

## Description

### Title of Invention

VAPORIZER HAVING COLD ENERGY RECOVERY FUNCTION, AND COLD ENERGY RECOVERY DEVICE

### Technical Field

[0001] The present invention relates to a vaporizer having a cold energy recovery function and a cold energy recovery device.

### Background Art

[0002] As disclosed in Patent Literature 1 to 4 described below, there has been known an intermediate fluid type vaporizer that vaporizes low-temperature liquefied gas such as liquefied natural gas (LNG) using an intermediate medium. The vaporizer of this type is provided with an intermediate medium evaporator that evaporates the intermediate medium through heat exchange between a heat source medium and the intermediate medium, and a low-temperature liquefied gas evaporator that vaporizes the low-temperature liquefied gas with the intermediate medium evaporated by the intermediate medium evaporator. Low-temperature gas such as natural gas (NG) evaporated by the low-temperature liquefied gas evaporator is supplied to the demand side.

[0003] An intermediate fluid type vaporizer disclosed in Patent Literature 4 also functions as a cooler that uses cold energy of the LNG. In the vaporizer, as shown in Figs. 3 and 4, a vaporization facility 81 is provided in which an intermediate medium evaporator and a low-temperature liquefied gas evaporator are disposed in the same casing. A circulation circuit 84 is formed in which a heat source medium circulates between the intermediate medium evaporator in the vaporization facility 81 and a use-side heat exchanger 83 provided in a freezer 82. The heat source medium cooled by the intermediate medium evaporator of the vaporization facility 81 circulates in the circulation circuit 84 and supplies cold energy to the use-side heat exchanger 83. A backup evaporator 86 is provided in the vaporizer. That is, in the low-temperature liquefied gas evaporator in the vaporization facility 81, an amount of natural gas corresponding to a requested amount from the demand side sometimes cannot be secured simply by vaporizing the natural gas according to a refrigeration load by the use-side heat exchanger 83. Therefore, a bypass 87 for bypassing the vaporization facility 81 is provided and the backup evaporator 86 that causes the bypass 87 to evaporate the liquefied natural gas is provided.

[0004] In the intermediate fluid type vaporizer disclosed in Patent Literature 4, since the backup evaporator 86 is provided, even when an LNG vaporization load exceeds the refrigeration load, it is possible to generate an amount of the natural gas corresponding to an NG demand amount and

supply the natural gas to the demand side. However, like the low-temperature liquefied gas evaporator in the vaporization facility 81, the backup evaporator 86 needs to have structure that can withstand extremely low temperature. Therefore, the backup evaporator 86 is extremely expensive and increased in size. Therefore, there is a problem in that the intermediate fluid type vaporizer disclosed in Patent Literature 4 is expensive and large. On the other hand, in the intermediate fluid type vaporizer, since the intermediate medium receives the cold energy of the low-temperature liquefied gas, it is important in improving efficiency of the intermediate fluid type vaporizer to recover the cold energy received by the intermediate medium from the low-temperature liquefied gas.

## **Citation List**

### **Patent Literature**

[0005]

Patent Literature 1: Japanese Patent Application Publication No. S53-5207

Patent Literature 2: Japanese Patent No. 3946398

Patent Literature 3: Japanese Patent Application Publication No. 2000-227200

Patent Literature 4: Japanese Patent Application Publication No. 2011-179534

### **Summary of Invention**

[0006] It is an object of the present invention to make it possible to recover cold energy received by an intermediate medium from low-temperature liquefied gas while suppressing an increase in device costs.

[0007] A vaporizer having a cold energy recovery function according to an aspect of the present invention includes: an intermediate medium evaporator that evaporates at least a part of an intermediate medium through heat exchange between a heat source medium and the intermediate medium; a low-temperature liquefied gas evaporator that vaporizes low-temperature liquefied gas with the intermediate medium evaporated by the intermediate-medium evaporator; an intermediate medium channel for extracting the intermediate medium liquefied by the low-temperature liquefied gas evaporator to the outside, and returning the intermediate medium to the intermediate medium evaporator or the low-temperature liquefied gas evaporator; a refrigerant circulation circuit in which a refrigerant circulates; a heat exchanger that performs heat exchange between the intermediate medium that flows in the intermediate medium channel and the refrigerant that circulates in the refrigerant circulation circuit; and adjusting means for adjusting, according to a demanded cold energy load, a cold energy amount supplied from the intermediate medium to the refrigerant in the refrigerant circulation circuit.

[0008] A cold energy recovery device according to another aspect of the present invention is a cold energy recovery device used by being connected to an intermediate fluid type vaporizer that

includes: an intermediate medium evaporator that evaporates at least a part of an intermediate medium through heat exchange between a heat source medium and the intermediate medium; and a low-temperature liquefied gas evaporator that vaporizes low-temperature liquefied gas with the intermediate medium evaporated by the intermediate-medium evaporator, the cold energy recovery device including: an intermediate medium channel, one end portion of which is configured to be connectable to the low-temperature liquefied gas evaporator and the other end portion of which is configured to be connectable to the intermediate medium evaporator; a coolant circulation circuit in which a coolant for supplying cold energy to a use side circulates; a heat exchanger that performs heat exchange between the intermediate medium that flows in the intermediate medium channel and the coolant that circulates in the coolant circulation circuit; and adjusting means for adjusting, according to a cold energy load requested on the use side, a cold energy amount supplied from the intermediate medium to the coolant.

### **Brief Description of Drawings**

[0009] [Fig. 1] Fig. 1 is a schematic diagram showing the overall configuration of a vaporizer having a cold energy recovery function according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is a schematic diagram showing the overall configuration of a vaporizer having a cold energy recovery function according to another embodiment of the present invention.

[Fig. 3] Fig. 3 is a schematic diagram showing the configuration of a conventional intermediate fluid type vaporizer.

[Fig. 4] Fig. 4 is a schematic diagram showing a main part of a conventional vaporizer having a configuration in which a backup evaporator is provided.

### **Description of Embodiments**

[0010] Modes for carrying out the present invention are explained in detail below with reference to the drawings.

[0011] As shown in Fig. 1, a vaporizer having a cold energy recovery function (hereinafter simply referred to as cold energy recovery vaporizer) 10 according to an embodiment includes an intermediate fluid type vaporizer (hereinafter simply referred to as vaporizer) 12 that generates low-temperature gas and a cold energy recovery device 14 that recovers cold energy from the vaporizer 12.

[0012] The vaporizer 12 is a device for vaporizing liquefied natural gas (LNG), which is low-temperature liquefied gas, and obtaining natural gas. Note that the vaporizer 12 is not limited to the device that vaporizes the LNG and can also be applied as, for example, a device that vaporizes cryogenic liquefied gas such as ethylene, liquefied oxygen, or liquefied nitrogen.

[0013] The vaporizer 12 is the vaporizer 12 of an intermediate fluid type. The vaporizer 12

includes an evaporator E1 and a vaporizer E2. The evaporator E1 is an intermediate medium evaporator that causes an intermediate medium 4 in a liquid form and a heat source medium to exchange heat and evaporates at least a part of the intermediate medium 4. The vaporizer E2 is a cryogenic liquefied gas vaporizer that causes the liquefied natural gas and the intermediate medium 4 in a gaseous form to exchange heat and vaporizes the liquefied natural gas.

[0014] In this embodiment, propane is used as the intermediate medium 4. Note that the intermediate medium 4 is not limited to the propane. For example, as the intermediate medium 4, a medium other than the propane can also be used as long as the medium is a medium that evaporates at the normal temperature and does not solidify at temperature in common use (low temperature) (a medium having a boiling point lower than the temperature of the atmosphere) such as propylene or alternative CFCs. In this embodiment, seawater is used as the heat source medium. However, the heat source medium is not limited to the seawater. For example, as the heat source medium, steam, hot water, or the like may be used.

[0015] A casing 18 of the evaporator E1 and the vaporizer E2 is configured by a common casing 18. That is, the casing 18, which is hollow inside, is provided. A lower part of the casing 18 is configured as the evaporator E1. A part above the evaporator E1 in the casing 18 is configured as the vaporizer E2.

[0016] The evaporator E1 includes a heat transfer tube 19 disposed in a position immersed in the liquid intermediate medium 4 stored in the casing 18. One end (an inflow end) of the heat transfer tube 19 is connected to an intake pipe 20 for taking in the heat source medium. A heat source pump 21 is provided in the intake pipe 20. The heat source pump 21 is a pump that is driven at a fixed rotating speed and discharges a fixed rate of the heat source medium. Note that the heat source pump 21 may be configured by a pump, the rotating speed of which is controllable by an inverter.

[0017] A discharge tube 22 for discharging the heat source medium is connected to the other end (an outflow end) of the heat transfer tube 19. The heat source medium cooled by the intermediate medium 4 in the heat transfer tube 19 is discharged through the discharge tube 22. That is, in the vaporizer 12, a heat source medium system 23, in which the heat source medium flows, is formed by the intake pipe 20, the heat transfer tube 19 of the evaporator E1, and the discharge tube 22.

[0018] The vaporizer E2 includes a heat transfer tube 25 disposed further on the upper side than the heat transfer tube 19 of the evaporator E1. The vaporizer E2 evaporates the liquefied natural gas in the heat transfer tube 25 using, as a heat source, condensation latent heat of the gaseous intermediate medium 4 in the casing 18.

[0019] One end portion (an inlet side end portion) of the heat transfer tube 25 is connected to an

introducing pipe 28 for introducing the liquefied natural gas. A flow-rate adjusting valve 29 is provided in the introducing pipe 28. The flow-rate adjusting valve 29 is controlled by a valve control unit 30 and adjusts a valve opening according to a signal from the valve control unit 30. The valve control unit 30 outputs a signal corresponding to a result of detection by a flow rate detector 30a. The liquefied natural gas, the flow rate of which is adjusted by the flow-rate adjusting valve 29, is introduced into the vaporizer E2.

[0020] The other end portion (an outlet side end portion) of the heat transfer tube 25 is connected to a supply pipe 32. Natural gas evaporated in the heat transfer tube 25 is supplied to the demand side through the supply pipe 32. That is, in the vaporizer 12, a gas system 35, in which the liquefied natural gas or the natural gas flows, is formed by the introducing pipe 28, the heat transfer tube 25 of the vaporizer E2, and the supply pipe 32.

[0021] A heater E3 is provided in the supply pipe 32. The heater E3 heats the natural gas in the supply pipe 32 with the heat source medium flowing in the discharge tube 22. Note that the heater E3 can be omitted depending on an outlet gas temperature. The heater E3 may be provided to heat the natural gas in the supply pipe 32 with the heat source medium flowing in the intake pipe 20.

[0022] In the casing 18, a pressure detecting unit 38a functioning as state detecting means and a state controller 38 are provided. The pressure detecting unit 38a detects the pressure in the casing 18 (in the evaporator E1 and in the vaporizer E2). The state controller 38 receives a signal corresponding to a detection value from the pressure detecting unit 38a. The state controller 38 outputs a signal corresponding to the detection value by the pressure detecting unit 38a. The state controller 38 is connected to a flow-rate adjusting valve 39 provided on the discharge tube 22 to be capable of transmitting and receiving electric signals to and from the flow-rate adjusting valve 39. The flow-rate adjusting valve 39 adjusts, according to a signal sent from the state controller 38, a valve opening such that the pressure in the casing 18 (in the evaporator E1 or in the vaporizer E2) is maintained within a predetermined range. That is, a flow rate of the heat source medium flowing in the heat source medium system 23 changes according to the adjustment of the valve opening of the flow-rate adjusting valve 39. Therefore, when the pressure in the casing 18 changed, the pressure in the casing 18 (in the evaporator E1 or in the vaporizer E2) is maintained at a substantially fixed pressure by adjusting the valve opening. The state controller 38 and the flow-rate adjusting valve 39 function as a heat-source-medium-flow-rate adjusting unit that adjusts a flow rate of the heat source medium according to the detection value of the pressure detecting unit 38a.

[0023] Note that, in this embodiment, a configuration in which the pressure detecting unit 38a is employed, but the configuration is not limited to this. For example, the vaporizer 12 may have

a configuration in which a temperature detecting unit (not shown in the figure) that detects the temperature in the casing 18 (in the evaporator E1 or in the vaporizer E2) is provided instead of the pressure detecting unit 38a. The temperature detecting unit outputs a signal corresponding to the detected temperature. In this case, the flow-rate adjusting valve 39 adjusts a valve opening according to a signal sent from the state controller 38 such that the temperature in the casing 18 (in the evaporator E1 or in the vaporizer E2) is maintained within a predetermined range.

[0024] When the heat source pump 21 provided on the intake pipe 20 is configured by the pump, the rotating speed of which is controllable, the state controller 38 may be connected to the heat source pump 21 to be capable of transmitting and receiving electric signals to and from the heat source pump 21. Consequently, it is possible to adjust a flow rate of the heat source medium according to the valve opening of the flow-rate adjusting valve 39 and the rotating speed of the heat source pump 21. In this case, the flow-rate adjusting valve 39 and the heat source pump 21 function as a heat-medium-flow-rate adjusting unit. The flow rate of the heat source medium may be adjusted according to only the rotating speed of the heat source pump 21. In this case, the heat source pump 21 functions as the heat-medium-flow-rate adjusting unit.

[0025] The cold energy recovery device 14 is a device for recovering cold energy from the vaporizer 12. The cold energy recovery device 14 includes an intermediate medium channel 40 configured to be connectable to the vaporizer 12, a refrigerant circulation circuit 42 in which a refrigerant is encapsulated, a heat exchanger 44 that causes the intermediate medium and the refrigerant to exchange heat, and adjusting means 46 for adjusting a cold energy supply amount.

[0026] The intermediate medium channel 40 is configured to be connectable to the casing 18. That is, in the casing 18 of the vaporizer 12, a first connecting section 18a and a second connecting section 18b, to which both end portions of the intermediate medium channel 40 in which the intermediate medium 4 flows are respectively connectable, are formed. The first connecting section 18a is provided in a part configuring the evaporator E1 in the casing 18. The second connecting section 18b is located above the first connecting section 18a. The second connecting section 18b is provided in a part configuring the vaporizer E2 in the casing 18. A first end portion 40a, which is one end portion of the intermediate medium channel 40, is connected to the first connecting section 18a formed in the bottom portion of the casing 18. A second end portion 40b, which is the other end portion of the intermediate medium channel 40, is connected to the second connecting section 18b formed in an upper part of the casing 18. That is, the intermediate medium channel 40 is configured to extract the intermediate medium 4 in the evaporator E1 to the outside and return the intermediate medium 4 to the vaporizer E2.

[0027] A circulation pump 48 is provided in the intermediate medium channel 40. The

circulation pump 48 is configured by a pump having a fixed discharge rate. When the circulation pump 48 is driven, the liquid intermediate medium 4 accumulating in the bottom in the casing 18 (in the evaporator E1) is sucked into the intermediate medium channel 40. The intermediate medium 4 flowed in the intermediate medium channel 40 is returned to the inside of the casing 18 (the inside of the vaporizer E2) through the second connecting section 18b. The intermediate medium 4 flowing in the intermediate medium channel 40 is a liquid intermediate medium cooled and condensed by the liquefied natural gas in the vaporizer E2 and accumulating in the evaporator E1.

[0028] The heat exchanger 44 is configured to exchange heat between the intermediate medium 4 flowing in the intermediate medium channel 40 and the refrigerant flowing in the refrigerant circulation circuit 42. In the heat exchanger 44, the refrigerant is cooled by the intermediate medium. That is, cold energy of the intermediate medium 4 is supplied to the refrigerant via the heat exchanger 44.

[0029] In the refrigerant circulation circuit 42, a use-side heat exchanger 50 and a refrigerant pump 52 are provided. The use-side heat exchanger 50 is disposed in, for example, a freezer and configured to cool the air in the freezer. The refrigerant pump 52 is driven, whereby the refrigerant circulates in the refrigerant circulation circuit 42 between the heat exchanger 44 and the use-side heat exchanger 50. Cold energy received from the intermediate medium in the heat exchanger 44 is supplied to the air in the freezer in the use-side heat exchanger 50. Consequently, it is possible to cool the air in the freezer. Note that, in the heat exchanger 44 and the use-side heat exchanger 50, latent heat of the refrigerant may be used or sensible heat may be used during the heat exchange.

[0030] The adjusting means 46 includes a refrigerant-flow-rate adjusting unit 55 and a temperature adjusting unit 58. The refrigerant-flow-rate adjusting unit 55 performs control for adjusting a circulation flow rate of the refrigerant in the refrigerant circulation circuit 42. The temperature adjusting unit 58 performs control for adjusting the temperature of the refrigerant such that the temperature of the refrigerant cooled in the heat exchanger 44 is within a predetermined range.

[0031] The refrigerant-flow-rate adjusting unit 55 includes a flow-rate adjusting valve 54 and a valve controller 56. The refrigerant-flow-rate adjusting unit 55 includes a connector 60 connected to a temperature sensor 62, which is capable of detecting, for example, the temperature of the air in the freezer, to be capable of transmitting and receiving signals to and from the temperature sensor 62. The valve controller 56 is configured to, in a state in which the valve controller 56 is connected to the temperature sensor 62, output, on the basis of a signal input from the temperature sensor 62, a signal for controlling a valve opening of the flow-rate

adjusting valve 54 provided in the refrigerant circulation circuit 42. Note that the refrigerant-flow-rate adjusting unit 55 receives a signal from a flow rate detector 56a provided in the refrigerant circulation circuit 42 and finely adjusts the valve opening of the flow-rate adjusting valve 54 according to a detection value.

[0032] When the valve opening of the flow-rate adjusting valve 54 of the refrigerant circulation circuit 42 is adjusted, a refrigerant circulation amount in the refrigerant circulation circuit 42 is adjusted. By adjusting the valve opening of the flow-rate adjusting valve 54, in the heat exchanger 44, it is possible to adjust a cold energy amount received by the refrigerant from the intermediate medium 4. As a result, in the use-side heat exchanger 50, it is possible to adjust a cold energy amount supplied to the air in the freezer.

[0033] The temperature adjusting unit 58 includes a temperature detecting unit 58a that detects the temperature of the refrigerant, an adjustment valve 58b that adjusts a flow rate of the intermediate medium in the intermediate medium channel 40, and a valve control unit 58c that controls the adjustment valve 58b according to a detection result of the temperature detecting unit 58a.

[0034] The temperature detecting unit 58a is configured to detect, in the refrigerant circulation circuit 42, the temperature of the refrigerant cooled by the intermediate medium in the heat exchanger 44. That is, the temperature detecting unit 58a detects a refrigerant temperature on an upstream side of the use-side heat exchanger 50 in the refrigerant circulation circuit 42. The temperature detecting unit 58a detects the temperature of the refrigerant flowing from the heat exchanger 44 to the use-side heat exchanger 50.

[0035] The valve control unit 58c is configured to output a signal corresponding to a detected value by the temperature detecting unit 58a. The adjustment valve 58b adjusts a valve opening on the basis of the signal sent from the valve control unit 58c. When the valve opening of the adjustment valve 58b is adjusted, a flow rate of the intermediate medium 4 flowing into the intermediate medium channel 40 from the inside of the casing 18 is adjusted. As a result, in the heat exchanger 44, a cold energy amount supplied from the intermediate medium 4 to the refrigerant is also adjusted. As a result, the temperature of the refrigerant passed through the heat exchanger 44 is adjusted to be within a predetermined range. That is, the temperature adjusting unit 58 is capable of controlling the refrigerant temperature to be within the predetermined range by adjusting the valve opening of the adjustment valve 58b provided in the intermediate medium channel 40.

[0036] The operation of the cold energy recovery vaporizer 10 in this embodiment is explained.

[0037] The liquefied natural gas introduced into the heat transfer tube 25 of the vaporizer E2 through the introducing pipe 28 exchanges heat with the gaseous intermediate medium 4 in the

casing 18 (in the vaporizer E2). Consequently, the liquefied natural gas evaporates and the intermediate medium 4 condenses. The vaporized natural gas flows into the supply pipe 32 and is further heated by the heat source medium in the heater E3. After being heated, the natural gas is supplied to the gas demand side through the supply pipe 32.

[0038] In the casing 18, the intermediate medium 4 is present in a saturated state. The intermediate medium 4 condensed in the vaporizer E2 is stored in the bottom portion in the casing 18. The liquid intermediate medium 4 accumulating in the casing 18 (in the evaporator E1) exchanges heat with the heat source medium flowing into the heat transfer tube 19 of the evaporator E1 through the intake pipe 20. At least a part of the liquid intermediate medium 4 is evaporated by the heat exchange. On the other hand, the heat source medium is cooled by the intermediate medium 4 (receives cold energy) and flows into the discharge tube 22. The heat source medium is further cooled by the natural gas in the heater E3 and discharged from the discharge tube 22. Note that the heat source pump 21 of the intake pipe 20 discharges a fixed rate of the heat source medium.

[0039] In the casing 18, control is performed such that the pressure in the casing 18 is maintained at a fixed pressure. For example, when a flow rate of the liquefied natural gas introduced into the vaporizer E2 through the introducing pipe 28 increased, the temperature and the pressure in the casing 18 drop. When detecting the pressure drop in the casing 18, the state controller 38 executes control for increasing the valve opening of the flow-rate adjusting valve 39 of the discharge tube 22. Consequently, a flow rate of the heat source medium supplied to the evaporator E1 increases. The pressure drop in the casing 18 can be suppressed. Consequently, the pressure in the casing 18 is maintained at the fixed pressure.

[0040] A part of the intermediate medium 4 accumulating in the bottom portion in the casing 18 (in the evaporator E1) flows in the intermediate medium channel 40 according to the driving of the circulation pump 48. In the heat exchanger 44, the intermediate medium 4 flowing in the intermediate medium channel 40 exchanges heat with the refrigerant in the refrigerant circulation circuit 42. The intermediate medium 4 cooled in the heat exchanger 44 returns to the inside of the casing 18 through the second connecting section 18b of the casing 18. At this moment, the intermediate medium 4 is flushed to change to a gaseous form and introduced into the casing 18 (into the vaporizer E2). Note that, in the heat exchanger 44, the intermediate medium 4 may be set to exchange heat with the refrigerant to thereby vaporize. In this case, the intermediate medium 4 in a gaseous form or a gas-liquid mixed state is introduced into the casing 18 (into the vaporizer E2).

[0041] The refrigerant cooled by the intermediate medium 4 in the heat exchanger 44 cools the air in the freezer in the use-side heat exchanger 50 and thereafter returns to the heat exchanger 44.

In the refrigerant circulation circuit 42, this circulation of the refrigerant is repeated.

[0042] In the refrigerant circulation circuit 42, a refrigerant circulation amount is adjusted according to a cold energy load within a range of a vaporization load and, on the other hand, adjusted such that the temperature of the refrigerant is maintained to be substantially fixed. This adjusting operation is specifically explained below.

[0043] The temperature sensor 62 provided in the use-side heat exchanger 50 detects the temperature of the air in the freezer. When the temperature of the air in the freezer detected by the temperature sensor 62 is higher than, for example, a set temperature, the refrigerant-flow-rate adjusting unit 55 performs, on the basis of a signal received from the temperature sensor 62, control for increasing the valve opening of the flow-rate adjusting valve 54 of the refrigerant circulation circuit 42. Consequently, an amount of the refrigerant circulating in the refrigerant circulation circuit 42 increases. This is because, when a circulation amount of the refrigerant increases, the temperature of the refrigerant rises according to the increase in the circulation amount and the refrigerant amount increases with respect to a cold energy amount received from the heat exchanger 44.

[0044] When the temperature of the refrigerant rises, the temperature detecting unit 58a detects the temperature rise. The valve control unit 58c outputs a signal corresponding to a temperature detection value. The adjustment valve 58b of the intermediate medium channel 40 receives the signal and operates to increase the valve opening. Consequently, a flow rate of the intermediate medium 4 flowing in the intermediate medium channel 40 increases. In the heat exchanger 44, the cold energy amount supplied from the intermediate medium 4 to the refrigerant increases. As a result, the temperature of the refrigerant flowing from the heat exchanger 44 toward the use-side heat exchanger 50 drops. The refrigerant temperature is maintained within a range of a predetermined temperature.

[0045] At this moment, the cold energy supplied from the intermediate medium 4 to the refrigerant increases according to the increase in the refrigerant circulation amount. Therefore, the temperature of the intermediate medium 4 returning to the casing 18 through the intermediate medium channel 40 rises. The pressure in the casing 18 also rises. When detecting the pressure rise in the pressure detecting unit 38a, the state controller 38 provided in the casing 18 outputs a signal for reducing the valve opening of the flow-rate adjusting valve 39. Consequently, a flow rate of the heat source medium flowing in the discharge tube 22 decreases. Therefore, the cold energy amount supplied from the intermediate medium 4 to the heat source medium decreases. Further, it is possible to reduce the pressure in the casing 18. As a result, it is possible to maintain the pressure in the casing 18 at the fixed pressure. That is, when the cold energy amount supplied to the refrigerant increases, the cold energy amount supplied to the

heat source medium (an indirect LNG vaporization supplement heat amount) is reduced by the increase. In total, the recovery of the cold energy by the refrigerant and the supply of the heat medium are performed within the range of the vaporization load.

[0046] On the other hand, when the temperature of the air in the freezer detected by the temperature sensor 62 is lower than, for example, the set temperature, the valve controller 56 reduces the valve opening of the flow-rate adjusting valve 54 of the refrigerant circulation circuit 42. Consequently, the refrigerant circulation amount decreases. At this moment, since the refrigerant temperature drops, the valve control unit 58c reduces the valve opening of the adjustment valve 58b of the intermediate medium channel 40. Consequently, since the pressure in the casing 18 drops, the state controller 38 increases the valve opening of the flow-rate adjusting valve 39 of the discharge tube 22. Consequently, it is possible to increase a cold energy amount supplied from the intermediate medium 4 to the heat source medium. Further, it is possible to suppress a rise in the pressure in the casing 18.

[0047] As explained above, in this embodiment, the vaporizer E2 vaporizes an amount of the low-temperature liquefied gas according to the demand of the low-temperature gas. At this moment, the cold energy is supplied to the intermediate medium 4 by the liquefied natural gas to liquefy the intermediate medium 4. Therefore, it is possible to supply the cold energy from the liquefied natural gas to the intermediate medium 4 within the range of the vaporization load of the liquefied natural gas. The cold energy is supplied from the intermediate medium 4 to the refrigerant in the refrigerant circulation circuit 42 via the heat exchanger 44. The cold energy is supplied to the use-side heat exchanger 50. Therefore, it is possible to recover the cold energy received by the intermediate medium 4 from the liquefied natural gas. The amount of this cold energy supplied to the use side via the use-side heat exchanger 50 is a heat amount within the range of the vaporization load of the liquefied natural gas. Moreover, in the heat exchanger 44 that performs the heat exchange between the intermediate medium 4 and the refrigerant, the adjusting means 46 adjusts a cold energy supply amount according to a demanded cold energy load. Therefore, when the demanded cold energy load is small, it is possible to reduce a cold energy amount extracted from the refrigerant circulation circuit 42. In other words, it is possible to extract an amount of the cold energy corresponding to the cold energy load from the refrigerant circulation circuit 42 and supply the cold energy to the use side within a range of a vaporization load of the liquefied natural gas requested from the demand side. Therefore, it is possible to use the cold energy recovery vaporizer 10 as an auxiliary cooling device. Unlike a conventional liquefied natural vaporizer used in a refrigeration warehouse or the like, since this embodiment is not based on the premise that an entire requested cold energy load is covered, it is unnecessary to provide a backup evaporator in addition to the vaporizer E2. Therefore, it is

possible to suppress device costs of the vaporizer 10.

[0048] In this embodiment, the refrigerant-flow-rate adjusting unit 55 adjusts a refrigerant circulation amount of the refrigerant circulation circuit 42 according to a cold energy load on the use side. Consequently, a cold energy amount supplied to the use side is adjusted. At this moment, the cold energy is supplied to the use side in the use-side heat exchanger 50. The temperature of the refrigerant warmed by the air in the freezer changes. The temperature adjusting unit 58 performs control for adjusting the temperature of the refrigerant such that the temperature of the refrigerant cooled in the heat exchanger 44 is within a predetermined range. Consequently, it is possible keep the temperature of the refrigerant, which is cooled by the intermediate medium in the heat exchanger 44 and supplies the cold energy to the use side, within the predetermined range. As a result, it is possible to accurately perform control of the cold energy amount supplied to the use side.

[0049] In this embodiment, when a cold energy amount supplied from the intermediate medium 4 in the intermediate medium channel 40 to the refrigerant in the refrigerant circulation circuit 42 is adjusted, the temperature and the pressure of the intermediate medium 4 introduced into the vaporizer E2 fluctuate. The state controller 38 detects the temperature or the pressure in the vaporizer E2. The flow-rate adjusting valve 39 adjusts a flow rate of the heat source medium according to a detection result by the pressure detecting unit 38a of the state controller 38 such that the temperature or the pressure is within a predetermined range. Therefore, the temperature or the pressure of the intermediate medium 4 in the vaporizer E2 is maintained within the predetermined range. Therefore, it is possible to maintain the temperature of the low-temperature gas vaporized by the vaporizer E2 within the predetermined range.

[0050] Since the refrigerant-flow-rate adjusting unit 55 is provided, a cold energy amount supplied to the refrigerant through the intermediate medium 4 is adjusted. In this case, a cold energy amount supplied from the liquefied natural gas to the refrigerant via the intermediate medium 4 changes according to the cold energy amount supplied from the intermediate medium 4 to the refrigerant. At this moment, a flow rate of the heat source medium is adjusted, whereby a supply heat amount to the intermediate medium 4 is adjusted. Therefore, a change in the cold energy amount supplied from the intermediate medium to the refrigerant can be absorbed by the adjustment of the supply heat amount by the heat source medium. As a result, it is possible to maintain the flow rate and the temperature of the low-temperature gas vaporized by the vaporizer E2 within predetermined ranges.

[0051] Note that the present invention is not limited to the embodiment. Various changes, improvements, and the like are possible in a range not departing from the spirit of the present invention. For example, in the configuration of the embodiment, the circulation pump 48 is

provided in the intermediate medium channel 40. The circulation pump 48 is driven, whereby the intermediate medium is forced to flow to the intermediate medium channel 40. Instead of this configuration, in the intermediate medium channel 40, the intermediate medium 4 may flow in a thermo-siphon system. In this case, as shown in Fig. 2, the circulation pump 48 of the intermediate medium channel 40 can be omitted. In this case, the intermediate medium flowing in the intermediate medium channel 40 is set to evaporate in the heat exchanger 44. That is, the liquid intermediate medium flows into the intermediate medium channel 40 from the inside of the casing 18. The intermediate medium vaporizes in the intermediate medium channel 40 to be returned to the inside of the casing 18. On the other hand, the refrigerant is set to be cooled in the heat exchanger 44 and heated in the use-side heat exchanger 50 to be raised in temperature.

[0052] In configuration of the embodiment, the evaporator E1 and the vaporizer E2 are provided in the common casing 18. However, the present invention is not limited to this configuration. That is, the evaporator E1 and the vaporizer E2 may be independently formed separately from each other. The evaporator E1 and the vaporizer E2 formed separately from each other may be connected by a pipe.

[0053] In the embodiment, the second connecting section 18b is provided in the part configuring the vaporizer E2 in the casing 18. However, the present invention is not limited to this. The second connecting section 18b may be provided in a part configuring the evaporator E1 in the casing 18. That is, the intermediate medium flowed in the intermediate medium channel 40 may be returned to the evaporator E1.

[0054] The embodiment is outlined.

[0055] (1) In this embodiment, in the low-temperature liquefied gas evaporator, an amount of the low-temperature liquefied gas corresponding to a demand of the low-temperature gas vaporizes. At this moment, the cold energy is supplied to the intermediate medium by the low-temperature liquefied gas and the intermediate medium is liquefied. Therefore, the cold energy can be supplied from the low-temperature liquefied gas to the intermediate medium within the range of the vaporization load of the low-temperature liquefied gas. The cold energy is supplied from the intermediate medium to the refrigerant in the refrigerant circulation circuit via the heat exchanger. The cold energy supplied to the refrigerant in the refrigerant circulation circuit can be supplied to the use side. Therefore, it is possible to recover the cold energy received by the intermediate medium from the low-temperature liquefied gas. This supplied cold energy amount is a heat amount within the range of the vaporization load of the low-temperature liquefied gas. Moreover, in the heat exchanger that performs the heat exchange between the intermediate medium and the refrigerant, the adjusting means adjusts the

cold energy supply amount according to a demanded cold energy load. Therefore, when the requested cold energy load is small, it is possible to reduce a cold energy amount extracted from the refrigerant circulation circuit. In other words, it is possible to extract an amount of the cold energy corresponding to the cold energy load from the refrigerant circulation circuit within a requested vaporization load. Therefore, it is possible to use the low-temperature liquefied vaporizer as an auxiliary cooling device. Unlike a conventional low-temperature liquefied vaporizer used in a refrigeration warehouse or the like, since this embodiment is not based on the premise that an entire demanded cold energy load is covered, it is unnecessary to provide a backup evaporator in addition to the low-temperature liquefied gas evaporator. Therefore, it is possible to suppress device costs of the intermediate fluid type vaporizer.

[0056] That is, in a conventional vaporization device that, like the low-temperature liquefied vaporizer or the like used in the refrigeration warehouse or the like, supplies the low-temperature gas vaporized from the low-temperature liquefied gas to the demand side, and on the other hand, recovers the cold energy of the low-temperature liquefied gas to thereby cover a cold energy load in the warehouse, an amount of the heat source medium necessary for vaporizing the low-temperature liquefied gas corresponding to a low-temperature gas request amount is supplied. Therefore, in some case, a vaporization load requested from the demand side exceeds the cold energy load in the warehouse. In such a case, when the entire amount of the low-temperature liquefied gas is vaporized, the cold energy is excessively supplied to the inside of the warehouse. To cope with this problem, the conventional device needs a backup evaporator for vaporizing the low-temperature liquefied gas that bypasses a vaporization facility that supplies the cold energy to the inside of the warehouse. On the other hand, in this embodiment, the low-temperature liquefied gas is vaporized according to a demanded vaporization load and, on the other hand, the cold energy is only extracted from the refrigerant circulation circuit within a range of the vaporization load. Therefore, although a cold energy amount corresponding to the cold energy request amount cannot always be supplied, it is unnecessary to provide the backup evaporator. When the demanded cold energy load is small, the adjusting means adjusts a refrigerant circulation amount in the refrigerant circulation circuit. Consequently, it is possible to reduce the cold energy amount extracted from the refrigerant circulation circuit. Therefore, it is possible to extract the cold energy by a necessary amount. Note that the vaporization load exceeding the cold energy load can be adjusted by the heat source medium flowing in the heat source medium channel.

[0057] (2) It is preferable that the adjusting means includes a refrigerant-flow-rate adjusting unit that adjusts a circulation amount of the refrigerant in the refrigerant circulation circuit and a temperature adjusting unit that performs control for adjusting the temperature of the refrigerant

such that the temperature of the refrigerant cooled in the heat exchanger is within a predetermined range.

[0058] In this form, the refrigerant circulation amount in the refrigerant circulation circuit is adjusted according to a cold energy load on the use side, whereby a cold energy amount supplied to the use side is adjusted. At this moment, the temperature of the refrigerant that supplies the cold energy to the use side changes. The temperature adjusting unit performs control for adjusting the temperature of the refrigerant such that the temperature of the refrigerant cooled in the heat exchanger is within a predetermined range. Consequently, the temperature of the refrigerant that cooled by the intermediate medium in the heat exchanger and supplies the cold energy to the use side can be within the predetermined range. As a result, it is possible to accurately perform control of the cold energy amount supplied to the use side.

[0059] (3) The vaporizer having a cold energy recovery function may include state detecting means for detecting the temperature or the pressure of the intermediate medium for vaporizing the low-temperature liquefied gas in the low-temperature liquefied gas evaporator and a heat-source-medium-flow-rate adjusting unit that adjusts a flow rate of the heat source medium according to a detection result of the state detecting means such that the temperature or the pressure detected by the state detecting means is within a predetermined range.

[0060] In this form, when a cold energy amount supplied from the intermediate medium in the intermediate medium channel to the refrigerant circulation circuit is adjusted, the temperature and the pressure of the intermediate medium introduced into the low-temperature liquefied gas evaporator fluctuate. The state detecting means detects the temperature or the pressure in the low-temperature liquefied gas evaporator. The heat-source-medium-flow-rate adjusting unit adjusts the flow rate of the heat source medium according to the detection result by the state detecting means such that the temperature or the pressure is within the predetermined range. Therefore, the temperature or the pressure of the intermediate medium in the low-temperature liquefied gas evaporator is maintained to be within the predetermined range. Therefore, it is possible to maintain the temperature of the low-temperature gas vaporized by the low-temperature liquefied gas evaporator within the predetermined range.

[0061] When the refrigerant-flow-rate adjusting unit is provided, the cold energy amount supplied to the refrigerant through the intermediate medium is adjusted. In this case, the cold energy amount supplied from the low-temperature liquefied gas to the refrigerant via the intermediate medium changes according to the cold energy amount supplied to the intermediate medium to the refrigerant. At this moment, the flow rate of the heat source medium is adjusted, whereby the cold energy amount absorbed by the heat source medium from the intermediate medium (an indirect low-temperature liquefied gas vaporization supplement heat amount) is

adjusted. Therefore, the change in the cold energy amount supplied to the refrigerant can be absorbed by the flow rate adjustment of the heat source medium. As a result, it is possible to maintain the flow rate and the temperature of the low-temperature gas vaporized by the low-temperature liquefied gas evaporator within the predetermined ranges.

[0062] (4) The cold energy recovery device in this embodiment is a cold energy recovery device used by being connected to an intermediate fluid type vaporizer that includes: an intermediate medium evaporator that evaporates at least a part of an intermediate medium through heat exchange between a heat source medium and the intermediate medium; and a low-temperature liquefied gas evaporator that vaporizes low-temperature liquefied gas with the intermediate medium evaporated by the intermediate-medium evaporator, the cold energy recovery device including: an intermediate medium channel, one end portion of which is configured to be connectable to the low-temperature liquefied gas evaporator and the other end portion of which is configured to be connectable to the intermediate medium evaporator; a refrigerant circulation circuit in which a refrigerant for supplying cold energy to a use side circulates; a heat exchanger that performs heat exchange between the intermediate medium that flows in the intermediate medium channel and the refrigerant that circulates in the refrigerant circulation circuit; and adjusting means for adjusting, according to a cold energy load demanded on the use side, a cold energy amount supplied from the intermediate medium to the refrigerant.

[0063] In the cold energy recovery device, by connecting the intermediate medium channel to the low-temperature liquefied gas evaporator and the intermediate medium evaporator, it is possible to recover the cold energy from the intermediate fluid type vaporizer.

[0064] As explained above, according to this embodiment, it is possible to suppress a rise in device costs and, on the other hand, recover the cold energy received by the intermediate medium from the low-temperature liquefied gas.

### Claims

1. A vaporizer having a cold energy recovery function, comprising:
  - an intermediate medium evaporator that evaporates at least a part of an intermediate medium through heat exchange between a heat source medium and the intermediate medium;
  - a low-temperature liquefied gas evaporator that vaporizes low-temperature liquefied gas with the intermediate medium evaporated by the intermediate-medium evaporator;
  - an intermediate medium channel for extracting the intermediate medium liquefied by the low-temperature liquefied gas evaporator to an outside, and returning the intermediate medium to the intermediate medium evaporator or the low-temperature liquefied gas evaporator;
  - a refrigerant circulation circuit in which a refrigerant circulates;
  - a heat exchanger that performs heat exchange between the intermediate medium that flows in the intermediate medium channel and the refrigerant that circulates in the refrigerant circulation circuit; and
  - adjusting means for adjusting, according to a demanded cold energy load, a cold energy amount supplied from the intermediate medium to the refrigerant in the refrigerant circulation circuit.
2. The vaporizer having a cold energy recovery function according to claim 1, wherein the adjusting means includes: a refrigerant-flow-rate adjusting unit that adjusts a circulation amount of the refrigerant in the refrigerant circulation circuit; and a temperature adjusting unit that performs control for adjusting temperature of the refrigerant such that the temperature of the refrigerant cooled in the heat exchanger is within a predetermined range.
3. The vaporizer having a cold energy recovery function according to claim 1 or 2, further comprising:
  - state detecting means for detecting temperature or pressure of the intermediate medium for vaporizing the low-temperature liquefied gas in the low-temperature liquefied gas evaporator; and
  - a heat-source-medium-flow-rate adjusting unit that adjusts a flow rate of the heat source medium according to a detection result of the state detecting means such that the temperature or the pressure detected by the state detecting means is within a predetermined range.
4. A cold energy recovery device used by being connected to an intermediate fluid type vaporizer that includes: an intermediate medium evaporator that evaporates at least a part of an intermediate medium through heat exchange between a heat source medium and the intermediate

medium; and a low-temperature liquefied gas evaporator that vaporizes low-temperature liquefied gas with the intermediate medium evaporated by the intermediate-medium evaporator, the cold energy recovery device comprising:

- an intermediate medium channel having one end portion configured to be connectable to the low-temperature liquefied gas evaporator and the other end portion configured to be connectable to the intermediate medium evaporator;

- a refrigerant circulation circuit in which a refrigerant for supplying cold energy to a use side circulates;

- a heat exchanger that performs heat exchange between the intermediate medium that flows in the intermediate medium channel and the refrigerant that circulates in the refrigerant circulation circuit; and

- adjusting means for adjusting, according to a demanded cold energy load, a cold energy amount supplied from the intermediate medium to the refrigerant.