

Description
Title of Invention
REFRIGERATION DEVICE

5 Technical Field

[0001]

The present disclosure relates to a refrigeration device.

Background Art

10 [0002]

As is commonly known, a turbo refrigeration device used as a heat source for district heating and cooling includes, for example, a turbo compressor for compressing a refrigerant, a condenser for condensing the compressed refrigerant, a control valve for expanding the condensed refrigerant, and an evaporator for evaporating the expanded refrigerant. The evaporator includes a pressure vessel forming an outer shell and heat transfer tubes disposed in the pressure vessel, and evaporates the refrigerant by exchanging heat between the expanded refrigerant supplied into the pressure vessel and a refrigerant to be cooled flowing through the heat transfer tubes.

20 [0003]

As an evaporator used in a turbo refrigeration device, a liquid film evaporator is known in which a liquid film of a refrigerant is formed on a surface of each heat transfer tube. In a liquid film evaporator, a refrigerant in a liquid phase is supplied from above to a heat transfer tube group through which a medium to be cooled flows and in which heat transfer tubes are arranged in a vertical direction and a horizontal direction to form a liquid film of the refrigerant on a surface of each of the heat transfer tubes. In such a liquid film evaporator, the refrigerant in a liquid phase accumulated at a lower portion of the pressure vessel without being evaporated by the heat transfer tube group may be recirculated to an upper portion of the evaporator and supplied again to the heat transfer tube group (for example, Patent Document 1).

[0004]

Patent Document 1 describes an evaporator including a tube bundle accommodated inside a shell and a distributor for supplying a refrigerant to the tube bundle from above. In the evaporator of Patent Document 1, a pump or an ejector is used to recirculate a liquid refrigerant from a lower part of the shell to the distributor.

Citation List
Patent Literature

[0005]

Patent Document 1: US 2011/0120181 A

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Summary of Invention
Technical Problem

[0006]

In a liquid film evaporator, only a portion of a surface of a heat transfer
10 tube on which a liquid film is formed serves as a heat transfer surface at which
heat exchange is performed. Thus, when the surface of the heat transfer tube
includes a portion on which no liquid film is formed (hereinafter, non-
formation of a liquid film on the surface of the heat transfer tube is also
referred to as "dry-out"), heat exchange is not performed at the portion where
15 the dry-out occurred, causing a problem that heat exchange efficiency is
reduced. In particular, in the liquid film evaporator, the refrigerant is supplied
to the heat transfer tube group from above, and thus the dry-out is more likely
to occur on the heat transfer tubes that are located at lower positions.
Therefore, in order to suppress a decrease in the heat exchange efficiency, it is
20 necessary to supply the refrigerant to the heat transfer tube group such that the
refrigerant is sufficiently spread down to the heat transfer tubes disposed at the
lowest stage.

However, the amount of the refrigerant guided to the evaporator varies
depending on the operation conditions of a refrigeration device (for example, a
25 load and a temperature of the refrigeration device). For this reason, for
example, in an evaporator for which the operation conditions of the
refrigeration device are not taken into consideration as in the evaporator
described in Patent Document 1, there is a possibility that the refrigerant is not
sufficiently supplied to the heat transfer tube group depending on the operation
30 conditions of the refrigeration device and whereby the heat exchange efficiency
is reduced.

[0007]

The present disclosure has been made in view of such circumstances,
and an object thereof is to provide a refrigeration device that can improve heat
35 exchange efficiency.

Solution to Problem

[0008]

In order to solve the problem described above, a refrigeration device of the present disclosure adopts the following devices.

A refrigeration device according to an aspect of the present disclosure includes: a compressor configured to compress a refrigerant; a condenser
5 configured to condense the refrigerant compressed by the compressor; an expansion valve configured to expand the refrigerant condensed by the condenser; an evaporator configured to evaporate the refrigerant expanded by the expansion valve; and an expansion valve control unit configured to control an opening degree of the expansion valve. The evaporator includes: a case
10 forming an outer shell; a heat transfer tube group accommodated inside the case and including a plurality of heat transfer tubes arranged in a vertical direction; a refrigerant supply unit configured to supply the refrigerant from above to the heat transfer tube group; and a circulation unit configured to guide the refrigerant accumulated at a lower portion of the case without being evaporated
15 by the heat transfer tube group to the refrigerant supply unit. The expansion valve control unit controls the opening degree of the expansion valve to bring a level of the refrigerant accumulated at the lower portion of the case to a level corresponding to an amount of the refrigerant circulated by the circulation unit, the amount varying depending on an operation condition of the refrigeration
20 device.

Advantageous Effects of Invention

[0009]

According to the present disclosure, the heat exchange efficiency of the
25 evaporator can be improved.

Brief Description of Drawings

[0010]

FIG. 1 is a schematic configuration diagram of a turbo refrigeration
30 device according to a first embodiment of the present disclosure.

FIG. 2 is a longitudinal cross-sectional view illustrating an evaporator according to the first embodiment of the present disclosure.

FIG. 3 is a longitudinal cross-sectional view illustrating the evaporator according to the first embodiment of the present disclosure.

35 FIG. 4 is a longitudinal cross-sectional view illustrating an evaporator according to a modification example of the first embodiment of the present disclosure.

FIG. 5 is a schematic configuration diagram of a turbo refrigeration device according to a second embodiment of the present disclosure.

FIG. 6 is a Mollier chart illustrating the turbo refrigeration device according to the second embodiment of the present disclosure.

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Description of Embodiments

[0011]

An embodiment of a refrigeration device according to the present disclosure will be described below with reference to the drawings.

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First Embodiment

Hereinafter, a first embodiment of the present disclosure will be described below with reference to FIGS. 1 to 3.

As illustrated in FIG. 1, a turbo refrigeration device (refrigeration device) 1 according to the present embodiment includes a turbo compressor (compressor) 2 that compresses a refrigerant, a condenser 3 that condenses the refrigerant compressed by the turbo compressor 2, an expansion valve 4 that expands the refrigerant condensed by the condenser 3, an evaporator 5 that evaporates the refrigerant expanded by the expansion valve 4, and the like, and forms a unit.

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[0012]

The turbo compressor 2 is connected to an upper portion of the condenser 3 by a discharge pipe 6. The discharge pipe 6 guides the refrigerant compressed by the turbo compressor 2 to the condenser 3. A bottom portion of the condenser 3, the expansion valve 4, and an upper portion of the evaporator 5 are connected by a refrigerant pipe 7. The refrigerant pipe 7 is provided with the expansion valve 4. The refrigerant pipe 7 guides the refrigerant condensed by the condenser 3 to the evaporator 5. An upper portion of the evaporator 5 is connected to the turbo compressor 2 by a suction pipe 8. The suction pipe 8 guides the refrigerant evaporated by the evaporator 5 to the turbo compressor 2.

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[0013]

A branch pipe 17 is branched from an intermediate position of the refrigerant pipe 7. The branch pipe 17 is branched from the refrigerant pipe 7 on an upstream side of the expansion valve 4. A downstream end of the branch pipe 17 is connected to an eductor 10. The branch pipe 17 guides part of the refrigerant condensed by the condenser 3 to the eductor 10. The eductor 10 is connected to the evaporator 5 by a first circulation pipe 14. An upstream end of the first circulation pipe 14 is connected to the bottom portion of a pressure

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vessel 11 of the evaporator 5. A downstream end of the first circulation pipe 14 is connected to the eductor 10. The first circulation pipe 14 guides the refrigerant in a liquid phase accumulated at a lower portion of the evaporator 5 to the eductor 10. An upstream end of a second circulation pipe 15 that
 5 discharges the refrigerant in the eductor 10 is connected to the eductor 10. A downstream end of the second circulation pipe 15 is connected to the refrigerant pipe 7 on a downstream side of the expansion valve 4. The second circulation pipe 15 guides the refrigerant discharged from the eductor 10 to the evaporator 5 via the refrigerant pipe 7.

10 [0014]

The turbo compressor 2 is of a known centrifugal turbine type that is rotationally driven by an electric motor 9, and is disposed above the evaporator 5 in an orientation in which the axis of the turbo compressor 2 extends in a substantially horizontal direction. The electric motor 9 is driven by an inverter
 15 unit. As will be described below, the turbo compressor 2 compresses the refrigerant in a gas phase supplied from a refrigerant outlet of the evaporator 5 through the suction pipe 8. As the refrigerant, for example, a low-pressure refrigerant such as R1233zd used at a maximum pressure of less than 0.2 MPaG is used.

20 [0015]

The condenser 3 and the evaporator 5 are formed in a cylindrical shell shape having a high pressure resistance, and are arranged in parallel and adjacent to each other in a state in which central axes of the condenser 3 and the evaporator 5 each extend in a substantially horizontal direction. The
 25 condenser 3 may be disposed at a relatively higher position than that of the evaporator 5.

[0016]

The eductor 10 sucks out the refrigerant in a liquid phase accumulated at the lower portion of the pressure vessel 11 by a flow velocity differential and a
 30 pressure differential of the refrigerant in a liquid phase flowing inside. Specifically, the refrigerant in a liquid phase guided from the branch pipe 17 to the eductor 10 (the refrigerant from the condenser 3) flows through a primary flow path inside the eductor 10 and is discharged from the eductor 10 to the second circulation pipe 15. As a result, the pressure at the connection portion
 35 with the first circulation pipe 14 provided at an outer peripheral portion of the primary flow path becomes low, and thus the refrigerant in a liquid phase in the pressure vessel 11 is sucked into the eductor 10 via the first circulation pipe 14. The refrigerant in a liquid phase that has been sucked into the eductor 10 is

discharged to the second circulation pipe 15 together with the refrigerant injected from the nozzle. In this way, the eductor 10 circulates the refrigerant by using the pressure differential in the turbo refrigeration device 1 (a difference between the pressure of the refrigerant in the condenser 3 and the pressure of the refrigerant in the evaporator 5, or the like).

[0017]

Hereinafter, the evaporator 5 will be described in detail with reference to FIG. 2.

As illustrated in FIG. 2, the evaporator 5 includes the pressure vessel (case) 11 forming an outer shell, a refrigerant inlet pipe 12 that introduces a refrigerant into the pressure vessel 11, a refrigerant tray (refrigerant supply unit) 13 provided below the refrigerant inlet pipe 12, a heat transfer tube group 16 accommodated inside the pressure vessel 11, and a refrigerant outlet pipe (not illustrated) that discharges an evaporated refrigerant from the pressure vessel 11.

[0018]

The pressure vessel 11 integrally includes a cylindrical portion 11a extending along a central axis, and two tube plates (not illustrated) that close both end portions of the cylindrical portion 11a in a direction along the central axis. As described above, the cylindrical portion 11a is disposed with the central axis being substantially horizontal. Each of the tube plates is a disc-like plate member.

In the following description, a direction along the central axis (a depth direction in FIG. 2) is referred to as a longitudinal direction. A vertical up-down direction is simply referred to as a vertical direction. A direction intersecting the longitudinal direction and the vertical direction is referred to as a lateral direction.

[0019]

The refrigerant inlet pipe 12 is a cylindrical member extending in the vertical direction, and is formed in a substantially linear shape. The refrigerant inlet pipe 12 is provided extending through an upper portion of the cylindrical portion 11a in the vertical direction. The refrigerant inlet pipe 12 is provided substantially at the center of the cylindrical portion 11a in a direction along the central axis. The refrigerant inlet pipe 12 is connected to the refrigerant pipe 7 (see FIG. 1). That is, the refrigerant expanded by the expansion valve 4 is guided into the pressure vessel 11 via the refrigerant pipe 7 and the refrigerant inlet pipe 12.

[0020]

The refrigerant tray 13 is a substantially rectangular plate-like member. The refrigerant tray 13 is disposed at an upper portion of the interior of the pressure vessel 11 with a plate surface of the refrigerant tray 13 being substantially horizontal. The refrigerant tray 13 is provided with the plate surface facing a lower end of the refrigerant inlet pipe 12. The refrigerant tray 13 is disposed with both end portions thereof in the lateral direction separated from the inside surface of the cylindrical portion 11a of the pressure vessel 11 by a predetermined distance. Further, the refrigerant tray 13 is provided over substantially the entire region of the pressure vessel 11 in the longitudinal direction. Both end portions of the refrigerant tray 13 in the longitudinal direction are fixed to the tube plates, respectively. The refrigerant tray 13 is formed with a large number of holes extending therethrough in the vertical direction. The large number of holes are formed in substantially the entire region of the refrigerant tray 13. The liquid refrigerant discharged from the refrigerant inlet pipe 12 is discharged onto the refrigerant tray 13. The refrigerant that has been discharged to the refrigerant tray 13 flows on the upper surface of the refrigerant tray 13 and then drops downward through the large number of holes. In this way, the refrigerant tray 13 distributes the refrigerant supplied from the refrigerant inlet pipe 12 in the longitudinal direction and the lateral direction.

[0021]

The heat transfer tube group 16 is disposed inside the pressure vessel 11. The heat transfer tube group 16 is disposed below the refrigerant tray 13. The heat transfer tube group 16 includes a plurality of heat transfer tubes 16a extending along the longitudinal direction. The plurality of heat transfer tubes 16a are disposed substantially in parallel. The plurality of heat transfer tubes 16a are arranged at predetermined intervals in the vertical direction and the lateral direction. Specifically, the plurality of heat transfer tubes 16a are arranged in a plurality of stages in the vertical direction and in a plurality of rows in the lateral direction. Water as a liquid to be cooled flows through each of the heat transfer tubes 16a. Each of the heat transfer tubes 16a is formed in a linear shape. Further, each of the heat transfer tubes 16a extends from one end to the other end of the pressure vessel 11 in the longitudinal direction and extends through the respective tube plates.

[0022]

The refrigerant outlet pipe is a cylindrical member extending in the vertical direction, and is provided communicating with an opening (not illustrated) formed in the upper portion of the cylindrical portion 11a. The

refrigerant outlet pipe is connected to the suction pipe 8 (see FIG. 1). That is, the refrigerant evaporated by the evaporator 5 is discharged to the outside of the pressure vessel 11 via the refrigerant outlet pipe and the suction pipe 8, and is guided to the turbo compressor 2.

5 [0023]

The turbo refrigeration device 1 further includes a control device 18. The control device 18 includes an expansion valve control unit that controls the opening degree of the expansion valve 4 and an IGV control unit (adjustment device control unit) that controls an inlet guide vane (IGV) (not illustrated)

10 provided at the turbo compressor 2.

[0024]

The control device 18 includes, for example, a central processing unit (CPU), a random access memory (RAM), a read only memory (ROM), and a computer-readable storage medium. A series of processing for implementing various functions is stored in a storage medium or the like in the form of a program, for example, and the CPU reads the program into the RAM or the like and executes information processing and computation processing, thereby implementing various functions. Note that the program may be preinstalled in the ROM or other storage medium, may be provided in the form of being stored in a computer-readable storage medium, or may be distributed through a wired or wireless communication device, or the like. The computer-readable storage medium includes a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, and a semiconductor memory.

20 [0025]

The expansion valve control unit can adjust the level of the refrigerant accumulated at the lower portion of the pressure vessel 11 by controlling the opening degree of the expansion valve 4. The expansion valve control unit controls the opening degree of the expansion valve 4 to bring the level of the refrigerant accumulated at the lower portion of the pressure vessel 11 to a level corresponding to the operation capability of the eductor 10 (the amount of the refrigerant that can be circulated by the eductor 10) which varies depending on the operation conditions of the turbo refrigeration device 1 (for example, the load and the temperature of the turbo refrigeration device 1).

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Specifically, for example, the expansion valve control unit may raise the level of the refrigerant when the operation capability of the eductor 10 decreases. On the other hand, the expansion valve control unit may lower the level of the refrigerant when the operation capability of the eductor 10 increases.

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[0026]

Specifically, the expansion valve control unit may adjust the level of the refrigerant to bring, of the heat transfer tubes 16a whose surfaces are sufficiently supplied with the refrigerant by the operation capability of the eductor 10, the heat transfer tubes 16a located at the lowest stage directly above the level of the refrigerant. That is, as illustrated in FIG. 3, when the refrigerant can be sufficiently supplied to the heat transfer tubes 16a at the first stage to the fifth stage from the top (see the liquid film heat transfer tube group 16A in FIG. 3) by the operation capability of the eductor 10, the level of the refrigerant may be adjusted to bring the heat transfer tubes 16a at the fifth stage directly above the level of the refrigerant so that the heat transfer tubes 16a at the sixth stage and the seventh stage from the top (see the flooded heat transfer tube group 16B in FIG. 3) are located below the level of the refrigerant. That is, the heat transfer tubes 16a at the sixth stage and the seventh stage may be immersed in the refrigerant.

On the other hand, as illustrated in FIG. 2, when the refrigerant can be sufficiently supplied to all the heat transfer tubes 16a by the operation capability of the eductor 10, the level of the refrigerant may be adjusted to be below the heat transfer tubes 16a at the seventh stage.

[0027]

The IGV control unit can adjust the pressure of the refrigerant flowing from the condenser 3 to the eductor 10. By adjusting the pressure of the refrigerant flowing to the eductor 10, the amount of the refrigerant circulated by the eductor 10 can be adjusted. The IGV control unit controls the opening degree of the IGV (circulation unit adjustment device) to make the amount of the refrigerant circulated by the eductor 10 larger than a predetermined amount.

Specifically, for example, the IGV control unit may increase the pressure of the refrigerant flowing from the condenser 3 to the eductor 10 when the operation capability of the eductor 10 decreases due to the operation conditions of the turbo refrigeration device 1 or the like. On the other hand, the IGV control unit may decrease the pressure of the refrigerant flowing from the condenser 3 to the eductor 10 when the operation capability of the eductor 10 increases.

[0028]

Specifically, when the amount of the refrigerant that can be circulated by the eductor 10 (the operation capability) is smaller than a predetermined amount, the IGV control unit may increase the pressure of the refrigerant flowing from the condenser 3 to the eductor 10, thereby increasing the amount

of the refrigerant that can be circulated by the eductor 10. Note that the predetermined amount may be an amount of the refrigerant with which the refrigerant is sufficiently supplied to the surfaces of the heat transfer tubes 16a located at the lowest stage, of the heat transfer tubes 16a that need to be
5 supplied with the refrigerant from the refrigerant tray 13 (that is, the heat transfer tubes 16a above the level of the refrigerant). Alternatively, the predetermined amount may be an amount calculated in advance according to the operation conditions of the turbo refrigeration device 1 or the like.

Further, the predetermined amount may be an amount ($q + Q$) obtained
10 by adding an amount q of the refrigerant evaporated by the heat transfer tube group 16 to an amount Q of the refrigerant accumulated at the lower portion of the pressure vessel 11 and circulated by the eductor 10 without being evaporated by the heat transfer tube group 16.

[0029]

15 According to the present embodiment, the following operational effects are obtained.

The amount of the refrigerant circulated by the eductor 10 (hereinafter may be referred to as "operation capability of the eductor 10") may vary depending on the operation conditions of the turbo refrigeration device 1. For
20 example, as in the present embodiment, the eductor 10 may circulate the refrigerant by using the pressure differential in the turbo refrigeration device 1 (a difference between the pressure of the refrigerant in the condenser 3 and the pressure of the refrigerant in the evaporator 5, or the like). In that case, for example, when the pressure differential in the turbo refrigeration device 1 is
25 small due to the operation conditions of the turbo refrigeration device 1, the amount of the refrigerant that can be circulated by the eductor 10 decreases. When the amount of the refrigerant that can be circulated decreases, the amount of the refrigerant supplied from the refrigerant tray 13 to the heat transfer tube group 16 also decreases. For this reason, the refrigerant cannot be sufficiently
30 supplied to the heat transfer tube group 16, and there is a possibility that a state in which the refrigerant does not sufficiently spread to the surfaces of the heat transfer tubes 16a (hereinafter, this state is referred to as "dry-out") occurs in some of the heat transfer tubes 16a (specifically, the heat transfer tubes 16a located at the lower portion).

35 On the other hand, in the present embodiment, the expansion valve control unit controls the opening degree of the expansion valve 4 to bring the level of the refrigerant accumulated at the lower portion of the pressure vessel 11 to a level corresponding to the operation capability of the eductor 10 which

varies depending on the operation conditions of the turbo refrigeration device 1. As a result, the level of the refrigerant can be brought to a level corresponding to the operation capability of the eductor 10. Thus, for example, when the operation capability of the eductor 10 decreases, the level of the refrigerant is raised by controlling the opening degree of the expansion valve 4, whereby the heat transfer tubes 16a of the heat transfer tube group 16 disposed at the lower portion can be brought below the level of the refrigerant. In other words, the heat transfer tubes 16a of the heat transfer tube group 16 disposed at the lower portion can be immersed in the accumulated refrigerant. Accordingly, it is possible to reduce the number of the heat transfer tubes 16a that need to be supplied with the refrigerant from the refrigerant tray 13 (that is, the heat transfer tubes 16a above the level of the refrigerant), and thus it is possible to suppress the occurrence of dry-out even when the amount of the refrigerant is small. As described above, in the present embodiment, the level of the refrigerant can be brought to a level corresponding to the operation capability of the eductor 10, and thus the heat exchange efficiency of the evaporator 5 can be improved.

[0030]

Further, in the present embodiment, the adjustment device control unit controls the IGV to make the amount of the refrigerant circulated by the eductor 10 larger than the predetermined amount. Thus, a sufficient amount of the refrigerant can be circulated and supplied from the refrigerant tray 13 to the heat transfer tube group 16. Accordingly, the occurrence of dry-out can be suppressed, and the heat exchange efficiency of the evaporator 5 can be improved.

[0031]

Modification Example

The first embodiment above has described an example in which the eductor 10 is adopted as a circulation unit that circulates a refrigerant, but the present disclosure is not limited thereto. For example, as illustrated in FIG. 4, a pump 19 may be provided instead of the eductor 10. The pump 19 pressurizes the refrigerant accumulated at the lower portion of the pressure vessel 11.

The rotational speed of the pump 19 can be changed by an inverter device (not illustrated) or the like. The control device 18 can adjust the rotational speed of the pump 19 by controlling the inverter device. That is, the control device 18 can adjust the operation capability of the pump 19 (the amount of the refrigerant that can be circulated by the pump 19).

With this type of configuration, the same effect as in the first embodiment can also be obtained.

[0032]

Second Embodiment

5 The first embodiment above has described an example in which the refrigeration device of the present disclosure is applied to the turbo refrigeration device 1 of a single-stage compression type, but the present disclosure is not limited thereto. As illustrated in FIGS. 5 and 6, the refrigeration device of the present disclosure may be applied to a turbo
10 refrigeration device 21 of a multi-stage compression type.

 The turbo refrigeration device 21 according to the present embodiment is different from the first embodiment in that the turbo refrigeration device 21 includes a low-stage compressor 2A and a high-stage compressor 2B, includes an intercooler 22 and the like, includes an intermediate pipe 23, and includes a
15 low-pressure expansion valve 4A and a high-pressure expansion valve 4B. Other points are similar to the first embodiment, so the same components are denoted by the same reference signs, and detailed descriptions thereof are omitted here.

[0033]

20 The refrigerant pipe 7 according to the present embodiment is provided with the high-pressure expansion valve 4B, the intercooler 22, and the low-pressure expansion valve 4A in this order from the upstream side. The low-pressure expansion valve 4A is provided downstream of the position at which the branch pipe 17 branches off. The high-pressure expansion valve 4B and the
25 intercooler 22 are provided upstream of the position at which the branch pipe 17 branches off.

 The intercooler 22 separates the refrigerant discharged from the condenser 3 into gas and liquid refrigerants. The gas-phase refrigerant is guided to a suction side of the high-stage compressor 2B via the intermediate pipe 23.
30 The liquid-phase refrigerant is guided to the evaporator 5 by the refrigerant pipe 7 and the like.

[0034]

 A method of adjusting the operation capability of the eductor 10 in the present embodiment will be described with reference to the Mollier chart of
35 FIG. 6.

 First, the refrigerant indicated by the solid lines in FIG. 6 will be described. A gas refrigerant (a) discharged from the high-stage compressor 2B flows into the condenser 3. The refrigerant having flowed into the condenser 3

is condensed by exchanging heat with water in the condenser 3. A high-temperature and high-pressure liquid refrigerant (b) discharged from the condenser 3 is expanded and decompressed by the high-pressure expansion valve 4B (c) to become a gas-liquid two phase refrigerant and flows into the intercooler 22. The gas-liquid two phase refrigerant having flowed into the intercooler 22 is separated into gas and liquid refrigerants, and the liquid refrigerant having a low enthalpy (d) is guided to the low-pressure expansion valve 4A. The liquid refrigerant (d) flows into the primary flow path of the eductor 10 via the branch pipe 17. The gas refrigerant having a higher enthalpy than that of the liquid refrigerant flows toward the high-stage compressor 2B via the intermediate pipe 23.

[0035]

The liquid refrigerant having flowed from the intercooler 22 into the low-pressure expansion valve 4A is expanded and decompressed by the low-pressure expansion valve 4A (e) to become a gas-liquid two phase refrigerant, and flows into the evaporator 5. The liquid refrigerant that has flowed into the evaporator 5 without being evaporated by the heat transfer tube group 16 (e) is guided to the eductor 10 via the first circulation pipe 14. That is, in the eductor 10, a pressure differential (P1 in FIG. 6) between the liquid refrigerant (d) and the liquid refrigerant (e) serves as a driving force.

In the present embodiment, the gas-liquid two phase refrigerant having flowed into the evaporator 5 is evaporated by exchanging heat with water and flows out of the evaporator 5 as a gas refrigerant. The gas refrigerant having flowed out of the evaporator 5 (f) is sucked into the low-stage compressor 2A and compressed (g).

[0036]

A gas refrigerant obtained by gas-liquid separation in the intercooler 22 is sucked between the low-stage compressor 2A and the high-stage compressor 2B via the intermediate pipe 23 and is merged with the gas refrigerant compressed by the low-stage compressor 2A (h), and the merged refrigerant is compressed by the high-stage compressor 2B and discharged (a).

[0037]

Next, a case in which the opening degree of the IGV provided at the inlet of the high-stage compressor 2B is reduced as indicated by dashed lines in FIG. 6 will be described. In this case, the pressure of a refrigerant (c') expanded and decompressed by the high-pressure expansion valve 4B is higher than the pressure of the refrigerant (c). The refrigerant (c') becomes a gas-liquid two phase refrigerant and flows into the intercooler 22. The gas-liquid two phase

refrigerant having flowed into the intercooler 22 is separated into gas and liquid refrigerants, and the liquid refrigerant having a low enthalpy (d') is guided to the low-pressure expansion valve 4A. The liquid refrigerant (d') flows into the primary flow path of the eductor 10 via the branch pipe 17. The gas refrigerant having a higher enthalpy than that of the liquid refrigerant flows toward the high-stage compressor 2B via the intermediate pipe 23.

[0038]

The liquid refrigerant having flowed from the intercooler 22 into the low-pressure expansion valve 4A is expanded and decompressed by the low-pressure expansion valve 4A (e') to become a gas-liquid two phase refrigerant, and flows into the evaporator 5. The liquid refrigerant that has flowed into the evaporator 5 without being evaporated by the heat transfer tube group 16 (e') is guided to the eductor 10 via the first circulation pipe 14. That is, in the eductor 10, a pressure differential (P2 in FIG. 6) between the liquid refrigerant (d') and the liquid refrigerant (e') serves as a driving force. As illustrated in FIG. 6, the pressure differential P2 is greater than the pressure differential P1. That is, the operation capability of the eductor 10 can be improved to a greater extent in the case indicated by the dashed lines in FIG. 6. In this way, the operation capability of the eductor 10 can be adjusted by adjusting the opening degree of the IGV.

[0039]

In the present embodiment, the gas-liquid two phase refrigerant having flowed into the evaporator 5 is evaporated by exchanging heat with water and flows out of the evaporator 5 as a gas refrigerant. The gas refrigerant having flowed out of the evaporator 5 (f) is sucked into the low-stage compressor 2A and compressed (g').

A gas refrigerant obtained by gas-liquid separation in the intercooler 22 is sucked between the low-stage compressor 2A and the high-stage compressor 2B via the intermediate pipe 23 and is merged with the gas refrigerant compressed by the low-stage compressor 2A (h'), and the merged refrigerant is compressed by the high-stage compressor 2B and discharged (a).

[0040]

Note that the present disclosure is not limited to the respective embodiments described above and can be modified as appropriate without departing from the gist of the present disclosure.

For example, in the respective embodiments described above, an example in which the control device 18 includes both of the expansion valve control unit or the IGV control unit has been described, but the present

disclosure is not limited to this configuration. The control device 18 may include only one of the expansion valve control unit and the IGV control unit. [0041]

5 The refrigeration device according to the embodiments described above is understood as follows, for example.

A refrigeration device according to an aspect of the present disclosure is a refrigeration device (1) including: a compressor (2) configured to compress a refrigerant; a condenser (3) configured to condense the refrigerant compressed by the compressor; an expansion valve (4) configured to expand the refrigerant
10 condensed by the condenser; an evaporator (5) configured to evaporate the refrigerant expanded by the expansion valve; and an expansion valve control unit configured to control an opening degree of the expansion valve. The evaporator includes: a case (11) forming an outer shell; a heat transfer tube group (16) accommodated inside the case and including a plurality of heat
15 transfer tubes (16a) arranged in a vertical direction; a refrigerant supply unit (13) configured to supply the refrigerant from above to the heat transfer tube group; and a circulation unit (10) configured to guide the refrigerant accumulated at a lower portion of the case without being evaporated by the heat transfer tube group to the refrigerant supply unit. The expansion valve control
20 unit controls the opening degree of the expansion valve to bring a level of the refrigerant accumulated at the lower portion of the case to a level corresponding to an amount of the refrigerant circulated by the circulation unit, the amount varying depending on an operation condition of the refrigeration device.

25 [0042]

The amount of the refrigerant circulated by the circulation unit (hereinafter may be referred to as "operation capability of the circulation unit") may vary depending on the operation conditions of the refrigeration device. For example, the circulation unit may be a device such as an eductor that circulates
30 the refrigerant by using a pressure differential in the refrigeration device (a difference between the pressure of the refrigerant in the condenser and the pressure of the refrigerant in the evaporator, or the like). In that case, for example, when the pressure differential in the refrigeration device is small due to the operation conditions of the refrigeration device, the amount of the
35 refrigerant that can be circulated by the circulation unit decreases. When the amount of the refrigerant that can be circulated decreases, the amount of the refrigerant supplied from the refrigerant supply unit to the heat transfer tube group also decreases. For this reason, the refrigerant cannot be sufficiently

supplied to the heat transfer tube group, and there is a possibility that a state in which the refrigerant does not sufficiently spread to the surfaces of the heat transfer tubes (hereinafter, this state is referred to as "dry-out") occurs in some of the heat transfer tubes (specifically, the heat transfer tubes located at the lower portion).

In the configuration described above, the expansion valve control unit controls the opening degree of the expansion valve to bring the level of the refrigerant accumulated at the lower portion of the case to a level corresponding to the operation capability of the circulation unit which varies depending on the operation conditions of the refrigeration device. As a result, the level of the refrigerant can be brought to a level corresponding to the operation capability of the circulation unit. Thus, for example, when the operation capability of the circulation unit decreases, the level of the refrigerant is raised by controlling the opening degree of the expansion valve, whereby the heat transfer tubes of the heat transfer tube group disposed at the lower portion can be brought below the level of the refrigerant. In other words, the heat transfer tubes of the heat transfer tube group disposed at the lower portion can be immersed in the accumulated refrigerant. Accordingly, it is possible to reduce the number of the heat transfer tubes that need to be supplied with the refrigerant from the refrigerant supply unit (that is, the heat transfer tubes above the level of the refrigerant), and thus it is possible to suppress the occurrence of dry-out even when the amount of the refrigerant is small. In this way, in the configuration described above, the level of the refrigerant can be brought to a level corresponding to the operation capability of the circulation unit, and thus the heat exchange efficiency of the evaporator can be improved.

[0043]

According to an aspect of the present disclosure, the refrigeration device includes a circulation unit adjustment device that adjusts the amount of the refrigerant circulated by the circulation unit, and an adjustment device control unit that controls the circulation unit adjustment device. The adjustment device control unit controls the circulation unit adjustment device to make the amount of the refrigerant circulated by the circulation unit larger than a predetermined amount.

[0044]

In the configuration described above, the adjustment device control unit controls the circulation unit adjustment device to make the amount of the refrigerant circulated by the circulation unit larger than the predetermined amount. Thus, a sufficient amount of the refrigerant can be circulated and

supplied from the refrigerant supply unit to the heat transfer tube group. Accordingly, the occurrence of dry-out can be suppressed, and the heat exchange efficiency of the evaporator can be improved.

Note that the predetermined amount may be an amount of the refrigerant with which the refrigerant is sufficiently supplied to the surfaces of the heat transfer tubes located at the lowest stage, of the heat transfer tubes that need to be supplied with the refrigerant from the refrigerant supply unit (that is, the heat transfer tubes above the level of the refrigerant). Alternatively, the predetermined amount may be an amount calculated in advance according to the operation conditions of the refrigeration device or the like.
[0045]

A refrigeration device according to an aspect of the present disclosure is a refrigeration device (1) including: a compressor (2) configured to compress a refrigerant; a condenser (3) configured to condense the refrigerant compressed by the compressor; an expansion valve (4) configured to expand the refrigerant condensed by the condenser; and an evaporator (5) configured to evaporate the refrigerant expanded by the expansion valve. The evaporator includes: a case (11) forming an outer shell; a heat transfer tube group (16) accommodated inside the case and including a plurality of heat transfer tubes (16a) arranged in a vertical direction; a refrigerant supply unit (13) configured to supply the refrigerant from above to the heat transfer tube group; and a circulation unit (10) configured to guide the refrigerant accumulated at a lower portion of the case without being evaporated by the heat transfer tube group to the refrigerant supply unit. The refrigeration device further includes a circulation unit adjustment device configured to adjust an amount of the refrigerant circulated by the circulation unit and an adjustment device control unit configured to control the circulation unit adjustment device. The adjustment device control unit controls the circulation unit adjustment device to make the amount of the refrigerant circulated by the circulation unit larger than a predetermined amount.
[0046]

According to an aspect of the present disclosure, in the refrigeration device, the circulation unit includes an eductor (10) that circulates the refrigerant by using a pressure differential between a pressure of the refrigerant in the condenser and a pressure of the refrigerant in the evaporator.
[0047]

In the configuration described above, the occurrence of dry-out can be suppressed even when the circulation capability of the eductor decreases, and thus the heat exchange efficiency of the evaporator can be improved.

[0048]

- 5 According to an aspect of the present disclosure, in the refrigeration device, the circulation unit includes a pump (19) that pressurizes the refrigerant accumulated at the lower portion of the case.

[0049]

- 10 In the configuration described above, the refrigerant can be circulated by using the pump.

Reference Signs List

[0050]

- 1: Turbo refrigeration device (refrigeration device)
- 15 2: Turbo compressor (compressor)
- 2A: Low-stage compressor
- 2B: High-stage compressor
- 3: Condenser
- 4: Expansion valve
- 20 4A: Low-pressure expansion valve
- 4B: High-pressure expansion valve
- 5: Evaporator
- 6: Discharge pipe
- 7: Refrigerant pipe
- 25 8: Suction pipe
- 9: Electric motor
- 10: Eductor (circulation unit)
- 11: Pressure vessel (case)
- 11a: Cylindrical portion
- 30 12: Refrigerant inlet pipe
- 13: Refrigerant tray (refrigerant supply unit)
- 14: First circulation pipe
- 15: Second circulation pipe
- 16: Heat transfer tube group
- 35 16A: Liquid film heat transfer tube group
- 16B: Flooded heat transfer tube group
- 16a: Heat transfer tube
- 17: Branch pipe

- 18: Control device
- 19: Pump
- 21: Turbo refrigeration device
- 22: Intercooler
- 5 23: Intermediate pipe

Claims

[Claim 1]

A refrigeration device comprising:

- a compressor configured to compress a refrigerant;
- a condenser configured to condense the refrigerant compressed by the compressor;
- an expansion valve configured to expand the refrigerant condensed by the condenser;
- an evaporator configured to evaporate the refrigerant expanded by the expansion valve; and
- an expansion valve control unit configured to control an opening degree of the expansion valve, wherein
 - the evaporator includes
 - a case forming an outer shell,
 - a heat transfer tube group accommodated inside the case and including a plurality of heat transfer tubes arranged in a vertical direction,
 - a refrigerant supply unit configured to supply the refrigerant from above to the heat transfer tube group, and
 - a circulation unit configured to guide the refrigerant accumulated at a lower portion of the case without being evaporated by the heat transfer tube group to the refrigerant supply unit, and
 - the expansion valve control unit controls the opening degree of the expansion valve to bring a level of the refrigerant accumulated at the lower portion of the case to a level corresponding to an amount of the refrigerant circulated by the circulation unit, the amount varying depending on an operation condition of the refrigeration device.

[Claim 2]

The refrigeration device according to claim 1, further comprising:

- a circulation unit adjustment device configured to adjust the amount of the refrigerant circulated by the circulation unit; and
- an adjustment device control unit configured to control the circulation unit adjustment device, wherein
 - the adjustment device control unit controls the circulation unit adjustment device to make the amount of the refrigerant circulated by the circulation unit larger than a predetermined amount.

[Claim 3]

A refrigeration device comprising:

- a compressor configured to compress a refrigerant;
- a condenser configured to condense the refrigerant compressed by the compressor;
- an expansion valve configured to expand the refrigerant condensed by the condenser; and
- an evaporator configured to evaporate the refrigerant expanded by the expansion valve, wherein
 - the evaporator includes
 - a case forming an outer shell,
 - a heat transfer tube group accommodated inside the case and including a plurality of heat transfer tubes arranged in a vertical direction,
 - a refrigerant supply unit configured to supply the refrigerant from above to the heat transfer tube group, and
 - a circulation unit configured to guide the refrigerant accumulated at a lower portion of the case without being evaporated by the heat transfer tube group to the refrigerant supply unit,
 - the refrigeration device further includes
 - a circulation unit adjustment device configured to adjust an amount of the refrigerant circulated by the circulation unit, and
 - an adjustment device control unit configured to control the circulation unit adjustment device, and
 - the adjustment device control unit controls the circulation unit adjustment device to make the amount of the refrigerant circulated by the circulation unit larger than a predetermined amount.

[Claim 4]

The refrigeration device according to any one of claims 1 to 3, wherein the circulation unit includes an eductor configured to circulate the refrigerant by using a pressure differential between a pressure of the refrigerant in the condenser and a pressure of the refrigerant in the evaporator.

[Claim 5]

The refrigeration device according to any one of claims 1 to 3, wherein the circulation unit includes a pump configured to pressurize the refrigerant accumulated at the lower portion of the case.