superheating protection control is ended in the above manner.

**[0077]** In the regular superheating protection control, since the rotational speed at which the compressor 21 is driven is already in excess of 82 rps, the determination in the startup superheating protection control is unnecessary.

<Characteristics of Air Conditioning Apparatus 1 of Present Embodiment>

**[0078]**

(1)

In induction heating by the electromagnetic induction heating unit 6, the temperature is quickly increased not in refrigerant flowing through portions in the refrigeration cycle somewhat distanced from the compressor 21, but in the refrigerant flowing through the accumulation tube F immediately before being drawn into the compressor 21. The refrigerant flowing through the intake side of the compressor 21 is either very dry or in a superheated state, and this refrigerant is more likely to have a change in sensible heat or a temperature increase, compared with cases of a latent heat change in gas-liquid two-phase refrigerant flowing further upstream. Since the refrigerant drawn into the compressor 21 is heated, the heat generated in the magnetic tube F2 is affected by heat transfer or the like, and it is therefore difficult to perceive the temperature of the refrigerant actually being drawn into the compressor 21.

In the control performed by the air conditioning apparatus 1 of the present embodiment in such a situation, it is not the temperature of the refrigerant actually drawn into the compressor 21 that is perceived by the electromagnetic induction thermistor 14, but rather the temperature situation of the magnetic tube F2 of the accumulation tube F where heat is generated by induction heating. Based on the temperature sensed by the electromagnetic induction thermistor 14, the opening degree of the outdoor electric expansion valve 24 can be increased and the refrigerant quantity supplied to the intake side of the compressor 21 can be increased so that there is no abnormal increase in the degree of superheating of the refrigerant drawn into the compressor 21. It is thereby possible, in cases of heating the refrigerant in the intake side of the compressor 21, for the heat quantity applied to the drawn-in refrigerant to be accounted for via the temperature sensed by the electromagnetic induction thermistor 14 and to minimize any abnormal increase in the degree of superheating in the refrigerant drawn into the compressor 21, even in cases in which it is difficult to perceive the actual temperature of the drawn-in refrigerant.

(2)

In the startup superheating protection control of the present embodiment, in situations in which the temperature of the magnetic tube F2 of the accumulation tube F suddenly increases due to induction heating during startup, it is possible to minimize abnormal increases in the degree of superheating in the refrigerant drawn into the compressor 21 by increasing the opening degree of the outdoor electric expansion valve 24 and supplying more refrigerant. This startup superheating protection control takes into account the rotational speed at which the compressor 21 is driven and increases the opening degree of the outdoor electric expansion valve 24 only when the temperature of the magnetic tube F2 suddenly increases even under circumstances in which the drive state of the compressor 21 is ensured, by selecting a pre-established superheat-minimizing estimated rotational speed as a rotational speed at which an abnormal temperature increase usually does not occur. Therefore, increases in the opening degree of the outdoor electric expansion valve 24 can be avoided during startup in the stage when the rotational speed at which the compressor 21 is driven has not yet increased by much. It is thereby unlikely that there will be a high-low pressure difference due to a greater increase than is necessary in the opening degree of the outdoor electric expansion valve 24, and it is possible to prevent increases in the time duration needed for the sensed pressure of the first pressure sensor 29a to reach the predetermined target high pressure of 39 kg/cm$^2$, and also to prevent high-temperature refrigerant from being unable to be supplied to the indoor heat exchanger 41.

The timing with which the opening degree of the outdoor electric expansion valve 24 is increased in the startup superheating protection control does not have a determination reference of whether or not the temperature sensed by the electromagnetic induction thermistor 14 has exceeded a certain temperature, but instead uses the rate of temperature increase as a determination reference. Therefore, there is no need to provide another new judgment temperature that is higher than the startup target accumulation tube temperature or to determine whether or not this judgment temperature has been exceeded. It is more when it has been perceived that a certain rate of temperature increase has been exceeded than when it is perceived that the judgment temperature has been exceeded that the subsequent temperature of the accumulation tube F quickly increases more rapidly. Therefore, reliability of the apparatus can be improved in the above embodiment wherein it is possible to perceive cases in which such abnormal increases in temperature occur readily.

For example, considering a case in which the control for increasing the opening degree of the outdoor electric expansion valve 24 when the judgment temperature has been exceeded, wherein 90°C is set as a temperature higher than the startup target accumulation tube temperature, several minutes is needed for the temperature sensed by the electromagnetic induction thermistor 14 to increase from 89°C to exceed 90°C, and the opening degree of the outdoor electric expansion valve 24 is increased even when it is estimated that the temperature will thereafter increase by no more than several degrees even with the passage of a long moment. By contrast, in the startup superheating protection control of the above embodiment, the opening degree of the outdoor electric expansion valve 24 is increased only when a rate of temperature increase is detected in which 80°C is exceeded in 20 seconds, and it is therefore possible to prevent decreases in the discharge refrigerant temperature caused by the opening degree of the outdoor electric expansion valve 24 being increased unnecessarily.

(3)

Furthermore, in the regular superheating protection control, when the temperature sensed by the electromagnetic induction thermistor 14 has exceeded the abnormally increased temperature of 110°C due to induction heating being performed during subcooling-degree-fixing control, the opening degree is increased further above the opening degree of the outdoor electric expansion valve 24 controlled by subcooling-degree-fixing control. Therefore, compared with control in which merely the opening degree of the outdoor electric expansion valve 24 is adjusted to a certain opening degree when the abnormally increased temperature of 110°C is exceeded, the refrigerant quantity passing through the accumulation tube F can be more reliably increased and any abnormal increases in the degree of superheating of the refrigerant drawn into the compressor 21 can therefore be more reliably minimized.

This regular superheating protection control is performed in a state in which the refrigerant circulation quantity of the refrigeration cycle is more stable than during startup, and sudden increases in the temperature of the accumulation tube F are unlikely; therefore, there is no need for determinations based on the rate of temperature increase, and reliability can be sufficiently ensured with a simple determination method for determining whether or not the abnormally increased temperature of 110°C has been exceeded.

It is also thereby possible to lengthen the time duration in which heat is input to the magnetic tube F2 by the induction heating by the electromagnetic induction heating unit 6 because the quantity of refrigerant drawn into the compressor 21 increases.

Until the electromagnetic induction thermistor 14 senses the abnormally increased temperature of 110°C, which is a higher temperature than 80°C at which induction heating by the electromagnetic induction heating unit 6 is stopped, the opening degree of the outdoor electric expansion valve 24 is maintained at the opening degree of the subcooling-degree-fixing control and the opening degree of the outdoor electric expansion valve 24 is not increased; therefore, the time duration during which a high refrigerant temperature can be maintained by induction heating can be lengthened further.

<Other Embodiments>

**[0079]** An embodiment of the present invention was described above based on the drawings, but the specific configuration is not limited to this embodiment, and modifications can be made within a range that does not deviate from the scope of the invention.

(A)

In the embodiment described above, an example was described of a case in which SUS430 is used as the material of the magnetic tube F2.

However, the present invention is not limited to this example. The magnetic tube can be, for example, iron, copper, aluminum, chrome, nickel, other conductors, and alloys containing at least two or more metals selected from these listed.

The example of the magnetic material given here contains, e.g., ferrite, martensite, or a combination of the two, but it is preferable to use a ferromagnetic metal which has a comparatively high electrical resistance and which has a higher Curie temperature than its service temperature range.

The accumulation tube F here requires more electricity, but it need not comprise a magnetic substance and a material containing a magnetic substance; it may include a material that will be the target of induction heating.

The magnetic material may, e.g., constitute the entire accumulation tube F, may be formed only in the inside surface of the accumulation tube F, or may be present only due to being included in the material constituting the accumulation tube F.

(B)

In the embodiment described above, an example was described of a case in which the condition for increasing the opening degree of the outdoor electric expansion valve 24 differs between the startup superheating protection control and the regular superheating protection control.

However, the present invention is not limited to this example. The condition for increasing the opening degree of the outdoor electric expansion valve 24 may be the same for both the startup superheating protection control and the regular superheating protection control, for example.

(C)

In the embodiment described above, an example was described of a case in which control is performed for keeping the degree of subcooling fixed after the control during startup is ended.

However, the present invention is not limited to this example. For example, control may be performed for maintaining the extent of change in the distribution state of the refrigerant in the refrigeration cycle for a predetermined time duration either at a predetermined distribution state or within a predetermined distribution range. To sense this refrigerant distribution state, the refrigerant distribution state may be perceived by providing a sight glass to the condenser of the refrigeration cycle or adopting another method to perceive the liquid surface of the refrigerant, and stability control may be performed so that the distribution state reaches a predetermined distribution state or comes within a predetermined distribution range.

(D)

In the embodiment described above, a case was described in which within the refrigerant circuit 10, the electromagnetic induction heating unit 6 is attached to the accumulation tube F.

However, the present invention is not limited to this example.

For example, the electromagnetic induction heating unit 6 may be provided to another refrigerant tube besides the accumulation tube F. In this case, the magnetic tube F2 or another magnetic element is provided to the refrigerant tube portion where the electromagnetic induction heating unit 6 is provided.

(E)

In the embodiment described above, a case was described in which the accumulation tube F is configured as a double-layered tube containing the copper tube F1 and the magnetic tube F2.

However, the present invention is not limited to this example.

A magnetic member F2a and two stoppers F1a, F1b may be disposed inside the accumulation tube F and a refrigerant tube as a heated object, for example, as shown in FIG. 12. The magnetic member F2a is a member containing a magnetic material whereby heat is generated by electromagnetic induction heating in the embodiment described above. The stoppers F1a, F1b are placed in two locations inside the copper tube F1, normally permitting refrigerant to pass through but not permitting the magnetic member F2a to pass through. The magnetic member F2a thereby does not move despite the flow of refrigerant. Therefore, the intended heating position in the accumulation tube F, for example, can be heated. Furthermore, since the heat-generating magnetic member F2a and the refrigerant are in direct contact, heat transfer efficiency can be improved.

(F)

The magnetic member F2a described above in the other embodiment (L) may be positioned within the tube without the use of the stoppers F1a, F2b.

As shown in FIG. 13, for example, bent portions FW may be provided in two locations in the copper tube F1, and the magnetic member F2a may be disposed inside the copper tube F1 between the bent portions FW provided in two locations. The movement of the magnetic member F2a can be restricted while allowing refrigerant to pass through in this manner as well.

(G)

In the embodiment described above, a case was described in which the coil 68 is wound around the accumulation tube F in a helical shape.

However, the present invention is not limited to this example.

For example, a coil 168 wound around a bobbin main body 165 may be disposed around the periphery of the accumulation tube F without being wound over the accumulation tube F, as shown in FIG. 14. The bobbin main body 165 is disposed so that its axial direction is substantially perpendicular to the axial direction of the accumulation tube F. Two bobbin main bodies 165 and coils 168 each are disposed separately so as to sandwich the accumulation tube F.

In this case, a first bobbin cover 163 and a second bobbin cover 164 which pass through the accumulation tube F may be disposed in a state of being fitted over the bobbin main body 165, as shown in FIG. 15, for example.

Furthermore, the first bobbin cover 163 and the second bobbin cover 164 may be fixed in place by being sandwiched by a first ferrite case 171 and a second ferrite case 172, as shown in FIG. 16. In FIG. 16, an example is shown of a case in which two ferrite cases are disposed so as to sandwich the accumulation tube F, but they may be arranged in four directions similar to the embodiment described above. The ferrite may also be housed similar to the embodiment described above.

(H)

In the embodiment described above, an example was described of a case in which whether or not the rate of temperature increase is fast is determined by referring to whether or not a time duration less than the temperature increase rate judgment time (20 seconds) is needed to reach the startup target accumulation tube temperature of 80°C after the initiation of induction heating by the electromagnetic induction heating unit 6.

However, the method of perceiving the rate of temperature increase is not limited to this perceiving method.

For example, instead of actually perceiving the rate of temperature increase, an information table may be stored in advance in the controller 90, and the control part 11 may perform control such as estimating the rate of temperature increase by referring to this information table and then increases the valve opening degree of the outdoor electric expansion valve 24.

An example of such an information table is data that correlates the current temperature sensed by the electromagnetic induction thermistor 14, the amount the accumulation tube F is heated by the electromagnetic induction heating unit 6, the refrigerant circulation quantity passing through the accumulation tube F, the density of the refrigerant passing through the accumulation tube F, the outdoor air temperature, and other conditions, as well as values calculated in advance as rates of temperature increase corresponding to these conditions. When the rates of temperature increase are calculated in advance in this manner, they are preferably calculated based on the thermal conductivity of the magnetic tube F2 and the copper tube F1, the thermal conductivity between the magnetic tube F2 and the copper tube F1, the thermal conductivity between the copper tube F1 and the refrigerant, and other factors.

The amount the accumulation tube F is heated by the electromagnetic induction heating unit 6 can be converted from the amount of electricity supplied by the electric current supply part 21e as sensed by the compressor electricity sensor 29f. The refrigerant circulation quantity passing through the accumulation tube F or the density of refrigerant passing through the accumulation tube F can be converted from the drive rotational speed of the piston of the compressor 21 as perceived by the rotational speed perceiving part 29r, the high pressure perceived by the first pressure sensor 29a, the low pressure perceived by the second pressure sensor, or the like. The outdoor air temperature can be perceived as the sensed temperature of the outdoor temperature sensor 29b. When an information table has been stored in advance in the controller 90 in this manner, the processing load of the control part 11 can be reduced.

Instead of storing such an information table in the controller 90, a predetermined relationship equation may be stored in the controller 90 and the control part 11 may calculate estimated rates of temperature increase on the basis of values perceived from the sensors described above.

The information table and the calculation can be simplified by establishing in advance the amount of electricity supplied to the electromagnetic induction heating unit 6 by the electric current supply part 21e in two patterns consisting of a predetermined output (e.g. 2 kW) and another predetermined output (e.g. 1.4 kW), on the basis of, e.g., the outdoor air temperature.

Thus, when the control part 11 does not actually perceive the rate of temperature increase but instead perceives it by calculating it from the information table or a predetermined relationship equation, or by another method, the time duration for actually gauging the rate of temperature increase is unnecessary, and a quicker process can therefore be performed.

(I)

In the embodiment described above, an example was described of a case in which during steady output control following the beginning of startup, a process is performed wherein induction heating by the electromagnetic induction heating unit 6 is initiated at the steady supplied electricity (1.4 kW) output when the temperature sensed by the electromagnetic induction thermistor 14 is 60°C or less, and induction heating by the electromagnetic induction heating unit 6 is stopped when the temperature sensed by the electromagnetic induction thermistor 14 reaches 80°C, so that the temperature sensed by the electromagnetic induction thermistor 14 is maintained in the vicinity of the startup target accumulation tube temperature of 80°C.

However, the control for maintaining the temperature sensed by the electromagnetic induction thermistor 14 in the vicinity of 80°C during the steady output control is not limited to such control.

For example, the control part 11 may maintain the temperature sensed by the electromagnetic induction thermistor 14 in the vicinity of 80°C by PI controlling the frequency of supplying an electric current to the electromagnetic induction heating unit 6 on the basis of the temperature sensed by the electromagnetic induction thermistor 14. In this PI control, wherein one set is the supply of an electric current to the electromagnetic induction heating unit 6 at a continuous fixed output of the steady supplied electricity (1.4 kW) for 30 seconds, the control part 11 may adjust the frequency with which this set is repeated, based on the elapsed time from the end of the most recent electric current supply to the electromagnetic induction heating unit 6 until the temperature sensed by the electromagnetic induction thermistor 14 falls back down to 80°C. Specifically, control may be performed so that the longer this elapsed time, the higher the frequency with which the above-described set is repeated.

<Other>

**[0080]** Embodiments of the present invention were described above in several examples, but the present invention is not limited to these embodiments. For example, the present invention also includes combined embodiments obtained by suitably combining different portions of the above embodiments, within a range that can be carried out based on the above descriptions by those skilled in the art.

## INDUSTRIAL APPLICABILITY

**[0081]** According to the present invention, even when refrigerant in the intake side of the compression mechanism is heated, it is possible to perform control that accounts for the heat quantity applied to the drawn-in refrigerant during superheating degree control of the refrigerant drawn into the compression mechanism, and the present invention is therefore particularly useful in an air conditioning apparatus which heats a refrigerant by induction heating.

## REFERENCE SIGNS LIST

**[0082]**

| | |
|---|---|
| 1 | Air conditioning apparatus |
| 11 | Control part (cooler-side-refrigerant-state-pereciving part) |
| 14 | Electromagnetic induction thermistor (generated heat temperature sensor) |
| 21 | Compressor (compression mechanism) |
| 23 | Outdoor heat exchanger (refrigerant heater) |
| 24 | Outdoor electric expansion valve (expansion mechanism) |
| 29a | First pressure sensor (cooler-side-refrigerant-state-perceiving part) |
| 29g | Second pressure sensor |
| 41 | Indoor heat exchanger (refrigerant cooler) |
| 44 | Indoor heat exchange temperature sensor (cooler-side-refrigerant-state-perceiving part) |
| 68 | Coil (magnetic field generator) |
| F | Accumulation tube (refrigerant tube, intake refrigerant tube) |

## CITATION LIST

### PATENT LITERATURE

**[0083]**

<Patent Literature 1> Japanese Laid-open Patent Publication No. 7-120083

## Claims

**1.** An air conditioning apparatus (1) which includes at least a compression mechanism (21), a refrigerant cooler (41), an expansion mechanism (24), and a refrigerant heater (23); the air conditioning apparatus (1) comprising:

a magnetic field generator (68) for generating a magnetic field in order to induction-heat a refrigerant tube (F) for circulating refrigerant to the compression mechanism (21), the refrigerant cooler (41), the expansion mechanism (24), and the refrigerant heater (23), and/or a member in thermal contact with the refrigerant flowing through the refrigerant tube (F);
a generated heat temperature sensor (14) for sensing the temperature of a portion that generates heat by the induction heating by the magnetic field generator (68); and
a control part (11) for performing superheating protection control for increasing the opening degree of the expansion mechanism (24) either when the temperature sensed by the generated heat temperature sensor (14) reaches or exceeds a predetermined generated heat temperature, or when the rate of increase of the temperature sensed by the generated heat temperature sensor (14) reaches or exceeds a predetermined rate of increase.

**2.** The air conditioning apparatus (1) according to claim 1;
wherein the magnetic field generator (68) generates a magnetic field for induction-heating an intake refrigerant tube (F) within the refrigerant tube in the intake side of the compression mechanism (21) and/or a member in thermal contact with the refrigerant flowing through the intake refrigerant tube (F).

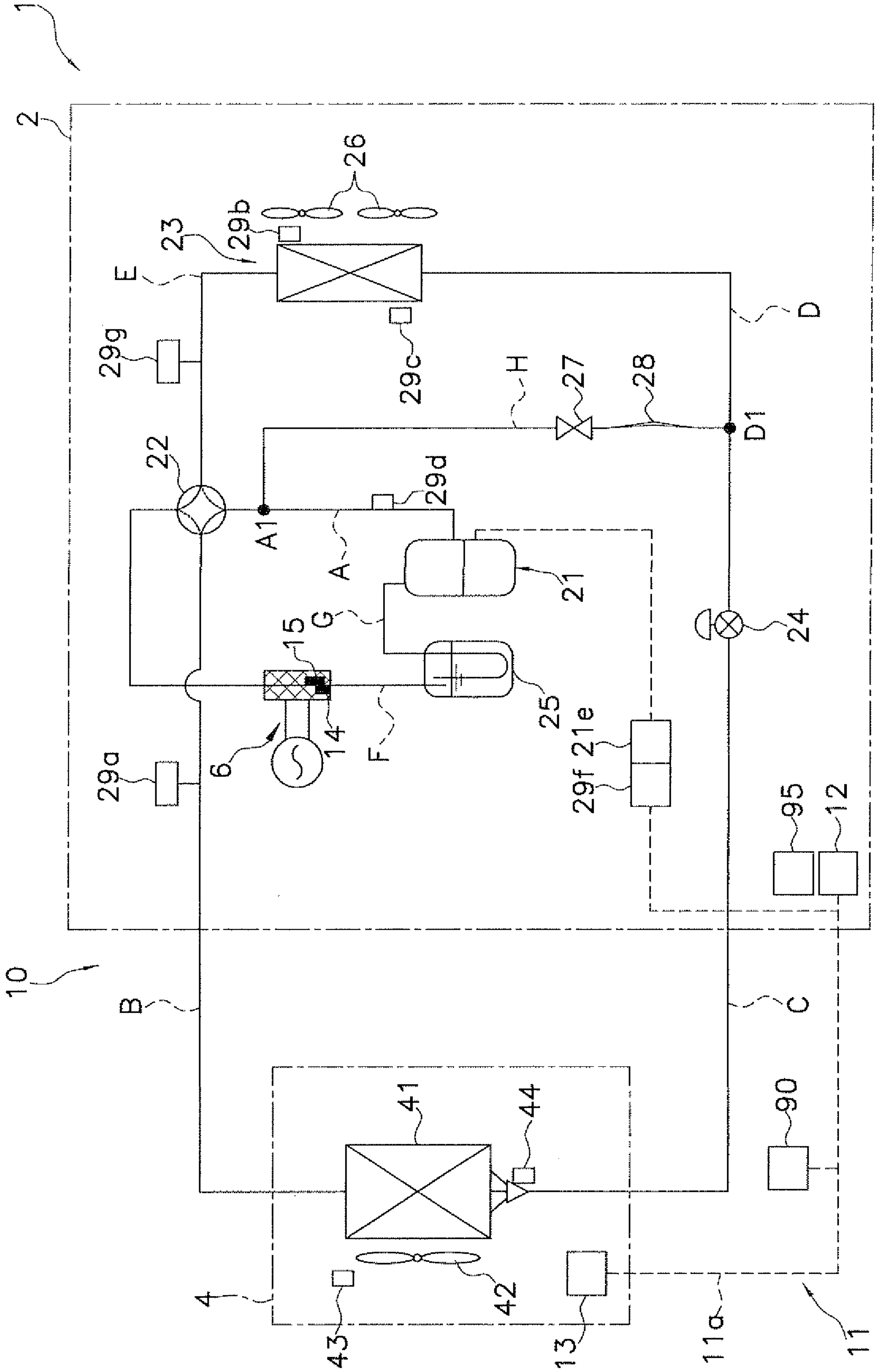
**3.** The air conditioning apparatus (1) according to claim

1 or 2;
wherein the control part (11) performs startup control for causing the magnetic field generator (68) to generate a magnetic field so that the temperature of the portion where heat is generated by the induction heating by the magnetic field generator (68) reaches a predetermined startup target temperature while driving of the compression mechanism (21) is initiated from a stopped state of the compression mechanism (21), as well as performing post-startup control after the startup control has ended; and
when the superheating protection control is performed at the same time the post-startup control is being performed, the control part (11) increases the opening degree of the expansion mechanism (24) when the temperature sensed by the generated heat temperature sensor (14) reaches or exceeds a post-startup predetermined generated heat temperature, which is a temperature equal to or greater than the predetermined startup target temperature.

**4.** The air conditioning apparatus (1) according to claim 3;
wherein when the superheating protection control is performed at the same time the startup control is being performed, the control part (11) increases the opening degree of the expansion mechanism (24) when the rate of increase of the temperature sensed by the generated heat temperature sensor (14) at the time the predetermined startup target temperature is reached reaches or exceeds the predetermined rate of increase.

**5.** The air conditioning apparatus (1) according to claim 4;
wherein when the predetermined rate of increase is determined to have been reached or exceeded, the control part (11) increases the opening degree of the expansion mechanism (24) only when the rotational speed of the compression mechanism (21) reaches or exceeds a predetermined rotational speed.

**6.** The air conditioning apparatus (1) according to any of claims 3 through 5;
further comprising a cooler-side-refrigerant-state-perceiving part (44, 29a, 11) for perceiving the state of refrigerant passing through from the refrigerant cooler (41) to the expansion mechanism (24);
wherein when the startup control has ended, the control part (11) initiates subcooling-degree-fixing control for controlling the opening degree of the expansion mechanism (24) so that the degree of subcooling of the refrigerant perceived using the value perceived by the cooler-side-refrigerant-state-perceiving part (44, 29a, 11) is kept fixed at a predetermined target degree of subcooling; and
when the superheating protection control is performed at the same time the subcooling-degree-fixing control is being performed, the control part (11) further increases the opening degree of the expansion mechanism (24) beyond the opening degree controlled by the subcooling-degree-fixing control when the temperature sensed by the generated heat temperature sensor (14) reaches or exceeds a predetermined subcooling-degree-fixing control generated heat temperature, which is a temperature equal to or greater than the predetermined startup target temperature.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29b
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D
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FIG. 1

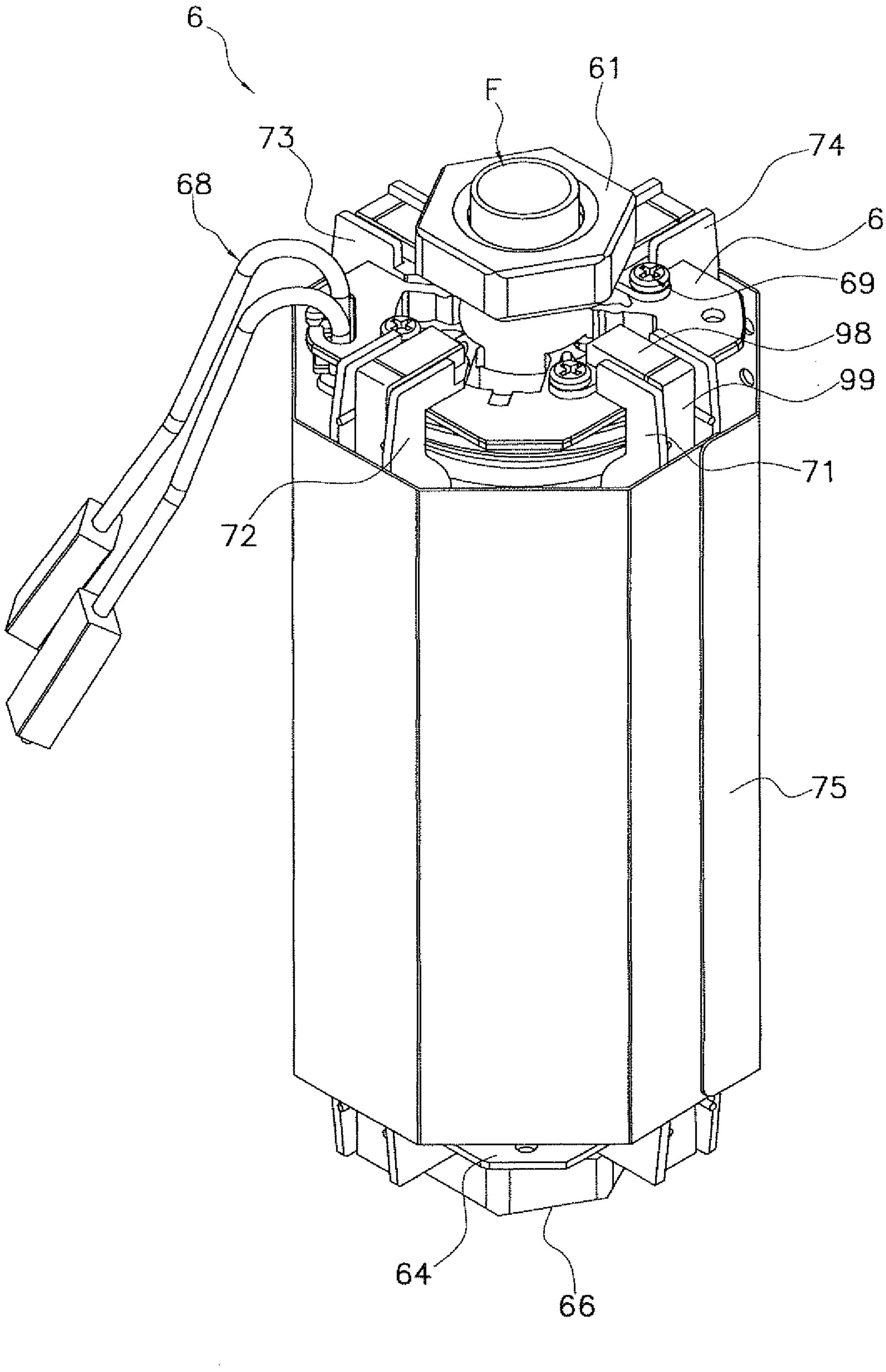


FIG. 2

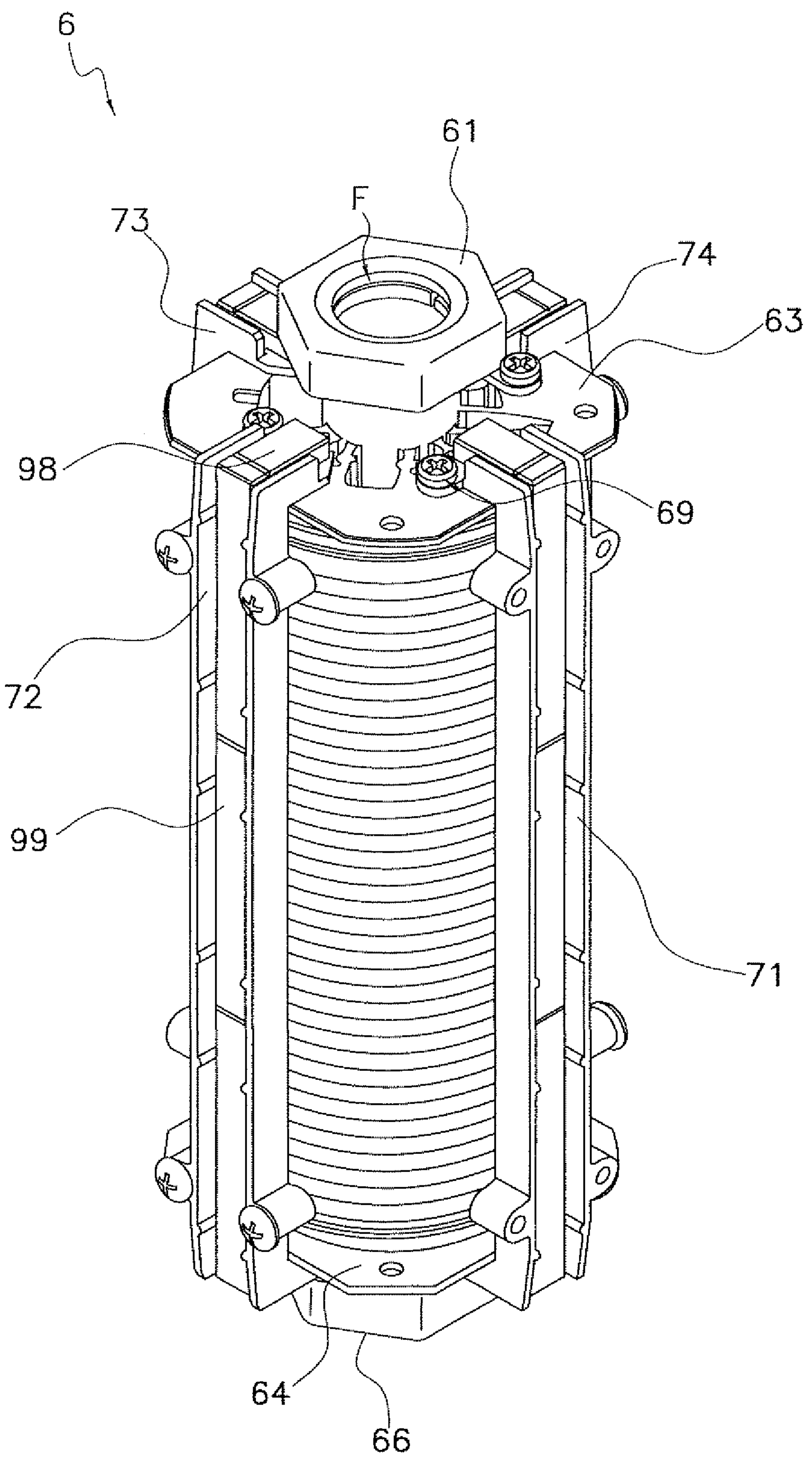


FIG. 3

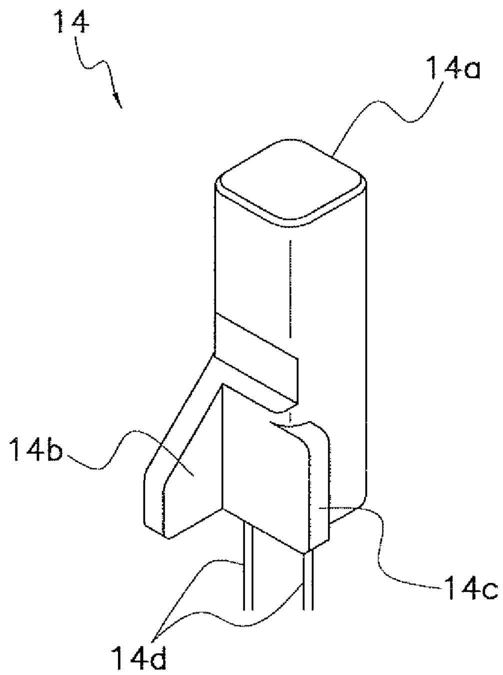


FIG. 4

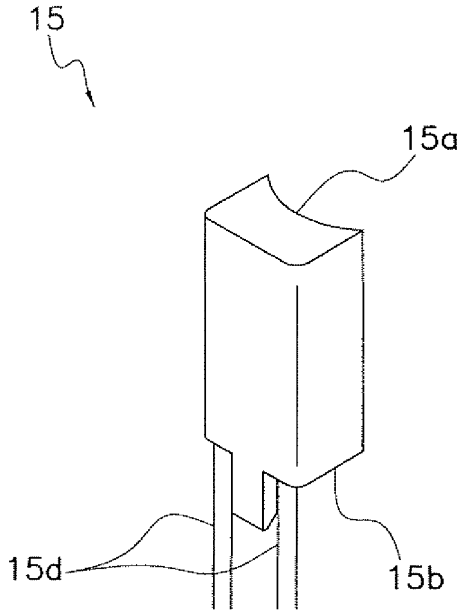


FIG. 5

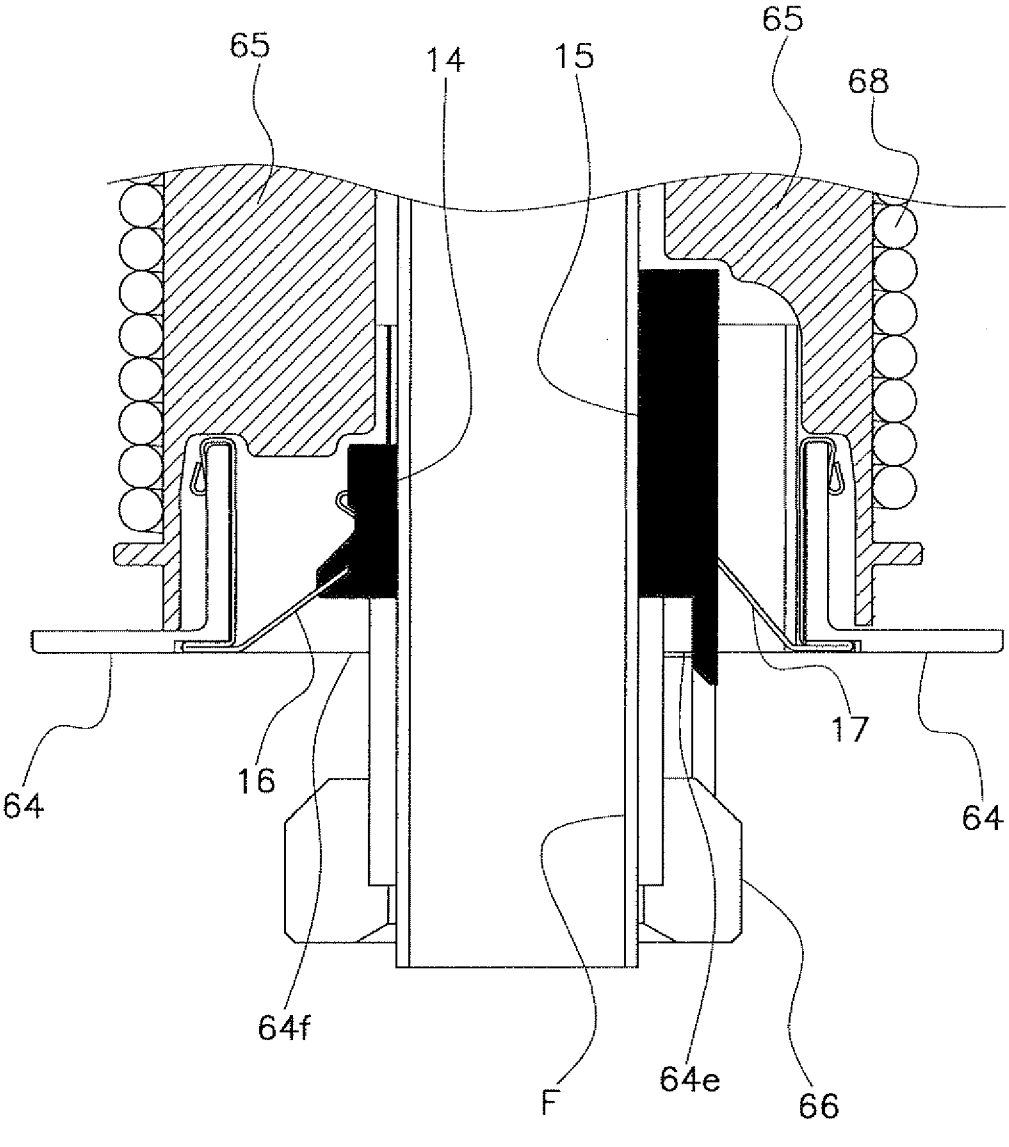


FIG. 6

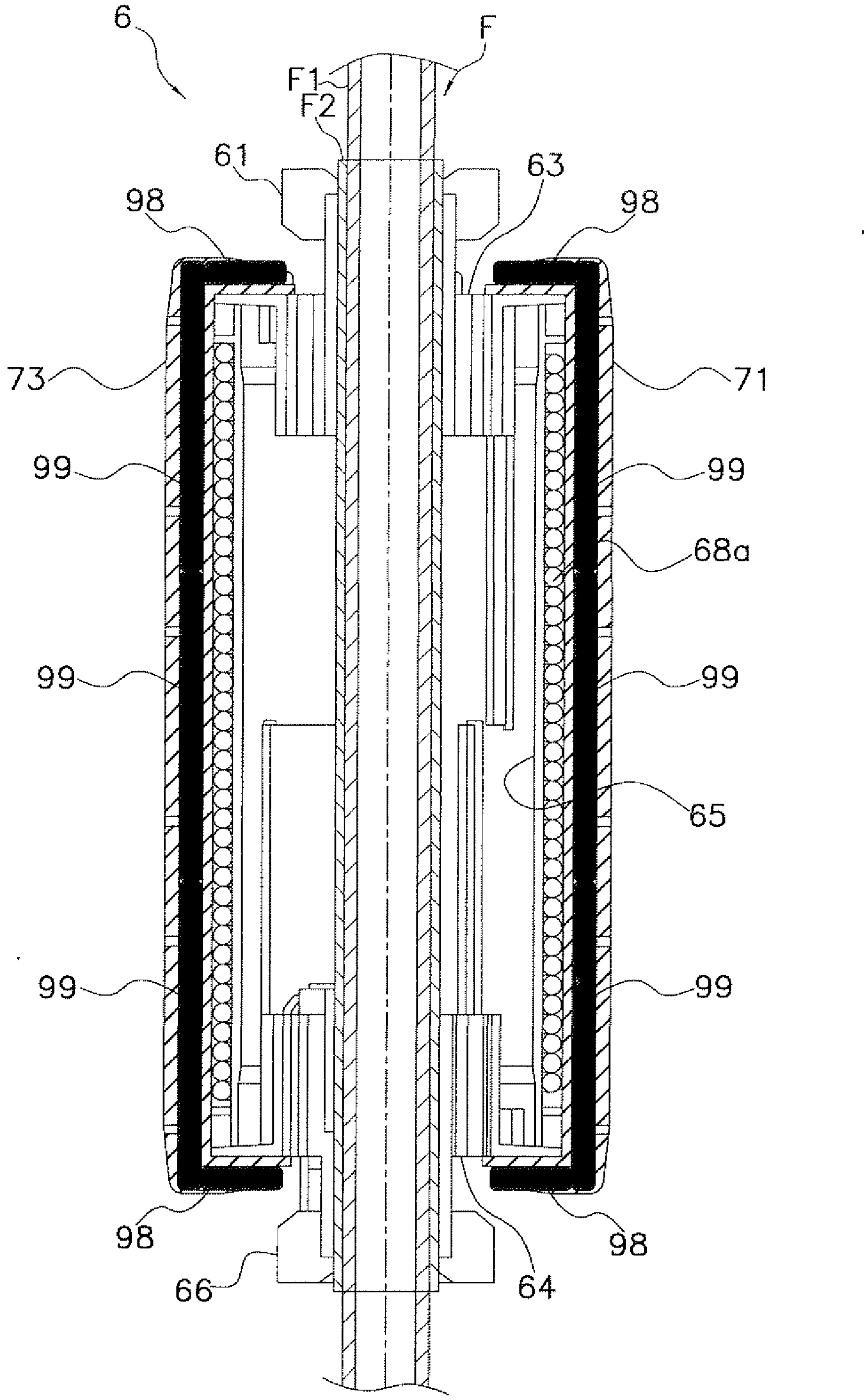


FIG. 7

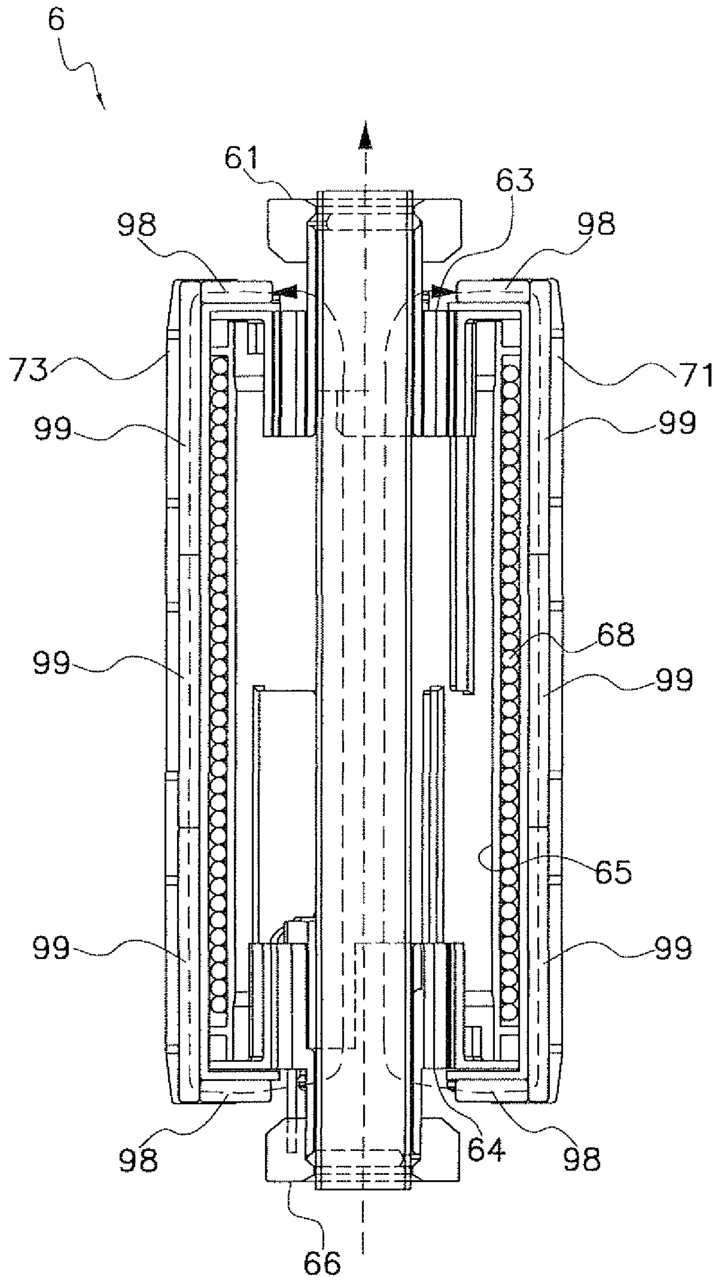


FIG. 8

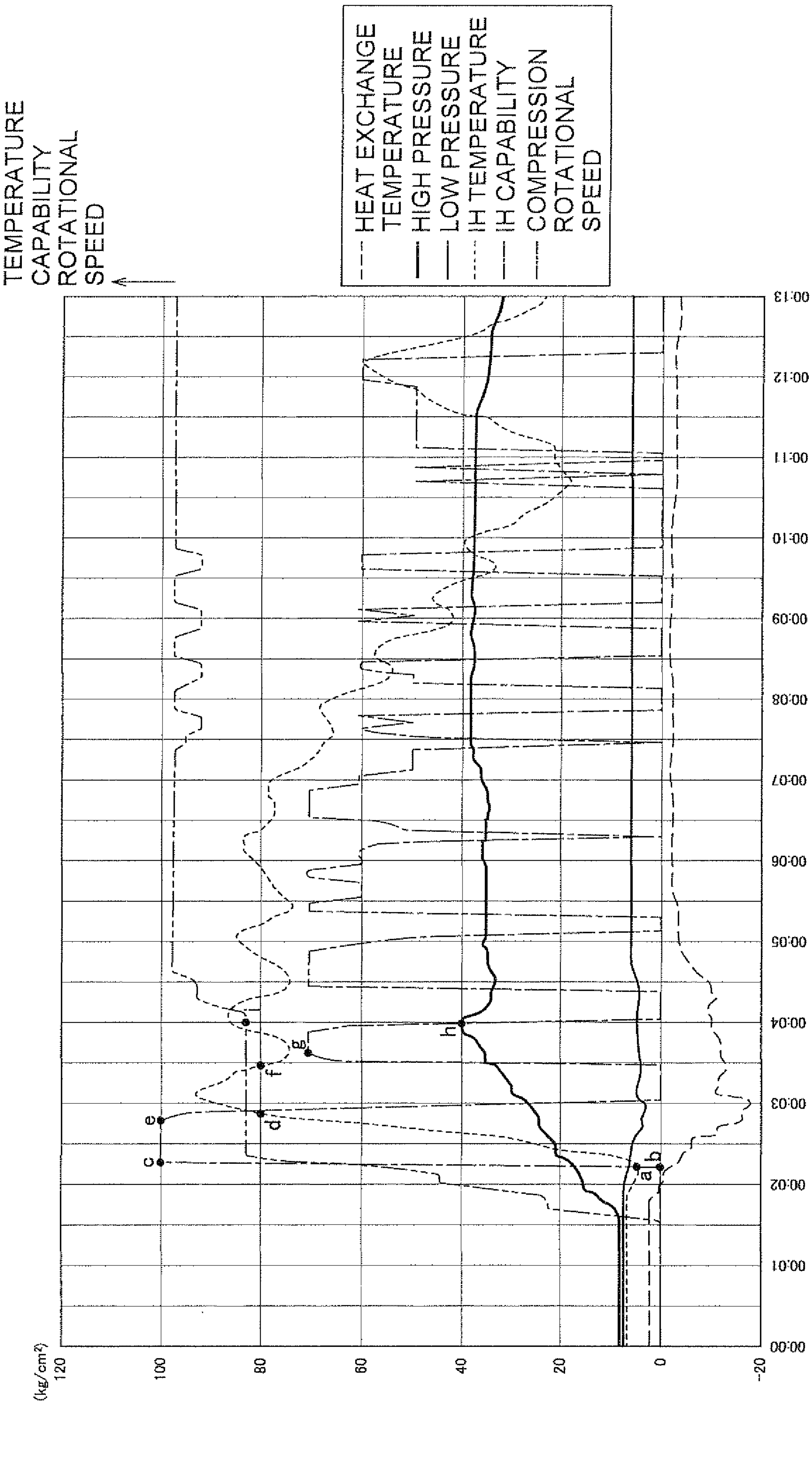
TEMPERATURE
CAPABILITY
ROTATIONAL
SPEED
HEAT EXCHANGE TEMPERATURE
HIGH PRESSURE
LOW PRESSURE
IH TEMPERATURE
IH CAPABILITY
COMPRESSION ROTATIONAL SPEED
(kg/cm²)
120
100
80
60
40
20
0
-20
00:00
00:01
00:02
00:03
00:04
00:05
00:06
00:07
00:08
00:09
00:10
00:11
00:12
00:13
a
b
c
d
e
f
g
h

FIG. 9

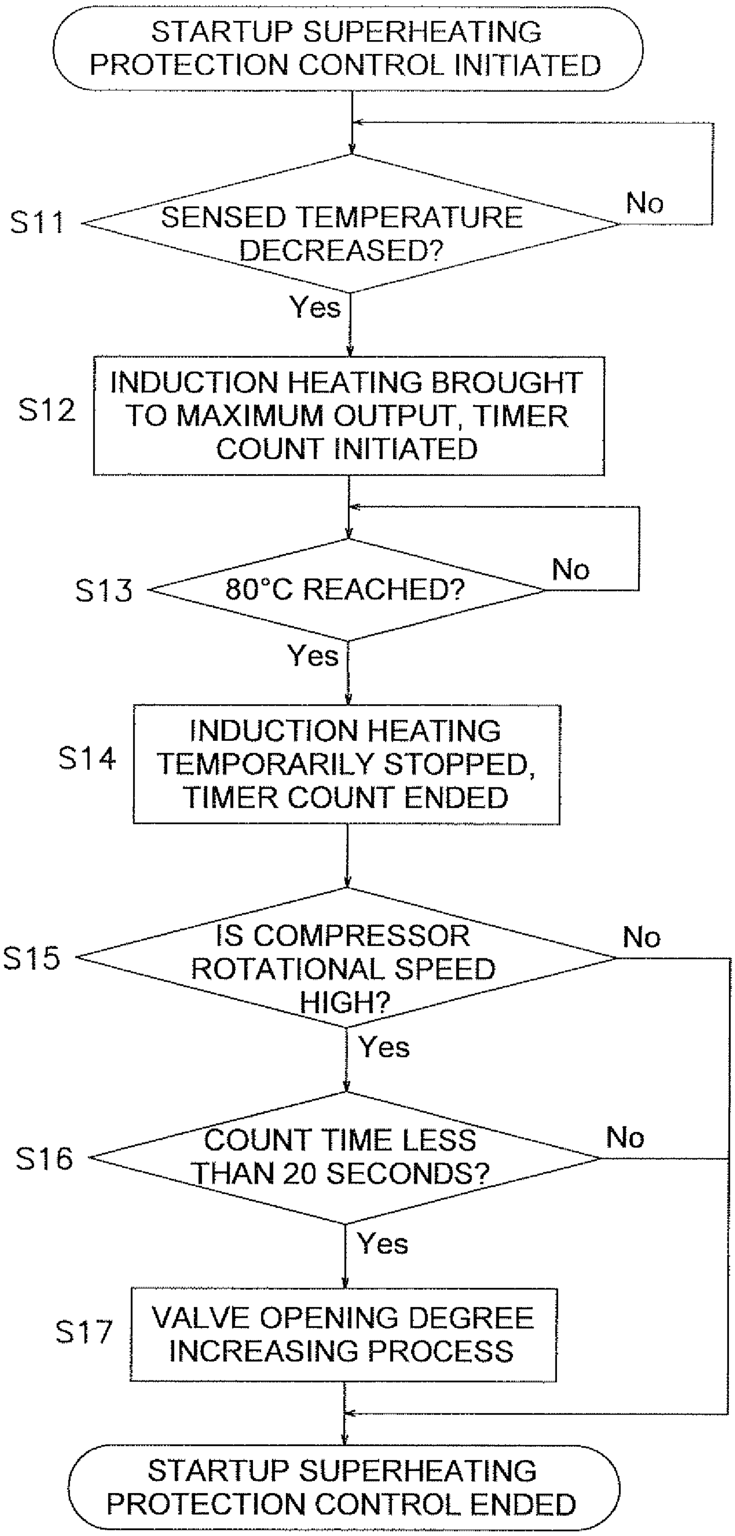
STARTUP SUPERHEATING PROTECTION CONTROL INITIATED
S11
SENSED TEMPERATURE DECREASED?
No
Yes
S12
INDUCTION HEATING BROUGHT TO MAXIMUM OUTPUT, TIMER COUNT INITIATED
S13
80°C REACHED?
No
Yes
S14
INDUCTION HEATING TEMPORARILY STOPPED, TIMER COUNT ENDED
S15
IS COMPRESSOR ROTATIONAL SPEED HIGH?
No
Yes
S16
COUNT TIME LESS THAN 20 SECONDS?
No
Yes
S17
VALVE OPENING DEGREE INCREASING PROCESS
STARTUP SUPERHEATING PROTECTION CONTROL ENDED

FIG. 10

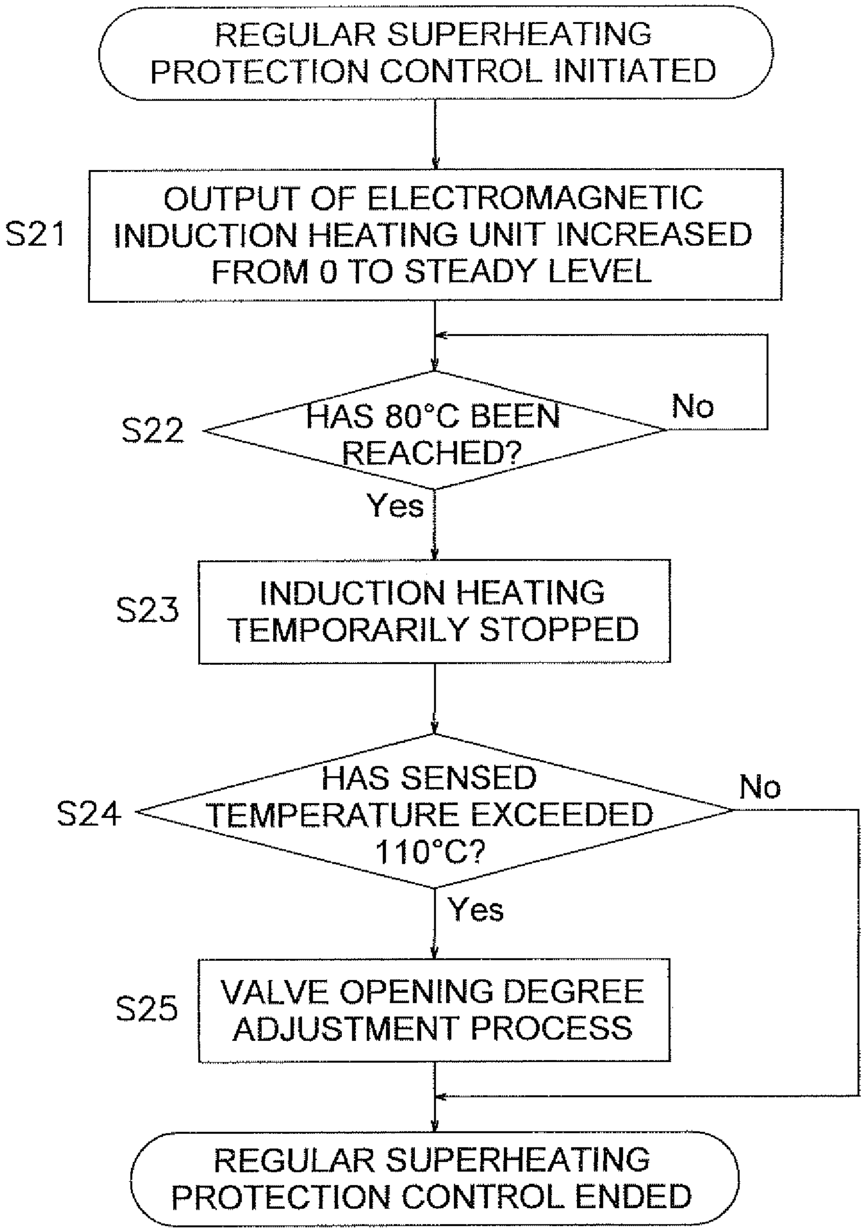
REGULAR SUPERHEATING PROTECTION CONTROL INITIATED
S21
OUTPUT OF ELECTROMAGNETIC INDUCTION HEATING UNIT INCREASED FROM 0 TO STEADY LEVEL
S22
HAS 80°C BEEN REACHED?
No
Yes
S23
INDUCTION HEATING TEMPORARILY STOPPED
S24
HAS SENSED TEMPERATURE EXCEEDED 110°C?
No
Yes
S25
VALVE OPENING DEGREE ADJUSTMENT PROCESS
REGULAR SUPERHEATING PROTECTION CONTROL ENDED

FIG. 11

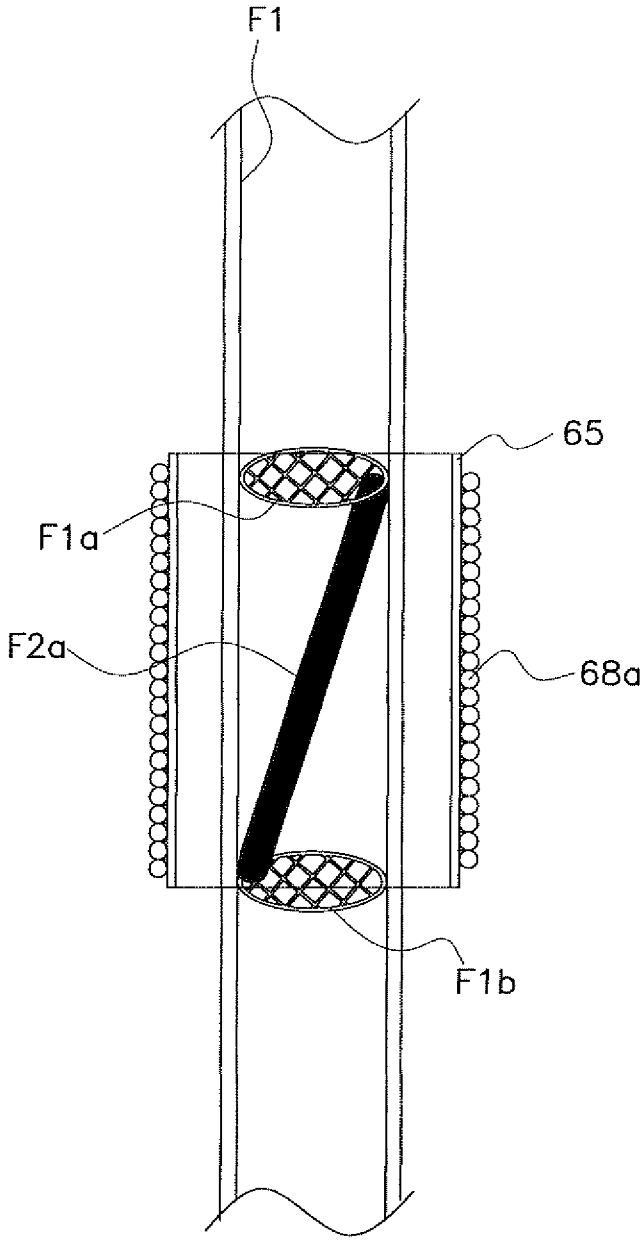


FIG. 12

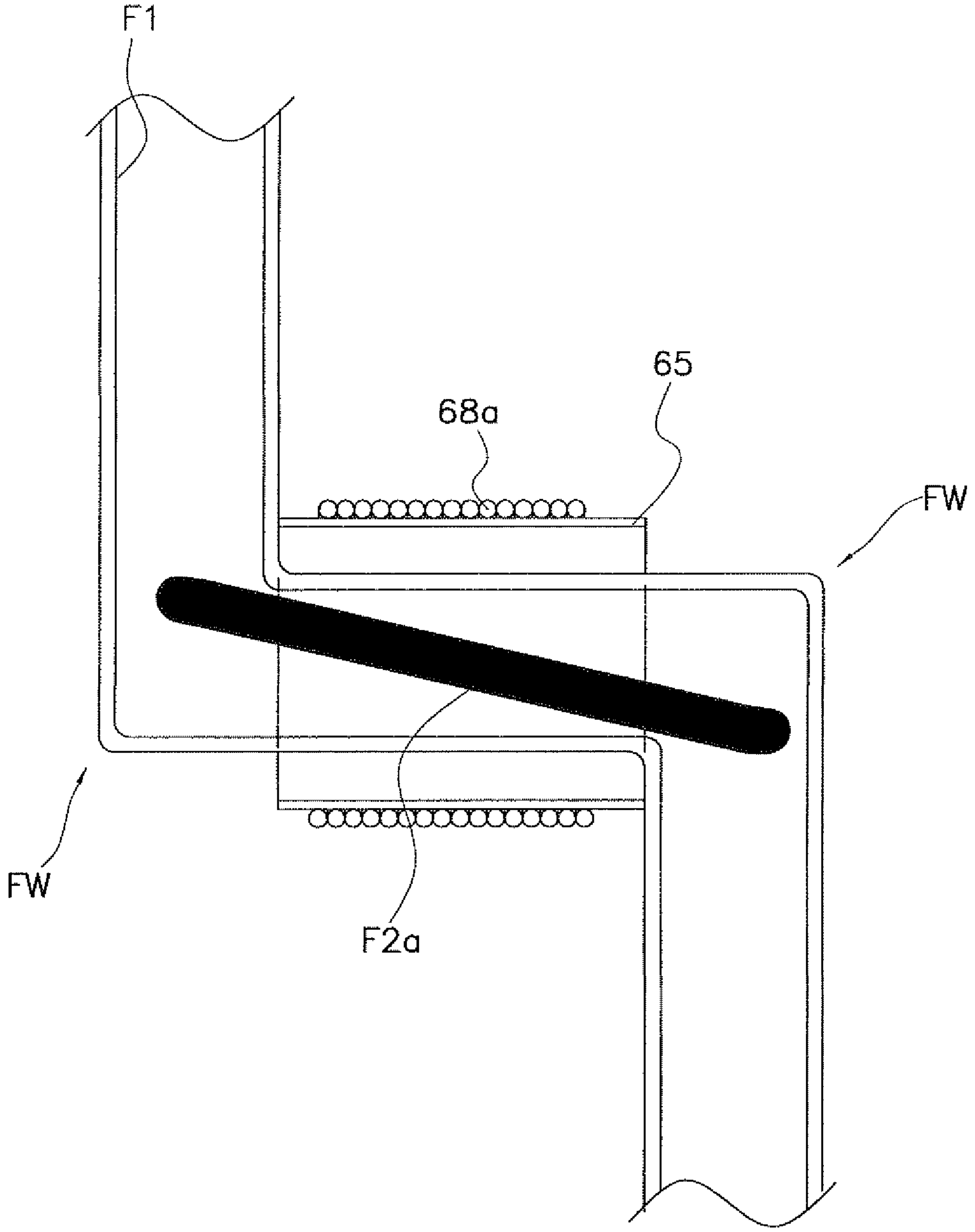


FIG. 13

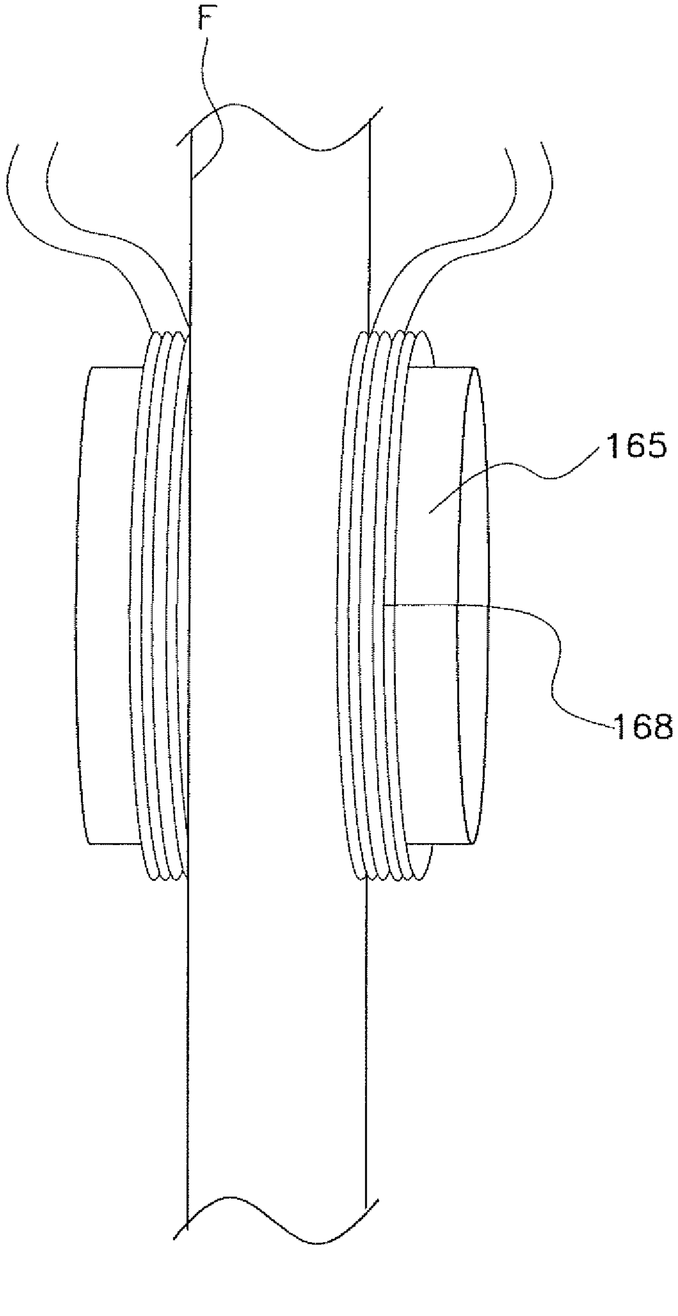


FIG. 14

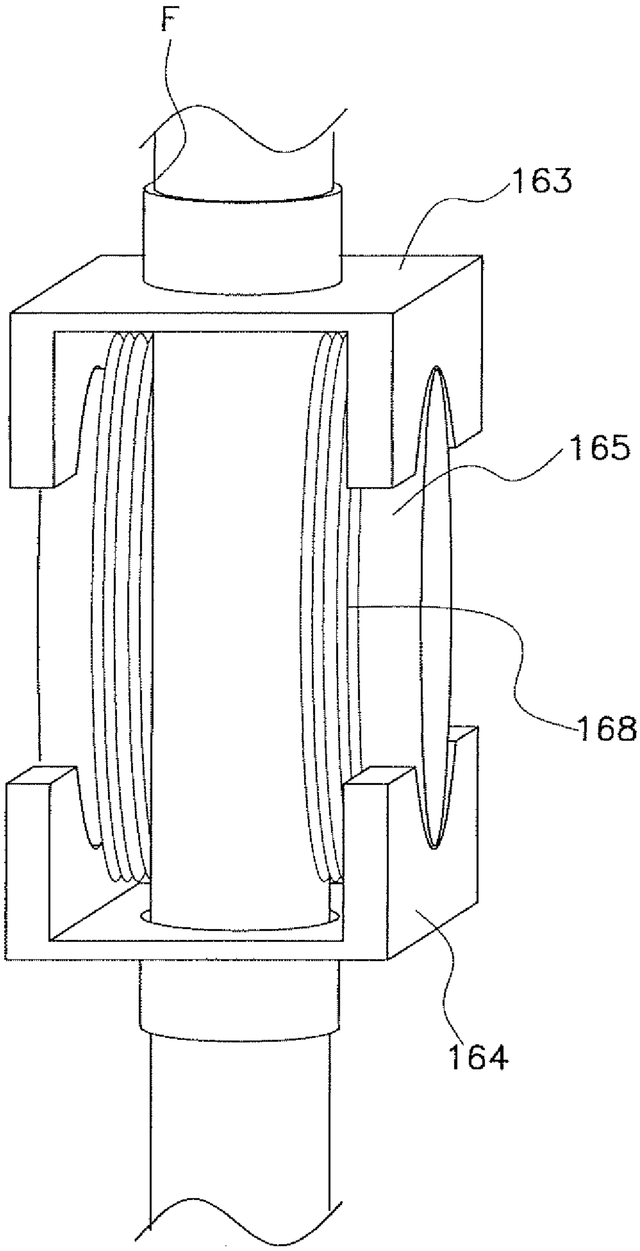


FIG. 15

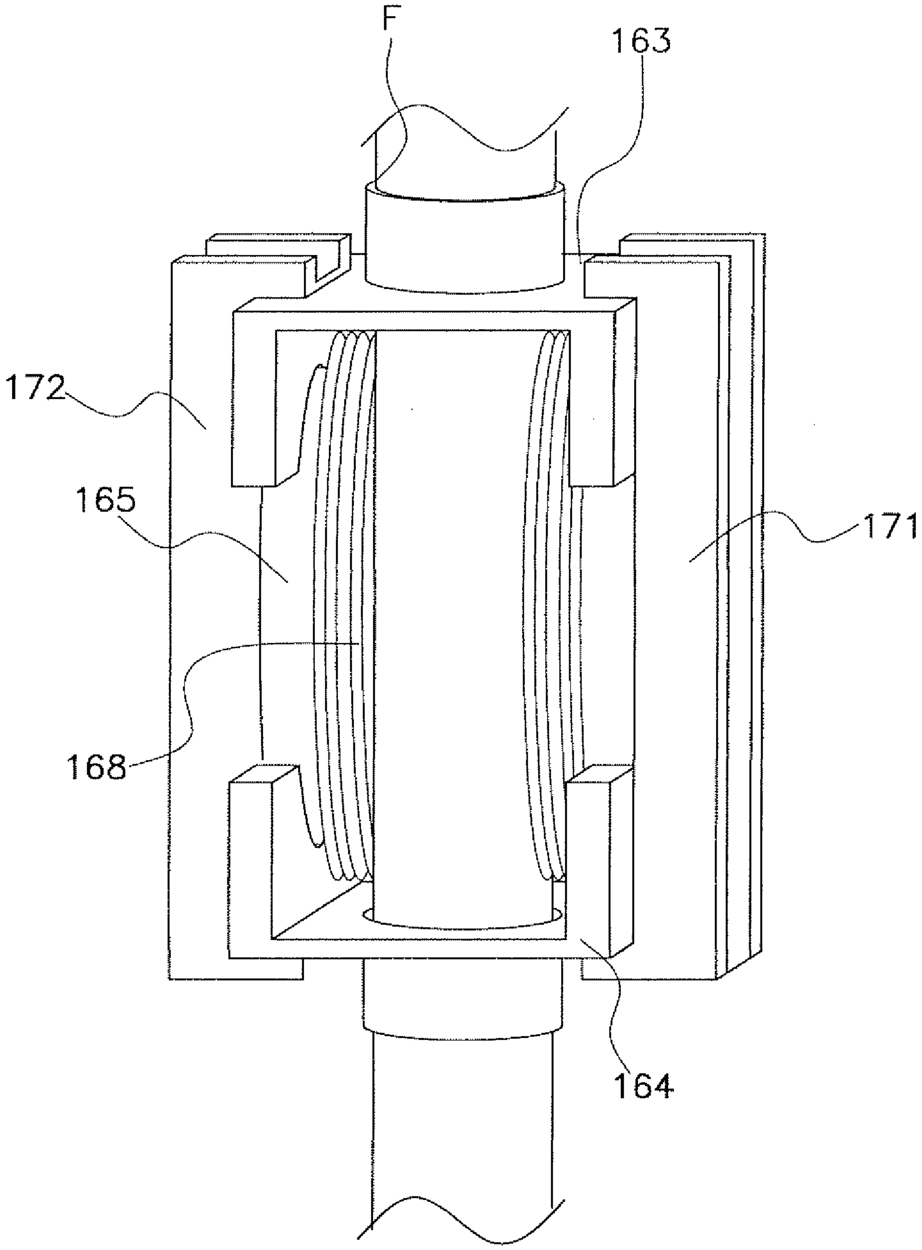


FIG. 16

**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2010/001994

A. CLASSIFICATION OF SUBJECT MATTER
*F25B1/00*(2006.01)i, *F25B13/00*(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)
F25B1/00, F25B13/00

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 | 1996-2010 |
| Kokai Jitsuyo Shinan Koho | 1971-2010 | Toroku Jitsuyo Shinan Koho | 1994-2010 |

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 2007-212035 A (Daikin Industries, Ltd.), 23 August 2007 (23.08.2007), entire text; all drawings & WO 2007/091566 A1 | 1-6 |
| A | JP 2000-220912 A (Daikin Industries, Ltd.), 08 August 2000 (08.08.2000), entire text; all drawings (Family: none) | 1-6 |
| A | JP 2002-5537 A (Daikin Industries, Ltd.), 09 January 2002 (09.01.2002), entire text; all drawings (Family: none) | 1-6 |

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 07 May, 2010 (07.05.10) | 18 May, 2010 (18.05.10) |

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

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2010/001994

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 11-248265 A (Matsushita Electric Industrial Co., Ltd.), 14 September 1999 (14.09.1999), claim 1; paragraph [0005]; fig. 1, 2 & JP 2947255 B | 1-6 |

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

## REFERENCES CITED IN THE DESCRIPTION



### Patent documents cited in the description

- JP 7120083 A **[0003] [0083]**