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(72) Inventor: **OKA, Masaru**
Tokyo 108-8215 (JP)

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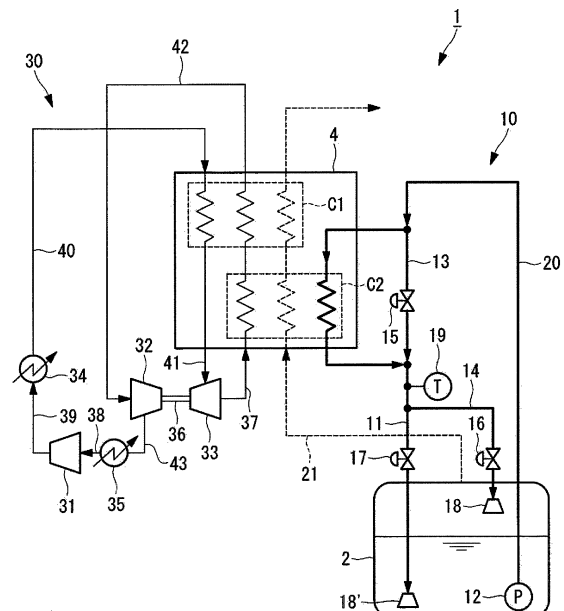
(74) Representative: **Henkel, Breuer & Partner**
Patentanwälte
Maximiliansplatz 21
80333 München (DE)

(71) Applicant: **Mitsubishi Heavy Industries, Ltd.**
Tokyo 108-8215 (JP)

(54) **PRESSURE RISE SUPPRESSION DEVICE FOR STORAGE TANK, PRESSURE RISE SUPPRESSION SYSTEM PROVIDED THEREWITH, SUPPRESSION METHOD THEREFOR, LIQUEFIED GAS CARRYING VESSEL PROVIDED THEREWITH, AND LIQUEFIED GAS STORAGE FACILITY PROVIDED THEREWITH**

(57) In order to suppress pressure rise in a storage tank for storing liquefied gas, simplify a facility and lower the cost of the facility, a pressure rise suppression device for a storage tank is provided with: the storage tank (2) in which liquefied gas is stored; a heat exchange means (4) in which the liquefied gas in a liquid state extracted from the storage tank (2) and a refrigerant exchange heat with seach other; a refrigerant compression means (31) which compresses the refrigerant led to the heat exchange means (4); a refrigerant expansion means (33) which reduces the pressure of the refrigerant compressed by the refrigerant compression means (31) and supplies the refrigerant to the heat exchange means (4), and a supply means (11) which supplies the liquefied gas in the liquid state cooled in the heat exchange means (4) to the liquefied gas in the liquid state in the storage tank (2).

FIG. 1



Description

{Technical Field}

[0001] The present invention relates to a storage-tank pressure-rise suppressing apparatus, a pressure-rise suppressing system including the same, a suppressing method for the same, a liquefied-gas cargo ship including the same, and liquefied-gas storage equipment including the same. In particular, the present invention relates to suppression of a pressure rise in a storage tank storing liquefied gas.

{Background Art}

[0002] Generally, in a storage tank (hereinafter referred to as a "cargo tank") storing liquefied gas such as liquefied natural gas (hereinafter referred to as "LNG") or liquefied petroleum gas (hereinafter referred to as "LPG") in the liquid phase, in order to suppress an increase in the internal pressure of the cargo tank due to liquefied gas that has vaporized naturally due to heat entering the cargo tank from the outside (hereinafter referred to as "boil-off gas"), the vaporized gas is reliquefied, or the boil-off gas is extracted from the cargo tank and is combusted or disposed of outside.

[0003] As a reliquefaction apparatus for boil-off gas, for example, as shown in Fig. 7, in a reliquefaction apparatus 101 of a liquefied-petroleum-gas cargo ship for transporting LPG, boil-off gas in a cargo tank 102 is compressed to high pressure by a boil-off-gas compressor 103, and the compressed boil-off gas is cooled in a condenser 104 by exchanging heat with seawater (design temperature: about 32 °C) supplied from outside the ship, whereby the boil-off gas is condensed at about 40 °C. The LPG condensed in this manner is fed to the cargo tank 102, and a portion of the LPG gasifies when the LPG is subjected to pressure reduction (expansion) in the cargo tank 102. At this time, the temperature of the liquid-phase LPG stored in the cargo tank 102 is lowered by using the heat of cooling due to the evaporation of the LPG, so that the total amount of boil-off gas (the total amount of the gas phase) in the cargo tank 102 is reduced, thereby suppressing the pressure in the cargo tank 102.

[0004] Fig. 8 shows a process diagram in the case where, for example, propane is reliquefied by using the reliquefaction apparatus 101 shown in Fig. 7. In Fig. 8, the vertical axis represents pressure (MPa), and the horizontal axis represents specific enthalpy (kJ/kg).

[0005] In Fig. 8, I indicates evaporation of the liquid-phase LNG stored in the cargo tank 102 shown in Fig. 7, becoming boil-off gas, II indicates compression of the boil-off gas by the boil-off-gas compressor 103, III indicates cooling of the boil-off gas with seawater in the condenser 104, and IV indicates expansion of the condensed LPG in the cargo tank 102, thus cooling the liquid-phase LPG stored in the cargo tank 102 by means of gas.

[0006] In the reliquefaction apparatus 101 shown in Fig. 7, for example, a reciprocal multi-stage boil-off-gas compressor 103 in which a piston 107 is provided inside a cylinder 105 and that includes a driving unit 111 that drives the piston 107 via a crankshaft 109 is used to compress boil-off gas to high pressure of about 16 to 20 atmospheres before it is fed to the condenser 104. A plate or shell-and-tube heat exchanger of a cooling system that utilizes seawater is used in the condenser 104.

[0007] In a reliquefaction apparatus that is installed in a liquefied-natural-gas cargo ship for transferring LNG, since methane, which is a major component of LNG, is a supercritical fluid in the vicinity of room temperature, it is not possible to liquefy LNG boil-off gas in the temperature range of the seawater (about 32 °C) fed to the condenser 104 shown in Fig. 7. Therefore, it is not possible to directly use the LPG reliquefaction apparatus 101 as an LNG reliquefaction apparatus.

[0008] Accordingly, as shown in Fig. 9, as an LNG reliquefaction apparatus 201, an indirect cooling system that uses nitrogen as a refrigerant and that is based on the Brayton cycle is adopted. More specifically, in the reliquefaction apparatus 201, boil-off gas generated in a cargo tank 202 is passed through a boil-off-gas feeding pipe 209, is subjected to pressurization by a boil-off-gas compressor 203 via a boil-off-gas thermal relaxation and separator 207, and is fed to a cold box 204 employing the indirect cooling system. Then, the boil-off gas exchanges heat with nitrogen serving as refrigerant in the cold box 204 employing the indirect cooling system. By exchanging heat with the nitrogen gas in the cold box 204, the boil-off gas is condensed and supercooled to enter the liquid phase. The liquid-phase condensed (reliquefied) LNG is passed through a reliquefied-gas pipe 205 and is again fed into the cargo tank: 202. A pressure rise in the cargo tank 202 is suppressed by reliquefying boil-off gas as described above.

[0009] A reliquefied-LNG feeding pipe 211 for extracting and feeding a portion of the LNG reliquefied in the cold box 204 is connected to the boil-off-gas thermal relaxation and separator 207. In the boil-off-gas thermal relaxation and separator 207, boil-off gas is cooled (thermally relaxed) by the reliquefied LNG fed from the reliquefied-LNG feeding pipe 211, and gas and liquid are separated from each other.

[0010] Fig. 10 shows a process diagram in the case where LNG is reliquefied by using the reliquefaction apparatus 201 shown in Fig. 9, in which the vertical axis represents pressure (MPa) and the horizontal axis represents specific enthalpy (kJ/kg).

[0011] Also in Fig. 10, similarly to Fig. 8, I indicates that LNG evaporates and becomes boil-off gas in the cargo tank 202 shown in Fig. 9, II indicates compression of the boil-off gas by the boil-off-gas compressor 203, III indicates cooling of the boil-off gas with nitrogen in the cold box 204, and IV indicates that the pressure in the cargo tank 202 is reduced.

[0012] Nitrogen is used as the refrigerant fed to the

cold box 204 of the reliquefaction apparatus 201 shown in Fig. 9. The nitrogen is compressed to high pressure through three stages constituted of a two-stage nitrogen compressor 231 and a nitrogen booster 232. More specifically, the nitrogen whose pressure has been made high by the nitrogen compressor 231 is fed to the cold box 204 and exchanges heat with low-pressure, low-temperature nitrogen gas obtained by cooling and condensing the boil-off gas, whereby the temperature of the high-pressure nitrogen is lowered. The high-pressure nitrogen at the lowered temperature is fed to a nitrogen expander 233 that is provided coaxially with the nitrogen booster 232. The high-pressure nitrogen fed to the nitrogen expander 233 is subjected to pressure reduction, whereby it becomes low-temperature, low-pressure nitrogen gas. The low-temperature, low-pressure nitrogen gas is again fed to the cold box 204, exchanges heat with the boil-off gas and the high-pressure nitrogen mentioned earlier, in that order, and is fed out from the cold box 204. The nitrogen fed out from the cold box 204 is fed to the nitrogen booster 232, is compressed by the nitrogen booster 232, and is fed to the inlet of the nitrogen compressor 231.

[0013] Before the nitrogen compressed by the nitrogen compressor 231 enters the cold box 204, it is cooled by a first heat exchanger 235, whereby the heat of compression is removed. A second heat exchanger 237 is provided between the nitrogen booster 232 and the nitrogen compressor 231 to remove the heat of compression of the nitrogen that has been boosted by the nitrogen booster 232.

{Citation List}

{Patent Literature}

[0014] {PTL 1} Japanese Unexamined Patent Application, Publication No. 2009-58199

{Summary of Invention}

{Technical Problem}

[0015] It has been believed that it is necessary to install both the LPG reliquefaction apparatus 101 shown in Fig. 7 and the LNG reliquefaction apparatus 201 shown in Fig. 9 on a vessel that carries and transports both LPG and LNG. However, in the case where these systems 101 and 201 are both installed in a single vessel, there have been problems in that increased equipment complexity and increased equipment costs result.

[0016] Although Patent Document 1 discloses that coolant stored in a coolant tank is cooled by exchanging heat with a refrigerant in a heat exchanger and that laser machining equipment is cooled with the coolant that has been cooled while being fed back to the coolant tank, this is temperature control of coolant for cooling laser machining equipment, and a method of suppressing a pressure rise in a cargo tank storing liquefied gas is not dis-

closed.

[0017] The present invention has been made in view of the situation described above, and it is an object thereof to provide a storage-tank pressure-rise suppressing apparatus with which it is possible to suppress a pressure rise in a storage tank storing liquefied gas and with which it is possible to simplify equipment and to reduce equipment costs, as well as a pressure-rise suppressing system for the same, a suppressing method for the same, a liquefied-gas cargo ship including the same, and liquefied-gas storage equipment including the same.

{Solution to Problem}

[0018] A storage-tank pressure-rise suppressing apparatus according to a first aspect of the present invention includes a storage tank storing liquefied gas; a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant; a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means; a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; and a feeding means for feeding the liquid-phase liquefied gas that has been cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank.

[0019] The liquid-phase liquefied gas extracted from the storage tank is cooled by exchanging heat with the refrigerant in the heat exchange means, and the cooled liquid-phase liquefied gas is fed back to the liquid-phase liquefied gas in the storage tank via the feeding means. Thus, it is possible to cool the liquid-phase liquefied gas stored in the storage tank by using the liquid-phase liquefied gas fed from the feeding means. This makes it possible to lower the overall temperature of the liquid-phase liquefied gas in the storage tank, suppressing gasification of the liquid-phase liquefied gas. At this time, since only the circulated liquefied gas in the liquid phase (single phase) is subjected to heat exchange in the heat exchange means, it suffices in the heat exchange means to impart, by means of the refrigerant compression means, a pressure difference corresponding to a temperature difference that is imparted by the refrigerant in the heat exchange means, so that it is possible to adjust the temperature of the liquid-phase liquefied gas fed to the storage tank to a temperature suitable for the storage tank. Accordingly, it is possible to suppress a pressure rise in the storage tank by cooling the liquid-phase liquefied gas stored in the storage tank.

[0020] When exchanging heat between the liquid-phase liquefied gas and the refrigerant in the heat exchange means, heat exchange takes place only in the liquid phase without involving a phase change in the liquefied gas, so that the temperature difference of the liquefied gas at the inlet and outlet of the heat exchange means becomes small. Accordingly, the refrigerant tem-

perature difference at the inlet and outlet of the heat exchange means also becomes small. Since the refrigerant temperature difference is proportional to the refrigerant pressure difference, the refrigerant pressure difference at the inlet and outlet of the heat exchange means is reduced as a result. This makes it possible to reduce the compression ratio of the refrigerant compression means, which compresses the refrigerant that is to be fed to the heat exchange means, making it possible to reduce the number of stages of the refrigerant compression means. The reduction in the number of stages of the refrigerant compression means simplifies the design of the refrigerant compression means, and mechanical loss in the refrigerant compression means can be reduced. Since the liquid-phase liquefied gas fed to the heat exchange means is cooled without involving a phase change, the heat exchange efficiency of the heat exchange means can be improved. Thus, it is possible to implement the heat exchange means in a compact form. Accordingly, it is possible to simplify the pressure-rise suppressing apparatus and to improve the overall efficiency of the apparatus.

[0021] As the liquefied gas, liquefied natural gas (LNG), liquefied petroleum gas (LPG), ethane, ethylene, ammonia, a mixture thereof, etc. can be used.

[0022] A storage-tank pressure-rise suppressing apparatus according to a second aspect of the present invention includes a storage tank storing liquefied gas; a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant; a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means; a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; and a spraying means for spraying the liquid-phase liquefied gas that has been cooled in the heat exchange means into the gas-phase liquefied gas in the storage tank.

[0023] The liquid-phase liquefied gas extracted from the storage tank is cooled by exchanging heat with the refrigerant in the heat exchange means, and the cooled liquid-phase liquefied gas is sprayed into the gas-phase liquefied gas in the storage tank by the spraying means. By exchanging heat between the cooled liquefied gas and the gas-phase liquefied gas in the storage tank as described above, it is possible to condense (reliquefy) the gas-phase liquefied gas. That is, due to the supercooling heat of the cooled liquid-phase liquefied gas, the droplet diameter of the cooled liquid-phase liquefied gas sprayed into the gas-phase liquefied gas increases. Then, the liquefied gas having an increased droplet diameter drops on the surface of the liquid-phase liquefied gas (liquid surface) stored in the storage tank. Thus, it is possible to suppress a pressure rise in the storage tank due to the gas-phase liquefied gas and to reduce the pressure in the storage tank.

[0024] A storage-tank pressure-rise suppressing ap-

paratus according to a third aspect of the present invention includes a storage tank storing liquefied gas; a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant; a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means; a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; a feeding means for feeding the liquid-phase liquefied gas that has been cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank; and a spraying means for spraying the liquid-phase liquefied gas that has been cooled in the heat exchange means into the gas-phase liquefied gas in the storage tank.

[0025] The liquid-phase liquefied gas extracted from the storage tank is cooled by exchanging heat with the refrigerant in the heat exchange means, and the cooled liquid-phase liquefied gas is fed to the liquid-phase liquefied gas in the storage tank via the feeding means and is also sprayed by the spraying means into the gas-phase liquefied gas in an upper part of the interior of the storage tank. With these measures, it is possible to lower the overall temperature of the liquid-phase liquefied gas in the storage tank, suppressing gasification of the liquid-phase liquefied gas, and to recondense (reliquefy) the gas-phase liquefied gas in the upper part of the interior of the storage tank. Thus, it is possible to suppress a pressure rise and to reduce the pressure in the storage tank.

[0026] In the storage-tank pressure-rise suppressing apparatus according to the present invention, the feeding means may include a feeding-flow-rate adjusting means for adjusting the feeding flow rate of the liquid-phase liquefied gas that has been cooled in the heat exchange means.

[0027] By providing the feeding means with the feeding-flow-rate adjusting means for adjusting the flow rate for feeding the liquid-phase liquefied gas cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank, it becomes possible to adjust the flow rate to a flow rate corresponding to heat that has entered the storage tank from the outside when the liquid-phase liquefied gas cooled by the heat exchange means is fed to the storage tank. Thus, even in the case where the overall temperature of the liquid-phase liquefied gas in the storage tank increases due to incoming heat, it is possible to suppress a pressure rise in the storage tank.

[0028] In the storage-tank pressure-rise suppressing apparatus according to the present invention, the spraying means may include a spraying-amount adjusting means for adjusting the spraying amount of the liquid-phase liquefied gas that has been cooled in the heat exchange means.

[0029] By providing the spraying means with the spraying-amount adjusting means for adjusting the spraying amount for feeding the liquid-phase liquefied gas cooled

in the heat exchange means to the gas-phase liquefied gas in the storage tank, it becomes possible to adjust the flow rate of the cooled liquid-phase liquefied gas that is sprayed into the gas-phase liquefied gas in the storage tank, thereby adjusting the rate of condensation (reliquefaction) of the gas-phase liquefied gas in the storage tank. Accordingly, it is possible to adjust the pressure due to the gas-phase liquefied gas in the storage tank, making the pressure in the storage tank less than or equal to a predetermined pressure.

[0030] The storage-tank pressure-rise suppressing apparatus according to the present invention may include a bypassing means for making a portion of the liquid-phase liquefied gas that is fed to the heat exchange means bypass the heat exchange means and for feeding the portion to the feeding means and/or the spraying means; and a bypass-flow-rate adjusting means for adjusting the bypass flow rate of the liquid-phase liquefied gas that is passed through the bypassing means.

[0031] By providing the bypassing means for making a portion of the liquid-phase liquefied gas extracted from the storage tank bypass the heat exchange means and for feeding the portion to the feeding means and/or the spraying means, and by providing the bypassing means with the bypass-flow-rate adjusting means for adjusting the flow rate of the liquid-phase liquefied gas that is passed through the bypassing means, it becomes possible to adjust the temperature of the liquid-phase liquefied gas that is fed to the feeding means and/or the spraying means by mixing together the liquid-phase liquefied gas that has been cooled by the heat exchange means and the liquid-phase liquefied gas that has not been cooled by the heat exchange means. Thus, it is possible to suppress a pressure rise in the storage tank by adjusting the rate of cooling of the liquid-phase liquefied gas stored in the storage tank and/or the rate of condensation (reliquefaction) of the gas-phase liquefied gas.

[0032] In the storage-tank pressure-rise suppressing apparatus according to the present invention, the storage tank may include a reserve tank and an intermediate tank that is provided between the reserve tank and the heat exchange means and that temporarily stores the liquid-phase liquefied gas and/or gas-phase liquefied gas extracted from the reserve tank, the feeding means and/or the spraying means may be provided at the intermediate tank, and the liquid-phase liquefied gas that has been cooled in the heat exchange means may be fed to the intermediate tank.

[0033] By providing the reserve tank and the intermediate tank and feeding the liquid-phase liquefied gas that has been cooled by the heat exchange means back to the intermediate tank, even in the case where the capacity of the reserve tank is relatively small, it becomes possible to store a portion of the liquid-phase liquefied gas that has been cooled in the heat exchange means in the intermediate tank, without feeding the whole liquid-phase liquefied gas that has been cooled in the heat exchange means to the reserve tank. Accordingly, even in the case

where the capacity of the reserve tank is relatively small, it is possible to cool the liquid-phase liquefied gas in the reserve tank to an appropriate temperature.

[0034] By providing the feeding means and the spraying means at the intermediate tank, it becomes possible to perform maintenance of the spraying means and the feeding means without making the reserve tank gas-free. This facilitates the maintenance of the pressure-rise suppressing apparatus.

[0035] A pressure-rise suppressing system according to a fourth aspect of the present invention includes the above-described storage-tank pressure-rise suppressing apparatus according to the present invention, wherein multiple storage tanks are provided as the storage tank and wherein the liquefied gas stored in the individual storage tanks are of gas kinds that vary among the storage tanks.

[0036] With the pressure-rise suppressing apparatus, in which only the liquid phase (single phase) of the circulated liquefied gas is subjected to heat exchange in the heat exchange means, it suffices to impart, by means of the refrigerant compression means, a pressure difference corresponding to a temperature difference that is imparted by the refrigerant in the heat exchange means. Thus, it is possible with a single pressure-rise suppressing apparatus to cool the variety of kinds of liquefied gas stored in the individual storage tanks. Accordingly, it is possible to simplify the pressure-rise suppressing system and to reduce equipment costs.

[0037] A liquefied-gas cargo ship according to a fifth aspect of the present invention includes the above-described pressure-rise suppressing system according to the fourth aspect of the present invention.

[0038] With the liquefied-gas cargo ship according to the fifth aspect of the present invention, since natural-gas processing equipment utilizing a compact reliquefaction plant is installed, it is possible to reduce the installation space needed for the equipment.

[0039] Accordingly, it becomes possible to simplify a pressure-rise suppressing system that is installed on a liquefied-gas cargo ship and to reduce equipment costs.

[0040] Liquefied-gas storage equipment according to a sixth aspect of the present invention includes the above-described pressure-rise suppressing system according to the fourth aspect of the present invention.

[0041] The pressure-rise suppressing system that can cool a variety of kinds of liquefied gas stored in the individual storage tanks by means of a single pressure-rise suppressing apparatus is used. Accordingly, it becomes possible to simplify a pressure-rise suppressing system that is installed on a liquefied-gas cargo ship and to reduce equipment costs.

[0042] In a storage-tank pressure-rise suppressing method according to a fifth aspect of the present invention, liquid-phase liquefied gas extracted from storage tank storing the liquefied gas is cooled by exchanging heat between the liquid-phase liquefied gas and a refrigerant that has been compressed and whose pressure

has then been reduced, and the liquid-phase liquefied gas that has been cooled by exchanging heat is fed to the liquid-phase liquefied gas and/or gas-phase liquefied gas stored in the storage tank.

[0043] Only the liquid phase (single phase) of the circulated liquefied gas is cooled by exchanging heat with the refrigerant, and the cooled liquid-phase liquefied gas is fed to the liquid-phase and/or gas phase liquefied gas in the storage tank. This makes it possible to lower the temperature of the whole liquid-phase liquefied gas in the storage tank, thereby suppressing gasification of the liquid-phase liquefied gas in the storage tank, and to condense and reliquefy the gas-phase liquefied gas in the storage tank.

{Advantageous Effects of Invention}

[0044] According to the present invention, the liquid-phase liquefied gas extracted from the storage tank is cooled by exchanging heat with the refrigerant in the heat exchange means, and the cooled liquid-phase liquefied gas is fed to the liquid-phase liquefied gas in the storage tank via the feeding means. Thus, it is possible to cool the liquid-phase liquefied gas stored in the storage tank by using the liquid-phase liquefied gas fed from the feeding means. This makes it possible to lower the overall temperature of the liquid-phase liquefied gas in the storage tank, suppressing gasification of the liquid-phase liquefied gas. At this time, since only the circulated liquefied gas in the liquid phase (single phase) is subjected to heat exchange in the heat exchange means, it suffices in the heat exchange means to impart, by means of the refrigerant compression means, a pressure difference corresponding to a temperature difference that is imparted by the refrigerant in the heat exchange means, so that it is possible to adjust the temperature of the liquid-phase liquefied gas fed to the storage tank to a temperature suitable for the storage tank. Accordingly, it is possible to suppress a pressure rise in the storage tank by cooling the liquid-phase liquefied gas stored in the storage tank.

[0045] When exchanging heat between the liquid-phase liquefied gas and the refrigerant in the heat exchange means, heat exchange takes place only in the liquid phase without involving a phase change in the liquefied gas, so that the temperature difference of the liquefied gas at the inlet and outlet of the heat exchange means becomes small. Accordingly, the refrigerant temperature difference at the inlet and outlet of the heat exchange means also becomes small. Since the refrigerant temperature difference is proportional to the refrigerant pressure difference, the refrigerant pressure difference at the inlet and outlet of the heat exchange means is reduced as a result. This makes it possible to reduce the compression ratio of the refrigerant compression means, which compresses the refrigerant that is to be fed to the heat exchange means, making it possible to reduce the number of stages of the refrigerant compression means. The reduction in the number of stages of the refrigerant

compression means simplifies the design of the refrigerant compression means, and mechanical loss in the refrigerant compression means can be reduced. Since the liquid-phase liquefied gas fed to the heat exchange means is cooled without involving a phase change, the heat exchange efficiency of the heat exchange means can be improved. Thus, it is possible to implement the heat exchange means in a compact form. Accordingly, it is possible to simplify the pressure-rise suppressing apparatus and to improve the overall efficiency of the apparatus.

{Brief Description of Drawings}

15 **[0046]**

{Fig. 1}

Fig. 1 is a schematic configuration diagram of a storage-tank pressure-rise suppressing apparatus installed in a liquefied-natural-gas cargo ship according to a first embodiment of the present invention.

{Fig. 2}

Fig. 2 is a schematic process diagram of pressure and specific enthalpy due to the pressure-rise suppressing apparatus shown in Fig. 1.

{Fig. 3}

Fig. 3 is a graph showing the relationship between the temperature of liquefied natural gas and the amount of heat exchanged in a cold box, in which (A) shows a conventional case and (B) shows the case of this embodiment.

{Fig. 4}

Fig. 4 is a schematic diagram showing the individual temperature differences of nitrogen and recirculated LNG at the inlet and outlet of the cold box shown in Fig. 1 and the pressure ratio of nitrogen at the inlet and outlet of a nitrogen compressor.

{Fig. 5}

Fig. 5 is a graph showing the relationship among the nitrogen temperature, the nitrogen temperature difference at the inlet and outlet of the cold box, and the pressure ratio shown in Fig. 4.

{Fig. 6}

Fig. 6 is a schematic configuration diagram of a storage-tank pressure-rise suppressing apparatus installed in a liquefied-natural-gas cargo ship according to a second embodiment of the present invention.

{Fig. 7}

Fig. 7 is a schematic configuration diagram showing a reliquefaction apparatus installed in a conventional liquefied-petroleum-gas cargo ship.

{Fig. 8}

Fig. 8 is a process diagram for propane in the case where the reliquefaction apparatus shown in Fig. 7 is used.

{Fig. 9}

Fig. 9 is a schematic configuration diagram showing a reliquefaction apparatus installed in a conventional

liquefied-natural-gas cargo ship.

{Fig. 10}

Fig. 10 is a process diagram for methane (liquefied natural gas) in the case where the reliquefaction apparatus shown in Fig. 9 is used.

{Description of Embodiments}

First Embodiment

[0047] A liquefied-natural-gas cargo ship equipped with a storage-tank pressure-rise suppressing system according to a first embodiment of the present invention will be described based on Figs. 1 and 2.

[0048] Fig. 1 is a schematic configuration diagram of a cargotank pressure-rise suppressing apparatus constituting the pressure-rise suppressing system installed in the liquefied-natural-gas cargo ship according to this embodiment. Fig. 2 shows a schematic process diagram of pressure and specific enthalpy due to the pressure-rise suppressing apparatus shown in Fig. 1, in which the vertical axis represents pressure (MPa) and the horizontal axis represents enthalpy (kJ/kg).

[0049] As shown in Fig. 1, in the liquefied-natural-gas cargo ship (liquefied-gas cargo ship), which is not shown, a pressure-rise suppressing apparatus 1 is installed, which is equipped with a cargo tank (storage tank) 2 that stores liquefied natural gas (liquefied gas), a cold box (heat exchange means) 4 in which liquid-phase liquefied natural gas extracted from the cargo tank 2 (hereinafter referred to as "recirculated LNG") exchanges heat with nitrogen (refrigerant), a nitrogen compressor (refrigerant compression means) 31 and a nitrogen booster (refrigerant compression means) 32 that compress nitrogen that is fed to the cold box 4, a nitrogen expander (refrigerant expansion means) 33 that reduces the pressure of the nitrogen compressed by the nitrogen compressor 31 and the nitrogen booster 32 and supplies the resulting nitrogen to the cold box 4, a pipe (feeding means) 11 for feeding the liquid-phase recirculated LNG cooled in the cold box 4 to the liquid-phase liquefied natural gas (hereinafter referred to as "LNG") stored in the cargo tank 2, and a boil-off-gas spraying nozzle (spraying means) 18 for spraying the liquid-phase recirculated LNG cooled in the cold box 4 to the boil-off gas (gas-phase LNG) stored in the upper space (not shown) in the cargo tank 2.

[0050] In the liquefied-natural-gas cargo ship equipped with the thus-configured pressure-rise suppressing apparatus 1, multiple cargo tanks 2 (only one tank is shown in Fig. 1) that store LNG as cargo are provided, and these multiple cargo tanks 2 and the pressure-rise suppressing apparatus 1 together constitute a pressure-rise suppressing system.

[0051] The pressure-rise suppressing apparatus 1 includes an LNG recirculating system 10 that cools a portion of the liquid-phase LNG stored as cargo in the cargo tank 2 and recirculates the LNG to the boil-off gas stored in the upper space in the cargo tank 2 and the liquid-

phase LNG stored in the lower part of the cargo tank 2, and also includes a nitrogen refrigerant cycle 30 for circulating nitrogen that has been subjected to heat exchange with the recirculated LNG, i.e., the liquid-phase LNG extracted from the cargo tank 2.

[0052] The LNG recirculating system 10 includes an LNG circulating pump 12 for extracting a portion of the liquid-phase LNG stored in the cargo tank 2; the cold box 4, in which the recirculated LNG extracted by the LNG circulating pump 12 exchanges heat with nitrogen, whereby the liquid-phase recirculated LNG is cooled; the pipe 11 for feeding the recirculated LNG cooled in the cold box 4 to the vicinity of the bottom of the cargo tank 2; a bypassing pipe (bypassing means) for making a portion of the recirculated LNG that is fed to the cold box 4 bypass the cold box 4 and merge with the pipe 11; a pipe 14 that branches from the pipe 11 on the downstream side of the point at which the bypassing pipe 13 merges with the pipe 11 and through which a portion of the cooled liquid-phase recirculated LNG is fed to the upper space in the cargo tank 2; and the boil-off-gas spraying nozzle 18, which is provided at the end of the pipe 14 and which sprays the cooled liquid-phase recirculated LNG into the boil-off gas stored in the upper space in the cargo tank 2.

[0053] A bypass-flow control valve (bypass-flow-rate adjusting means) 15 for adjusting the bypass flow rate of the recirculated LNG fed to the bypassing pipe 13 is provided on the bypassing pipe 13 of the LNG recirculating system 10, and a spraying control valve (spraying-amount adjusting means) 16 for adjusting the spraying amount of the liquid-phase recirculated LNG cooled in the cold box 4 is provided on the pipe 14, and a recirculation control valve (feeding-flow-rate adjusting means) 17 for adjusting the recirculating amount (feeding flow rate) of the liquid-phase recirculated LNG cooled in the cold box 4 is provided on the pipe 11 on the downstream side of the point at which the pipe 14 merges with the pipe 11.

[0054] On the pipe 11 between the point at which the pipe 11 and the bypassing pipe 13 merge together and the point at which the pipe 11 and the pipe 14 merge together, a temperature measurement means 19 for measuring the temperature of the liquid-phase recirculated LNG passing through the pipe 11 is provided.

[0055] The cargo tank 2 stores liquid LNG as cargo. Although the cargo tank 2 has a heat-insulating structure, due to heat entering the cargo tank 2 from the outside, the liquid LNG stored in the cargo tank 2 is warmed, and a portion of the liquid LNG evaporates. The evaporated LNG is stored as boil-off gas in the upper space above the liquid surface of the liquid-phase LNG stored in the cargo tank 2.

[0056] In the cargo tank 2, a loading pump that is immersed in the stored liquid-phase LNG and that is used to load the liquid-phase LNG is provided. Although the LNG circulating pump 12 used to circulate the recirculated LNG in the LNG recirculating system 10 also works as this loading pump in the case of this embodiment,

there is no limitation to this embodiment.

[0057] In the cargo tank 2, in addition to the pipe 11 and the pipe 14, a vent pipe 21 that allows removing the boil-off gas stored in the upper space in the cargo tank 2 from the inside to the outside of the cargo tank 2 is connected to the top of the cargo tank 2.

[0058] The cold box 4 is a heat exchanger of an indirect cooling system that cools the liquid-phase recirculated LNG by way of heat exchange between the nitrogen fed from the nitrogen refrigerant cycle 30 and the liquid-phase recirculated LNG fed from the LNG recirculating system 10. The cold box 4 includes a precooling unit C1 and a cooling unit C2. In the precooling unit C1, heat is exchanged between low-pressure, low-temperature nitrogen gas fed from the nitrogen refrigerant cycle 30, which will be described later, and high-pressure nitrogen compressed by the nitrogen compressor 31. In the cooling unit C2, heat is exchanged between low-temperature, low-pressure nitrogen gas and the liquid-phase recirculated LNG fed from the LNG recirculating system 10.

[0059] The nitrogen refrigerant cycle 30 feeds nitrogen, which serves as refrigerant, to the cold box 4. The nitrogen refrigerant cycle 30 includes the cold box 4 described above, in which the liquid-phase recirculated LNG fed from the LNG recirculating system 10 exchanges heat with nitrogen; the nitrogen expander 33, which reduces the pressure of the nitrogen whose pressure has been made high by the nitrogen compressor 31 and the nitrogen booster 32, a first heat exchanger 34 that cools the high-pressure nitrogen compressed by the nitrogen compressor 31, and a second heat exchanger 35 that cools the nitrogen compressed by the nitrogen booster 32.

[0060] The nitrogen compressor 31 is a single-stage compressor, and it sucks and compresses nitrogen, which serves as refrigerant, to make it high-temperature, high-pressure nitrogen.

[0061] The nitrogen booster 32 compresses the nitrogen that has exchanged heat in the cold box 4 with the liquid-phase recirculated LNG fed from the LNG recirculating system 10. The nitrogen booster 32 has a rotation shaft 36, and the nitrogen expander 33 is provided coaxially with the rotation shaft 36.

[0062] The nitrogen expander 33 reduces the pressure of and thereby expands the high-pressure nitrogen whose temperature has been reduced while passing through the cold box 4 from the nitrogen compressor 31, thereby making it low-temperature, low-pressure nitrogen gas. The rotation shaft 36 is driven by using the expanding force of the compressed nitrogen as a rotating force, whereby the nitrogen booster 32 is driven to rotate.

[0063] The first heat exchanger 34, by using clean water, etc. serving as refrigerant, cools and lowers the temperature of the nitrogen whose pressure has been made high by the nitrogen compressor 31.

[0064] The second heat exchanger 35, by using clean water, etc. serving as refrigerant, cools and lowers the temperature of the nitrogen that has been compressed

by the nitrogen booster 32.

[0065] The refrigerant used in the first heat exchanger 34 and the second heat exchanger 35 may be seawater.

[0066] Next, the suppressing method of the pressure-rise suppressing apparatus 1 according to this embodiment will be described by using Figs. 1 and 2.

[0067] Here, Fig. 2 shows a schematic process diagram of pressure and specific enthalpy due to the pressure-rise suppressing apparatus 1 shown in Fig. 1.

[0068] In the LNG recirculating system 10 shown in Fig. 1, the liquid-phase LNG stored in the cargo tank 2 is fed out to a pipe 20 by the LNG circulating pump 12 (I in Fig. 2). The liquid-phase recirculated LNG fed out to the pipe 20 is fed from the pipe 20 to the cold box 4 (II in Fig. 2). In the cooling unit C2 of the cold box 4, the liquid-phase recirculated LNG fed to the cold box 4 exchanges heat with the low-temperature, low-pressure nitrogen gas fed from a pipe 37 of the nitrogen refrigerant cycle 30 to the cold box 4, whereby the recirculated LNG is cooled (III in Fig. 2).

[0069] Here, in the case of this embodiment, when the liquid-phase recirculated LNG exchanges heat with the nitrogen gas in the cooling unit C2 of the cold box 4, the liquid-phase recirculated LNG is directly cooled in a single phase without undergoing a condensation process, as opposed to the case where gas-phase LNG, i.e., boil-off gas, is condensed and supercooled in a cold box 204 provided in a conventional LNG reliquefaction apparatus 201 shown in Fig. 9.

[0070] The bypassing pipe 13 for detouring (bypassing) the cold box 4 is connected to the pipe 20. The bypass-flow control valve 15 is provided on the bypassing pipe 13. Thus, by opening the bypass-flow control valve 15, a portion of the liquid-phase recirculated LNG fed from the pipe 20 to the cold box 4 is made to pass through the bypassing pipe 13.

[0071] The liquid-phase recirculated LNG cooled in the cold box 4 and the liquid-phase recirculated LNG passed through the bypassing pipe 13 without being cooled merge together and are mixed in the pipe 11. The mixed liquid-phase recirculated LNG is fed into the cargo tank 2 through the pipe 11 and is fed to the vicinity of the bottom of the interior of the cargo tank 2 via a nozzle 18-2, whereby the overall temperature of the liquid-phase LNG stored in the cargo tank 2 is lowered (IV in Fig. 2).

[0072] Here, by adjusting the degree of opening of the bypass-flow control valve 15 based on the temperature of the liquid-phase recirculated LNG passing through the pipe 11, measured by the temperature measurement means 19 provided on the pipe 11, it is possible to adjust the temperature of the liquid-phase recirculated LNG circulated inside the cargo tank 2.

[0073] A portion of the recirculated LNG obtained by mixing together the liquid-phase recirculated LNG that has been cooled in the cold box 4 and the liquid-phase recirculated LNG that has not been cooled (that has passed through the bypassing pipe 13) is branched off from the pipe 11 to the pipe 14 and is sprayed from the

boil-off-gas spraying nozzle 18 into the boil-off gas stored in the upper space in the cargo tank 2 (V in Fig. 2).

[0074] By subjecting the supercooled liquid-phase recirculated LNG that has been sprayed to form a mist (droplets) to heat exchange with the boil-off gas in the tank, the boil-off gas is condensed due to the supercooling heat of the droplets. The condensed and reliquefied boil-off gas drops onto the liquid surface of the liquid-phase LNG stored in the cargo tank 2 (VI in Fig. 2). As the boil-off gas stored in the cargo tank 2 is reliquefied as described above, the pressure due to the boil-off gas inside the cargo tank 2 decreases. Thus, it becomes possible to prevent a pressure rise and to reduce pressure in the cargo tank 2.

[0075] The recirculation control valve 17 and the spraying control valve 16 are provided on the pipe 11 and the pipe 14 in the vicinity of the exterior of the cargo tank 2. By adjusting the degrees of opening of the recirculation control valve 17 and the spraying control valve 16, it is possible to adjust the flow rates of the supercooled liquid-phase recirculated LNG individually supplied to the liquid-phase LNG and boil-off gas stored in the cargo tank 2.

[0076] In the nitrogen refrigerant cycle 30, the nitrogen compressor 31 is driven by a driving source, which is not shown, to compress nitrogen that is fed via a pipe 38, making it high-temperature, high-pressure nitrogen. The compressed, high-temperature nitrogen is fed from the nitrogen compressor 31 to the first heat exchanger 34 via a pipe 39. The high-temperature, high-pressure nitrogen fed to the first heat exchanger 34 exchanges heat with clean water serving as refrigerant. The high-pressure nitrogen that has been cooled by exchanging heat with the clean water is fed out from the first heat exchanger 34 to a pipe 40. The high-pressure nitrogen at a lower temperature, fed out to the pipe 40, is fed into the cold box 4.

[0077] In the precooling unit C1 provided in the cold box 4, the high-pressure nitrogen fed into the cold box 4 from the pipe 40 exchanges heat with nitrogen gas fed into the cold box 4 from the pipe 37, which will be described later, whereby the high-pressure nitrogen is cooled. The high-pressure nitrogen cooled in the precooling unit C1 is fed from the precooling unit C1 to the nitrogen expander 33 via a pipe 41.

[0078] The high-pressure nitrogen fed into the nitrogen expander 33 is expanded by reducing its pressure, becoming low-temperature, low-pressure nitrogen gas. Via the pipe 37, in the cooling unit C2 in the cold box 4, the low-temperature, low-pressure nitrogen gas exchanges heat with the liquid-phase recirculated LNG fed into the cold box 4 from the pipe 20 of the LNG recirculating system 10. The low-temperature, low-pressure nitrogen gas fed into the cooling unit C2 from the pipe 37 imparts its cooling heat to the liquid-phase recirculated LNG, whereby the liquid-phase recirculated LNG is cooled. The nitrogen gas that has exchanged heat with the liquid-phase recirculated LNG in the cooling unit C2 is further fed to the precooling unit C1 in the cold box 4, whereby the

high-pressure nitrogen fed from the pipe 40, described earlier, is cooled.

[0079] The nitrogen gas that has exchanged heat with the high-pressure nitrogen fed from the pipe 40 in the precooling unit C1 is fed out to a pipe 42 via the pipe 41 and the nitrogen expander 33, whereby it is fed to the nitrogen booster 32. The nitrogen booster 32 compresses the nitrogen fed from the pipe 42. The compressed, high-temperature nitrogen is fed out to a pipe 43 connected between the nitrogen booster 32 and the second heat exchanger 35. The compressed, high-temperature nitrogen fed out to the pipe 43 is fed into the second heat exchanger 35, where the nitrogen is cooled by exchanging heat with clean water serving as refrigerant. The cooled nitrogen is fed from the second heat exchanger 35 to the nitrogen compressor 31 via the pipe 38.

[0080] The nitrogen refrigerant cycle 30 is repeated in the manner described above.

[0081] The vent pipe 21 connected to the top of the cargo tank 2 communicates with the outside via the cold box 4. The boil-off gas fed from the vent pipe 21 to the cold box 4 exchanges heat with the nitrogen gas fed from the pipe 37 of the nitrogen refrigerant cycle 30 in the cooling unit C2 and the precooling unit C1, in that order, in the cold box 4. The boil-off gas is cooled by exchanging heat with the nitrogen gas in the nitrogen refrigerant cycle 30, as described above. The cooled boil-off gas is fed out from the cold box 4 and is fed to a boiler, etc., which is not shown, where the gas is used as fuel gas, etc.

[0082] Now, heat exchange by boil-off gas in the cold box 204 of the conventional LNG reliquefaction apparatus 201 (see Fig. 9) and heat exchange by the liquid-phase recirculated LNG in the cold box 4 of the pressure-rise suppressing apparatus 1 according to this embodiment will be compared. Fig. 3 is a graph showing how these heat exchanges occur. Fig. 3 (A) shows heat exchange by boil-off gas in the cold box 204 of the conventional reliquefaction apparatus 201 shown in Fig. 9, and Fig. 3(B) shows heat exchange by the liquid-phase recirculated LNG in the cold box 4 provided in the pressure-rise suppressing apparatus 1 according to this embodiment. In Figs. 3(A) and 3(B), the vertical axis represents the temperature T of the boil-off gas, liquid-phase recirculated LNG, or refrigerant, and the horizontal axis represents the amount of heat exchanged.

[0083] Fig. 4 shows a schematic diagram representing the temperature differences of nitrogen and liquid-phase recirculated LNG at the inlet and outlet of the cold box 4 according to this embodiment and the nitrogen pressure ratio at the inlet and outlet of the nitrogen compressor 31.

[0084] Fig. 5 shows a graph representing the relationship among the nitrogen temperature and the temperature difference and pressure ratio at the inlet and outlet of the cold box, shown in Fig. 4. In Fig. 5, the left vertical axis represents the temperature of the nitrogen gas serving as refrigerant at the outlet of the cold box 4, the horizontal axis represents the nitrogen pressure ratio at the inlet and outlet of the cold box 4, and the right vertical

axis represents the temperature difference at the inlet and outlet of the cold box. In Fig. 5, broken line L1 represents the saturation temperature of the nitrogen gas, line L2 represents the temperature of the nitrogen gas at the outlet of the cold box 4, and line L3 represents the temperature difference of the nitrogen gas at the inlet and outlet of the cold box 4.

[0085] In the case of the conventional reliquefaction apparatus 201, as shown in Fig. 3(A), the boil-off gas fed to the cold box 204 is cooled in the cold box 204 by low-temperature, low-pressure nitrogen gas serving as refrigerant. At this time, the LNG fed to the inlet of the cold box 204 is in the gas phase, as represented by gas I in Fig. 3(A), and it is cooled by the nitrogen gas (II in Fig. 3(A)) and enters the gas-liquid dual phase (III in Fig. 3(A)) constituted of the liquid phase and the gas phase. The LNG in the gas-liquid dual phase is condensed and reliquefied (into the liquid phase) (IV in Fig. 3(A)) by further exchanging heat with the nitrogen gas in the cold box 204.

[0086] As described above, in the conventional reliquefaction apparatus 201, since the boil-off gas is cooled (I in Fig. 3(A)) and is then condensed (IV in Fig. 3(A)) into the liquid phase, the temperature differences of boil-off gas and nitrogen at the inlet and outlet of the cold box 204 become large (V in Fig. 3(A)). Thus, in order to increase the nitrogen temperature difference at the inlet and outlet of the cold box 204, it becomes necessary to increase the pressure difference of nitrogen serving as refrigerant at the inlet and outlet of the condenser 204.

[0087] On the other hand, in the case of this embodiment, liquid-phase recirculated LNG is fed to the cold box 4. Thus, as shown in Fig. 3(B), heat is simply exchanged between single-phase (liquid-phase) recirculated LNG (I in Fig. 3(B)) and nitrogen gas (II in Fig. 3(B)). Accordingly, the temperature differences of the liquid-phase recirculated LNG and nitrogen at the inlet and outlet of the cold box 4 become smaller (V in Fig. 3(B)) compared with the conventional case shown in Fig. 3(A).

[0088] As indicated by I in Fig. 4 and by Fig. 5, the nitrogen temperature difference at the inlet and outlet of the cold box 4 is proportional to the nitrogen pressure ratio at the inlet and outlet of the cold box 4. That is, the nitrogen temperature difference at the inlet and outlet of the cold box 4 is proportional to the pressure difference (pressure ratio) at the inlet and outlet of the nitrogen compressor 31, as indicated by II in Fig. 4 and by Fig. 5. Thus, if the nitrogen temperature difference becomes smaller, it is possible to reduce the pressure difference generated by the nitrogen compressor 31. Accordingly, it is possible to reduce the required intake/discharge pressure ratio of the nitrogen compressor 31 provided in the nitrogen refrigerant cycle 30 and to reduce the number of stages compared with a conventional two-stage nitrogen compressor 231 (see Fig. 9), realizing the single-stage nitrogen compressor 31.

[0089] In the case of this embodiment, since liquid-phase recirculated LNG in a single phase is cooled by exchanging heat with nitrogen gas in the cold box 4, the

heat exchange efficiency of the cold box 4 is improved compared with the conventional cold box 104 (see Fig. 9), which makes it possible to implement the cold box 4 in a compact form.

[0090] As described above, with the pressure-rise suppressing apparatus 1 for the cargo tank 2 according to this embodiment, the pressure-rise suppressing system including the same, the suppressing method for the same, and the liquefied-natural-gas cargo ship equipped with the same, the following operations and advantages are realized.

[0091] Liquid-phase LNG (liquefied gas, recirculated LNG) extracted from the cargo tank (storage tank) 2 is cooled by exchanging heat with nitrogen gas (refrigerant) in the cold box (heat exchange means) 4, and the cooled liquid-phase recirculated LNG is fed to the liquid-phase LNG stored in the cargo tank 2 via the pipe (feeding means) 11. Thus, it is possible to cool the liquid-phase LNG stored in the cargo tank 2 by using the liquid-phase recirculated LNG fed from the pipe 11. This makes it possible to lower the overall temperature of the liquid-phase LNG stored in the cargo tank 2, suppressing gasification of the liquid-phase LNG. At this time, since only the recirculated LNG in the liquid phase (single phase) is subjected to heat exchange in the cold box 4, it suffices in the cold box 4 to import, by means of the nitrogen compressor (refrigerant compression means) 31 and the nitrogen booster (refrigerant compression means) 32, a pressure difference corresponding to a temperature difference that is imparted by gas-phase nitrogen in the cold box 4, so that it is possible to adjust the temperature of the liquid-phase recirculated LNG fed to the cargo tank 2 to a temperature suitable for the cargo tank 2. Accordingly, it is possible to suppress a pressure rise in the cargo tank 2 by cooling the liquid-phase LNG stored in the cargo tank 2.

[0092] When exchanging heat between liquid-phase recirculated LNG and nitrogen gas in the cold box 4, heat exchange takes place only in the liquid phase without involving a phase change in the recirculated LNG, so that the temperature difference of the liquid-phase recirculated LNG at the inlet and outlet of the cold box 4 becomes small. Accordingly, the temperature difference of nitrogen at the inlet and outlet of the cold box 4 also becomes small. Since the nitrogen temperature difference is proportional to the nitrogen pressure difference, the nitrogen pressure difference at the inlet and outlet of the cold box 4 is reduced as a result. This makes it possible to reduce the compression ratio of the nitrogen compressor 31, which compresses nitrogen fed to the cold box 4, realizing the single-stage nitrogen compressor 31 (it is possible to reduce the number of stages of the nitrogen compressor 31). Adopting the single-stage nitrogen compressor 31 simplifies the design of the nitrogen compressor 31, and mechanical loss in the nitrogen compressor 31 can be reduced. Since the liquid-phase recirculated LNG fed to the cold box 4 is cooled without involving a phase change, the heat exchange efficiency of the cold box 4

can be improved. Thus, it is possible to implement the cold box 4 in a compact form. Accordingly, it is possible to simplify the pressure-rise suppressing apparatus 1 and to improve the overall efficiency of the pressure-rise suppressing apparatus 1.

[0093] Liquid-phase recirculated LNG extracted from the cargo tank 2 is cooled by exchanging heat with nitrogen gas in the cold box 4, and the cooled liquid-phase recirculated LNG is sprayed into the boil-off gas (gas-phase LNG) in the cargo tank 2 by means of the boil-off-gas spraying nozzle (spraying means) 18. By exchanging heat between the cooled liquid-phase recirculated LNG and the boil-off gas in the cargo tank 2 as described above, it is possible to condense (reliquefy) the boil-off gas. That is, due to the supercooling heat of the cooled liquid-phase recirculated LNG, the droplet diameter of the cooled liquid-phase recirculated LNG sprayed in the boil-off gas increases. Then, the liquid-phase recirculated LNG having an increased droplet diameter drops on the surface of the liquid-phase LNG (liquid surface) stored in the cargo tank 2. Thus, it is possible to suppress a pressure rise in the cargo tank 2 due to boil-off gas and to reduce the pressure in the cargo tank 2.

[0094] The recirculation control valve {feeding-flow-rate adjusting means) 17 for adjusting the recirculating amount (flow rate) of the liquid-phase recirculated LNG cooled in the cold box 4, which is fed to the liquid-phase LNG stored in the cargo tank 2, is provided at the feeding means. This makes it possible to adjust the flow rate of the liquid-phase recirculated LNG cooled by the cold box 4 to a flow rate corresponding to heat that has entered the cargo tank 2 from the outside when the liquid-phase recirculated LNG is fed to the cargo tank 2. Thus, even in the case where the overall temperature of the liquid-phase LNG stored in the cargo tank 2 increases due to incoming heat, it is possible to suppress a pressure rise in the cargo tank 2.

[0095] The spraying control valve (spraying-amount adjusting means) 16 for adjusting the spraying amount of the liquid-phase recirculated LNG cooled in the cold box 4, which is fed to the boil-off gas in the cargo tank 2, is provided at the boil-off-gas spraying nozzle 18. This makes it possible to adjust the flow rate of the cooled liquid-phase recirculated LNG that is sprayed into the boil-off gas in the cargo tank 2, thereby adjusting the rate of condensation (reliquefaction) of the boil-off gas in the cargo tank 2. Accordingly, it is possible to adjust the pressure due to the boil-off gas in the cargo tank 2, making the pressure in the cargo tank 2 less than or equal to a predetermined pressure.

[0096] The bypassing pipe (bypassing means) 13 is provided for making a portion of the liquid-phase recirculated LNG extracted from the cargo tank 2 bypass (detour) the cold box 4 and feeding it to the pipe 11 and (and/or) the boil-off-gas spraying nozzle 18. On the bypassing pipe 13, the bypass-flow control valve (bypass-flow-rate adjusting means) 15 is provided for adjusting the bypassing flow rate (flow rate) of the liquid-phase

recirculated LNG that is passed through the bypassing pipe 13. With these means, it is possible to adjust the temperature of the recirculated LNG that is fed to the pipe 11 and the boil-off-gas spraying nozzle 18 by mixing together the liquid-phase recirculated LNG that has been cooled by the cold box 4 and the liquid-phase recirculated LNG that has not been cooled by the cold box 4 (that has been passed through the bypassing pipe 13). Thus, it is possible to suppress a pressure rise in the cargo tank 2 by adjusting the rate of cooling of the liquid-phase LNG stored in the cargo tank 2 and (and/or) the rate of reliquefaction of the boil-off gas.

[0097] The pressure-rise suppressing system (not shown) is provided with the pressure-rise suppressing apparatus 1 that can cool single-phase (liquid-phase) recirculated LNG to cool liquid-phase LNG or reliquefy boil-off gas stored in the cargo tanks 2 installed in the liquefied-natural-gas cargo ship (liquefied gas cargo ship). Thus, it is possible to simplify and reduce equipment costs of the pressure-rise suppressing system installed in the liquefied-natural-gas cargo ship.

Second Embodiment

[0098] This embodiment differs from the first embodiment in that a flash tank for storing a portion of boil-off gas and liquid-phase LNG extracted from a cargo tank is provided, and the liquid-phase LNG extracted from the flash tank is circulated to the flash tank as recirculated LNG, and is otherwise the same. Thus, regarding the same components and the suppressing method, the same reference signs will be attached thereto, and descriptions thereof will be omitted.

[0099] Fig. 6 shows a schematic diagram of the construction of a pressure-rise suppressing apparatus 51 according to this embodiment.

[0100] As shown in Fig. 6, an LNG recirculating system 60 includes a cargo tank (reserve tank) 61 that is provided as a storage tank, a flash tank (intermediate tank) 62 that is provided between the cargo tank 61 and the cold box (heat exchange means) 4, and an LNG circulating pump 63 for recirculating the liquid-phase LNG (liquefied gas) stored in the flash tank 62.

[0101] As opposed to the case of the first embodiment, the LNG circulating pump 63 in this embodiment is provided separately from an LNG loading pump.

[0102] The flash tank 62 temporarily stores liquid-phase LNG extracted from the cargo tank 61 and boil-off gas (gas-phase LNG) generated in the cargo tank 61.

[0103] A portion of the liquid-phase LNG is fed to this flash tank 62 from the cargo tank 61 by a loading pump, which is not shown, and the boil-off gas stored in the upper space in the cargo tank 61 is also fed thereto.

[0104] A portion of the liquid-phase LNG stored in the flash tank 62 (recirculated LNG) is fed out to the pipe 20 by the LNG circulating pump 63. The liquid-phase recirculated LNG fed out to the pipe 20 is fed to the cold box 4 and exchanges heat in the cooling unit C2 in the cold

box 4 with low-temperature, low-pressure nitrogen gas (refrigerant) fed from the nitrogen refrigerant cycle 30. Thus, the liquid-phase recirculated LNG is cooled and fed out to the pipe (feeding means) 11.

[0105] The cooled liquid-phase recirculated LNG fed out to the pipe 11 is fed from the vicinity of the bottom of the flash tank 62 to the liquid-phase LNG stored in the flash tank 62 via a nozzle 18'. Thus, the liquid-phase LNG in the flash tank 62 is cooled by the recirculated LNG.

[0106] The portion of the liquid-phase recirculated LNG fed out to the pipe 11 is fed to the upper space of the flash tank 62 and is sprayed into the boil-off gas in the flash tank 62 via the boil-off-gas spraying nozzle (spraying means) 18. Thus, the boil-off gas in the flash tank 62 is condensed, and the condensed (reliequified) boil-off gas drops onto the liquid phase in the flash tank 62.

[0107] Between the cargo tank 61 and the flash tank 62, a liquid transfer pipe 65 for transferring the liquid-phase LNG in the flash tank 62 to the cargo tank 61, a liquid pressure-application and transfer pipe 66 for applying pressure to the liquid-phase LNG in the cargo tank 61 and transferring the LNG to the lower part in the flash tank 62, and a gas transfer pipe 67 for transferring the boil-off gas in the cargo tank 61 to the upper part in the flash tank 62 are provided.

[0108] As described above, the liquid-phase LNG that has been cooled in the flash tank 62 is fed from the flash tank 62 into the cargo tank 61 via the liquid transfer pipe 65. By feeding the cooled liquid-phase LNG in the flash tank 62 from the flash tank 62 into the cargo tank 61, the liquid-phase LNG stored in the cargo tank 61 is cooled. This makes it possible to suppress a pressure rise in the cargo tank 61.

[0109] As described above, with the pressure-rise suppressing apparatus 51 for a cargo tank according to this embodiment, a pressure-rise suppressing system including the same, a suppressing method for the same, and a liquefied-natural-gas cargo ship equipped with the same, the following operations and advantages are realized.

[0110] The cargo tank (reserve tank) 61, and the flash tank (intermediate tank) 62 between the cargo tank 61 and the cold box (heat exchange means) 4, are provided, and the liquid-phase recirculated LNG (liquefied gas) that has been cooled by the cold box 4 is fed back to the flash tank 62. Thus, even in the case where the capacity of the cargo tank 61 is relatively small, it is possible to store a portion of the liquid-phase recirculated LNG that has been cooled in the cold box 4 in the flash tank 62, without feeding the whole liquid-phase recirculated LNG that has been cooled in the cold box 4 to the cargo tank 61. Accordingly, even in the case where the capacity of the cargo tank 61 is relatively small, it is possible to cool the liquid-phase LNG stored in the cargo tank 61 to an appropriate temperature.

[0111] The pipe (feeding means) 11 and the boil-off-gas spraying nozzle (spraying means) 18 are provided

at the flash tank 62. Thus, it is possible to perform maintenance of the boil-off-gas spraying nozzle 18 and the LNG circulating pump 63 without making the cargo tank 61 gas-free. This facilitates the maintenance of the pressure-rise suppressing apparatus 51.

[0112] It should be noted that the pressure-rise suppressing system according to the present invention is applicable not only to a liquefied-natural-gas cargo ship but also to liquefied-natural-gas storage equipment (not shown) that stores LNG.

[0113] Although liquefied natural gas (LNG) is used as liquefied gas in the description of the first and second embodiments, the present invention is not limited thereto, and the liquefied gas may be liquefied petroleum gas (LPG), ethane, ethylene, ammonia, or a mixture thereof.

[0114] Although the first and second embodiments have been described such that the liquid-phase recirculated LNG that has been cooled by the cold box 4 is fed to both liquid-phase LNG and boil-off gas stored in the cargo tank 2 or the flash tank 62, the liquid-phase recirculated LNG may be fed to either liquid-phase LNG or boil-off gas stored in the cargo tank 2 or the flash tank 62.

[0115] In the case where the cooled liquid-phase recirculated LNG is fed only to the liquid-phase LNG stored in the cargo tank 2 or the flash tank 62, it is possible to lower the temperature of all of the liquid-phase LNG stored in the cargo tank 2 or 61, which makes it possible to prevent the generation of boil-off gas from the liquid-phase LNG. As a result, it is possible to suppress a pressure rise in the cargo tank 2 or 61.

[0116] On the other hand, in the case where the cooled liquid-phase recirculated LNG is fed only to the boil-off gas, reliequfaction of the boil-off gas is promoted, which makes it possible to suppress a pressure rise or to reduce the pressure in the cargo tank 2 or 61 due to the boil-off gas.

[0117] Although the first and second embodiments have been described in the context of pressure-rise suppressing systems in which only one kind of liquefied gas, namely, LNG, is used in multiple cargo tanks, the pressure-rise suppressing system may be configured such that a variety of kinds of liquefied gas, varying among cargo tanks installed in a liquefied-gas cargo ship or cargo tanks installed in liquefied-gas storage equipment, is stored.

[0118] In this case, since only the liquid phase (single phase) of the recirculated liquefied gas is subjected to heat exchange in the cold box, it suffices to impart, by means of the nitrogen compressor (refrigerant compression means), a pressure difference corresponding to a temperature difference imparted by nitrogen gas (refrigerant) in the cold box. Thus, it is possible with a single pressure-rise suppressing apparatus to cool the variety of kinds of liquefied gas stored in the individual cargo tanks (storage tanks). Accordingly, it is possible to simplify the pressure-rise suppressing system and to reduce equipment costs.

[0119] Since the pressure-rise suppressing system is

configured such that it is possible with the single pressure-rise suppressing apparatus to cool the variety of kinds of liquefied gas stored in the individual cargo tanks, it is possible to simplify a pressure-rise suppressing system installed in a liquefied-gas cargo ship or liquefied-gas storage equipment and to reduce equipment costs.

{Reference Signs List}

[0120]

- | | | |
|--------|---|----|
| 1, 51 | Pressure-rise suppressing apparatus | |
| 2 | Storage tank (cargo tank) | |
| 4 | Heat exchange means (cold box) | |
| 11 | Feeding means (pipe) | 15 |
| 13 | Bypassing means (bypassing pipe) | |
| 15 | Bypass-flow-rate adjusting means (bypass-flow control valve) | |
| 16 | Spraying-amount adjusting means (spraying control valve) | 20 |
| 17 | Feeding-flow-rate adjusting means (recirculation control valve) | |
| 18 | Spraying means (boil-off-gas spraying nozzle) | |
| 31, 32 | Refrigerant compression means (nitrogen compressor, nitrogen booster) | 25 |
| 33 | Refrigerant expansion means (nitrogen expander) | |
| 61 | Reserve tank (cargo tank) | |
| 62 | Intermediate tank (flash tank) | 30 |

Claims

1. A storage-tank pressure-rise suppressing apparatus comprising:

a storage tank storing liquefied gas;
a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant;
a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means;
a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; and
a feeding means for feeding the liquid-phase liquefied gas that has been cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank.

2. A storage-tank pressure-rise suppressing apparatus comprising:

a storage tank storing liquefied gas;
a heat exchange means for exchanging heat be-

tween the liquid-phase liquefied gas extracted from the storage tank and a refrigerant;
a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means;
a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; and
a spraying means for spraying the liquid-phase liquefied gas that has been cooled in the heat exchange means into the gas-phase liquefied gas in the storage tank.

3. A storage-tank pressure-rise suppressing apparatus comprising:

a storage tank storing liquefied gas;
a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant;
a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means;
a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means;
a feeding means for feeding the liquid-phase liquefied gas that has been cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank; and
a spraying means for spraying the liquid-phase liquefied gas that has been cooled in the heat exchange means into the gas-phase liquefied gas in the storage tank.

4. A storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 3, wherein the feeding means includes a feeding-flow-rate adjusting means for adjusting the feeding flow rate of the liquid-phase liquefied gas that has been cooled in the heat exchange means.

5. A storage-tank pressure-rise suppressing apparatus according to any one of Claims 2 to 4, wherein the spraying means includes a spraying-amount adjusting means for adjusting the spraying amount of the liquid-phase liquefied gas that has been cooled in the heat exchange means.

6. A storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 5, comprising:

a bypassing means for making a portion of the liquid-phase liquefied gas that is fed to the heat

- exchange means bypass the heat exchange means and feeding the portion to the feeding means and/or the spraying means; and a bypass-flow-rate adjusting means for adjusting the bypass flow rate of the liquid-phase liquefied gas that is passed through the bypassing means. 5
7. A storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 6, wherein the storage tank includes: 10
- a reserve tank; and an intermediate tank that is provided between the reserve tank and the heat exchange means and that temporarily stores the liquid-phase liquefied gas and/or gas-phase liquefied gas extracted from the reserve tank, wherein the feeding means and/or the spraying means are provided at the intermediate tank, and 20
- wherein the liquid-phase liquefied gas that has been cooled in the heat exchange means is fed to the intermediate tank. 25
8. A pressure-rise suppressing system comprising a storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 7, wherein multiple storage tanks are provided as the storage tank, and 30
- wherein the liquefied gas stored in the individual storage tanks are of gas kinds that vary among the storage tanks.
9. A liquefied-gas cargo ship comprising a pressure-rise suppressing system according to Claim 8. 35
10. Liquefied-gas storage equipment comprising a pressure-rise suppressing system according to Claim 8. 40
11. A storage-tank pressure-rise suppressing method wherein liquid-phase liquefied gas extracted from a storage tank storing the liquefied gas is cooled by exchanging heat between the liquid-phase liquefied gas and a refrigerant that has been compressed and whose pressure has then been reduced, and the liquid-phase liquefied gas that has been cooled by exchanging heat is fed to the liquid-phase liquefied gas and/or gas-phase liquefied gas stored in the storage tank. 50

Amended claims under Art. 19.1 PCT

1. (Currently amended) A storage-tank pressure-rise suppressing apparatus comprising: 55
- a storage tank storing liquefied gas;

a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant; a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means; a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; [[and]] a feeding means for feeding the liquid-phase liquefied gas that has been cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank; a bypassing means for making a portion of the liquid-phase liquefied gas that is fed to the heat exchange means bypass the heat exchange means and feeding the portion to the feeding means; a bypass-flow-rate adjusting means for adjusting the bypass flow rate of the liquid-phase liquefied gas that is passed through the bypassing means; and a temperature measurement means for measuring temperature of liquefied gas that is merged and mixed the portion of the liquid-phase liquefied gas passed through the heat exchanger and the portion of the liquid-phase liquefied gas passed through the bypass means, wherein the bypass-flow-rate adjusting means adjusts the bypass flow rate on the basis of the measuring result by the temperature measurement means.

2. (Currently amended) A storage-tank pressure-rise suppressing apparatus comprising:

a storage tank storing liquefied gas; a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant; a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means; a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means; [[and]] a spraying means for spraying the liquid-phase liquefied gas that has been cooled in the heat exchange means into the gas-phase liquefied gas in the storage tank; a bypassing means for making a portion of the liquid-phase liquefied gas that is fed to the heat exchange means bypass the heat exchange means and feeding the portion to the feeding

means;

a bypass-flow-rate adjusting means for adjusting the bypass flow rate of the liquid-phase liquefied gas that is passed through the bypassing means; and

a temperature measurement means for measuring temperature of a liquefied gas that is merged and mixed the portion of the liquid-phase liquefied gas passed through the heat exchanger and the portion of the liquid-phase liquefied gas passed through the bypass means, wherein

the bypass-flow-rate adjusting means adjusts the bypass flow rate on the basis of the measuring result by the temperature measurement means.

3. (Currently amended) A storage-tank pressure-rise suppressing apparatus comprising:

a storage tank storing liquefied gas;

a heat exchange means for exchanging heat between the liquid-phase liquefied gas extracted from the storage tank and a refrigerant;

a refrigerant compression means for compressing the refrigerant that is to be fed to the heat exchange means;

a refrigerant expansion means for reducing the pressure of the refrigerant that has been compressed by the refrigerant compression means and feeding the refrigerant to the heat exchange means;

a feeding means for feeding the liquid-phase liquefied gas that has been cooled in the heat exchange means to the liquid-phase liquefied gas in the storage tank; [[and]]

a spraying means for spraying the liquid-phase liquefied gas that has been cooled in the heat exchange means into the gas-phase liquefied gas in the storage tank;

a bypassing means for making a portion of the liquid-phase liquefied gas that is fed to the heat exchange means bypass the heat exchange means and feeding the portion to the feeding means and/or the spraying means;

a bypass-flow-rate adjusting means for adjusting the bypass flow rate of the liquid-phase liquefied gas that is passed through the bypassing means; and

a temperature measurement means for measuring temperature of a liquefied gas that is merged and mixed the portion of the liquid-phase liquefied gas passed through the heat exchanger and the portion of the liquid-phase liquefied gas passed through the bypass means, wherein

the bypass-flow-rate adjusting means adjusts the bypass flow rate on the basis of the meas-

uring result by the temperature measurement means.

4. (Original) A storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 3, wherein the feeding means includes a feeding-flow-rate adjusting means for adjusting the feeding flow rate of the liquid-phase liquefied gas that has been cooled in the heat exchange means.

5. (Original) A storage-tank pressure-rise suppressing apparatus according to any one of Claims 2 to 4, wherein the spraying means includes a spraying-amount adjusting means for adjusting the spraying amount of the liquid-phase liquefied gas that has been cooled in the heat exchange means.

6. (Cancelled)

7. (Original) A storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 6, wherein the storage tank includes:

a reserve tank; and

an intermediate tank that is provided between the reserve tank and the heat exchange means and that temporarily stores the liquid-phase liquefied gas and/or gas-phase liquefied gas extracted from the reserve tank, wherein the feeding means and/or the spraying means are provided at the intermediate tank, and

wherein the liquid-phase liquefied gas that has been cooled in the heat exchange means is fed to the intermediate tank.

8. (Original) A pressure-rise suppressing system comprising a storage-tank pressure-rise suppressing apparatus according to any one of Claims 1 to 7, wherein multiple storage tanks are provided as the storage tank, and wherein the liquefied gas stored in the individual storage tanks are of gas kinds that vary among the storage tanks.

9. (Original) A liquefied-gas cargo ship comprising a pressure-rise suppressing system according to Claim 8.

10. (Original) Liquefied-gas storage equipment comprising a pressure-rise suppressing system according to Claim 8.

11. (Currently amended) A storage-tank pressure-rise suppressing method wherein liquid-phase liquefied gas extracted from a storage tank storing the liquefied gas is cooled by exchanging heat between the liquid-phase liquefied gas and a refrigerant that

has been compressed and whose pressure has then
been reduced, and the liquid-phase liquefied gas that
has been cooled by exchanging heat is fed to the
liquid-phase liquefied gas and/or gas-phase lique-
fied gas stored in the storage tank, the method com- 5
prises
a bypassing step for making a portion of the liquid-
phase liquefied gas that is fed to the storage tank
bypassed without exchanging heat with the refriger- 10
ant,
a bypass-flow-rate adjusting step for adjusting the
bypass flow rate of the liquid-phase liquefied gas that
is bypassed by the bypassing step, and
a temperature measurement step for measuring 15
temperature of a liquefied gas that is merged and
mixed the portion of the liquid-phase liquefied gas
that is cooled by the exchanging heat and the portion
of the liquid-phase liquefied gas that is bypassed by
the bypassing step, wherein
the bypass-flow-rate adjusting step adjusts the 20
bypass flow rate on the basis of the measuring result
by the temperature measurement step.

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FIG. 1

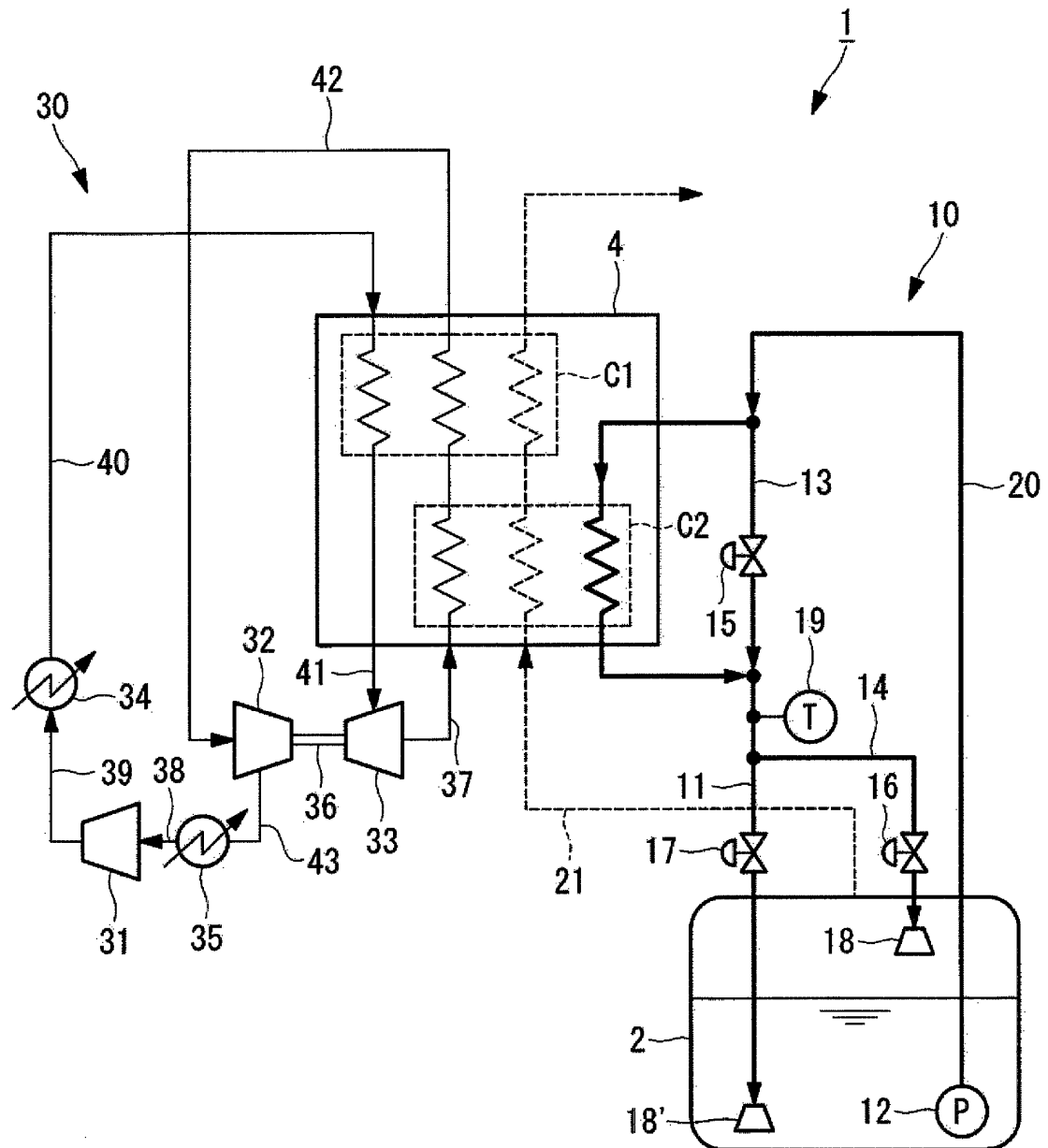


FIG. 2

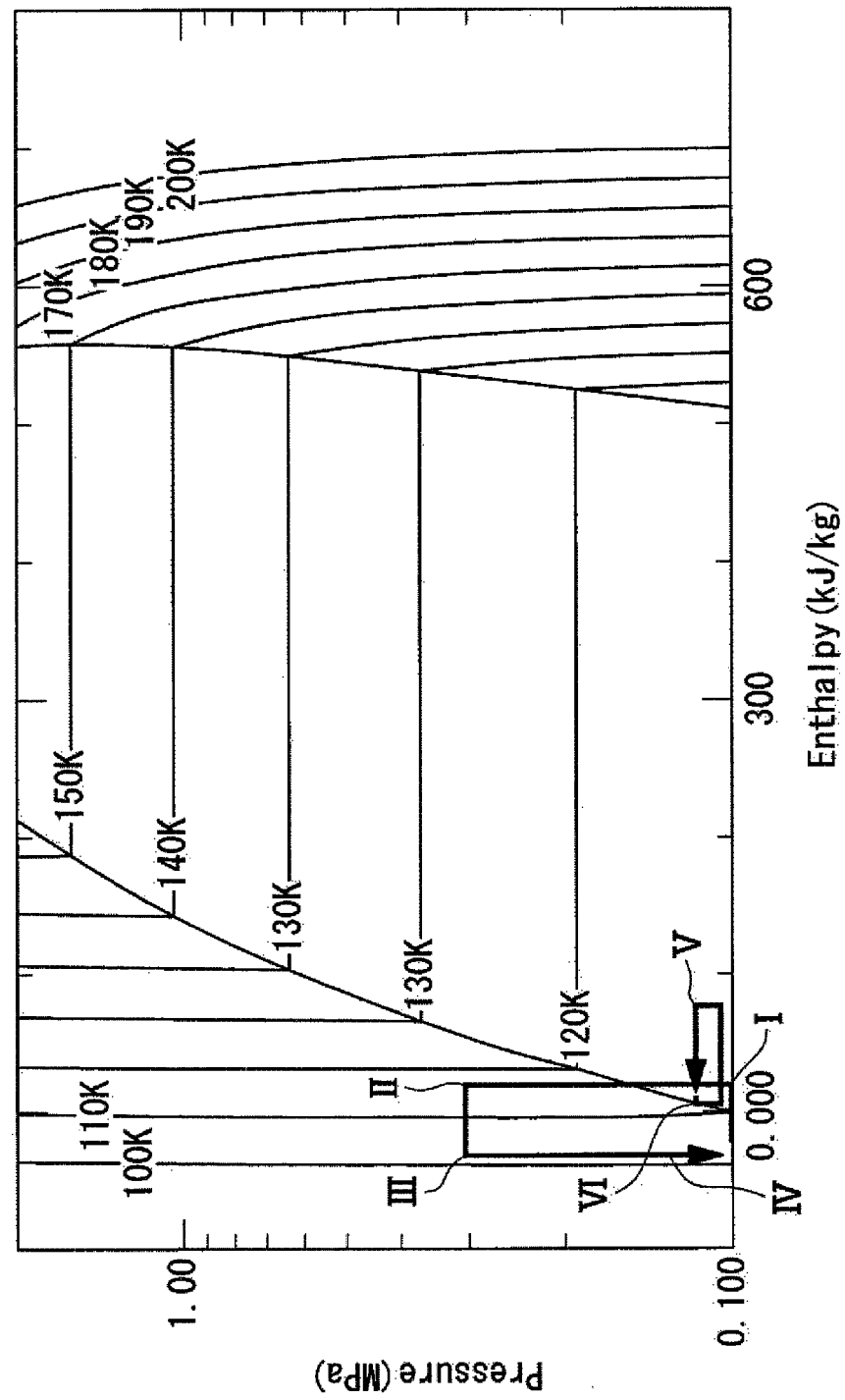


FIG. 3

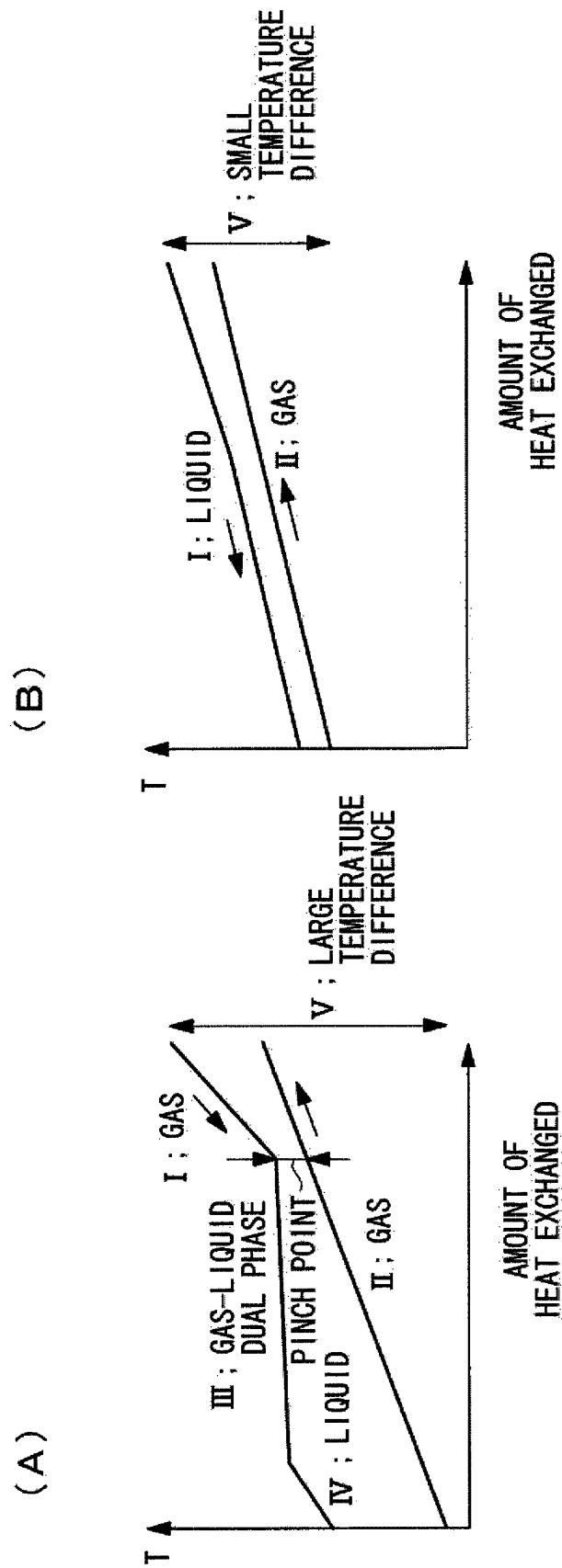


FIG. 4

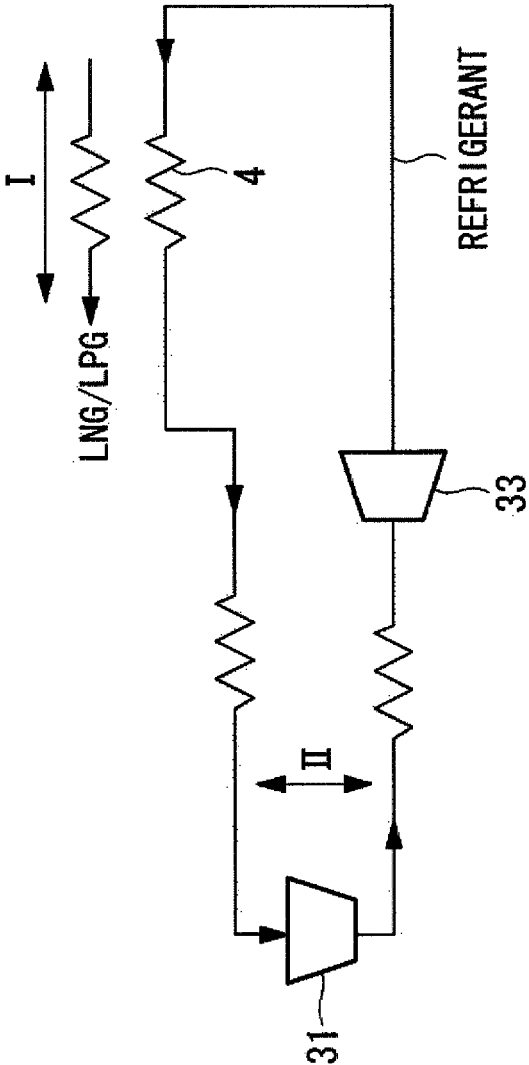


FIG. 5

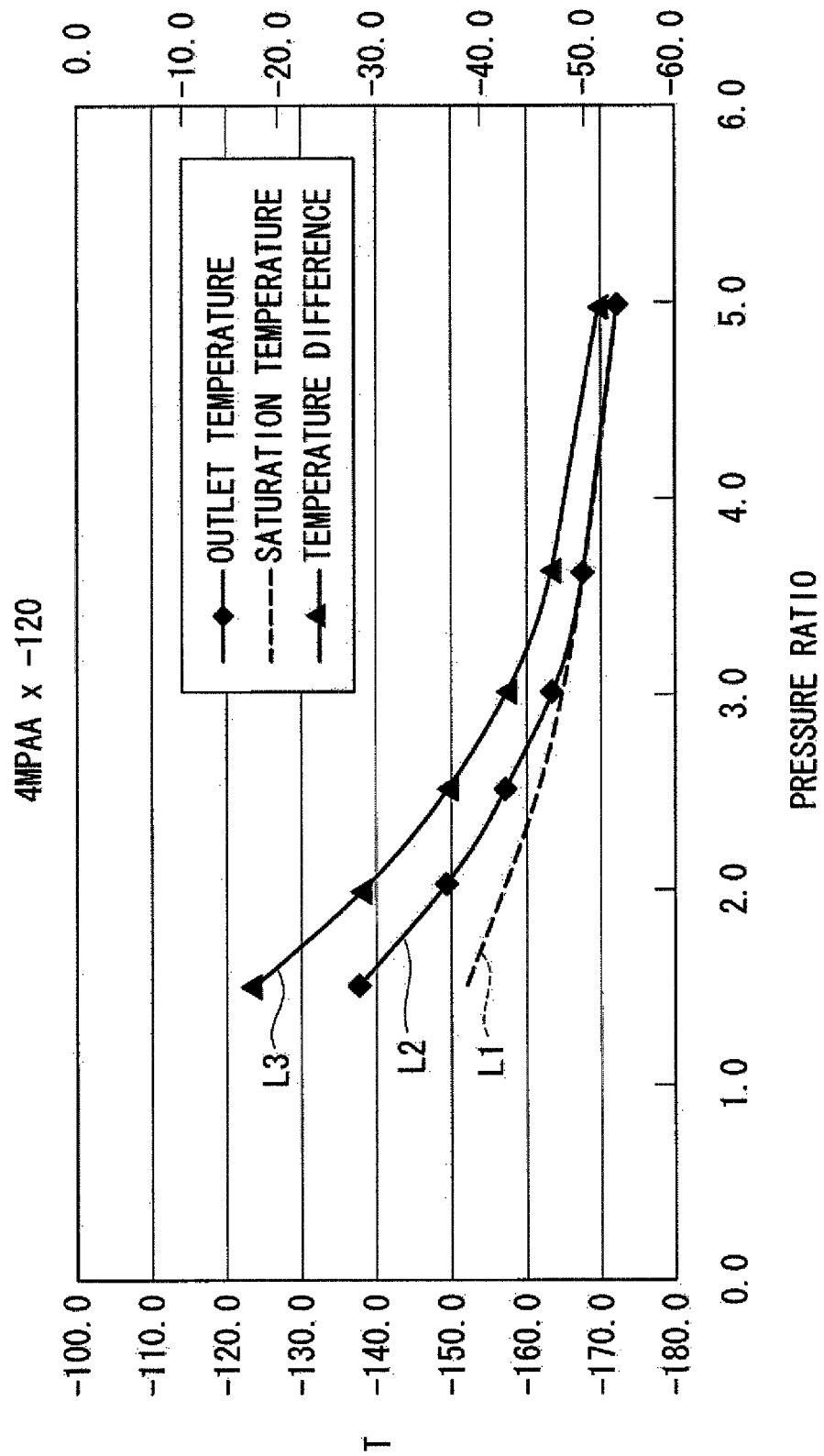


FIG. 6

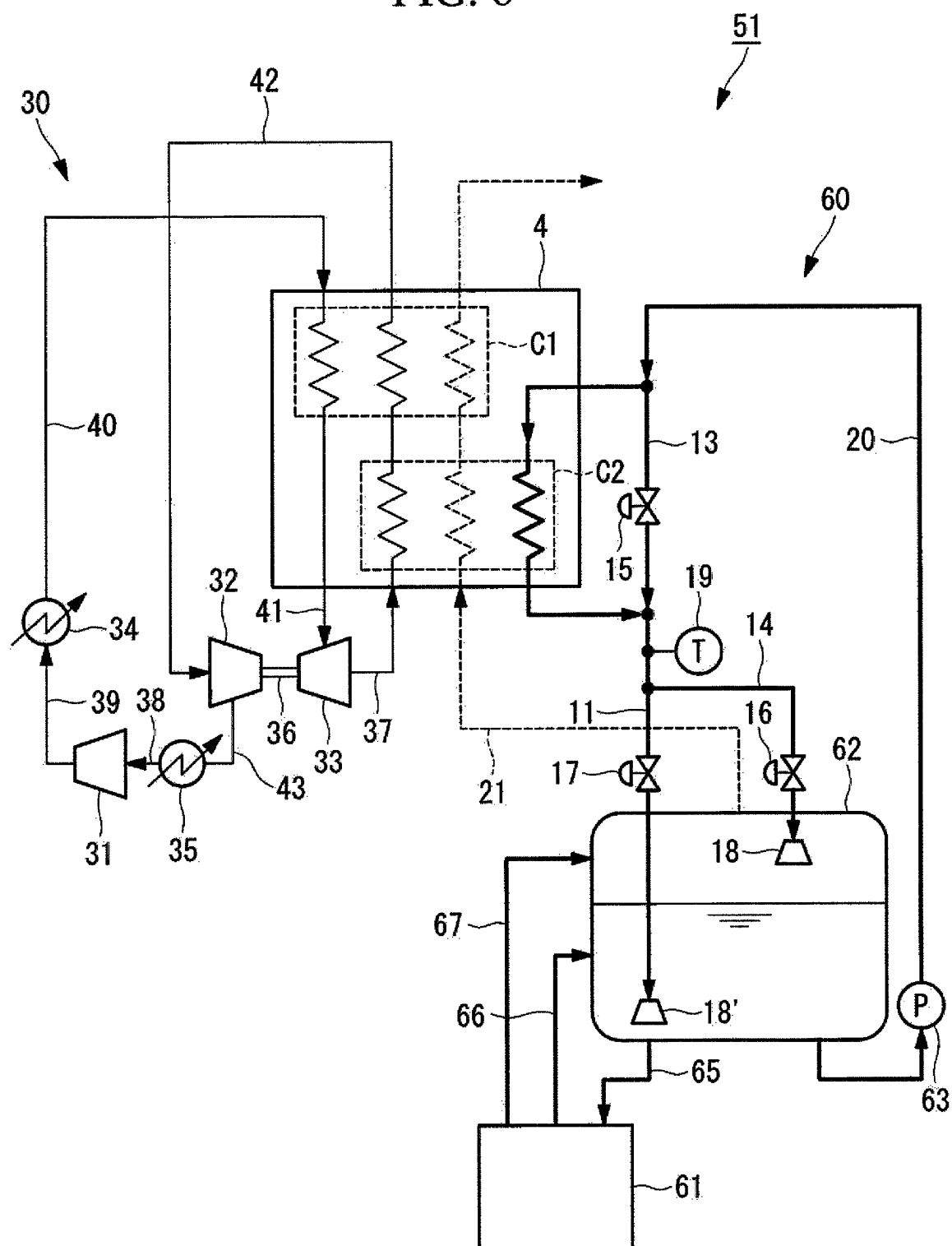


FIG. 7

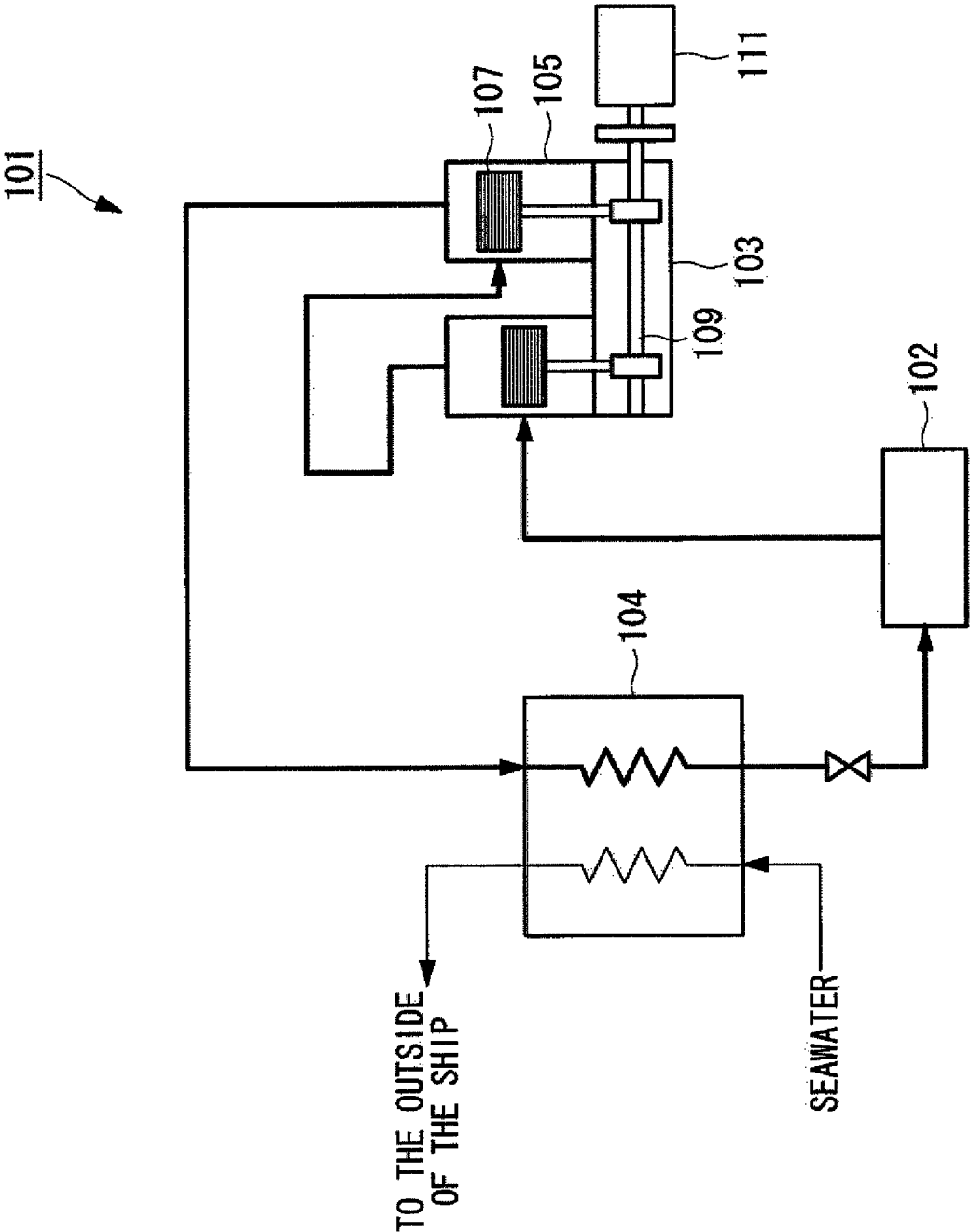


FIG. 8

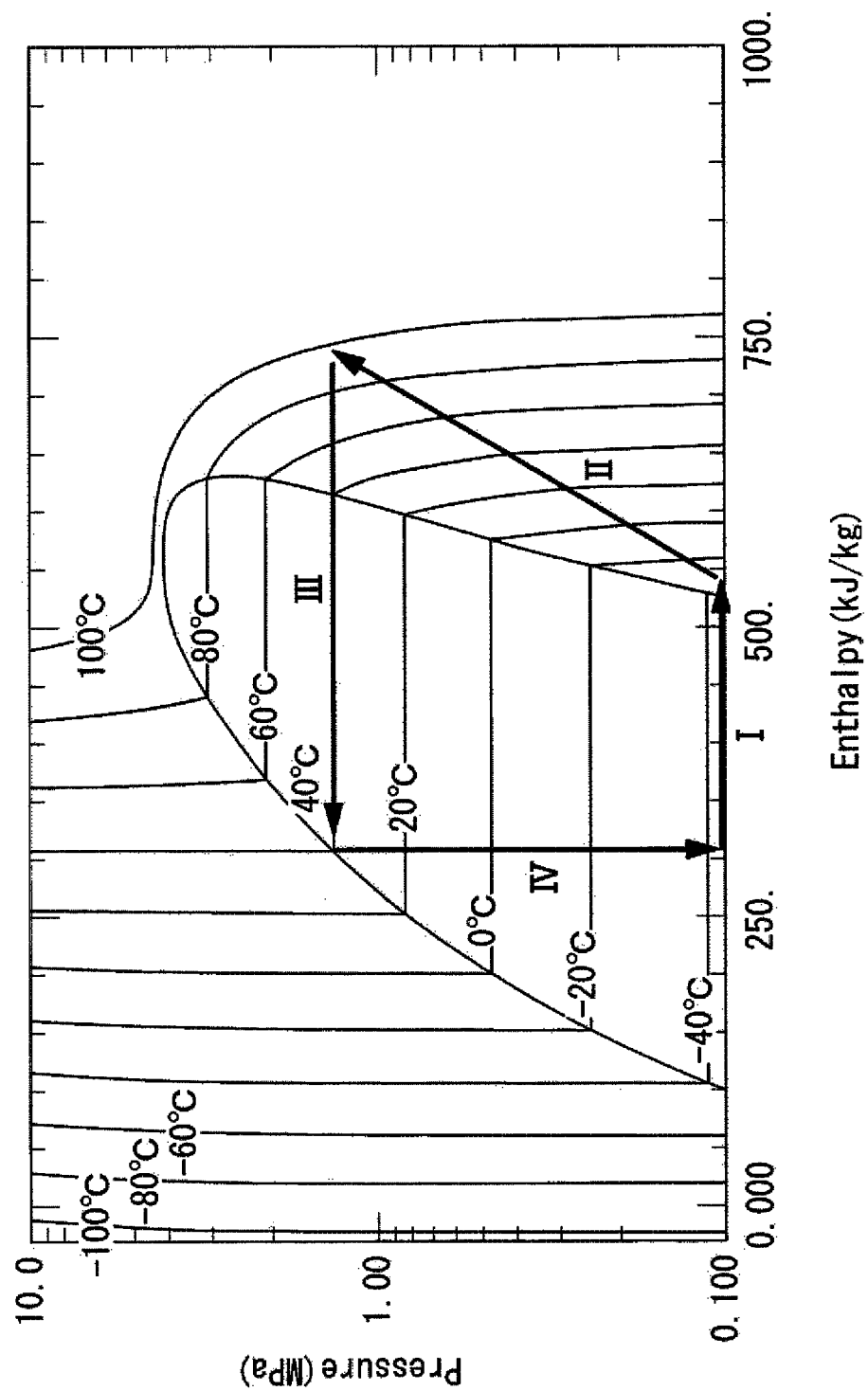


FIG. 9

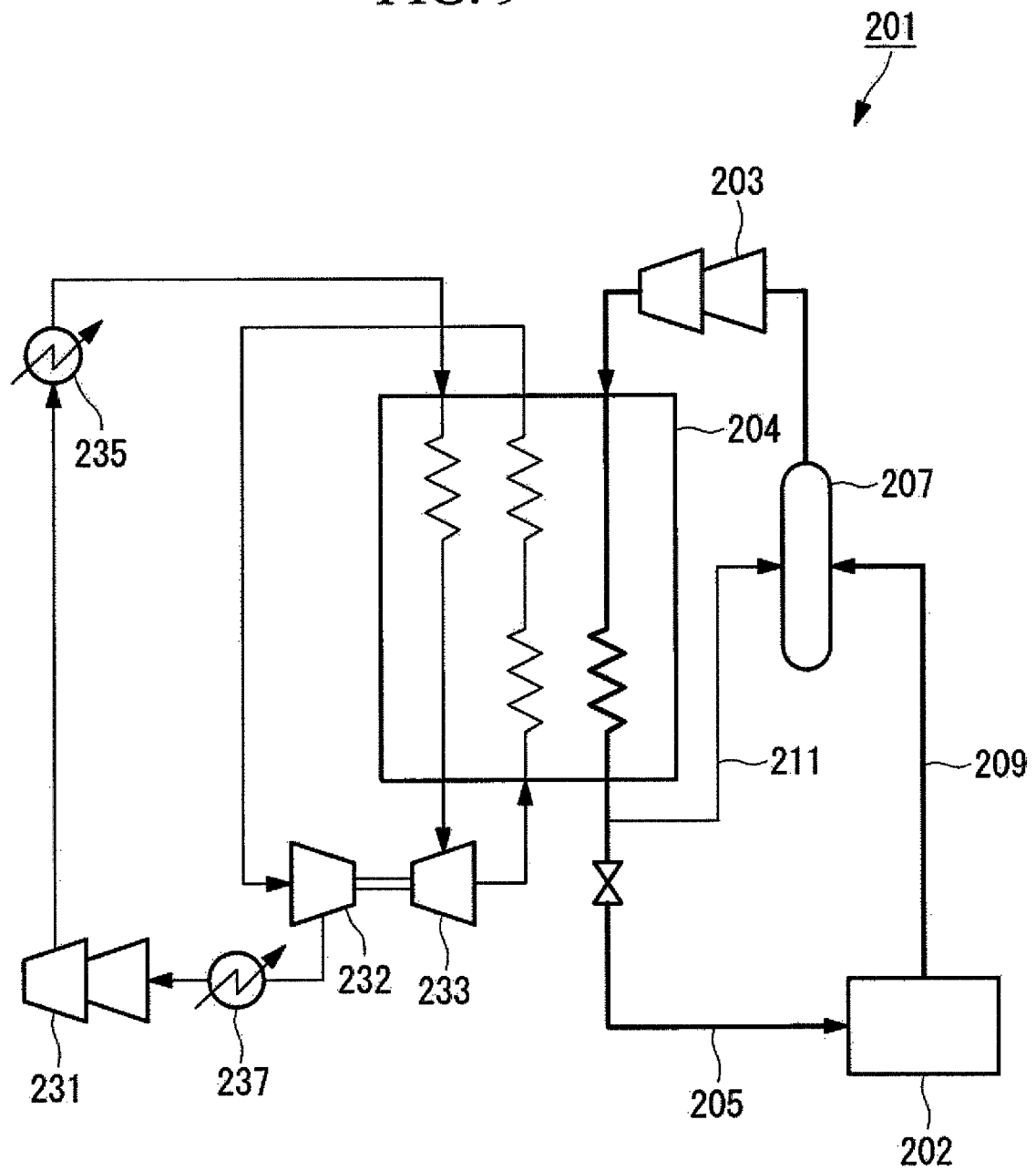
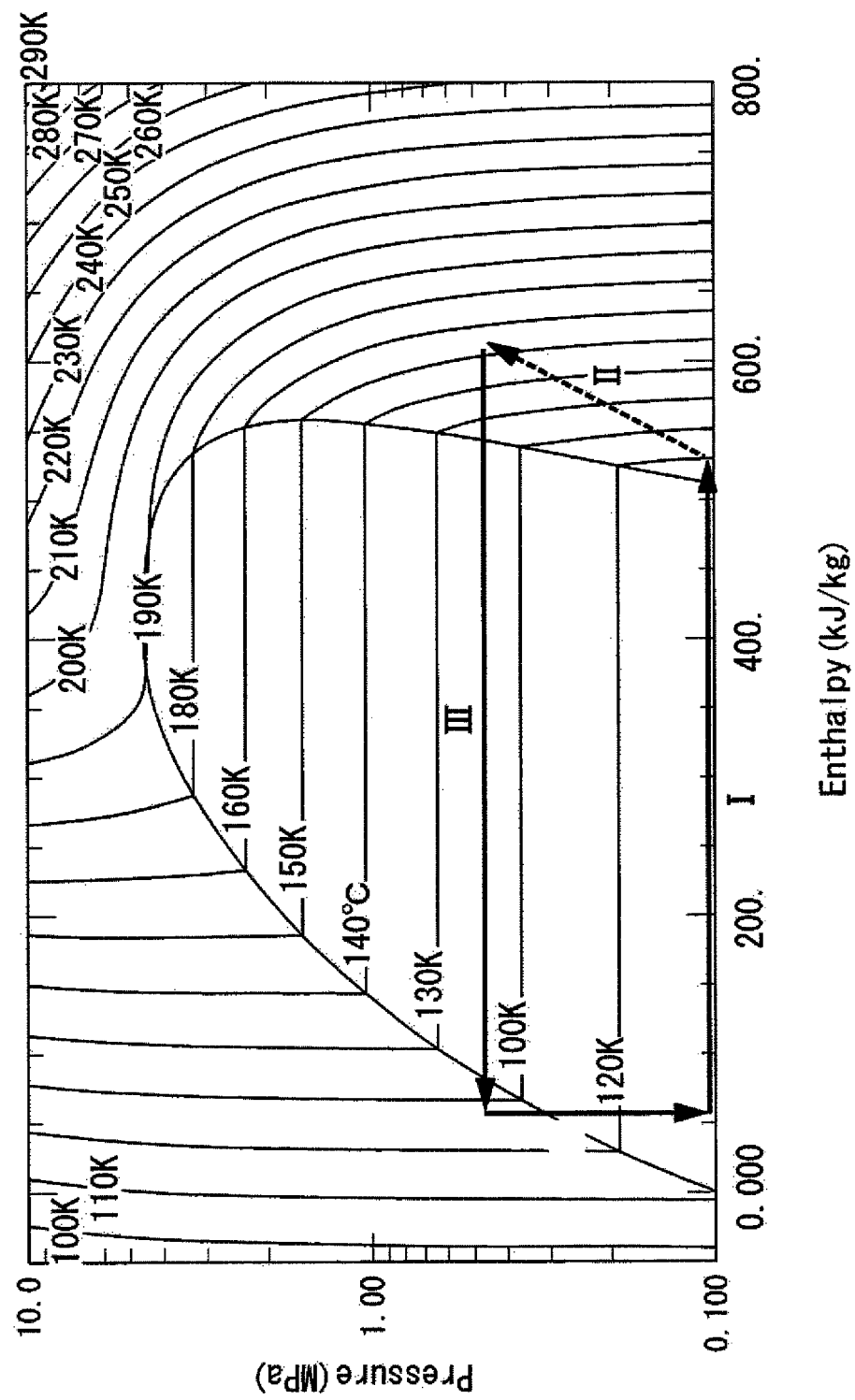


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/076921

A. CLASSIFICATION OF SUBJECT MATTER

F17C13/00 (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)

F17C13/00

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 1996-2012
 Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 6-341598 A (Chiyoda Corp.), 13 December 1994 (13.12.1994), paragraphs [0003], [0007], [0013] to [0016], [0020]; fig. 1 (Family: none)	1-11
A	JP 10-512940 A (Chicago Bridge & Iron Technical Services Co.), 08 December 1998 (08.12.1998), page 22, lines 13 to 20; page 31, lines 22 to 25; fig. 1 to 3 & US 5687776 A & WO 1996/001391 A1 & BR 9508216 A & CA 2194223 A1	1-11

☐ 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

"I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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
21 November, 2012 (21.11.12)Date of mailing of the international search report
04 December, 2012 (04.12.12)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/076921

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

A matter common to the inventions in claims 1 to 11 is a pressure rise suppressing device set forth in claim 1. However, the search reveals that the matter is disclosed in JP 6-341598 A (Chiyoda Corp.), 13 December 1994 (13.12.1994), paragraphs [0003], [0007], [0013] to [0016], [0020]; fig. 1 and hence is not novel.

As a result, the above-said common matter is not a special technical feature within the meaning of PCT Rule 13.2, second sentence, since the matter does not make a contribution over the prior art.

(Continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/076921

Continuation of Box No.III of continuation of first sheet(2)

Consequently, these inventions have no technical relationship involving one or more of the same or corresponding special technical features, and therefore cannot be considered to be so linked as to form a single general inventive concept.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2009058199 A [0014]