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(54) **REFRIGERATING MACHINE**

KÜHLMASCHINE

MACHINE FRIGORIFIQUE

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Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigerating machine.

BACKGROUND ART OF THE INVENTION

[0002] GM refrigerating machines are being utilized for measurement of physical properties of samples under cryogenic temperature environments near 4 K, measurement of various physical quantities using sensors that utilize a very low temperature environment, and the like. These refrigerating machines cool a target object by repeating compression and expansion (freezing cycle) of a refrigerant gas such as He gas. However, temperature oscillations occur in the mounting face on which the target object is mounted as a result of heat flow pulses attributable to the freezing cycle mentioned above. Reductions in these temperature oscillations are desired in order to stably cool the target object.

[0003] In Patent Document 1, there is disclosed a cryogenic refrigerating machine that includes; a regeneration device which is provided on a cooling unit to which a target object is attached, that stores helium gas or helium gas and liquid helium in its interior, and a helium gas introducing and discharging device that connects a compressed helium gas supply device and the regeneration device.

[0004] In Patent Document 2, there is disclosed a cryogenic temperature damper furnished with; a helium gas introduction inlet that introduces a required amount of helium gas at room temperature, a condenser chamber that condenses the helium gas, and a liquid helium chamber that stores the condensed liquid helium.

Patent Document 1: Japanese Patent No. 2773793

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2004-76955

[0005] Document US 2006/0048522 A1 discloses a partition member that partitions off a cooling stage of a refrigerator from a refrigerant container, containing a refrigerant gas condensed by the cooling stage, of a cooling system, and a low melting point metal held in the partition member that brings the cooling stage into thermal contact with the refrigerant container. This makes it possible to exchange only the broken refrigerator without stopping the operation of the cooling system.

[0006] Document EP1 557 624 A2 discloses a cryogenic system that includes a space formed between a cooling stage of a cryocooler unit and an element to be cooled, and a thermal joint placed in the space, wherein the thermal joint is composed of a substance that has a melting point higher than the cooling temperature of the element to be cooled and that is in a liquid or gaseous state at room temperature and atmospheric pressure.

[0007] Document US 3,188,830 A discloses a device for filtering heat flux excursions or oscillations and more particularly a thermal filter for smoothing oscillations in heat flux or cold being conducted from a cyclic refrigerator to an infrared detector at cryogenic temperatures.

DISCLOSURE OF INVENTION

Problems to be solved by the invention

[0008] However, since the temperature oscillation in the refrigerating machine disclosed in Patent Document 1 is approximately 30 mK, further reduction in the temperature oscillation is desired.

[0009] On the other hand, the construction of the cryogenic damper in Patent Document 2 is complex. Since the heat conduction flow path from the target object is long and nonaxisymmetric, there is concern that the cooling becomes uneven and unstable.

[0010] The present invention was made in order to solve the aforementioned problems, and has an object of providing a refrigerating machine which enables the temperature oscillations in the mounting face on which the target object is mounted to be reduced, and furthermore, enables cooling of the target object to be uniform and stable.

Means for solving the problem

[0011] In order to solve the abovementioned problems, the present invention employs the following. That is to say, a refrigerating machine according to the present invention includes: a cooling stage that cools a target object; a He condensation section which stores liquid He in its interior and comprises a table onto which said object is mounted the table being arranged on the bottom face of said He condensation section; a reservoir that communicates with said He condensation section, and is filled with He gas; and a heat transfer buffer member that is arranged between the bottom face of said cooling stage and the top face of said He condensation section, and is composed of a material having a thermal conductivity lower than that of said He condensation section, wherein corrugations are formed on a contact face between said heat transfer buffer member and said cooling stage or said condensation stage.

[0012] According to this configuration, the heat flow pulses attributable to the freezing cycles of the refrigerating machine are absorbed by evaporation and condensation (phase transitions) of the He in the He condensation section. At that time, since the heat transfer buffer member functions as a mechanism for restricting the heat flow, the transfer of temperature oscillations in the cooling stage is controlled. As a result, it is possible to reduce the temperature oscillations in the mounting face on which the target object is mounted. Further, since the cooling stage, the heat transfer buffer member, the He condensation section, and the target object are sequen-

tially arranged in a coaxial manner, uniform and stable cooling of the target object becomes possible. Since, according to this configuration, the contact area between the heat transfer buffer member and the cooling stage or the He condensation section becomes smaller, transfer of the temperature oscillations to the cooling stage can be suppressed. As a result, the temperature oscillations in the mounting face on which the target object is mounted can be reduced.

[0013] It may be arranged such that the He condensation section is composed of a material with a thermal conductivity of 200 W/(m·K) or more at temperatures near 4 K.

[0014] According to this configuration, the target object can be efficiently cooled by the liquid He that has been condensed in the He condensation section.

[0015] It may be arranged such that the heat transfer buffer member is composed of a material with a thermal conductivity of less than 100 W/(m·K) at temperatures near 4 K.

[0016] According to this configuration, the transfer of temperature oscillations in the cooling stage can be prevented with certainty.

[0017] It may be arranged such that a volume capacity of the He condensation section is 10 cc or more and 100 cc or less.

[0018] According to this configuration, the He condensation section can be made compact while ensuring the storage volume of liquid He that is required for cooling the target object.

[0019] It may be arranged such that a volume capacity of the reservoir is 5 to 100 times the volume capacity of the He condensation section.

[0020] According to this configuration, the reservoir can be made compact while ensuring the storage volume of He gas that is required for cooling the target object.

[0021] It may be arranged such that a pressure of the He gas filled in the reservoir is 0.1 MPa or more and 1.0 MPa or less at room temperature.

[0022] According to this configuration, even if the refrigerating machine stops and the liquid He of the He condensation section evaporates, a situation where the reservoir and He condensing section become a high pressure can be prevented.

[0023] It may be arranged such that a fin is vertically installed on an inner surface of the He condensation section.

[0024] Further, it may be arranged such that a porous structure is installed on an inner surface of the He condensation section.

[0025] According to these configurations, since the contact area between the inner surface of the He condensation section and the liquid He becomes larger, the target object that is mounted on the He condensation section can be efficiently cooled.

[0026] In addition, it may be arranged such that the refrigerating machine further includes: a temperature sensor and a heater that are installed in the He conden-

sation section; and a control section that drives the heater based on measurement results of the temperature sensor.

[0027] According to this configuration, in the case where the temperature of the He condensation section falls below a predetermined value, the heater can be driven to restore the temperature of the He condensing section to a predetermined value. Consequently, the temperature oscillations in the mounting face on which the target object is mounted can be reduced.

Advantageous effects of the invention

[0028] According to the present invention, by providing a heat transfer buffer member, transfer of the temperature oscillations in the cooling stage are prevented, and as a result, the temperature oscillations in the mounting face on which the target object is mounted can be reduced. Furthermore, since the cooling stage, the heat transfer buffer member, the He condensation section, and the target object are sequentially arranged in a coaxial manner, uniform and stable cooling of the target object becomes possible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029]

FIG. 1 is a schematic block diagram of a refrigerating machine according to a first embodiment of the present invention.

FIG. 2 is a graph showing a relationship between temperature of a second cooling stage and temperature oscillations.

FIG. 3 is a graph showing a relationship between a volume ratio of liquid He in the He condensation section and temperature oscillations.

FIG. 4 is a graph showing a relationship between temperature of the second cooling stage and cooling capacity.

FIG. 5 is a graph showing a relationship between cooling time and temperature of the second cooling stage.

FIG. 6 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to a second embodiment of the present invention.

FIG. 7 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to a third embodiment of the present invention.

FIG. 8 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to a fourth embodiment of the present invention.

FIG. 9 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to a fifth embodiment of the present

invention.

Description of the reference symbols

[0030]

1	Refrigerating machine
14	Second cooling stage (cooling stage)
16	Heat transfer buffer member
18	Corrugations
20	He condensation section
30	Reservoir
40	Target object
50	He gas
62	Control section
64	Temperature sensor
66	Heater
222	First fin (fin)
224	Second fin (fin)
322	Porous structure

BEST MODE FOR CARRYING OUT THE INVENTION

[0031] Hereunder is a description of embodiments of the present invention with reference to the drawings.

(First Embodiment)

[0032] FIG. 1 is a schematic block diagram of a refrigerating machine according to a first embodiment of the present invention. The refrigerating machine 1 according to the present embodiment includes; a second cooling stage 14 for cooling a target object 40, a He condensation section 20 onto which the target object 40 is mounted, a reservoir 30 which is filled with He gas 50 and that communicates with the He condensation section 20, and a heat transfer buffer member 16 that is arranged between the second cooling stage 14 and the He condensation section 20 and is composed of a material that has a lower thermal conductivity than the He condensation section 20.

[0033] The refrigerating machine 1 is primarily furnished with a compressor 4, a main body 2, and a cooling unit 15. The compressor 4 compresses low pressure He gas that is supplied from a low-pressure pipe 8 and supplies it to a high pressure piping 6 as high-pressure He gas. The main body 2 continuously switches a connection of the He gas flow path between the high pressure piping 6 and the low pressure piping 8 within the cooling unit 15 mentioned below, by a driving force from a motor or the like.

[0034] The cooling unit 15 is provided so as to be continuous with the main body 2. The cooling unit 15 is arranged in the interior of a vacuum chamber 10 that is maintained at a vacuum environment, and generates coldness by expansion of the He gas that circulates within the interior. In the cooling unit 15 there is sequentially provided a first cooling section 11, a first cooling stage

12, a second cooling section 13, and the second cooling stage 14. The first cooling section 11 and the second cooling section 13 are formed in a cylindrical shape, and the first cooling stage 12 and the second cooling stage 14 are formed in a disk shape, and are coaxially arranged. A He gas flow path (not shown in the drawings) is formed in the interior of the cooling unit 15. The high-pressure He gas that is supplied to the He gas flow path expands endothermically in the second cooling stage 14, and changes into low-pressure He gas.

[0035] The heat transfer buffer member 16 is provided on the bottom face of the second cooling stage 14, the bottom face being between the second cooling stage 14 and the He condensation section 20 mentioned below. The heat transfer buffer member 16 is formed in a plate shape, for example with a diameter of several tens of mm, and a thickness of around 2 mm. The heat transfer buffer member 16 is configured by a material such as stainless material, that has a lower thermal conductivity than the later mentioned He condensation section 20 at temperatures near 4 K. In particular, if the heat transfer buffer member 16 is composed of a material with a thermal conductivity lower than 100 W/(m·K) at temperatures near 4 K, the transfer of the temperature oscillations of the second cooling stage 14 to the He condensation section 20 can be suppressed.

[0036] In order to increase the thermal connectivity, the second cooling stage 14, the heat transfer buffer member 16, and the He condensation section 20 are fastened while In foil or the like is placed on both surfaces of the heat transfer buffer member 16.

[0037] The He condensation section 20 on which the target object is mounted, is provided on the bottom face of the heat transfer buffer member 16. The He condensation section 20 is configured by a material such as Cu, Ag, or A1, that has a higher thermal conductivity than the aforementioned heat transfer buffer member 16 at temperatures near 4 K. In the present embodiment, the He condensation section 20 is formed from oxygen-free copper. In particular, if the He condensation section 20 is configured by a material with a thermal conductivity of 200 W/(m·K) or more at temperatures near 4 K, the target object 40 can be cooled efficiently by the liquid He condensed in the He condensation section 20.

[0038] The He condensation section 20 is formed in a cylindrical shape with both ends sealed, and stores liquid He in its interior. If the volume capacity of the He condensation section is made to be 10 cc or more and 100 cc or less, the He condensation section can be made compact while ensuring the storage volume of liquid He required for cooling the target object. In the present embodiment, the volume capacity of the He condensation section 20 is set as 40 cc.

[0039] A table 41 is arranged on the bottom face of the He condensation section 20. The bottom face of the table 41 is a cooling position, which is the mounting location of the target object 40. The table 41 is composed of a material that has similar physical properties to the He

condensation section 20. In the present embodiment, the He condensation section 20 and the table 41 are fastened to each other while In foil or the like is placed between the He condensation section 20 and the table 41, and between the table 41 and the target object 40. The target object 40 may be placed with good thermal contact to the He condensation section 20, without providing the table 41.

[0040] The second cooling stage 14 of the cooling unit 15, the heat transfer buffer member 16, the He condensation section 20, and the target object 40 constitute a heat conduction flow path from the target object. In the present embodiment, by sequentially arranging these in a coaxial manner, it is possible to shorten the distance of the heat conduction flow path. As a result, it is possible to reduce cooling losses, and the target object 40 can be efficiently cooled to the target temperature in a short time. Further, it is possible to make the heat conduction flow path axisymmetric, so that the whole of the target object 40 can be uniformly and stably cooled.

[0041] A narrow tube 32 is extended from the He condensation section 20 and is constantly connected to the reservoir 30 that is arranged on the exterior of the vacuum chamber 10. It is desirable to make the volume capacity of the reservoir 30 from 5 to 100 times the volume capacity of the He condensation section 20. In the present embodiment, the volume capacity of the reservoir 30 is set as 3250 cc. As a result, the reservoir 30 can be made compact while ensuring the storage volume of He gas required for cooling the target object 40.

[0042] He gas is filled in the interior of the reservoir 30. It is preferable for the pressure of the He gas to be 0.1 MPa or more and 1.0 MPa or less at room temperature. In the present embodiment, He gas 50 that has a pressure of 0.4 MPa at room temperature is filled in the reservoir 30. As a result, even if the refrigerating machine 1 stops and the liquid He 52 in the He condensation section 20 evaporates, the reservoir 30 will not become a high pressure. A thermal anchor 34 for heat exchange with the first cooling stage 12 is formed in a central portion of the narrow tube 32.

[0043] Next is a description of the operation of the refrigerating machine 1 according to the present embodiment. As mentioned above, the high-pressure He gas that is supplied to the cooling unit 15 from the compressor 4, expands endothermically in the second cooling stage 14, and changes into low-pressure He gas. The main body 2 continuously switches the connection of the He gas flow path of the cooling unit 15, between the high pressure piping 6 and the low pressure piping 8. As a result, the compression and expansion (freezing cycle) of the He gas is repeated, and thereby the temperature of the second cooling stage 14 becomes a cryogenic temperature.

[0044] The He condensation section 20 is provided on the lower side of the second cooling stage 14. When the He condensation section 20 is cooled by the second cooling stage 14, the He gas in the interior of the He conden-

sation section 20 is condensed and liquefied, and liquid He 52 is produced. In the present embodiment, the liquid He is produced such that the volume ratio with respect to the volume capacity of the He condensation section 20 is 30% or less (for example, around 20%).

[0045] Incidentally, due to the heat flow pulses attributable to the aforementioned freezing cycle, temperature oscillations occur in the second cooling stage 14. However, in the present embodiment, the heat flow pulses attributable to the freezing cycle are absorbed by evaporation and condensation (phase transition) of the He. Consequently temperature oscillations equivalent to those in the second cooling stage 14 do not occur in the He condensation section 20, and thereby the temperature oscillations in the He condensation section 20 become small.

[0046] In addition, in the present embodiment, the heat transfer buffer member 16, which is composed of a material having a thermal conductivity lower than that of the He condensation section 20, is provided between the second cooling stage 14 and the He condensation section 20. The heat transfer buffer member 16 functions as a mechanism for restricting the heat flow. Therefore transfer of the temperature oscillations in the second cooling stage 14 to the He condensation section 20 can be suppressed. Consequently the temperature oscillations in the mounting face on which the target object is mounted can be reduced.

[0047] FIG. 2 is a graph showing a relationship between the temperature of the second cooling stage and temperature oscillations. Here the temperature oscillations were measured for three types of apparatus configurations. Specifically, (1) temperature oscillations in the He condensation section 20 in the case where, as with the present embodiment, the second cooling stage 14, the heat transfer buffer member 16, and the He condensation section 20 were provided (diamond symbol plot), (2) temperature oscillations in the He condensation section 20 in the case where the second cooling stage 14 and the He condensation section 20 were provided without the heat transfer buffer member 16 (triangle symbol plot), and (3) temperature oscillations in the second cooling stage 14 in the case where neither the heat transfer buffer member 16 nor the He condensation section 20 were provided (circle symbol plot), were measured. The horizontal axis represents the temperature at the cooling position (position where the temperature oscillation were measured), which is the mounting location of the target object. The volume of the reservoir 30 was set as 3250 cc, the fill pressure of the He gas to the reservoir 30 was set as 0.4 MPa, and the volume ratio of the liquid He in the He condensation section 20 was set as 20%.

[0048] As a result, the magnitudes of the temperature oscillations in the apparatus configurations were in order of (3) > (2) > (1). The higher the temperature at the cooling position, the greater the difference in the temperature oscillations between the apparatus configurations. Further, in the apparatus configuration (1), the temperature

oscillations of the He condensation section 20 could be suppressed to ± 9 mK in the case of a cooling position temperature of 4.2 K. The above measurement results confirmed that, compared to the apparatus configuration (3) with only the second cooling stage 14, the temperature oscillations are significantly lowered in the apparatus configuration (2) in which the He condensation section 20 has been added, and the temperature oscillations in the apparatus configuration (1), in which the heat transfer buffer member 16 and the He condensation section 20 are added, are further lowered compared to the configuration (2).

[0049] FIG. 3 is a graph showing a relationship between the volume ratio of liquid He in the He condensation section and the temperature oscillations. Here, (1) temperature oscillations in the case where, as with the present embodiment, a heat transfer buffer member was provided (diamond symbol plot), and (2) temperature oscillations in the case where a heat transfer buffer member was not provided (triangle symbol plot), were measured. The volume capacity of the reservoir 30 was set as 3250 cc, the maximum fill pressure of the He gas to the reservoir 30 was set as 0.48 MPa, and the temperature at the cooling position was set as 4.2 K.

[0050] As a result, regardless of the volume ratio of the liquid He, the magnitudes of the temperature oscillations were in order of (2) > (1). Moreover the temperature oscillations became large in the case where there was no liquid He. However in the case where even a small amount of liquid He was present, the temperature oscillations became small. Further, in the case where the volume percentage of the liquid He in (1) was 1% to 30%, the temperature oscillations of the He condensation section 20 were suppressed to ± 9 mK for both. From the above it was confirmed that even with a small amount of liquid He there was the effect that the temperature oscillations can be significantly reduced.

[0051] Incidentally, in the present embodiment, it was thought that since a heat transfer buffer member 16 with a thermal conductivity lower than that of the He condensation section 20 was provided, the cooling capacity of the refrigerating machine would be decreased. Therefore, the inventors of the present invention investigated differences in the cooling capacity with the presence or absence of the heat transfer buffer member 16.

[0052] FIG. 4 is a graph showing a relationship between the temperature at the cooling position and cooling capacity. Here, (1) the cooling capacity in the case where, as with the present embodiment, the heat transfer buffer member 16 was provided (diamond symbol plot), and (2) the cooling capacity in the case where the heat transfer buffer member was not provided (square symbol plot), were measured. The volume ratio of the liquid He in the He condensation section 20 was set as 20%.

[0053] As a result, regardless of the temperature at the cooling position, the rate of decrease of the cooling capacity due to the provision of the heat transfer buffer member 16 was approximately 25%. Consequently it was

confirmed that the loss in cooling capacity can be suppressed to several tens of percent.

[0054] Furthermore, in the present embodiment, it was thought that since the heat transfer buffer member 16 with a thermal conductivity lower than that of the He condensation section 20 was provided, the cooling time would be increased. Therefore the inventors of the present invention investigated differences in the cooling time with the presence or absence of the heat transfer buffer member 16.

[0055] FIG. 5 is a graph showing a relationship between the cooling time and the temperature at the cooling position. Here, (1) the temperature at the cooling position in the case where, as with the present embodiment, the heat transfer buffer member was provided (solid line), and (2) the temperature at the cooling position in the case where the heat transfer buffer member was not provided (square symbol plot), were measured. As a result, it was confirmed that there was almost no difference in the cooling time with the presence or the absence of the heat transfer buffer member 16.

[0056] As described in detail above, the refrigerating machine (refer to FIG. 1) according to the present embodiment was configured with the heat transfer buffer member 16 composed of a material having a thermal conductivity lower than that of the He condensation section 20, provided between the He condensation section 20 on which the target object 40 is mounted, and the second cooling stage 14. According to this configuration, the heat flow pulses attributable to the freezing cycle of the refrigerating machine 1 are absorbed by evaporation and condensation (phase transition) of the He in the He condensation section. At that time, the heat transfer buffer member 16 functions as a mechanism for restricting the heat flow. Therefore transfer of the temperature oscillations in the second cooling stage 14 is suppressed. As a result, temperature oscillations in the mounting face on which the target object 40 is mounted can be reduced. Further, since the second cooling stage 14, the heat transfer buffer member 16, the He condensation section 20, and the target object 40 are sequentially arranged in a coaxial manner, the heat conduction flow path from the target object becomes axisymmetric and a short distance. Consequently, uniform and stable cooling of the target object 40 becomes possible.

[0057] In addition, according to the present embodiment, the volume ratio of the liquid He 52 in the He condensation section 20 can be suppressed to 30% or less. Consequently it is possible to miniaturize the reservoir 30 that is filled with the He gas 50. Moreover it is possible to lower the fill pressure of the He gas 50 at room temperature with respect to the reservoir 30. As a result, even if the refrigerating machine 1 stops and the liquid He 52 of the He condensation section 20 evaporates, a situation where the reservoir 30 and the He condensation section become a high pressure can be prevented.

(Second Embodiment)

[0058] Next is a description of a refrigerating machine according to a second embodiment of the present invention.

[0059] FIG. 6 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to the present embodiment. In the refrigerating machine according to the present embodiment, fins 222 and 224 are vertically installed on inner surfaces 221 and 223 of a He condensing section 220. Detailed description of parts with the same configuration as in the first embodiment is omitted.

[0060] The He condensation section 220 is arranged between a second cooling stage 14 and a target object 40.

[0061] The He condensation section 220 is a cylindrical hollow container composed of a material such as Cu, Ag, or A1, and is filled with He gas 50. When the He condensation section 220 is cooled by the second cooling stage 14, the He gas becomes condensed to be liquid He 52. By means of the liquid He 52, the target object 40 is cooled.

[0062] A plurality of the fins 222 and 224 is vertically installed on the inner surfaces of the He condensation section 220. It is preferable for the fins 222 and 224 to be composed of a material with a high thermal conductivity, as with the He condensation section 220. The fins 222 and 224 may be either integrally formed with the He condensation section 220, or formed separately and attached to the He condensation section 220.

[0063] The first fins 222 are formed towards the ceiling surface 223 from the bottom surface 221 of the He condensation section 220. As a result it becomes possible for the contact area between the inner surface of the He condensation section 220 and the liquid He 52 to be made large. Consequently the target object 40 mounted on the He condensation section 220 can be efficiently cooled.

[0064] The second fins 224 are formed towards the bottom surface 221 from the ceiling surface 223 of the He condensation section 220. As a result it becomes possible for the contact area between the inner surface of the He condensation section 220 and the He gas 50 to be made large. Consequently the He gas 50 in the interior of the He condensation section 220 can be efficiently cooled and condensed.

(Third Embodiment)

[0065] Next is a description of a refrigerating machine according to a third embodiment of the present invention.

[0066] FIG. 7 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to the present embodiment. In the refrigerating machine according to the present embodiment, a porous structure 322 is installed on the inner surface of a He condensation section 320. Detailed description of parts with the same configuration as in the

first embodiment is omitted.

[0067] The porous structure 322 is installed on the inner surface of the He condensation section 320. The porous structure 322 is composed of a material such as mesh, foamed metal, sintered metal, or the like. The porous structure 322 may fill the entire interior of the He condensation section 320, or may fill only a part.

[0068] The porous structure 322 is installed on the inner surface of the He condensation section 320 using an adhesive or the like, in order to maintain good thermal connectivity with the inner surface of the He condensation section 320.

[0069] By providing the porous structure 322, it becomes possible for the contact area between the inner surface of the He condensation section 320 and the liquid He 52 to be made large. Consequently the target object 40 mounted on the He condensation section 320 can be efficiently cooled. Further, by providing the porous structure 322, it becomes possible for the contact area between the inner surface of the He condensation section 320 and the He gas 50 to be made large. Consequently the He gas 50 in the interior of the He condensation section 320 can be efficiently cooled and condensed.

(Fourth Embodiment)

[0070] Next is a description of a refrigerating machine according to a fourth embodiment of the present invention.

[0071] FIG. 8 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to the present embodiment. In the refrigerating machine according to the present embodiment, corrugations 18 are formed on the contact face of the heat transfer buffer member 16 with the second cooling stage 14. Detailed description of parts with the same configuration as in the first embodiment is omitted.

[0072] The heat transfer buffer member 16 is composed of a material such as a stainless material that has a low thermal conductivity. The corrugations 18 are formed on its contact face with the second cooling stage 14. The corrugations 18 may be regularly formed or irregularly (randomly) formed. Further, the corrugations 18 may be formed in a cone shape such that they make point contact with the second cooling stage 14, or the corrugations 18 may be formed in a truncated pyramid shape such that they make facial contact with the second cooling stage 14. In addition, the corrugations 18 may be convex with a triangular cross-section such that they make line contact with the second cooling stage 14, or the corrugations 18 may be convex with a trapezoidal cross-section such that they make facial contact in a belt-like shape with the second cooling stage 14.

[0073] In the present embodiment, since the corrugations 18 are formed on the contact face of the heat transfer buffer member 16 with the second cooling stage 14, the contact area between the heat transfer buffer member 16 and the second cooling stage 14 becomes smaller.

As a result, compared to the case where the heat transfer buffer member 16 and the second cooling stage 14 make complete facial contact, the function for restricting the heat flow is strengthened. Therefore it becomes possible to suppress the transfer of the temperature oscillations of the second cooling stage 14 to the He condensation section 420. Consequently the temperature oscillations in the mounting face on which the target object is mounted can be reduced.

[0074] In the present embodiment, the corrugations 18 are formed on the contact face of the heat transfer buffer member 16 with the second cooling stage 14. However the corrugations may be formed on the contact face of the second cooling stage 14 with the heat transfer buffer member 16. Moreover the corrugations may be formed on the contact face of the heat transfer buffer member 16 with the He condensation section 420, or the corrugations may be formed on the contact face of the He condensation section 420 with the heat transfer buffer member 16. That is to say, it is sufficient if the corrugations are formed on the contact face between the second cooling stage 14 or the He condensation section 420 with the heat transfer buffer member 16. In all cases, it becomes possible to suppress the transfer of the temperature oscillations in the second cooling stage 14 to the He condensation section 420. Consequently the temperature oscillations in the mounting face on which the target object is mounted can be reduced.

(Fifth Embodiment)

[0075] Next is a description of a refrigerating machine according to a fifth embodiment of the present invention.

[0076] FIG. 9 is a schematic block diagram of the vicinity of the He condensation section of a refrigerating machine according to the present embodiment. The refrigerating machine according to the present embodiment is provided with a temperature sensor 64 and a heater 66 installed on a He condensation section 520, and a control section 62 that drives the heater 66 based on measurement results of the temperature sensor 64. Detailed description of parts with the same configuration as in the first embodiment is omitted.

[0077] In the present embodiment, the temperature sensor 64 is installed near the mounting face on which the target object 40 is mounted in the He condensation section 520. Further, the heater 66 which is provided with electrically-heated wires or the like is installed on the He condensation section 520. The temperature sensor 64 and the heater 66 are connected to the control section 62. The control section 62 drives the heater 66 based on the measurement results of the temperature sensor 64. That is to say, it converts an output signal of the temperature sensor 64 into a driving current for the heater 66. In addition, it performs control by flowing a feedback current to the heater 66 so that the temperature pulses attributable to the heat generation become a minimum.

[0078] Specifically, at first a set temperature of the

mounting face on which the target object 40 is mounted and the measured temperature of the temperature sensor 64 are compared. When the measured temperature is lower than the set temperature, the heater is driven to heat the He condensation section 520. As a result, it becomes possible for the temperature of the mounting face on which the target object 40 is mounted to be raised and returned to the set temperature. Consequently the temperature oscillations in the mounting face on which the target object 40 is mounted can be reduced.

[0079] The technological scope of the present invention is in no way limited by the aforementioned embodiments, and includes embodiments in which various modifications have made to the aforementioned embodiments, within a scope which does not depart from the gist of the present invention. That is to say, the specific materials and configurations mentioned in the embodiments are merely an example, and appropriate modifications are possible.

INDUSTRIAL APPLICABILITY

[0080] It is possible to provide a refrigerating machine which enables temperature oscillations in the mounting face on which a target object is mounted to be reduced, and enables cooling of the target object to be uniform and stable.

Claims

1. A refrigerating machine (1) comprising:

- a cooling stage (14) that cools a target object (40);
- a He condensation section (20);
- a reservoir (30) that communicates with said He condensation section (20), and is filled with He gas (50); and
- a heat transfer buffer member (16) that is arranged between the bottom face of said cooling stage (14) and the top face of said He condensation section (20), and is composed of a material having a thermal conductivity lower than that of said He condensation section (20),

wherein the He condensation section (20) stores liquid He in its interior and comprises a table onto which said object is mounted, the table being arranged on the bottom face of said He condensation section (20),

characterized in that:

- corrugations (18) are formed on a contact face between said heat transfer buffer member (16) and said cooling stage (14) or said He condensation section (20).

2. The refrigerating machine (1) according to claim 1, wherein said He condensation section (20) is composed of a material with a thermal conductivity of 200 W/(m·K) or more at temperatures near 4 K.
3. The refrigerating machine (1) according to claim 1, wherein said heat transfer buffer member (16) is composed of a material with a thermal conductivity of less than 100 W/(m·K) at temperatures near 4 K.
4. The refrigerating machine (1) according to claim 1, wherein a volume capacity of said He condensation section (20) is 10 cc or more and 100 cc or less.
5. The refrigerating machine (1) according to claim 1, wherein a volume capacity of said reservoir (30) is 5 to 100 times the volume capacity of said He condensation section (20).
6. The refrigerating machine (1) according to claim 1, wherein a pressure of said He gas (50) filled in said reservoir (30) is 0.1 MPa or more and 1.0 MPa or less at room temperature.
7. The refrigerating machine (1) according to claim 1, wherein a fin is vertically in-stalled on an inner surface (221, 223) of said He condensation section (20).
8. The refrigerating machine (1) according to claim 1, wherein a porous structure is installed on an inner surface (221, 223) of said He condensation section (20).
9. The refrigerating machine (1) according to claim 1, further comprising:

a temperature sensor (64) and a heater (66) that are installed in said He condensation section (20); and
a control section (62) that drives said heater (66) based on measurement results of said temperature sensor (64).

Patentansprüche

1. Kühlmaschine (1), umfassend:

eine Kühlstufe (14), die ein Zielobjekt (40) kühlt;
einen He-Kondensationsabschnitt (20);
einen Vorratsbehälter (30), der mit dem He-Kondensationsabschnitt (20) kommuniziert, und der mit He-Gas (50) gefüllt ist; und
ein Wärmeübertragungspufferelement (16), das zwischen der Unterseite der Kühlstufe (14) und der Oberseite des He-Kondensationsabschnitts (20) angeordnet ist, und das aus einem Material gemacht ist, das eine Wärmeleitfähigkeit auf-

weist, die geringer ist als die des He-Kondensationsabschnitts (20),

wobei der He-Kondensationsabschnitt (20) flüssiges He in seinem Inneren speichert und einen Tisch umfasst, auf dem das Objekt angebracht ist, wobei der Tisch an der Unterseite des He-Kondensationsabschnitts (20) angeordnet ist,

dadurch gekennzeichnet, dass:

Riffeln (18) an einer Kontaktfläche zwischen dem Wärmeübertragungspufferelement (16) und der Kühlstufe (14) oder dem He-Kondensationsabschnitt (20) gebildet sind.

2. Kühlmaschine (1) nach Anspruch 1, wobei der He-Kondensationsabschnitt (20) aus einem Material mit einer Wärmeleitfähigkeit von 200 W / (m·K) oder mehr bei Temperaturen nahe 4 K gemacht ist.
3. Kühlmaschine (1) nach Anspruch 1, wobei das Wärmeübertragungspufferelement (16) aus einem Material mit einer Wärmeleitfähigkeit von weniger als 100 W/(m·K) bei Temperaturen nahe 4 K gemacht ist.
4. Kühlmaschine (1) nach Anspruch 1, wobei eine Volumenkapazität des He-Kondensationsabschnitts (20) 10 cc oder mehr und 100 cc oder weniger beträgt.
5. Kühlmaschine (1) nach Anspruch 1, wobei eine Volumenkapazität des Vorratsbehälters (30) das 5- bis 100-fache der Volumenkapazität des He-Kondensationsabschnitts (20) beträgt.
6. Kühlmaschine (1) nach Anspruch 1, wobei ein Druck des in den Vorratsbehälter (30) gefüllten He-Gases (50) 0,1 MPa oder mehr und 1,0 MPa oder weniger bei Raumtemperatur beträgt.
7. Kühlmaschine (1) nach Anspruch 1, wobei eine Finne vertikal an einer inneren Oberfläche (221, 223) des He-Kondensationsabschnitts (20) installiert ist.
8. Kühlmaschine (1) nach Anspruch 1, wobei eine poröse Struktur an einer inneren Oberfläche (221, 223) des He-Kondensationsabschnitts (20) installiert ist.
9. Kühlmaschine (1) nach Anspruch 1, des Weiteren umfassend:

einen Temperatursender (64) und ein Heizelement (66), die in dem He-Kondensationsabschnitt (20) installiert sind; und
einen Steuerabschnitt (62), der das Heizelement (66) basierend auf Messergebnissen des Temperatursensors (64) betreibt.

Revendications**1.** Machine (1) frigorifique, comprenant :

un étage (14) de refroidissement, qui refroidit un objet (40) cible ;
 une section (20) de condensation à l'hélium ;
 un réservoir (30), qui communique avec la section (20) de condensation d'hélium, et est rempli d'hélium (50) gazeux et
 un élément (16) tampon de transfert thermique, qui est agencé entre la face de fond de l'étage (14) de refroidissement et la face supérieure de la section (20) de condensation d'hélium et qui est composé d'un matériau ayant une conductivité thermique inférieure à celle de la section (20) de condensation d'hélium, dans lequel la section (20) de condensation d'hélium stocke de l'hélium liquide en son sein et comporte une table sur laquelle l'objet est monté, la table étant agencée sur la face de fond de la section (20) de condensation d'hélium,

caractérisée en ce que :

des ondulations (18) sont formées sur une face de contact entre l'élément (16) de tampon de transfert thermique et l'étage (14) de refroidissement ou la section (20) de condensation d'hélium.

- 2.** Machine (1) frigorifique suivant la revendication 1, dans laquelle la section (20) de condensation d'hélium est constituée d'un matériau ayant une conductivité thermique de 200 W/(m·K) ou plus à des températures proches de 4 K.
- 3.** Machine (1) frigorifique suivant la revendication 1, dans laquelle l'élément (16) tampon de transfert thermique est constitué d'un matériau ayant une conductivité thermique inférieure à 100 W/(m·K) à des températures proches de 4 K.
- 4.** Machine (1) frigorifique suivant la revendication 1, dans laquelle une capacité volumique de la section (20) de condensation d'hélium est de 10 cm³ ou plus et de 100 cm³ ou moins.
- 5.** Machine (1) frigorifique suivant la revendication 1, dans laquelle une capacité de volume du réservoir (30) est de 5 à 100 fois la capacité de volume de la section (20) de condensation d'hélium.
- 6.** Machine (1) frigorifique suivant la revendication 1, dans laquelle une pression de l'hélium (50) gazeux qui remplit le réservoir (30) est de 0,1 MPa ou plus et de 1,0 MPa ou moins à la température ambiante.

7. Machine (1) frigorifique suivant la revendication 1, dans laquelle une ailette est montée verticalement sur une surface (221, 223) intérieure de la section (20) de condensation d'hélium.

8. Machine (1) frigorifique suivant la revendication 1, dans laquelle une structure poreuse est installée sur une surface intérieure (221, 223) de la section (20) de condensation d'hélium.

9. Machine (1) frigorifique suivant la revendication 1, comprenant, en outre :

une sonde (64) de température et un dispositif (66) de chauffage, qui sont montés dans la section (20) de condensation d'hélium et une section (62) de commande qui entraîne le dispositif (66) de chauffage sur la base des résultats de mesure de la sonde (64) de température.

FIG. 1

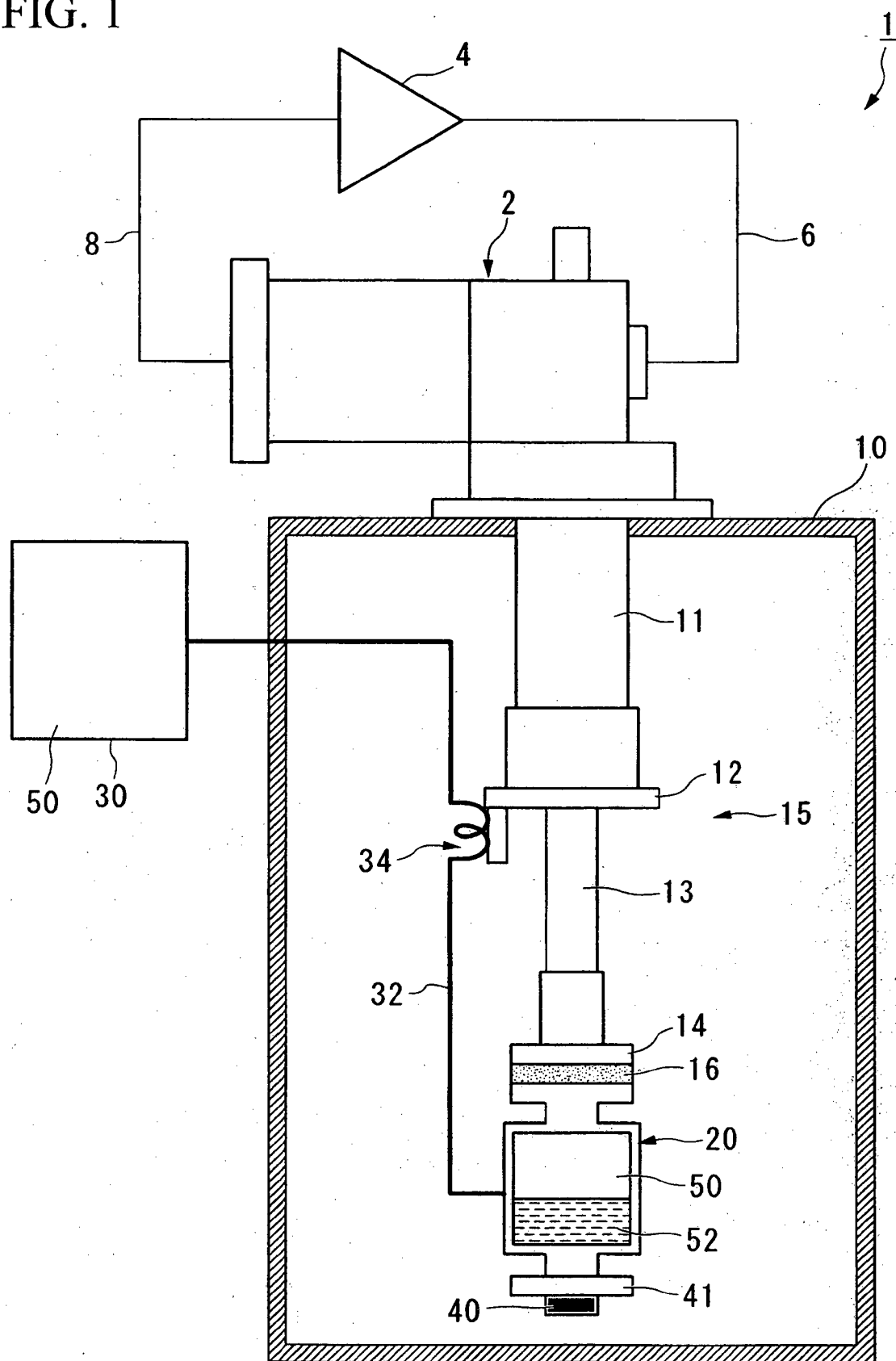


FIG. 2

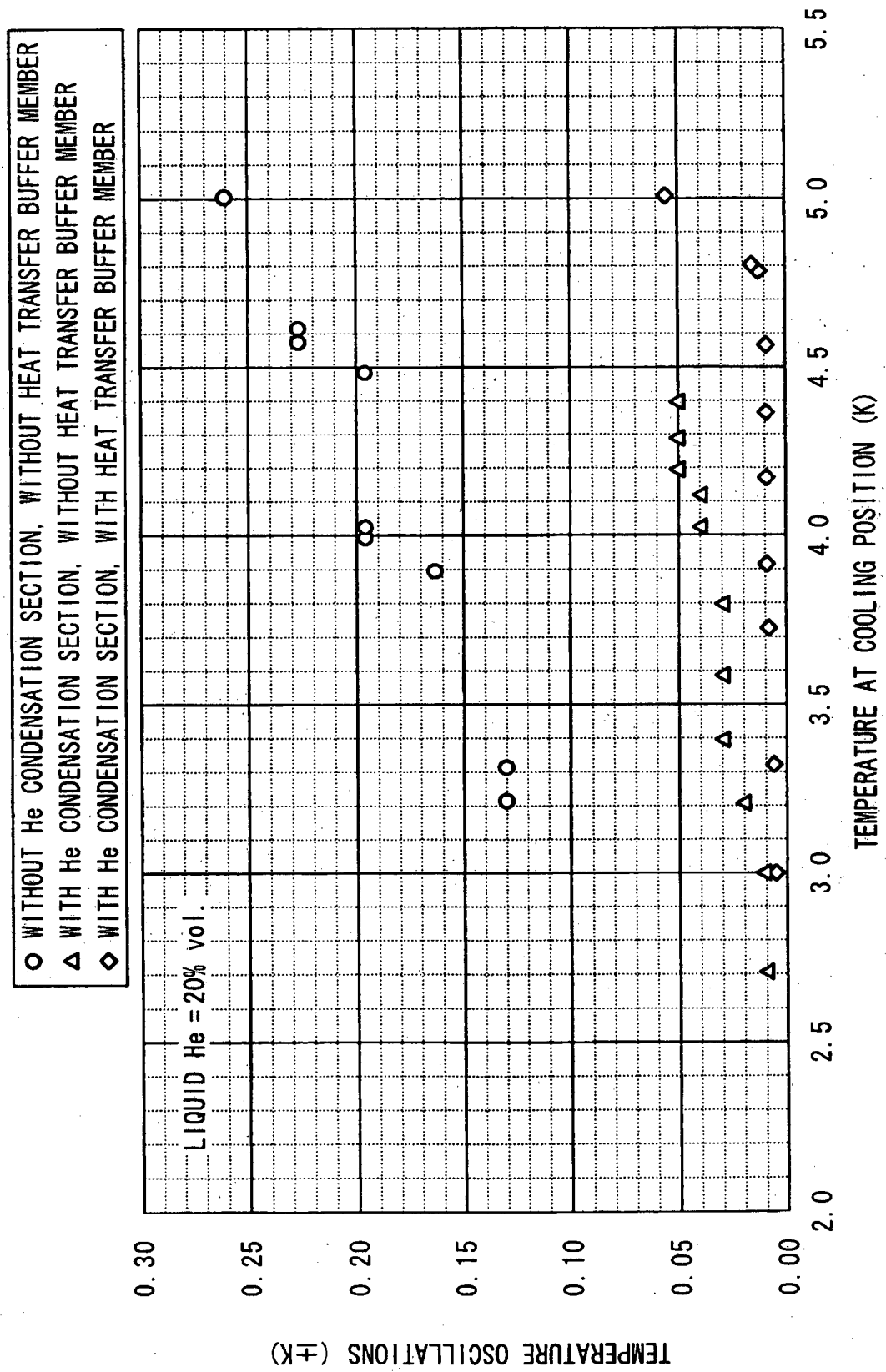


FIG. 3

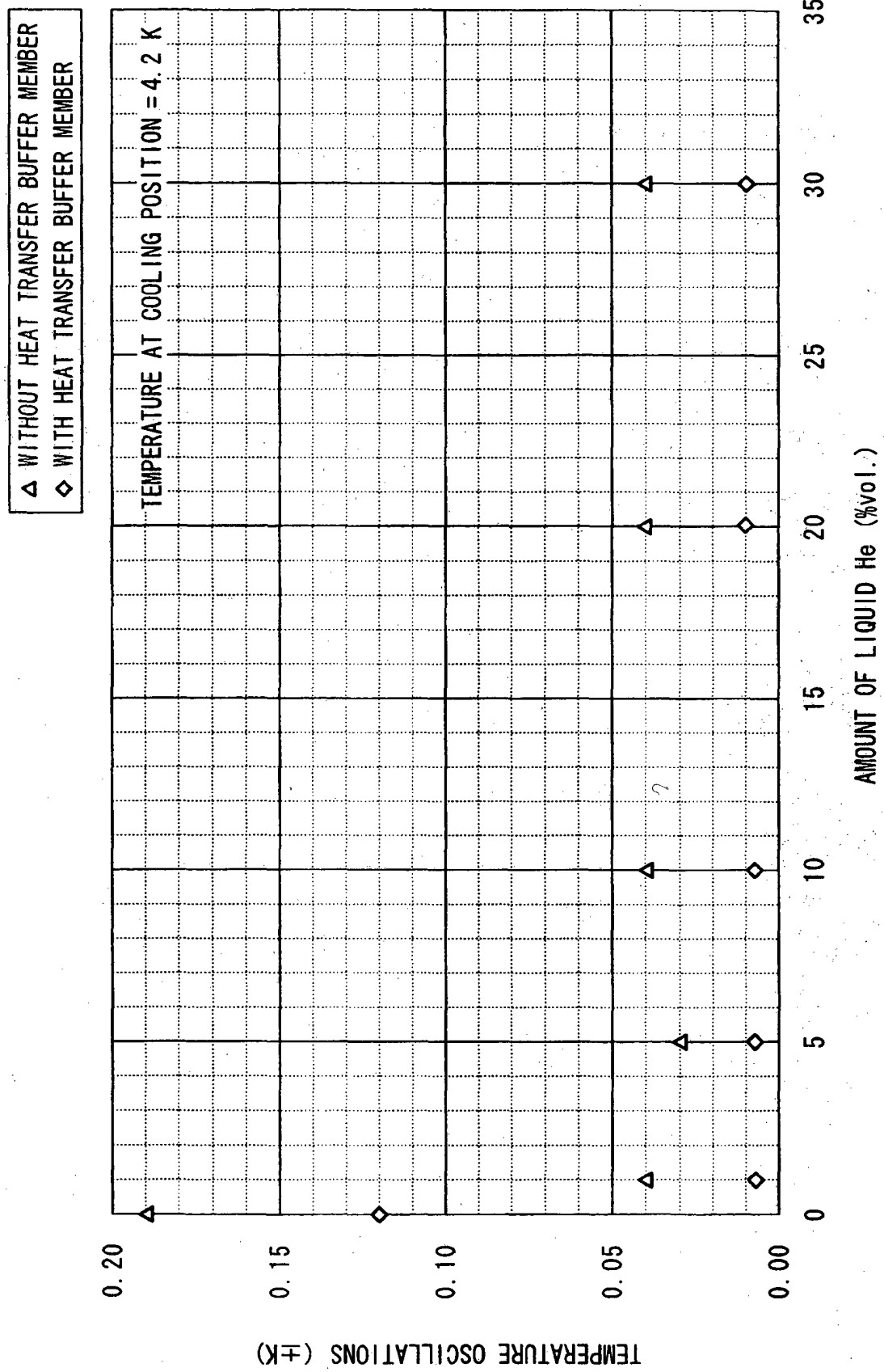


FIG. 4

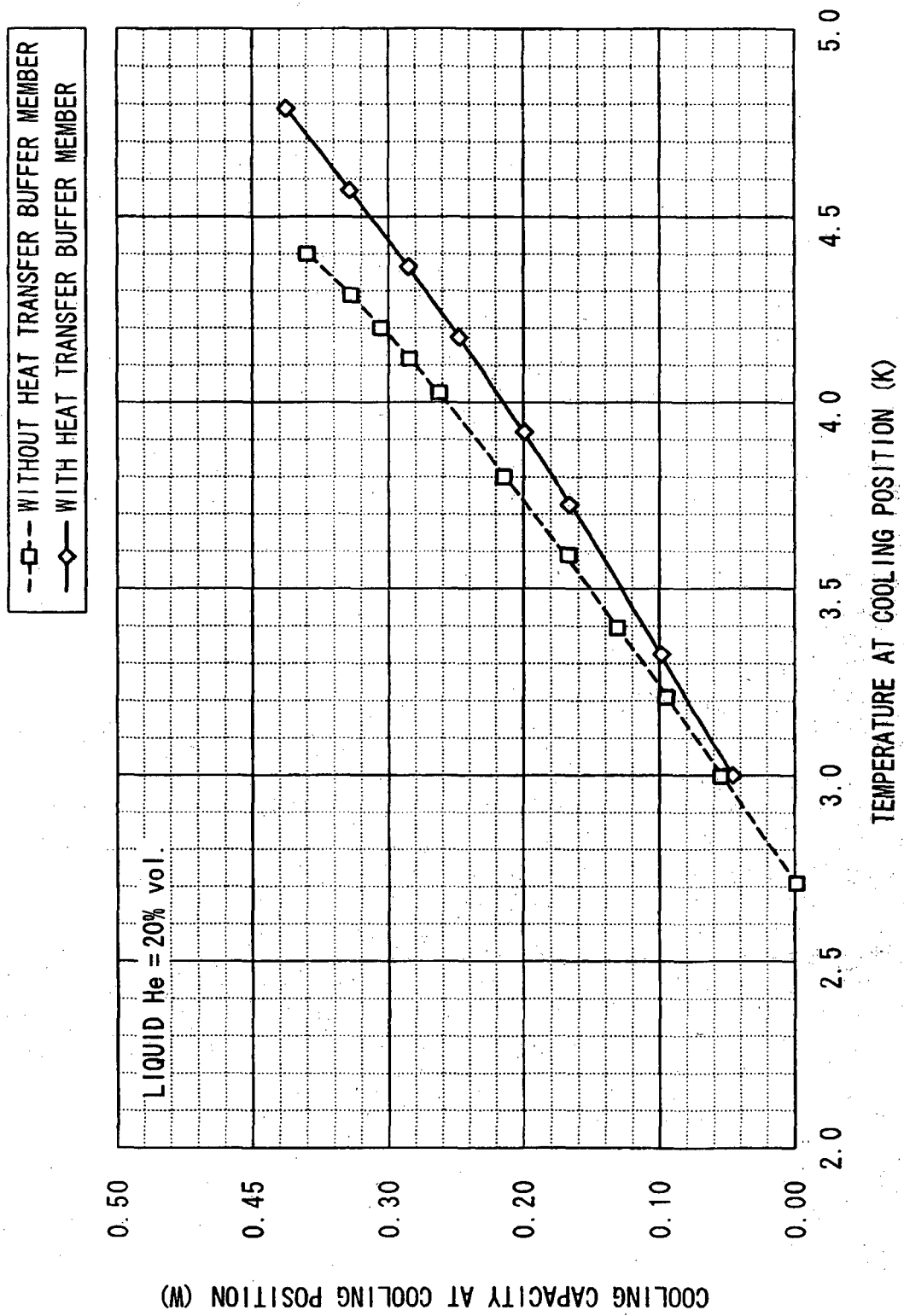


FIG. 5

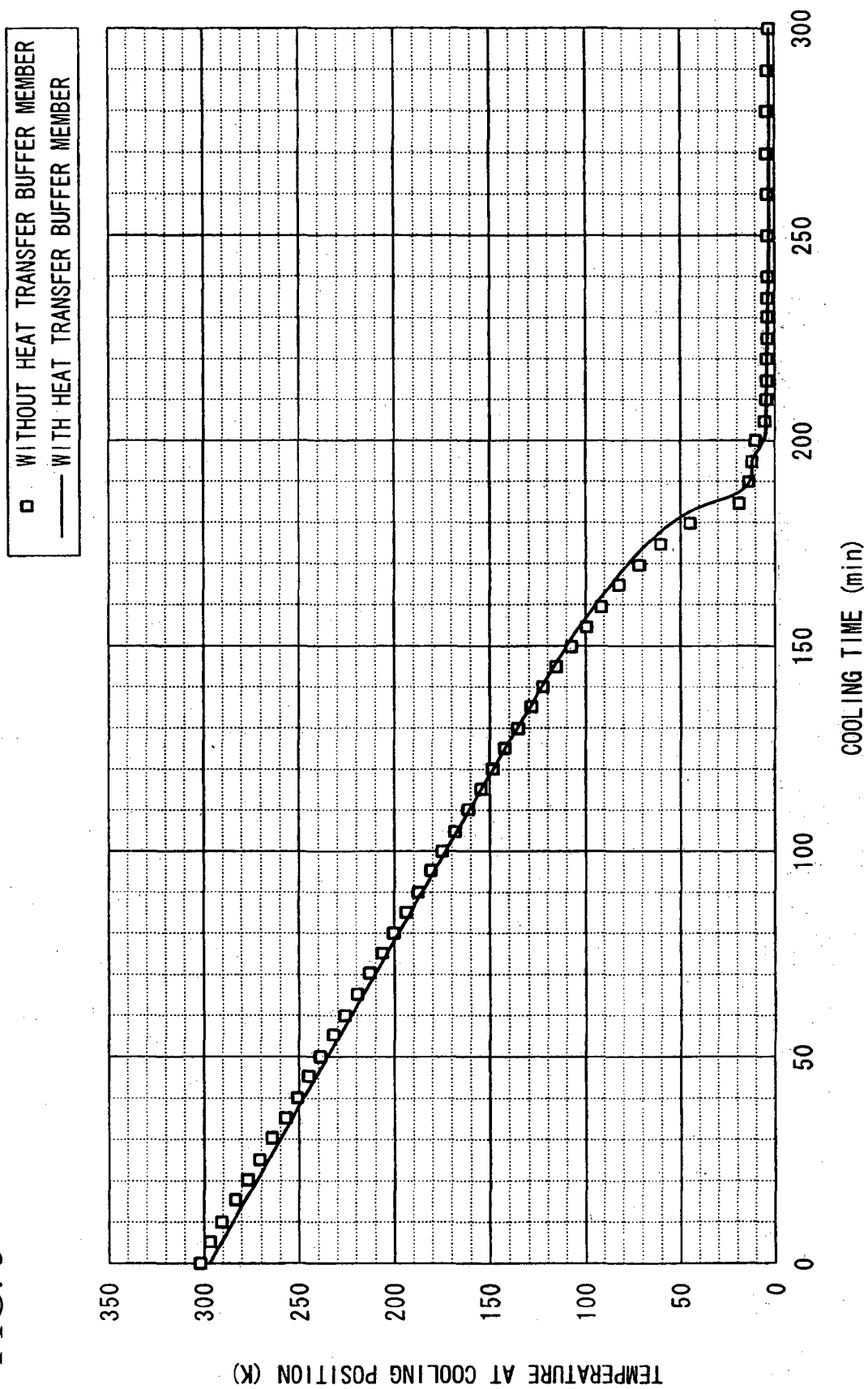


FIG. 6

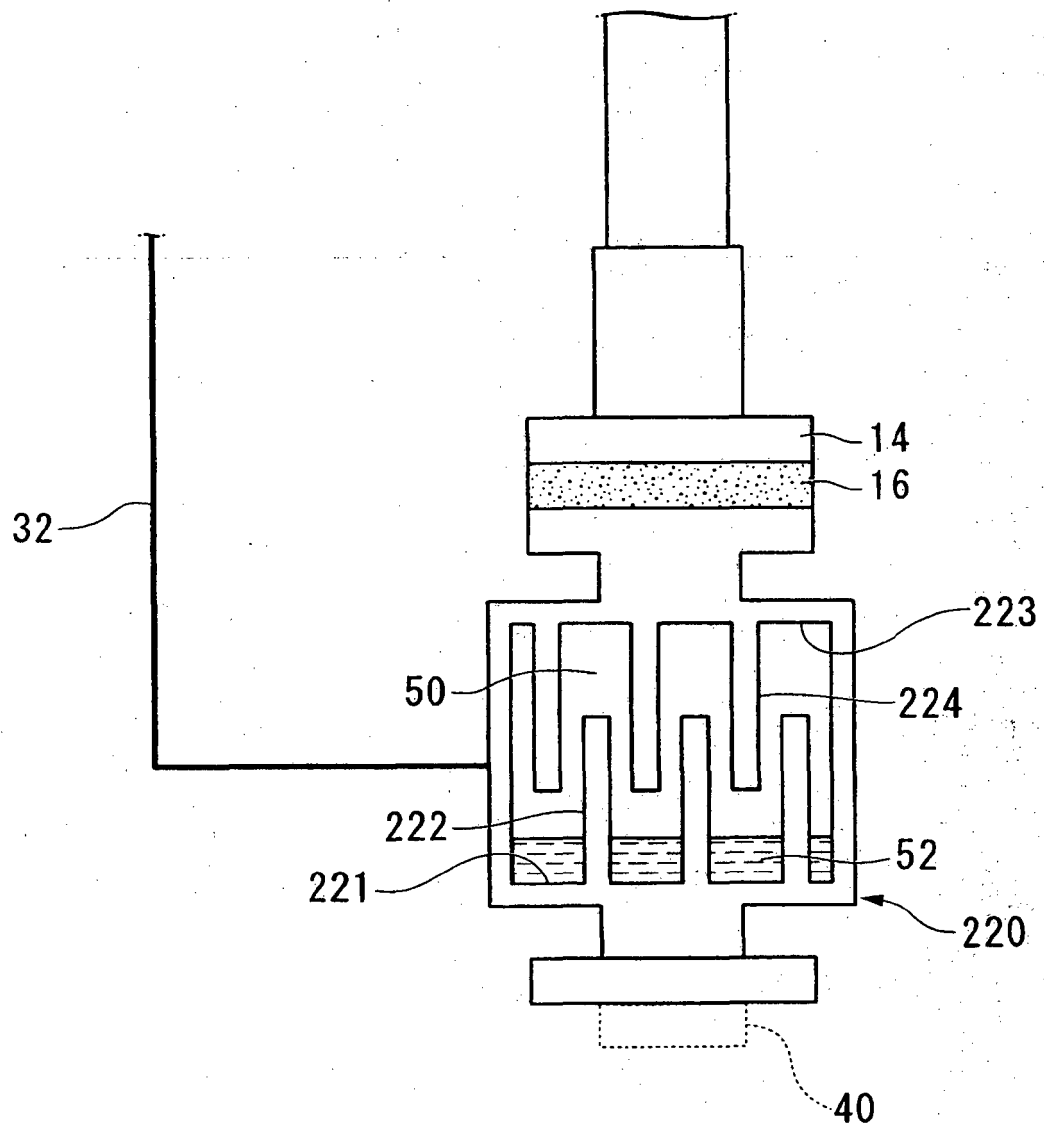


FIG. 7

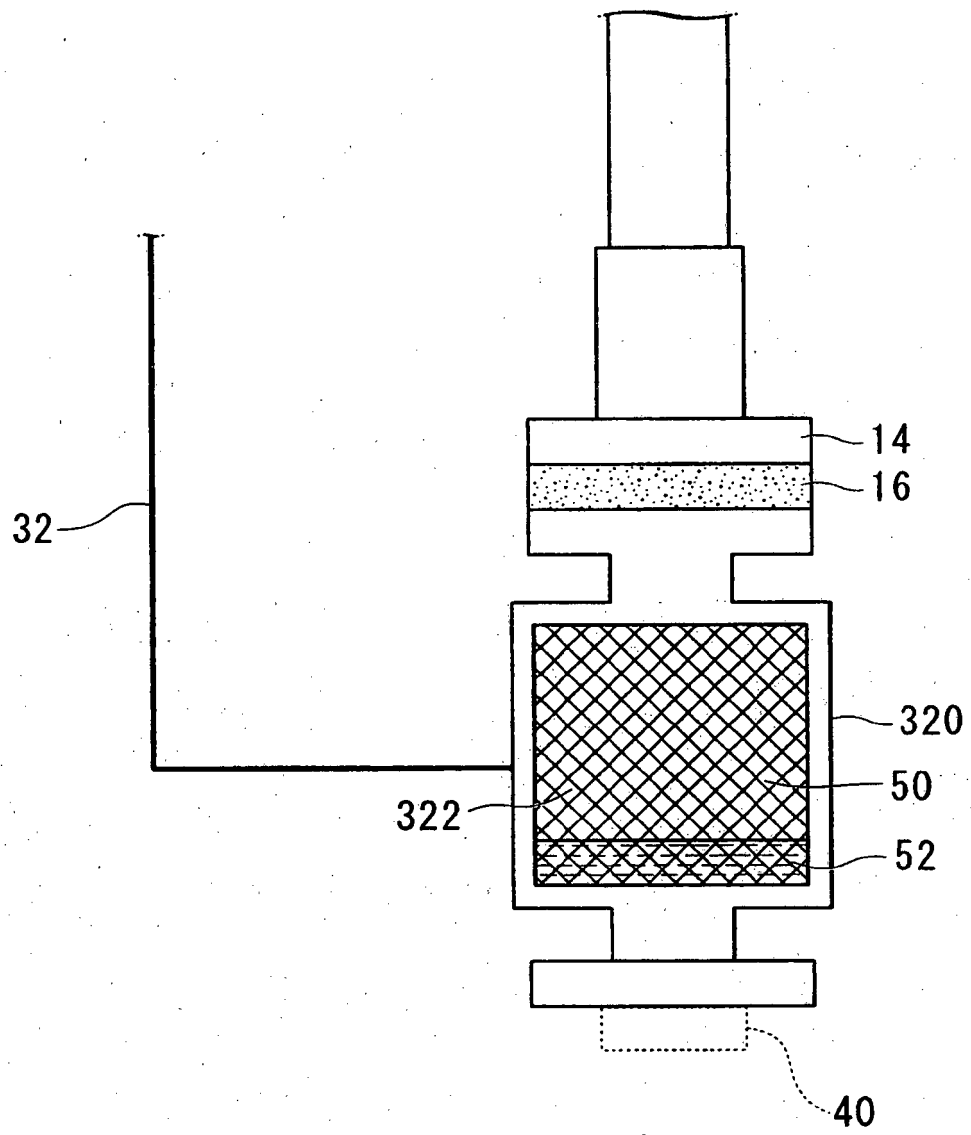


FIG. 8

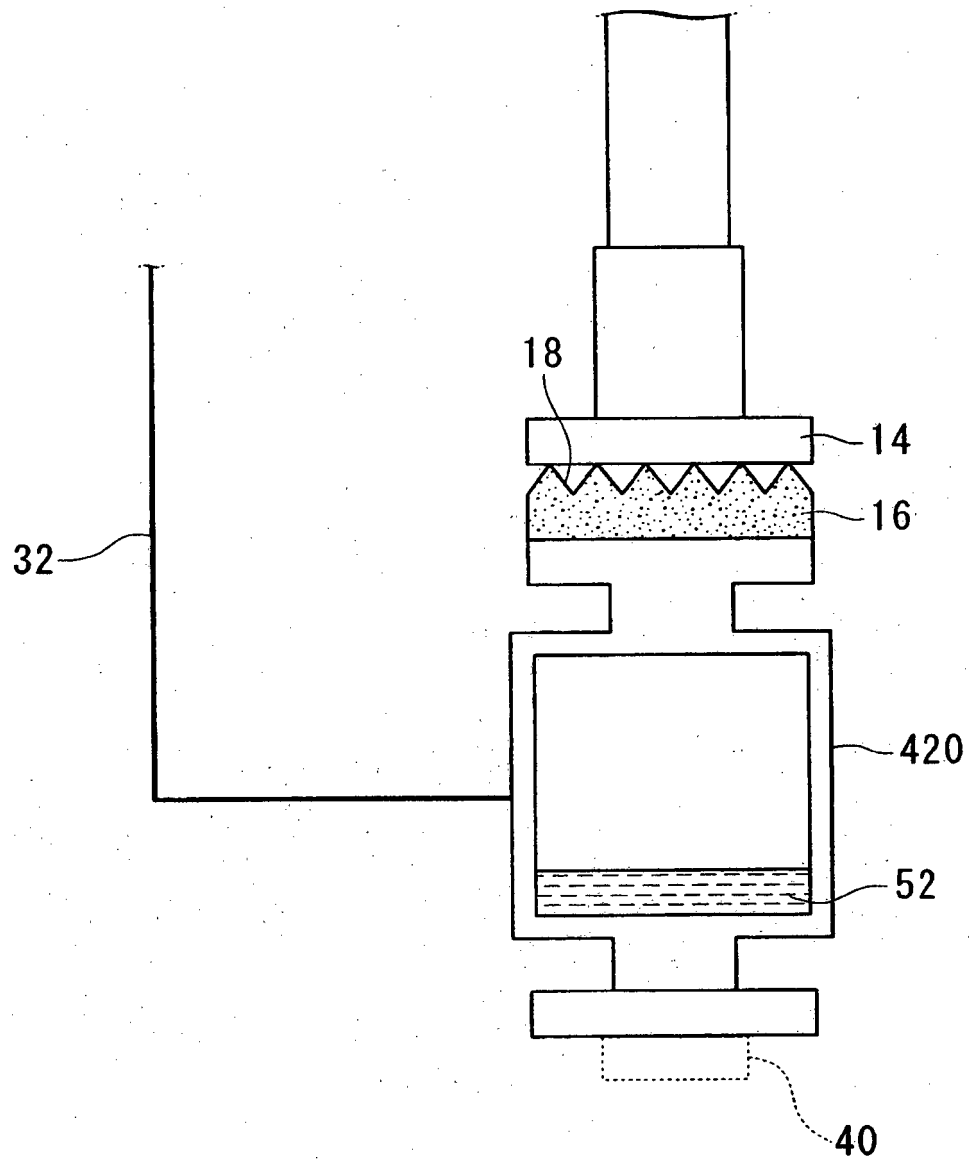
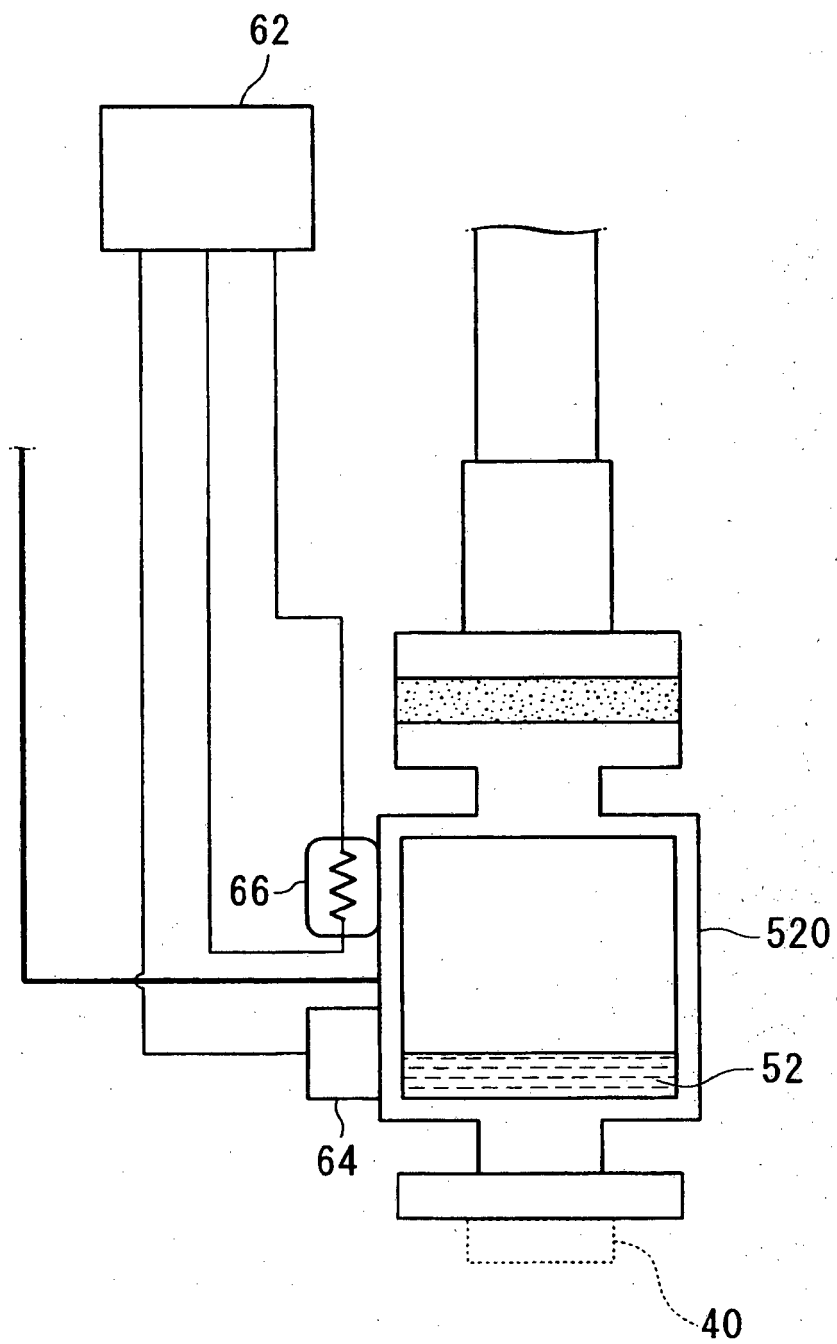


FIG. 9



REFERENCES CITED IN THE DESCRIPTION

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