

## DESCRIPTION

### AIR CONDITIONER

#### TECHNICAL FIELD

[0001] The present invention relates to an air conditioner for controlling temperature and humidity.

#### BACKGROUND ART

[0002] There is a known two-stage compression type refrigerator that controls overheating of the discharged gas from a high stage-side thereof (see Patent Literature 1).

Also, there is a known air conditioner that increases energy efficiency while ensuring safety (see Patent Literature 2) or carries out a multi-stage compressing operation to increase operational efficiency in both cooling and heating operations (see Patent Literature 3).

#### CITATION LIST

##### Patent Literature

[0003] Patent Literature 1 Japanese Patent Application Laid-open No. 2007-255864 (see the claims and Fig. 1)

Patent Literature 2 Japanese Patent Application Laid-open No. 2006-029744 (see the claims and Figs. 1 to 3)

Patent Literature 3 Japanese Patent Application Laid-open No. 2010-112618 (see the claims and Figs. 1 to 3)

#### SUMMARY OF INVENTION

##### Technical Problem

[0004] When conditioning the air in a relatively large space

such as the interior of a factory or building, however, an air conditioner needs to lower the temperature of conditioning target air, such as indoor air of the space, to a much lower temperature than a target temperature of the indoor air for dehumidifying the conditioning target air, wasting a lot of energy.

More particularly, when the air conditioner dehumidifies the conditioning target air and processes a latent heat load that accounts for a relatively small percentage of the whole heat load borne on the air conditioner, the air conditioner operates inefficiently to lower the temperature of the conditioning target air to a temperature required for dehumidifying the whole conditioning target air.

[0005] Thus, a technical problem to be solved by the present invention, or an object of the present invention, is to provide an air conditioner capable of saving energy needed for eliminating latent heat and sensible heat of the conditioning target air in a cooling and dehumidifying operation and also capable of operating safely and nature-friendly.

#### Solution to Problem

[0006] According to a first aspect of the present invention, an air conditioner includes an air supply duct for supplying conditioning target air including at least indoor air and optionally outdoor air of a building to be air-conditioned into the interior of the building, a high stage-side cooler provided in the air supply duct for mainly eliminating sensible heat of the conditioning target air, a low stage-side cooler provided downstream of the high stage-side cooler in the air supply duct for mainly eliminating latent heat of the

conditioning target air whose heat load has been partly eliminated by the high stage-side cooler, and an indoor cooler for mainly eliminating latent heat of the indoor air.

[0007] According to a second aspect of the present invention, the air conditioner includes a first heat recovery unit provided upstream of the high stage-side cooler in the air supply duct and a second heat recovery unit provided between the high stage-side cooler and the low stage-side cooler in the air supply duct.

[0008] According to a third aspect of the present invention, the air conditioner includes an indoor air intake fan provided at an inlet of the air supply duct for taking the indoor air into the air supply duct.

[0009] According to a fourth aspect of the present invention, the air conditioner includes a first inter-refrigerant heat exchanger for exchanging heat between a primary refrigerant and a secondary refrigerant, the secondary refrigerant circulating in a secondary refrigerant circulation pathway and being supplied to the high stage-side cooler, the low stage-side cooler, and the indoor air cooler for absorbing sensible heat and latent heat of the conditioning target air and sensible heat of the indoor air, the primary refrigerant circulating in a primary refrigerant circulation pathway for cooling the secondary refrigerant, the secondary refrigerant pathway and the primary refrigerant pathway being physically separated from each other.

[0010] According to a fifth aspect of the present invention, the first inter-refrigerant heat exchanger is provided outside of the building. The secondary refrigerant includes two mutually different kinds of refrigerants, one of which is used

in the high stage-side cooler and the low stage-side cooler, and the other of which is used in the indoor air cooler. The refrigerant used in the indoor air cooler is safer than the refrigerant used in the high stage-side cooler and the low stage-side cooler. The air conditioner includes a second inter-refrigerant heat exchanger provided outside of the building for exchanging heat between the refrigerant used in the high stage-side cooler and the low stage-side cooler and the refrigerant used in the indoor air cooler.

[0011] According to a sixth aspect of the present invention, the primary refrigerant is ammonia, which has an excellent quality as a refrigerant, and the secondary refrigerant is water or brine, which is safer in comparison with other kinds of refrigerants.

[0012] According to a seventh aspect of the present invention, the primary refrigerant is chlorofluorocarbon, ammonia, water, carbon dioxide, or hydrocarbon, and the secondary refrigerant is carbon dioxide.

[0013] According to an eighth aspect of the present invention, a high stage-side compressor connected to the high stage-side cooler and a low stage-side compressor connected to the low stage-side cooler are turbo refrigerators having a variable speed control feature.

#### Advantageous Effects of Invention

[0014] Because the air conditioner of the first aspect of the present invention includes the air supply duct for supplying conditioning target air including at least indoor air and optionally outdoor air of a building to be air-conditioned into the interior of the building, the high

stage-side cooler provided in the air supply duct for mainly eliminating sensible heat of the conditioning target air, the low stage-side cooler provided downstream of the high stage-side cooler in the air supply duct for mainly eliminating latent heat of the conditioning target air whose heat load has been partly eliminated by the high stage-side cooler, and the indoor cooler for mainly eliminating latent heat of the indoor air, it is possible to process as much heat load as possible by the high stage-side cooler to reduce heat load borne on the low stage-side cooler and to avoid lowering the temperature of an unnecessarily large amount of the conditioning target air to an unreasonably low temperature. It is also possible to avoid lowering the evaporating temperature of the refrigerant to an unreasonably low temperature to save energy, ensure safety, and protect the environment.

When the conditioning target air is cooled and dehumidified, the absolute humidity of the conditioning target air in a cooling operation has one-to-one relationship with the temperature of the conditioning target air. Thus, a temperature of the conditioning target air lower than the temperature corresponding to the target absolute humidity is called "unreasonably low temperature".

[0015] Because the air conditioner of the second aspect of the present invention includes the first heat recovery unit provided upstream of the high stage-side cooler in the air supply duct and the second heat recovery unit provided between the high stage-side cooler and the low stage-side cooler in the air supply duct, the heat of the conditioning target air can be absorbed by the first heat recovery unit, the high stage-side cooler, the second heat recovery unit, and the low

stage-side cooler in a sequential manner, instead of being absorbed by only the high stage-side cooler and the low stage-side cooler. Thus, it is possible to reduce the heat absorption load borne on the low stage-side cooler by using the second heat recovery unit while increasing the ratio of the heat absorption load borne on the high stage-side cooler to achieve efficient operation, and to save the total power of a high stage-side compressor and a low stage-side compressor needed for driving the high stage-side cooler and the low stage-side cooler.

Also, by using the first heat recovery unit to warm up the conditioning target air that has been overcooled in comparison with a target temperature of the indoor air for eliminating latent heat closer to the temperature of the indoor air before supplying the conditioning target air to the interior of the building, it is possible to prevent cold draft, a phenomenon in which the conditioning target air at a low temperature blows into the interior of the building to make people there feel uncomfortable.

[0016] Because the air conditioner of the third aspect of the present invention includes the indoor air intake fan provided at an inlet of the air supply duct for taking the indoor air into the air supply duct, it is possible to adjust the amount of the indoor air supplied to the air supply duct by controlling the indoor air intake fan so that cooling load borne on the low stage-side cooler is minimized due to the ratio of latent heat load of the indoor air and the outdoor air.

It is also possible to use the indoor air cooler, such as an evaporator connected to the high stage-side of the two-stage compression type refrigerator, to eliminate the remaining

sensible heat load that has not been processed by the high stage-side cooler and the low stage-side cooler to further increase the energy efficiency of the whole air conditioner.

It is also possible to carry out intended dehumidification without lowering the temperature of the conditioning target air to an unreasonably low temperature.

[0017] Because the air conditioner of the fourth aspect of the present invention includes the first inter-refrigerant heat exchanger for exchanging heat between the primary refrigerant and the secondary refrigerant, the secondary refrigerant circulating in the secondary refrigerant circulation pathway and being supplied to the high stage-side cooler, the low stage-side cooler, and the indoor air cooler for absorbing sensible heat and latent heat of the conditioning target air and sensible heat of the indoor air, the primary refrigerant circulating in the primary refrigerant circulation pathway for cooling the secondary refrigerant, the secondary refrigerant pathway and the primary refrigerant pathway being physically separated from each other, the primary refrigerant does not leak from the primary refrigerant circulation pathway into the interior of the building. Thus, it is possible to increase energy efficiency of the air conditioner while securing safety without causing harmful effects on people at the interior of the building even if the primary refrigerant harmful to human health is used in favor of energy efficiency.

[0018] According to the air conditioner of the fifth aspect of the present invention, the first inter-refrigerant heat exchanger is provided outside of the building. The secondary refrigerant includes two mutually different kinds of

refrigerants, one of which is used in the high stage-side cooler and the low stage-side cooler, and the other of which is used in the indoor air cooler. The refrigerant used in the indoor air cooler is safer than the refrigerant used in the high stage-side cooler and the low stage-side cooler. The air conditioner includes the second inter-refrigerant heat exchanger provided outside of the building for exchanging heat between the refrigerant used in the high stage-side cooler and the low stage-side cooler and the refrigerant used in the indoor air cooler. Because of this configuration, the primary refrigerant and the secondary refrigerant does not leak into the interior of the building in large amounts. Thus, it is possible to increase energy efficiency of the air conditioner while securing safety without causing harmful effects on people at the interior of the building even if the primary refrigerant harmful to human health is used in favor of energy efficiency.

[0019] According to the air conditioner of the sixth aspect of the present invention, the primary refrigerant is ammonia, which has an excellent quality as a refrigerant, and the secondary refrigerant is water or brine, which is safer in comparison with other kinds of refrigerants. In this configuration, ammonia, which is harmful to human health, circulates outside of the building only. Thus, it is possible to use a natural refrigerant to achieve environmentally-friendly and energy efficient operation while securing safety at the interior of the building.

Having "an excellent quality as a refrigerant" means that the refrigerant has a high coefficient of performance in comparison with other kinds of refrigerants.

[0020] According to the air conditioner of the seventh aspect of the present invention, because the primary refrigerant is chlorofluorocarbon, ammonia, water, carbon dioxide, or hydrocarbon, and the secondary refrigerant is carbon dioxide, it is possible to avoid the decrease of energy efficiency of the refrigerator due to the large temperature difference between the refrigerant and the conditioning target air and the increase of the power needed for driving a pump for circulating the water, which are the drawbacks of using ammonia as the primary coolant and water as the secondary coolant. It is also possible to secure safety by using carbon dioxide, which is relatively safe, as the secondary refrigerant.

[0021] According to the air conditioner of the eighth aspect of the present invention, because the high stage-side compressor connected to the high stage-side cooler and the low stage-side compressor connected to the low stage-side cooler are turbo refrigerators having a variable speed control feature, the compression ratio of both the high stage-side compressor and the low stage-side compressor is reduced. Thus, it is possible to efficiently cool and dehumidify the conditioning target air. It is also possible to variably control the speed of the high stage-side compressor or the low stage-side compressor to adjust a high stage-side evaporating temperature and a low stage-side evaporating temperature to an optimum temperature to increase the energy efficiency of the whole air conditioner.

#### BRIEF DESCRIPTION OF DRAWINGS

[0022] Fig. 1 is a block diagram illustrating a

configuration of an air conditioner as a first embodiment of the present invention;

Fig. 2 is a block diagram illustrating a configuration of an air conditioner as a second embodiment of the present invention;

Fig. 3 is a block diagram illustrating a configuration of an air conditioner as a third embodiment of the present invention; and

Fig. 4 is a block diagram illustrating a configuration of an air conditioner as a fourth embodiment of the present invention.

#### DESCRIPTION OF EMBODIMENTS

[0023] The detailed embodiment of an air conditioner of the present invention does not matter, as long as the air conditioner includes an air supply duct for supplying conditioning target air including at least indoor air and optionally outdoor air of a building be air-conditioned into the interior of the building, a high stage-side cooler provided in the air supply duct for mainly eliminating sensible heat of the conditioning target air, a low stage-side cooler provided downstream of the high stage-side cooler in the air supply duct for mainly eliminating latent heat of the conditioning target air whose heat load has been partly eliminated by the high stage-side cooler, and an indoor cooler for mainly eliminating latent heat of the indoor air.

[0024] For example, first and second heat recovery units, such as heat pipes, may be used to absorb the heat of the conditioning target air and supply the absorbed heat to the conditioning target air after the conditioning target air has

been dehumidified and overcooled in the air supply duct to increase the temperature of the conditioning target air so that cold draft is avoided.

The "cold draft" means a phenomenon in which the conditioning target air, which has been overcooled in comparison with the temperature of the indoor air in a cooling operation, is supplied to the interior of the building and directly hits people there to make them feel uncomfortable.

[0025] The air supply duct may have a plurality of intakes corresponding to the indoor air and the outdoor air so that the indoor air and the outdoor can be supplied.

[0026] An air conditioner of first to fourth embodiments of the present invention will now be described with reference to Figs. 1 to 4.

Fig. 1 is a block diagram illustrating a configuration of an air conditioner as a first embodiment of the present invention. Fig. 2 is a block diagram illustrating a configuration of an air conditioner as a second embodiment of the present invention. Fig. 3 is a block diagram illustrating a configuration of an air conditioner as a third embodiment of the present invention. Fig. 4 is a block diagram illustrating a configuration of an air conditioner as a fourth embodiment of the present invention.

[First Embodiment]

[0027] An air conditioner 100 as a first embodiment of the present invention will now be described with reference to Fig. 1.

As shown in Fig. 1, the air conditioner 100 includes an air supply duct 110, a two-stage compression type refrigerator

100A, an indoor air cooler 140, and an indoor air intake fan 150.

The two-stage compression type refrigerator 100A includes a high stage-side cooler 120, a low stage-side cooler 130, an evaporative condenser EC, a high stage-side compressor HP, a high pressure liquid receiver HR, an intermediate liquid receiver MR, a low stage-side compressor LP, and a low pressure liquid receiver LR. The two-stage compression type refrigerator 100A supplies a refrigerant C to the high stage-side cooler 120, the low stage-side cooler 130, and the indoor air cooler 140 to cool conditioning target air CA.

[0028] The evaporative condenser EC has a large ventilation area in which a low-lift, high-capacity fan can effectively operate to efficiently achieve a low condensing temperature. The rotating speed of the fan can be controlled for managing the condensing temperature.

The high stage-side compressor HP is a turbo compressor having a low compression ratio and efficient vane characteristics. The rotating speed, or capacity, of the high stage-side compressor HP is controlled by an inverter.

The intermediate liquid receiver MR is a device for stably carrying out two-stage compression and two-stage expansion. The intermediate liquid receiver MR delivers the refrigerant C in a liquid state to the high stage-side cooler 120 and the indoor air cooler 140, both of which are flooded air coolers, receives the returned refrigerant in which liquid and gas are mixed, separates only the gas from the returned refrigerant, and delivers the gas back to the high stage-side compressor HP. The intermediate liquid receiver MR also works as an intercooler for cooling the discharged gas from the low

stage-side compressor LP.

The low stage-side compressor LP is a turbo compressor having a low compression ratio and efficient vane characteristics. The rotating speed, or capacity, of the low stage-side compressor LP is controlled by an inverter.

An effective intermediate pressure can be achieved by controlling the rotating speed of the high stage side compressor HP and the rotating speed of the low stage-side compressor LP.

The rotating speed of the high stage side compressor HP and the rotating speed of the low stage-side compressor LP can be controlled independently.

The low pressure liquid receiver LR delivers the refrigerant C in a liquid state to the lower stage-side cooler 130, which is a flooded type evaporator for recovering latent heat, receives the returned refrigerant in which liquid and gas are mixed, separates only the gas from the returned refrigerant, and delivers the gas back to the low stage-side compressor LP.

The high stage-side cooler 120 and the indoor air cooler 140 efficiently process the sensible heat load of the conditioning target air CA and an indoor air IA at a relatively high evaporating temperature.

The low stage-side cooler 130 eliminates water in the conditioning target air CA by lowering the temperature of the conditioning target air CA until the absolute humidity of the conditioning target air CA becomes a target value to condense the water.

[0029] The air conditioner 100 includes the air supply duct 110 for supplying the conditioning target air CA including at

least the indoor air IA and optionally an outdoor air OA of a building B to be air-conditioned into the interior of the building B, the high stage-side cooler 120 provided in the air supply duct 100 for mainly eliminating sensible heat of the conditioning target air CA, the lower stage-side cooler 130 provided downstream of the high stage-side cooler 120 in the air supply duct 110 for mainly eliminating latent heat of the conditioning target air CA whose heat load has been partly eliminated by the high stage-side cooler 120, and the indoor air cooler 140 for mainly eliminating sensible heat of the indoor air IA. Thus, it is possible to process as much heat load as possible by the high stage-side cooler 120 to reduce the heat load borne on the low stage-side cooler 130 and to avoid lowering the temperature of an unnecessarily large amount of the conditioning target air CA to an unreasonably low temperature. It is also possible to avoid lowering the evaporating temperature of the refrigerant C to an unreasonably low temperature to save energy, ensure safety, and protect the environment.

Furthermore, it is possible to minimize energy consumption by minimizing the flow rate of the conditioning target air CA to minimizing the cooling load of the conditioning target air CA and performing necessary sensible heat load processing with the efficient indoor air cooler 140, such as an evaporator connected to the high stage-side of the two-stage compression type refrigerator 100A.

[0030] Specifically, when the atmospheric temperature is 35°C and the wet bulb temperature is 27°C in midsummer, for example, most of sensible heat and latent heat can be processed by setting the evaporating temperature on the high stage-side

to 20°C, the evaporating temperature on the low stage-side to 10°C, the target indoor temperature to 28°C, and the condensing temperature to 32°C. In this case, because the compression ratio on both the high and low stage-sides of the two-stage compression type refrigerator 100A is approximately 1.4, the air conditioner 100 can increase a coefficient of performance of the two-stage type refrigerator 100A to 12 or higher when a turbo refrigerator is used as the high stage-side compressor HP and the low stage-side compressor LP.

The air conditioner 100 can also increase the coefficient of performance of the two-stage-type refrigerator 100A to 10 or higher by optimizing the environmental conditions in dehumidification and the setting conditions of the air conditioner 100.

[0031] In an ideal vapor compression type refrigerator, the relation between a coefficient of performance (COP), an evaporating temperature (TE), and a condensing temperature (TC) can be expressed as  $COP = TE / (TC - TE)$ . Similarly, in a real-world refrigerator, COP becomes higher as TE becomes higher and the TC becomes lower.

In case of the air conditioner 100, the cooling load includes latent heat load and sensible heat load. The sensible heat load can be processed when the evaporating temperature is lower than a target indoor temperature. In order to process the latent heat load, however, the evaporating temperature must be lower than a saturation temperature corresponding to a target absolute humidity. This means that the evaporating temperature for processing the latent heat load is much lower than the evaporating temperature for processing the sensible heat load.

Because sensible heat and latent heat are commonly processed with one evaporator, the evaporating temperature for eliminating latent heat is used. This causes an air conditioner to operate at an unreasonably low temperature and consume excess energy.

According to the above described air conditioner 100, these problems can be addressed to achieve efficient air-conditioning operation.

[0032] The air conditioner 100 also includes an indoor air intake fan 150 provided at an inlet 111 of the air supply duct 110 for taking the indoor air IA into the air supply duct 110. The air conditioner 100 adjust the amount of the indoor air IA supplied into the air supply duct 110 by controlling the indoor air intake fan 150 so that the cooling load borne on the low stage-side cooler 130 is minimized due to the ratio of latent heat load of the indoor air IA and the outdoor air OA.

Also, the air conditioner 100 can carry out intended dehumidification without lowering the temperature of the conditioning target air CA to an unreasonably low temperature.

[0033] When the latent heat load generated at the interior of the building is so much that dehumidifying only the outdoor air OA cannot keep the intended humidity, then the evaporating temperature of the low stage-side cooler 130 needs to be greatly decreased. Thus, the air conditioner 100 uses the indoor air intake fan 150 to take the indoor air IA into the air supply duct 110 as at least a part of the conditioning target air CA to maintain the efficient operation of the two-stage compression type refrigerator 100A.

[0034] If increasing energy efficiency is the sole purpose,

then chlorofluorocarbon may be used as the refrigerant C of the air conditioner 100.

The air conditioner 100 is also capable of using the indoor air cooler 140, such as an evaporator connected to the high stage-side of the two-stage compression type refrigerator, to eliminate the remaining sensible heat load that has not been processed by the high stage-side cooler 120 and the low stage-side cooler 130 to further increase the energy efficiency of the whole air conditioner.

[Second embodiment]

[0035] An air conditioner 200 as a second embodiment of the present invention will now be described with reference to Fig. 2.

In the following description of the second to fourth embodiments, the same numbers in the 200s, 300s, and 400s, respectively, will be used for the similar components to the first embodiment to avoid detailed description.

[0036] As shown in Fig. 2, the air conditioner 200 includes an air supply duct 210 provided at the interior of the building B, a first heat recovery unit 260, and a second heat recovery unit 270.

The first heat recovery unit 260, such as a heat pipe, is provided at an upstream duct portion 210A of the air supply duct 210, the portion 210A being upstream of a high stage-side cooler 220. The second heat recovery unit 270, such as a heat pipe, is provided at an inter-evaporator duct portion 210B, which is the portion of the air duct 210 between the high stage-side cooler 220 and a low stage-side cooler 230. The heat of the conditioning target air CA is absorbed by the first

heat recovery unit 260, the high stage-side cooler 220, the second heat recovery unit 270, and the low stage-side cooler 230 in a sequential manner, rather than being absorbed by only the high stage-side cooler 220 and the low stage-side cooler 230. Because of this configuration, the air conditioner 200 is capable of reducing the heat absorption load borne on the low stage-side cooler 230 by using the second heat recovery unit 270 while increasing the ratio of the heat absorption load borne on the high stage-side cooler 220 to achieve efficient operation, and to save the total power of a high stage-side compressor HP and a low stage-side compressor LP needed for driving the high stage-side cooler 220 and the low stage-side cooler 230.

[0037] Specifically, suppose that the temperature of the conditioning target air CA cooled by the low stage-side cooler 230 for dehumidification is  $14^{\circ}\text{C}$  and the target temperature of the indoor air IA is  $28^{\circ}\text{C}$ . If the air conditioner 200 operates to maintain the target temperature at  $28^{\circ}\text{C}$  by mixing the indoor air IA, whose temperature should be  $30^{\circ}\text{C}$  after most of the sensible heat of the indoor air IA caused by an indoor load has been eliminated by the indoor air cooler 240, which is an evaporator connected to the high stage-side of the two-stage compression type refrigerator, and the conditioning target air CA at  $14^{\circ}\text{C}$ , then an irreversible change occurs and entropy increases to waste energy.

More specifically, mixing the conditioning target air CA at  $14^{\circ}\text{C}$  cooled by the evaporator having an evaporating temperature at  $10^{\circ}\text{C}$  and the indoor air IA at  $30^{\circ}\text{C}$  to maintain the indoor air IA at  $28^{\circ}\text{C}$  results in wasting more energy than using the evaporator having an evaporating temperature at  $20^{\circ}\text{C}$

to maintain the indoor air IA at 28°C.

If the wasted energy is recovered by the first heat recovery unit 260 and the second heat recovery unit 270 to increase the temperature of the air that will be supplied to the interior of the building from 14°C to 21°C, for example, the wasted energy can be reduced for approximately 50 percent.

[0038] The air conditioner 200 also uses the first heat recovery unit 260 to warm up the conditioning target air CA which has been overcooled with respect to the target temperature of the indoor air IA for eliminating latent heat so as to prevent cold draft, a phenomenon in which the conditioning target air CA at a low temperature blows from an air supply opening 212 into the interior of the building to make people there feel uncomfortable.

[Third embodiment]

[0039] An air conditioner 300 as a third embodiment of the present invention will now be described with reference to Fig. 3.

As shown in Fig. 3, the air conditioner 300 includes high and low stage-side chillers 380A and 380B, each of which is an example of a first inter-refrigerant heat exchanger, a high stage-side cooler 320, a low stage-side cooler 330, the evaporative condenser EC, the high stage-side compressor HP, the high pressure liquid receiver HR, the intermediate liquid receiver MR, the low stage-side compressor LP, the low pressure liquid receiver LR, cold water tanks WT1 and WT2, and cold water pumps WP1 and WP2.

A two-stage compression type refrigerator 300A supplies a secondary refrigerant C2 to the high stage-side cooler 320

and the low stage-side cooler 330 to cool the conditioning target air CA.

[0040] The air conditioner 300 includes the high stage-side chiller 380A and the low stage-side chiller 380B for exchanging heat between a primary refrigerant C1 and the secondary refrigerant C2, the secondary refrigerant C2 circulating in a secondary refrigerant circulation pathway P2 and being supplied to the high stage-side cooler 320, the low stage-side cooler 330, and an indoor air cooler 340 for absorbing sensible heat and latent heat of the conditioning target air CA and sensible heat of the indoor air IA, the primary refrigerant C1 circulating in a primary refrigerant circulation pathway P1 for cooling the secondary refrigerant C2, the secondary refrigerant pathway P2 and the primary refrigerant pathway P1 being physically separated from each other. Because of this configuration, the primary refrigerant C1 does not leak from the primary refrigerant circulation pathway P1 into the interior of the building B. Thus, it is possible to increase energy efficiency of the air conditioner 300 while securing safety without causing harmful effects on people at the interior of the building even if the primary refrigerant harmful to human health is used in favor of energy efficiency.

[0041] In the air conditioner 300, the primary refrigerant C1 is ammonia, which has an excellent quality as a refrigerant, and the secondary refrigerant C2 is water or brine, which is safer in comparison with other kinds of refrigerants. In this configuration, ammonia, which is harmful to human health, circulates outside of the building only. Thus, it is possible to use a natural refrigerant to achieve environmentally-friendly and energy efficient operation while

securing safety at the interior of the building.

Using ammonia as the primary refrigerant C1 is advantageous in terms of efficiency, cost, and physical properties in comparison with using water as the primary refrigerant C1.

In the air conditioner 300, the primary refrigerant C1 may be chlorofluorocarbon, ammonia, water, carbon dioxide, or hydrocarbon, and the secondary refrigerant C2 may be carbon dioxide.

By using these primary refrigerant C1 and secondary refrigerant C2, it is possible to carry out latent heat transportation by utilizing carbon dioxide to avoid the decrease of energy efficiency of the refrigerator due to the large temperature difference between the refrigerant and the conditioning target air and the increase of power needed for driving a pump for circulating the water, which are the drawbacks of using ammonia as the primary coolant C1 and water as the secondary coolant C2. It is also possible to secure safety by using carbon dioxide, which is relatively safe, as the secondary refrigerant C2.

[0042] When the primary refrigerant C1 is chlorofluorocarbon, ammonia, water, carbon dioxide, or hydrocarbon and the secondary refrigerant C2 is carbon dioxide, it is possible to avoid the large difference between the evaporating temperature and the temperature of the conditioning target air in sensible heat transportation and the increase of power needed for driving a pump for circulating the water, in comparison with the case in which the primary refrigerant C1 is ammonia and the secondary refrigerant C2 is water. It is also possible to prevent the primary refrigerant C1, whose amount is relatively larger than that of the secondary

refrigerant C2, from leaking into the interior of the building to avoid oxygen deficiency in the building. Furthermore, because heat can be relatively efficiently exchanged between the conditioning target air CA and the carbon dioxide in comparison with using water as the secondary refrigerant C2, it is possible to avoid energy loss due to the heat exchange to increase energy efficiency of the whole air conditioner.

Sensible heat transportation means transporting heat by utilizing exchange of heat involving temperature change.

Latent heat transportation means transporting heat by utilizing exchange of heat involving phase transition.

[Fourth Embodiment]

[0043] An air conditioner 400 as a fourth embodiment of the present invention will now be described with reference to Fig. 4.

As shown in Fig. 4, the air conditioner 400 includes an air supply duct 410, a two-stage compression type refrigerator 400A, a first heat recovery unit 460, a second heat recovery unit 470, and an indoor air intake fan 450.

[0044] The two-stage compression type refrigerator 400A includes high and low stage-side cascade condenser 490A and 490B, each of which is an example of a first inter-refrigerant heat exchanger, a high stage-side cooler 420, which is an evaporator connected to the high stage-side of the two-stage compression type refrigerator 400A, a low stage-side cooler 430, which is an evaporator connected to the low stage-side of the two-stage compression type refrigerator 400A, the evaporative condenser EC, the high stage-side compressor HP, the high pressure liquid receiver HR, the intermediate liquid

receiver MR, the low stage-side compressor LP, the low pressure liquid receiver LR, a high stage carbon dioxide liquid receiver HGR, which is an example of a second inter-refrigerant heat exchanger, a low stage carbon dioxide liquid receiver HGR, and refrigerant pumps CP1-1, CP1-2, and CP2. The two-stage compression type refrigerator 400A supplies the secondary refrigerant C2 to the high stage-side cooler 420 and the low stage-side cooler 430 to cool the conditioning target air CA.

[0045] The liquid carbon dioxide cooled and liquefied by the high stage-side cascade condenser 490A enters the high stage carbon dioxide liquid receiver HGR and is then delivered to the high stage-side cooler 420 and the indoor air cooler 440 by means of a liquid head difference or a liquid pump.

The primary refrigerant C1, such as ammonia, is delivered to the high stage-side cascade condenser 490A and the low stage-side cascade condenser 490B to liquefy secondary refrigerants C2-1 and C2-2, such as carbon dioxide, passing through a portion of the high stage-side cascade condenser 490A and the low stage-side cascade condenser 490B connected to the indoor side of the air conditioner 400.

The liquefied secondary refrigerant C2-2, such as carbon dioxide, on the indoor side is then delivered to the low stage-side cooler 430 by means of a liquid head difference or a liquid pump, eliminates mainly latent heat to evaporate, and goes back to the low stage-side cascade condenser 490B.

[0046] The secondary refrigerant C2-1, such as carbon dioxide, is delivered to the high stage-side cooler 420, eliminates a part of the heat load of the conditioning target air CA at a relatively high evaporating temperature, and goes back to the high stage carbon dioxide liquid receiver HGR.

The heat exchange and heat transportation carried out with the carbon dioxide involve latent heat change and are thus much more efficient than using water to utilize sensible heat.

[0047] The high stage-side cascade condenser 490A and the low stage-side cascade condenser 490B such as these are used in a situation where leakage of gas at the interior of the building could cause a serious accident such as intoxication or oxygen deficiency if the gas binds to the large amount of the primary refrigerant C1, or ammonia, stored in the main body of the two-stage compression refrigerant 400A. The high stage-side cascade condenser 490A and the low stage-side cascade condenser 490B may not be used in a factory, for example, where a large space is available and ventilation is relatively easy.

[0048] The high stage-side cascade condenser 490A and the low stage-side cascade condenser 490B are provided outside of the building B. The refrigerants C2-1 and C2-2 used in the high stage-side cooler 420 and the low stage-side cooler 430, respectively, and the refrigerant C2-3 used in the indoor air cooler 440 are different kinds from each other. The refrigerant C2-3 used in the indoor air cooler 440 is safer than the refrigerants C2-1 and C2-2 used in the high stage-side cooler 420 and the low stage-side cooler 430, respectively. The high stage carbon dioxide liquid receiver HGR, which exchanges heat between the refrigerants C2-1 and C2-2 used in the high stage-side cooler 420 and the low stage-side cooler 430, respectively, and the refrigerant C2-3 used in the indoor air cooler 440, is provided outside of the building B. Because of this configuration, the air conditioner 400 prevents the primary refrigerant C1 from leaking into the interior of the

building in large amounts. Thus, it is possible to increase energy efficiency while securing safety without causing harmful effects on people at the interior of the building even if the primary refrigerant C1 harmful to human health is used in favor of energy efficiency

[0049] In the air conditioner 400, the primary refrigerant C1 may be ammonia and the secondary refrigerant C2 may be water or brine, as with the air conditioner 300. Or, the primary refrigerant C1 may be chlorofluorocarbon, ammonia, water, carbon dioxide, or hydrocarbon, and the secondary refrigerant C2 may be carbon dioxide to achieve the same effect as the air conditioner 300.

#### REFERENCE SIGNS LIST

[0050] 100, 200, 300, 400 Air conditioner  
110, 210, 310, 410 Air supply duct  
210A, 310A, 410A Upstream duct portion  
210B, 310B, 410B Inter-evaporator duct portion  
210C, 310C, 410C Downstream duct portion  
111, 211, 311, 411 Intake  
100A, 200A, 300A, 400A Two-stage compression type refrigerator  
120, 220, 320, 420 High stage-side cooler  
130, 230, 330, 430 Low stage-side cooler  
140, 240, 340, 440 Indoor air cooler  
212, 312, 412 Air supply opening  
260, 360, 460 First heat recovery unit  
270, 370, 470 Second heat recovery unit  
150, 250, 350, 450 Outdoor air intake fan  
380A High stage-side chiller

380B Low stage-side chiller  
 490A High stage-side cascade condenser  
 490B Low stage-side cascade condenser  
 EC Evaporative condenser  
 HP High stage-side compressor  
 HR High pressure liquid receiver  
 MR Intermediate liquid receiver  
 LP Low stage-side compressor  
 LR Low pressure liquid receiver  
 CA Conditioning target air  
 OA Outdoor air  
 IA Indoor air  
 C Refrigerant  
 C1 Primary refrigerant  
 C2-1, C2-2, C2-3 Secondary refrigerant  
 P1 Primary refrigerant circulation pathway  
 P2 Secondary refrigerant circulation pathway  
 B Building  
 WT1, WT2 Cold water tank  
 WP1, WP2 Cold water pump  
 CP1-1, CP1-2, CP2 Refrigerant pump

## CLAIMS

1. An air conditioner comprising:

an air supply duct for supplying conditioning target air including at least indoor air and optionally outdoor air of a building to be air-conditioned into the interior of the building;

a high stage-side cooler provided in the air supply duct for mainly eliminating sensible heat of the conditioning target air;

a low stage-side cooler provided downstream of the high stage-side cooler in the air supply duct for mainly eliminating latent heat of the conditioning target air whose heat load has been partly eliminated by the high stage-side cooler; and

an indoor cooler for mainly eliminating latent heat of the indoor air.

2. The air conditioner according to claim 1, comprising:

a first heat recovery unit provided upstream of the high stage-side cooler in the air supply duct; and

a second heat recovery unit provided between the high stage-side cooler and the low stage-side cooler in the air supply duct.

3. The air conditioner according to claim 1 or 2, comprising an indoor air intake fan provided at an inlet of the air supply duct for taking the indoor air into the air supply duct.

4. The air conditioner according to claim 3, wherein the air conditioner comprises a first inter-refrigerant heat

exchanger for exchanging heat between a primary refrigerant and a secondary refrigerant, the secondary refrigerant circulating in a secondary refrigerant circulation pathway and being supplied to the high stage-side cooler, the low stage-side cooler, and the indoor air cooler for absorbing sensible heat and latent heat of the conditioning target air and sensible heat of the indoor air, the primary refrigerant circulating in a primary refrigerant circulation pathway for cooling the secondary refrigerant, the secondary refrigerant pathway and the primary refrigerant pathway being physically separated from each other.

5. The air conditioner according to claim 4, wherein the first inter-refrigerant heat exchanger is provided outside of the building,

the secondary refrigerant includes two mutually different kinds of refrigerants, one of which is used in the high stage-side cooler and the low stage-side cooler, and the other of which is used in the indoor air cooler,

the refrigerant used in the indoor air cooler is safer than the refrigerant used in the high stage-side cooler and the low stage-side cooler, and

the air conditioner comprises a second inter-refrigerant heat exchanger provided outside of the building for exchanging heat between the refrigerant used in the high stage-side cooler and the low stage-side cooler and the refrigerant used in the indoor air cooler.

6. The air conditioner according to claim 4 or 5, wherein the primary refrigerant is ammonia, which has an excellent

quality as a refrigerant, and

the secondary refrigerant is water or brine, which is safer in comparison with other kinds of refrigerants.

7. The air conditioner according to claim 4 or 5, wherein the primary refrigerant is chlorofluorocarbon, ammonia, water, carbon dioxide, or hydrocarbon, and the secondary refrigerant is carbon dioxide.

8. The air conditioner according to any one of claims 1 to 7, wherein

a high stage-side compressor connected to the high stage-side cooler and a low stage-side compressor connected to the low stage-side cooler are turbo refrigerators having a variable speed control feature.