

DESCRIPTION

TITLE OF THE INVENTION:

REFRIGERATION DEVICE AND COOLING SYSTEM

TECHNICAL FIELD

[0001]

Embodiments of the present invention relate to a refrigeration device and a cooling system.

BACKGROUND ART

[0002]

Refrigeration devices for circulating a fluorocarbon refrigerant are widely used in various fields. However, many fluorocarbon refrigerants currently used in such refrigeration devices have a high global warming potential (GWP) and are required to be replaced with refrigerants with a low environmental load.

[0003]

Fluorocarbon refrigerants with an extremely low GWP are being developed, and for example, R1234yf has a GWP of less than 1. However, R1234yf has flammability, and its use may be restricted from the viewpoint of safety. For example, in semiconductor manufacturing factories, in general, use of a flammable refrigerant is restricted.

[0004]

On the other hand, refrigeration devices using a natural refrigerant such as nitrogen, helium, or air are known. The natural refrigerant has a GWP of 0 and is non-flammable. For this reason, the refrigeration device using a natural refrigerant can ensure appropriate safety and at the same time, suppress the environmental load.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0005]

Patent Document 1: JP 2012-137291 A

SUMMARY OF THE INVENTION

[0006]

For example, a large-output refrigeration device using a natural refrigerant is generally large in size. Therefore, the introduction thereof may be postponed due to the size. For example, in semiconductor manufacturing

factories, severe restriction conditions are often imposed on the footprint of manufacturing facilities. In the field of semiconductor manufacturing, it cannot be necessarily said that the number of introduction records of the large-output refrigeration device using a natural refrigerant is large. One of the reasons is considered to be the size.

[0007]

In order to spread the refrigeration device using a natural refrigerant in various fields, it is important to suppress the size of the refrigeration device. If this problem is solved, it is considered that the spread thereof will progress remarkably in combination with the advantage of low environmental load.

[0008]

The present disclosure has been made in view of the above circumstances, and an object of the present disclosure is to provide a refrigeration device and a cooling system capable of suppressing the size thereof while suppressing an environmental load and ensuring safety.

[0009]

An embodiment of the present invention relates to the following aspects "1" to "11".

[0010]

[1] A refrigeration device including: a compressor; a compressor downstream-side heat exchanger; an expander; and an expander downstream-side heat exchanger, in which

a natural refrigerant flowing out of the compressor passes through the compressor downstream-side heat exchanger, the expander, and the expander downstream-side heat exchanger in this order and then circulates to the compressor,

the compressor and the expander are coupled to each other by a drive shaft that is common to the compressor and the expander,

the compressor downstream-side heat exchanger cools the natural refrigerant flowing out of the compressor,

the expander downstream-side heat exchanger exchanges heat between the natural refrigerant flowing out of the expander and a temperature control target, and

the compressor downstream-side heat exchanger and the expander downstream-side heat exchanger are arranged to be aligned in a direction parallel to an axial direction of the drive shaft or on the axial direction.

[0011]

[2] The refrigeration device according to [1], in which the compressor downstream-side heat exchanger includes an external heat exchanger that

cools the natural refrigerant flowing out of the compressor with a heat medium different from the natural refrigerant, and an internal heat exchanger that cools the natural refrigerant flowing out of the compressor with the natural refrigerant received from the expander downstream-side heat exchanger, and at least one of the external heat exchanger and the internal heat exchanger and the expander downstream-side heat exchanger are aligned in a direction parallel to an axial direction of the drive shaft or on the axial direction.

[0012]

[3] The refrigeration device according to [2], in which the expander downstream-side heat exchanger and the internal heat exchanger are aligned in this order along a direction from the expander toward the compressor in the axial direction.

[0013]

[4] The refrigeration device according to [2] or [3], in which at least a part of a range occupied by the compressor, the drive shaft, and the expander overlaps at least a part of a range occupied by the expander downstream-side heat exchanger and the internal heat exchanger in a radial direction of the drive shaft orthogonal to the axial direction.

[0014]

[5] The refrigeration device according to any one of [2] to [4], in which the expander, the drive shaft, and the expander are arranged between both ends in a direction parallel to the axial direction of a range occupied by the expander downstream-side heat exchanger and the internal heat exchanger.

[0015]

[6] The refrigeration device according to any one of [2] to [5], in which the expander downstream-side heat exchanger, the internal heat exchanger, and the external heat exchanger are aligned in this order along a direction from the expander toward the compressor in the axial direction.

[0016]

[7] The refrigeration device according to [6], in which the external heat exchanger, the internal heat exchanger, and the expander downstream-side heat exchanger are integrated.

[0017]

[8] The refrigeration device according to any one of [2] to [5], in which the internal heat exchanger and the expander downstream-side heat exchanger are integrated so as to be adjacent to each other, and

the internal heat exchanger and the external heat exchanger are integrated so as to be adjacent to each other in a direction orthogonal to a direction in which the internal heat exchanger and the expander downstream-

side heat exchanger are adjacent to each other.

[0018]

[9] A heat exchanger unit including: a first external heat exchanger; an internal heat exchanger; and a second external heat exchanger, in which

each of the first external heat exchanger, the internal heat exchanger, and the second external heat exchanger includes a heat exchange unit that enables heat exchange between fluids flowing through separate flow paths, and a casing that houses the heat exchange unit,

the casing of the first external heat exchanger, the casing of the internal heat exchanger, and the casing of the second external heat exchanger are integrated to form a common casing,

one of two fluid outlet ports of the heat exchange unit in the first external heat exchanger is connected to one of two fluid inlet ports of the heat exchange unit in the internal heat exchanger inside the common casing, and

one of two fluid outlet ports of the heat exchange unit in the second external heat exchanger is connected to the other of two fluid inlet ports of the heat exchange unit in the internal heat exchanger inside the common casing.

[0019]

[10] The heat exchanger unit according to [9], in which the first external heat exchanger, the internal heat exchanger, and the second external heat exchanger are integrated so as to be linearly aligned in this order.

[0020]

[11] A cooling system including:

the refrigeration device according to any one of [1] to [8]; and

a fluid circulation device that is connected to the expander downstream-side heat exchanger and circulates a fluid as the temperature control target, the fluid being heat-exchanged with the natural refrigerant flowing out of the expander.

[0021]

According to the present invention, it is possible to provide the refrigeration device and the cooling system capable of suppressing the size thereof while suppressing the environmental load and ensuring safety.

BRIEF DESCRIPTION OF DRAWINGS

[0022]

[Fig. 1] Fig. 1 is a perspective view of a cooling system according to a first embodiment.

[Fig. 2] Fig. 2 is a diagram illustrating a case provided in the cooling

system according to the first embodiment.

[Fig. 3] Fig. 3 is a diagram illustrating a piping configuration of the cooling system according to the first embodiment.

[Fig. 4] Fig. 4 is an arrow view when the cooling system according to the first embodiment is viewed in a direction of an arrow IV illustrated in Figs. 1 and 2.

[Fig. 5] Fig. 5 is an arrow view when the cooling system according to the first embodiment is viewed in a direction of an arrow V illustrated in Figs. 1 and 2.

[Fig. 6] Fig. 6 is a perspective view of a cooling system according to a second embodiment.

[Fig. 7] Fig. 7 is an arrow view when the cooling system according to the second embodiment is viewed in a direction of an arrow VII illustrated in Fig. 6.

[Fig. 8] Fig. 8 is an arrow view when the cooling system according to the second embodiment is viewed in a direction of an arrow VIII illustrated in Fig. 6.

[Fig. 9] Fig. 9 is a perspective view of a cooling system according to a third embodiment.

[Fig. 10] Fig. 10 is a diagram illustrating a cooling system according to a fourth embodiment.

[Fig. 11] Fig. 11 is a diagram illustrating a cooling system according to a fifth embodiment.

[Fig. 12] Fig. 12 is a diagram illustrating a cooling system according to a sixth embodiment.

MODE FOR CARRYING OUT THE INVENTION

[0023]

Hereinafter, each embodiment will be described.

[0024]

<First Embodiment>

Fig. 1 is a perspective view of a cooling system S1 according to a first embodiment. A configuration of the cooling system S1 according to the first embodiment will be described below.

[0025]

(Configuration of Cooling System)

As illustrated in Fig. 1, the cooling system S1 includes a refrigeration device 10 and a fluid circulation device 100. In the cooling system S1, the refrigeration device 10 and the fluid circulation device 100 are connected.

[0026]

The refrigeration device 10 cools a fluid as a temperature control target circulated by the fluid circulation device 100. The fluid circulation device 100 circulates the fluid cooled by the refrigeration device 10 to a secondary temperature control target T_r . As a result, the temperature of the secondary temperature control target T_r can be controlled by the fluid circulated by the fluid circulation device 100.

[0027]

In the present embodiment, the fluid that has controlled the temperature of the secondary temperature control target T_r returns to the fluid circulation device 100 and is cooled again by the refrigeration device 10. The secondary temperature control target T_r is not particularly limited, but may be, for example, a wafer that is an intermediate component of a semiconductor, a stage for holding the wafer, or the like. In addition, the secondary temperature control target T_r may be a mold, a space in a refrigerating/freezing compartment, or the like.

[0028]

The size of the cooling system S1 according to the present embodiment is suppressed by devising the layout of the components of the refrigeration device 10 and the components of the fluid circulation device 100. Fig. 2 is a diagram illustrating a case 1 provided in the cooling system S1 with a two-dot chain line. The components of the refrigeration device 10 and the components of the fluid circulation device 100 can be compactly housed in the rectangular parallelepiped case 1. Note that the case 1 need not be provided. Hereinafter, the refrigeration device 10 and the fluid circulation device 100 will be described in detail.

[0029]

[Refrigeration Device]

The refrigeration device 10 is a reverse Brayton refrigeration cycle device that circulates a natural refrigerant. In the present embodiment, the refrigeration device 10 circulates nitrogen as the natural refrigerant, for example. Here, the refrigeration device 10 may be configured to circulate air, helium, or the like.

[0030]

Fig. 3 is a diagram illustrating a piping configuration of the cooling system S1. Referring to Figs. 1 and 3, the refrigeration device 10 includes a compressor 11, a compressor downstream-side heat exchanger 12, an expander 21, and an expander downstream-side heat exchanger 22.

[0031]

In the cooling system S1, the natural refrigerant flowing out of the compressor 11 passes through the compressor downstream-side heat exchanger 12, the expander 21, and the expander downstream-side heat exchanger 22 in this order, and then circulates to the compressor 11. The compressor 11, the compressor downstream-side heat exchanger 12, the expander 21, and the expander downstream-side heat exchanger 22 are connected by a refrigerant circulation path 16 (see Fig. 3) so as to perform such circulation.

[0032]

The compressor downstream-side heat exchanger 12 is a heat exchanger for cooling the natural refrigerant flowing out of the compressor 11. On the other hand, the expander downstream-side heat exchanger 22 is a heat exchanger that exchanges heat between the natural refrigerant flowing out of the expander 21 and the fluid as a temperature control target circulated by the fluid circulation device 100.

[0033]

In the present embodiment, the compressor downstream-side heat exchanger 12 includes an external heat exchanger 13 that cools the natural refrigerant flowing out of the compressor 11 with a heat medium different from the natural refrigerant, and an internal heat exchanger 14 that cools the natural refrigerant flowing out of the compressor 11 with the natural refrigerant received from the expander downstream-side heat exchanger 22. The natural refrigerant flowing out of the compressor 11 passes through the external heat exchanger 13 and the internal heat exchanger 14 in this order. Therefore, specifically, the internal heat exchanger 14 cools the natural refrigerant passing from the compressor 11 through the external heat exchanger 13 and then flowing into the internal heat exchanger 14 from the external heat exchanger 13 with the natural refrigerant received from the expander downstream-side heat exchanger 22.

[0034]

The compressor 11 compresses the natural refrigerant flowing from the expander downstream-side heat exchanger 22 into the compressor 11, and then delivers the compressed natural refrigerant to the external heat exchanger 13. Thereafter, the natural refrigerant is cooled stepwise by the external heat exchanger 13 and the internal heat exchanger 14, and then flows into the expander 21, and the expander 21 delivers the natural refrigerant to the expander downstream-side heat exchanger 22. The external heat exchanger 13 is connected to a cooling heat medium flow path 30 and receives a cooling heat medium from the cooling heat medium flow path 30.

The external heat exchanger 13 then exchanges heat between the high-temperature natural refrigerant flowing out of the compressor 11 and the cooling heat medium to cool the natural refrigerant. The cooling heat medium is not particularly limited, and may be water or brine. In addition, the external heat exchanger 13 may be an air-cooled heat exchanger.

[0035]

The internal heat exchanger 14 cools the natural refrigerant passing from the compressor 11 through the external heat exchanger 13 and then flowing into the internal heat exchanger 14 from the external heat exchanger 13 with the natural refrigerant received from the expander downstream-side heat exchanger 22, and then delivers the natural refrigerant to the expander 21. The expander 21 expands the natural refrigerant from the internal heat exchanger 14, and then delivers the expanded natural refrigerant to the expander downstream-side heat exchanger 22. The expander downstream-side heat exchanger 22 is connected to the fluid circulation device 100 as illustrated in Fig. 3, cools the fluid circulated by the fluid circulation device 100, and then causes the fluid to flow out to the compressor 11.

[0036]

Here, the natural refrigerant flowing from the expander downstream-side heat exchanger 22 toward the compressor 11 passes through the internal heat exchanger 14 and then flows into the compressor 11. Therefore, the internal heat exchanger 14 cools the natural refrigerant flowing from the external heat exchanger 13 into the internal heat exchanger 14 with the natural refrigerant received from the expander downstream-side heat exchanger 22. As a result, the natural refrigerant before flowing from the compressor 11 into the expander 21 is cooled stepwise by the external heat exchanger 13 and the internal heat exchanger 14 as described above.

[0037]

The refrigeration device 10 can lower the temperature of nitrogen expanded by the expander 21 in a range of, for example, -60°C to -180°C and cause the nitrogen to flow into the expander downstream-side heat exchanger 22. Since the refrigeration device 10 can lower the temperature of the natural refrigerant to an extremely low-temperature range as described above, it is possible to generally maintain high refrigeration capacity even in the natural refrigerant after heat exchange with the fluid in the expander downstream-side heat exchanger 22. Therefore, in the present embodiment, the natural refrigerant flowing out of the expander downstream-side heat exchanger 22 is used to cool the natural refrigerant flowing out of the compressor 11 in the internal heat exchanger 14, thereby improving efficiency. Here, the internal

heat exchanger 14 need not be provided.

[0038]

In addition, in the refrigeration device 10, the compressor 11 and the expander 21 are coupled by a drive shaft 18A of a common motor 18 (see Fig. 3). As a result, the compressor 11 and the expander 21 rotate in conjunction with each other by the rotation of the drive shaft 18A. Specifically, the compressor 11 is coupled to the drive shaft 18A on one end side of the drive shaft 18A, and the expander 21 is coupled to the drive shaft 18A on the other end side of the drive shaft 18A.

[0039]

Hereinafter, the layout of the components of the refrigeration device 10 will be described in detail. Reference sign UD in Fig. 1 indicates an up-down direction. The up-down direction UD means a vertical direction. Reference sign Ax indicates the axial direction of the drive shaft 18A, which is a direction passing through the center of the drive shaft 18A. In the present embodiment, the axial direction Ax of the drive shaft 18A extends along the up-down direction UD. As a result, the compressor 11 and the expander 21 are aligned in the up-down direction UD. In the present embodiment, the compressor 11 is disposed above the expander 21, but the compressor 11 may be disposed below the expander 21. Furthermore, the axial direction Ax need not extend along the up-down direction UD, and for example, the compressor 11 and the expander 21 may be arranged such that the axial direction Ax extends along a horizontal direction.

[0040]

Referring to Fig. 1, first, the compressor downstream-side heat exchanger 12 and the expander downstream-side heat exchanger 22 are arranged to be aligned in a direction parallel to the axial direction Ax. Specifically, in the present embodiment, the internal heat exchanger 14 in the compressor downstream-side heat exchanger 12 and the expander downstream-side heat exchanger 22 are aligned in the direction parallel to the axial direction Ax and aligned in the up-down direction UD. The internal heat exchanger 14 is then disposed above the expander downstream-side heat exchanger 22. That is, the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 are arranged in this order along a direction from the expander 21 toward the compressor 11 (a direction from bottom to top) in the axial direction Ax.

[0041]

The internal heat exchanger 14 includes a heat exchange unit 14A that enables heat exchange between fluids (natural refrigerants) flowing through

different flow paths, and a casing 14B that houses the heat exchange unit 14A. The expander downstream-side heat exchanger 22 includes a heat exchange unit 22A that enables heat exchange between fluids (the natural refrigerant and the fluid of the fluid circulation device 100) flowing through different flow paths, and a casing 22B that houses the heat exchange unit 22A. Here, as illustrated in Figs. 1 and 3, the casing 14B of the internal heat exchanger 14 is integrated with the casing 22B of the expander downstream-side heat exchanger 22. As a result, in the present embodiment, the internal heat exchanger 14 is integrated with the expander downstream-side heat exchanger 22, handling is improved, and the number of pipes and the pipe length can be suppressed.

[0042]

The casing 14B of the internal heat exchanger 14 and the casing 22B of the expander downstream-side heat exchanger 22 may be formed with a common casing. In addition, the casing 14B of the internal heat exchanger 14 and the casing 22B of the expander downstream-side heat exchanger 22 may be detachably integrated by a fastening member such as a bolt, or may be integrated by welding or the like. Note that the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 may be separated from each other.

[0043]

Fig. 4 is an arrow view when the cooling system S1 is viewed in a direction of an arrow IV illustrated in Figs. 1 and 2. Fig. 5 is an arrow view when the cooling system S1 is viewed in a direction of an arrow V illustrated in Figs. 1 and 2. As illustrated in Figs. 4 and 5, in the present embodiment, at least a part of a range A1 occupied by the expander 21, the drive shaft 18A, and the compressor 11 in the axial direction Ax overlaps at least a part of a range A2 occupied by the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 in the direction parallel to the axial direction Ax in a radial direction DD1 of the drive shaft 18A orthogonal to the axial direction Ax. Specifically, the entire range A1 overlaps the range A2 in the radial direction DD1. As a result, the compressor 11, the drive shaft 18A, and the expander 21 are arranged between both ends in the axial direction Ax of the range A2. In this case, in the cooling system S1, the dimension in the axial direction Ax can be effectively suppressed.

[0044]

On the other hand, the external heat exchanger 13 is disposed so as to overlap (in other words, be adjacent to) the internal heat exchanger 14 in a direction (see a radial direction DD2 in Fig. 4) orthogonal to the direction in

which the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 are adjacent to each other (that is, a direction parallel to the axial direction Ax). As illustrated in Fig. 5, the external heat exchanger 13 is disposed between both ends in the axial direction Ax of the range A2 occupied by the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 in the axial direction Ax.

[0045]

The external heat exchanger 13 includes a heat exchange unit 13A that enables heat exchange between fluids (the natural refrigerant and the cooling heat medium) flowing through different flow paths, and a casing 13B that houses the heat exchange unit 13A. In the present embodiment, the casing 13B of the external heat exchanger 13 has a rectangular parallelepiped shape. In addition, the casing 14B of the internal heat exchanger 14 and the casing 22B of the expander downstream-side heat exchanger 22, which are integrated with each other, also have a rectangular parallelepiped shape as a whole. As illustrated in Figs. 4 and 5, one surface 51 of six surfaces of the casing 13B of the external heat exchanger 13 and one surface 52 of six surfaces of the casing 14B of the internal heat exchanger 14 and the casing 22B of the expander downstream-side heat exchanger 22, the casing 14B and the casing 22B being integrated with each other, extend in parallel to the axial direction Ax and face each other in the horizontal direction.

[0046]

Reference sign C1 in Fig. 4 indicates a midpoint on a horizontal cross-section of the casing 13B of the external heat exchanger 13, and reference sign C2 indicates a midpoint on a horizontal cross-section of the casing 14B of the internal heat exchanger 14 and the casing 22B of the expander downstream-side heat exchanger 22, the casing 14B and the casing 22B being integrated with each other. Here, the radial direction DD1 described above in which the external heat exchanger 13 overlaps the range A2 occupied by the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 in the axial direction Ax corresponds to the radial direction passing through the center of the drive shaft 18A and the midpoint C1 of the casing 13B of the external heat exchanger 13 among the radial directions of the drive shaft 18A. Furthermore, the radial direction DD2 described above in which the external heat exchanger 13 overlaps the internal heat exchanger 14 corresponds to the radial direction passing through the center of the drive shaft 18A and the midpoint C2 of the casing 13B of the external heat exchanger 13 among the radial directions of the drive shaft 18A.

[0047]

In the present embodiment, as illustrated in Fig. 4, the layout is adopted in which the angle θ formed by the radial direction DD1 and the radial direction DD2 is equal to or less than 45 degrees. As a result, the external heat exchanger 13, the integrated body of the internal heat exchanger 14, and the expander downstream-side heat exchanger 22, and the integrated body of the expander 21, the drive shaft 18A, and the compressor 11 are collectively arranged. Note that the angle θ may be equal to or less than 60 degrees, and is preferably equal to or more than 30 degrees and equal to or less than 45 degrees.

[0048]

In addition, the external heat exchanger 13 is disposed away from the integrated body of the expander 21, the drive shaft 18A, and the compressor 11 with an installation space PS in the radial direction DD2. A pipe connecting the external heat exchanger 13 to the compressor 11 is mainly disposed in the installation space PS. In addition, the external heat exchanger 13 is disposed on the compressor 11 side, that is, above the midpoint in the axial direction Ax of the expander 21, the drive shaft 18A, and the compressor 11. As a result, a flow path arrangement space FS in which the fluid circulation device 100 is to be installed is formed below the external heat exchanger 13 (see Fig. 2).

[0049]

Fig. 4 further illustrates a control box 40. The control box 40 houses a controller or the like that executes control of the refrigeration device 10, such as adjustment of the rotation speed of the drive shaft 18A, and control of the fluid circulation device 100, such as fluid flow rate control. In the present embodiment, when a virtual line is drawn on the radial direction DD2 described above passing through the center of the drive shaft 18A and the midpoint C2 of the casing 13B of the external heat exchanger 13 and the refrigeration device 10 is viewed from above, the control box 40 is disposed on one side and the external heat exchanger 13 is disposed on the other side with the line interposed therebetween. In this manner, the components of the cooling system S1 can be housed.

[0050]

Next, pipes between the components in the refrigeration device 10 will be described. As described above, the refrigerant circulation path 16 connects the compressor 11, the compressor downstream-side heat exchanger 12, the expander 21, and the expander downstream-side heat exchanger 22. Specifically, as illustrated in Figs. 1 and 3, the refrigerant circulation path 16 includes a first pipe 161 that connects the compressor 11 and the external

heat exchanger 13, a second pipe 162 that connects the external heat exchanger 13 and the internal heat exchanger 14, a third pipe 163 that connects the internal heat exchanger 14 and the expander 21, a fourth pipe 164 that connects the expander 21 and the expander downstream-side heat exchanger 22, and a fifth pipe 165 that connects the internal heat exchanger 14 and the compressor 11.

[0051]

The first pipe 161 receives the high-temperature natural refrigerant flowing out of the compressor 11, and delivers the natural refrigerant to the external heat exchanger 13. Referring to Fig. 1, the outlet port of the natural refrigerant in the compressor 11 and the inlet port of the natural refrigerant in the external heat exchanger 13 are at the same height in the up-down direction UD, for example. In this case, the first pipe 161 can connect the compressor 11 and the external heat exchanger 13 while the pipe length and the number of bends are suppressed. As a result, pressure loss in the first pipe 161 can be suppressed.

[0052]

The second pipe 162 receives the cooled natural refrigerant flowing out of the external heat exchanger 13 and delivers the natural refrigerant to the internal heat exchanger 14. The outlet port of the natural refrigerant in the external heat exchanger 13 and the compressed refrigerant inlet port of the natural refrigerant in the internal heat exchanger 14 are at the same height in the up-down direction UD, for example. In this case, the second pipe 162 can connect the external heat exchanger 13 and the internal heat exchanger 14 while the pipe length and the number of bends are suppressed. As a result, pressure loss in the second pipe 162 can be suppressed.

[0053]

Here, the inlet port of the natural refrigerant and the outlet port of the natural refrigerant in the external heat exchanger 13 described above are opened on a surface of the casing 13B facing the compressor 11 side. The first pipe 161 and the second pipe 162 are arranged in the installation space PS illustrated in Fig. 4. As a result, the first pipe 161 and the second pipe 162 are compactly arranged.

[0054]

The natural refrigerant flowing from the external heat exchanger 13 into the internal heat exchanger 14 flows from top to bottom in the internal heat exchanger 14, and is cooled during that time. The natural refrigerant cooled by the internal heat exchanger 14 then flows out of the compressed refrigerant outlet port provided below the compressed refrigerant inlet port

described above. The third pipe 163 receives the natural refrigerant flowing out of the compressed refrigerant outlet port of the internal heat exchanger 14 and delivers the natural refrigerant to the expander 21. The compressed refrigerant inlet port and the compressed refrigerant outlet port of the natural refrigerant in the internal heat exchanger 14 are formed on the surface 52 of the casing 14B facing the external heat exchanger 13.

[0055]

The fourth pipe 164 receives the natural refrigerant flowing out of the expander 21, and delivers the natural refrigerant to the expander downstream-side heat exchanger 22. The expander downstream-side heat exchanger 22 receives the natural refrigerant flowing out of the expander 21 at an expanded refrigerant inlet port. The expanded refrigerant inlet port is provided below the compressed refrigerant outlet port. The natural refrigerant flowing into the expander downstream-side heat exchanger 22 flows bottom to top, and at that time, exchanges heat with the fluid circulated by the fluid circulation device 100. The natural refrigerant flowing out of the expander downstream-side heat exchanger 22 after the heat exchange with the fluid flows into the internal heat exchanger 14, and flows from bottom to top. At this time, heat exchange is performed between the natural refrigerant flowing out of the expander downstream-side heat exchanger 22 and flowing from bottom to top and the natural refrigerant flowing out of the external heat exchanger 13 and flowing from top to bottom.

[0056]

The natural refrigerant flowing from the expander downstream-side heat exchanger 22 into the internal heat exchanger 14 flows out of the expanded refrigerant outlet port of the internal heat exchanger 14. The expanded refrigerant outlet port is provided above the compressed refrigerant inlet port in the internal heat exchanger 14. The fifth pipe 165 receives the natural refrigerant flowing out of the expanded refrigerant outlet port and delivers the natural refrigerant to the compressor 11. The natural refrigerant flowing into the compressor 11 is compressed by the compressor 11, and then flows into the external heat exchanger 13 again via the first pipe 161.

[0057]

[Fluid Circulation Device]

Next, the fluid circulation device 100 will be described. As illustrated in Fig. 2, in the present embodiment, the flow path arrangement space FS is formed below the external heat exchanger 13. As illustrated in Fig. 1, the fluid circulation device 100 is disposed such that at least a part thereof is located in the flow path arrangement space FS. In other words, the fluid

circulation device 100 is disposed such that at least a part thereof overlaps the external heat exchanger 13 in the axial direction Ax.

[0058]

As illustrated in Figs. 1 and 3, the fluid circulation device 100 includes an upstream-side flow path 101U connected to a fluid inlet port 22i of the expander downstream-side heat exchanger 22, a downstream-side flow path 101D connected to a fluid outlet port 22e of the expander downstream-side heat exchanger 22, a heater 102, a pump 103, and a three-way valve 104 provided on the upstream-side flow path 101U, and a bypass flow path 105 connecting the upstream-side flow path 101U and the downstream-side flow path 101D.

[0059]

As described above, in the present embodiment, the fluid circulation device 100 circulates the fluid cooled by the refrigeration device 10 (the expander downstream-side heat exchanger 22) to the secondary temperature control target Tr. The fluid that has controlled the temperature of the secondary temperature control target Tr returns to the fluid circulation device 100 and is cooled again by the refrigeration device 10. The fluid circulated by the fluid circulation device 100 is a liquid, specifically, brine in the present embodiment. Here, the fluid circulated by the fluid circulation device 100 is not particularly limited, and may be a gas. The pump 103 generates a driving force for circulating the fluid.

[0060]

The upstream-side flow path 101U receives the fluid returning from the secondary temperature control target Tr via its upstream end. In the upstream-side flow path 101U, the fluid is heated by the heater 102 as necessary and then flows into the pump 103. The fluid flowing out of the pump 103 passes through two ports of the three-way valve 104 forming a part of the upstream-side flow path 101U, and flows into the expander downstream-side heat exchanger 22 from the fluid inlet port 22i to which the downstream end of the upstream-side flow path 101U is connected.

[0061]

The fluid flowing into the expander downstream-side heat exchanger 22 is cooled by the natural refrigerant, and then flows out of the fluid outlet port 22e. The fluid flowing out of the fluid outlet port 22e circulates through the downstream-side flow path 101D, reaches the secondary temperature control target Tr, and controls the temperature of the secondary temperature control target Tr. The bypass flow path 105 extends from another port different from the two ports of the three-way valve 104 forming a part of the

upstream-side flow path 101U to the downstream-side flow path 101D. By adjusting the opening of the three-way valve 104, the flow rate of the fluid that does not flow into the expander downstream-side heat exchanger 22 can be controlled, and the temperature of the fluid flowing to the secondary temperature control target T_r can be adjusted.

[0062]

As illustrated in Fig. 1, in the present embodiment, a part of the fluid circulation device 100 is disposed in the flow path arrangement space FS below the external heat exchanger 13. As a result, the space below the external heat exchanger 13 is not a dead space but the arrangement space of the fluid circulation device 100, so that the overall size is suppressed.

[0063]

On the other hand, in the other portion of the fluid circulation device 100 protruding laterally from the flow path arrangement space FS, a pipe portion extending in a direction parallel to the axial direction Ax is formed, and such a pipe portion extending in the direction parallel to the axial direction Ax is disposed close to the compressor 11 and the expander 21, so that the increase in the occupied range of the fluid circulation device 100 in the radial direction is suppressed. In particular, in the upstream-side flow path 101U, an inverted U-shaped pipe portion having a bottom facing upward in the up-down direction UD is formed, and the heater 102 as a fluid treatment component is provided in a linear portion of the inverted U-shape extending in the up-down direction UD. The heater 102 has a cylindrical appearance, and the heater 102 is disposed such that its longitudinal direction is parallel to the axial direction Ax (the up-down direction UD). In addition, by forming the inverted U-shaped pipe portion, the circulation of the fluid mixed with bubbles is suppressed, and the stability of temperature control can be improved. In addition to or instead of the heater 102, a fluid treatment component such as a tank, a pump, or a filter having a longitudinal direction may be disposed, and in this case, a compact layout of the components may be achieved.

[0064]

<Operation and Effect>

Operations and effects of the cooling system S1 according to the first embodiment will be described below.

[0065]

When cooling is performed by the cooling system S1, the compressor 11 and the expander 21 are driven. The compressor 11 compresses the natural refrigerant and then delivers the compressed natural refrigerant to the

external heat exchanger 13. The natural refrigerant flowing into the external heat exchanger 13 is cooled by the cooling heat medium, then flows into the internal heat exchanger 14, and is further cooled by the internal heat exchanger 14. Thereafter, the natural refrigerant flowing out of the internal heat exchanger 14 flows into the expander 21. The expander 21 expands the natural refrigerant to lower the temperature thereof. Thereafter, the natural refrigerant flowing out of the expander 21 flows into the expander downstream-side heat exchanger 22, and exchanges heat with the fluid circulated by the fluid circulation device 100 to cool the fluid.

[0066]

The refrigeration device 10 circulates nitrogen as the natural refrigerant and achieves low-temperature cooling in the expander downstream-side heat exchanger 22 by a reverse Brayton cycle. Since nitrogen has a GWP of 0 and is non-flammable, the environmental load can be suppressed, and safety can be ensured. Even in a case where helium is used as the natural refrigerant, safety can be obtained by ensuring non-flammability. On the other hand, although air or the like has oxidizing properties, it is not flammable, so that suitable safety can be ensured.

[0067]

As described above, in the present embodiment, the internal heat exchanger 14 in the compressor downstream-side heat exchanger 12 and the expander downstream-side heat exchanger 22 are arranged to be aligned in the direction parallel to the axial direction A_x of the compressor 11 and the expander 21. In this case, by arranging the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 close to the compressor 11 and the expander 21 in the radial direction of the common drive shaft 18A of the compressor 11 and the expander 21, it is possible to suppress the range occupied by the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 in the radial direction of the drive shaft 18A. Specifically, in the present embodiment, the drive shaft 18A is disposed vertically to extend in the up-down direction, so that the horizontal dimension of the refrigeration device 10 is suppressed, and the footprint can be suppressed.

[0068]

Therefore, according to the cooling system S1 of the first embodiment, it is possible to suppress the size of the cooling system S1 while suppressing the environmental load and ensuring safety.

[0069]

Furthermore, in the present embodiment, the expander downstream-

side heat exchanger 22 and the internal heat exchanger 14 are aligned in this order along the direction from the expander 21 toward the compressor 11 in the axial direction Ax of the drive shaft 18A. As a result, the pipe length between the expander 21 and the expander downstream-side heat exchanger 22 (the pipe length of the fourth pipe 164) can be suppressed.

[0070]

In addition, at least a part of the range A1 occupied by the compressor 11, the drive shaft 18A, and the expander 21 overlaps at least a part of the range A2 occupied by the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 in the radial direction of the drive shaft 18A. In this case, the compressor 11, the drive shaft 18A, and the expander 21 overlap the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 in the radial direction, so that the dimension of the refrigeration device 10 in the axial direction Ax can be suppressed. In particular, in the present embodiment, the compressor 11, the drive shaft 18A, and the expander 21 are arranged between both ends in the direction parallel to the axial direction Ax of the range A2 occupied by the expander downstream-side heat exchanger 22 and the internal heat exchanger 14. As a result, the compressor 11, the drive shaft 18A, and the expander 21 do not protrude in the axial direction Ax from the expander downstream-side heat exchanger 22 and the internal heat exchanger 14, so that the dimension of the refrigeration device 10 in the axial direction Ax can be effectively suppressed.

[0071]

<Second Embodiment>

Next, a cooling system S2 according to a second embodiment will be described with reference to Figs. 6 to 8. The same components as those in the first embodiment among the components in the present embodiment are denoted by the same reference signs, and redundant description will be omitted.

[0072]

Fig. 6 is a perspective view of the cooling system S2 according to the second embodiment. Fig. 7 is an arrow view when the cooling system S2 is viewed in a direction of an arrow VII illustrated in Fig. 6. Fig. 8 is an arrow view when the cooling system S2 is viewed in a direction of an arrow VIII illustrated in Fig. 6.

[0073]

In the present embodiment, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat

exchanger 13 are arranged in this order along a direction from the expander 21 toward the compressor 11 (a direction from bottom to top) in the axial direction Ax of the drive shaft 18A. That is, the position of the external heat exchanger 13 is different from that in the first embodiment.

[0074]

In addition, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 are integrated. As a result, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 constitute a heat exchanger unit EU in which three heat exchangers are integrated. Specifically, the casing 22B of the expander downstream-side heat exchanger 22, the casing 14B of the internal heat exchanger 14, and the casing 13B of the external heat exchanger 13 are integrated to form a common casing CC. As a result, the three heat exchangers are integrated.

[0075]

Furthermore, as illustrated in Figs. 7 and 8, at least a part of the range A1 occupied by the expander 21, the drive shaft 18A, and the compressor 11 in the axial direction Ax overlaps at least a part of a range A2' occupied by the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 in the direction parallel to the axial direction Ax in the radial direction of the drive shaft 18A orthogonal to the axial direction Ax. Moreover, the compressor 11, the drive shaft 18A, and the expander 21 are arranged between both ends in the direction parallel to the axial direction Ax of the range A2'.

[0076]

Referring to Figs. 6 and 8, in the present embodiment, the first pipe 161 extends upward from the compressor 11 and is connected to the external heat exchanger 13. The first pipe 161 delivers the high-temperature natural refrigerant compressed by the compressor 11 to the external heat exchanger 13, and the external heat exchanger 13 cools the natural refrigerant with the cooling heat medium from the cooling heat medium flow path 30. The natural refrigerant flowing out of the external heat exchanger 13 flows downward and flows into the internal heat exchanger 14, and also flows downward in the internal heat exchanger 14 and flows into the third pipe 163. The subsequent flows of the natural refrigerant in the fourth pipe 164 and the fifth pipe 165 are the same as those in the first embodiment.

[0077]

Referring to Fig. 8, the flow path structure in the heat exchanger unit EU will be described. One (an outlet port of the natural refrigerant) of two

fluid outlet ports of the heat exchange unit 13A in the external heat exchanger 13 is connected to one (an inlet port of the compressed natural refrigerant) of two fluid inlet ports of the heat exchange unit 14A in the internal heat exchanger 14 inside the common casing CC. In addition, one (an outlet port of the natural refrigerant) of two fluid outlet ports of the heat exchange unit 22A in the expander downstream-side heat exchanger 22 is connected to the other (an inlet port of the expanded natural refrigerant) of the two fluid inlet ports of the heat exchange unit 14A in the internal heat exchanger 14 inside the common casing CC. Here, the inlet port of the compressed natural refrigerant and the inlet port of the expanded natural refrigerant in the heat exchange unit 14A of the internal heat exchanger 14 open in directions opposite to each other. The inlet port of the compressed natural refrigerant and the inlet port of the expanded natural refrigerant in the heat exchange unit 14A need not be opened in directions opposite to each other, but it is preferable that one of the inlet port of the compressed natural refrigerant and the inlet port of the expanded natural refrigerant be opened on one end side of the internal heat exchanger 14 and the other inlet port be opened on the other end side opposite to the one end side of the internal heat exchanger 14. Such a layout of the inlet ports can suppress complication of a connection mode with other heat exchangers (the external heat exchanger 13 and the expander downstream-side heat exchanger 22).

[0078]

Note that when the heat exchanger unit EU is separated from the refrigeration device 10 and viewed by itself, the external heat exchanger 13 of the present embodiment is configured to correspond to a first external heat exchanger, and the expander downstream-side heat exchanger 22 is configured to correspond to a second external heat exchanger.

[0079]

According to the present embodiment, the function of the internal heat exchanger 14 that makes the exhaust heat of the natural refrigerant flowing out of the expander downstream-side heat exchanger 22 available for the temperature control of the natural refrigerant flowing out of the external heat exchanger 13 can be achieved in an easily handled and compact mode. In addition, the number of pipes can be reduced, and thus the occupied range of the pipes can be suppressed, and further, heat loss and pressure loss can be suppressed, so that efficiency can be improved.

[0080]

<Third Embodiment>

Next, a cooling system S3 according to a third embodiment will be

described with reference to Fig. 9. The same components as those in the first and second embodiments among the components in the present embodiment are denoted by the same reference signs, and redundant description will be omitted.

[0081]

In the present embodiment, as illustrated in Fig. 9, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 are integrated. As a result, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 constitute a heat exchanger unit EU in which three heat exchangers are integrated. On the other hand, the position of the external heat exchanger 13 is different from that of the second embodiment.

[0082]

Specifically, in the present embodiment, the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 are integrated so as to be adjacent to each other in a direction parallel to the axial direction Ax. On the other hand, the internal heat exchanger 14 and the external heat exchanger 13 are integrated to be adjacent to each other in a direction (the horizontal direction) orthogonal to the direction in which the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 are adjacent to each other. The integrated state of the casings, the internal flow path configuration, and the like are similar to those of the second embodiment.

[0083]

The present embodiment can obtain effects similar to those of the second embodiment. On the other hand, it is advantageous, for example, in a case where it is desired to suppress the height in the up-down direction UD. In the present embodiment, the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 are integrated so as to be adjacent to each other in the direction parallel to the axial direction Ax, but the external heat exchanger 13 and the expander downstream-side heat exchanger 22 may be integrated so as to be adjacent to each other in the direction parallel to the axial direction Ax, and the internal heat exchanger 14 and the external heat exchanger 13 may be integrated so as to be adjacent to each other in the direction (the horizontal direction) orthogonal to the direction in which the external heat exchanger 13 and the expander downstream-side heat exchanger 22 are adjacent to each other.

[0084]

<Fourth Embodiment>

Next, a cooling system S4 according to a fourth embodiment will be

described with reference to Fig. 10. The same components as those in the first to third embodiments among the components in the present embodiment are denoted by the same reference signs, and redundant description will be omitted.

[0085]

In the present embodiment, as illustrated in Fig 10, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 are aligned on the axial direction Ax of the drive shaft 18A. Specifically, the expander downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 are aligned in this order so as to be separated from the expander 21. Such an embodiment is advantageous in a case where suppression of radial protrusion is emphasized.

[0086]

<Fifth Embodiment>

Next, a cooling system S5 according to a fifth embodiment will be described with reference to Fig. 11. The same components as those in the first to fourth embodiments among the components in the present embodiment are denoted by the same reference signs, and redundant description will be omitted.

[0087]

In the present embodiment, as illustrated in Fig. 11, the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 are aligned on the axial direction Ax of the drive shaft 18A. Specifically, the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 are aligned in this order so as to be separated from the expander 21. On the other hand, the external heat exchanger 13 is disposed so as to face the internal heat exchanger 14 in the radial direction of the drive shaft 18A orthogonal to the axial direction Ax. According to such an embodiment, the overall size can also be suppressed.

[0088]

<Sixth Embodiment>

Next, a cooling system S6 according to a sixth embodiment will be described with reference to Fig. 12. The same components as those in the first to fifth embodiments among the components in the present embodiment are denoted by the same reference signs, and redundant description will be omitted.

[0089]

In the present embodiment, as illustrated in Fig. 12, the expander

downstream-side heat exchanger 22, the internal heat exchanger 14, and the external heat exchanger 13 are aligned on the axial direction Ax of the drive shaft 18A. Specifically, the expander downstream-side heat exchanger 22 and the internal heat exchanger 14 are aligned in this order so as to be separated from the expander 21. On the other hand, the external heat exchanger 13 is disposed so as to be adjacent to the compressor 11 in the axial direction Ax. Such an embodiment is also advantageous in a case where suppression of radial protrusion is emphasized.

[0090]

Although the embodiments of the present invention have been described above, the present invention is not limited to the embodiments described above, and various further modifications can be made to the embodiments described above.

[0091]

For example, in the first embodiment described above, the internal heat exchanger 14 and the expander downstream-side heat exchanger 22 are aligned in the direction parallel to the axial direction Ax, but the external heat exchanger 13 and the expander downstream-side heat exchanger 22 may be aligned in the direction parallel to the axial direction Ax, and the internal heat exchanger 14 may be disposed at a position shifted in the direction orthogonal to the direction in which the external heat exchanger 13 and the expander downstream-side heat exchanger 22 are aligned. In addition, the present invention may also be applied in a direct cooling configuration. Specifically, for example, a refrigeration device may be configured in which the external heat exchanger 13 and the internal heat exchanger 14 are arranged to be aligned in the direction parallel to the axial direction Ax of the drive shaft 18A or on the axial direction Ax, and the natural refrigerant flowing from the internal heat exchanger 14 into the expander 21 is expanded and the expanded refrigerant is supplied from the expander 21 to, for example, a chamber. Such a direct cooling refrigeration device is also advantageous in terms of size suppression.

REFERENCE SIGNS LIST

[0092]

- | | |
|----------|---|
| S1 to S6 | cooling system |
| 1 | case |
| 10 | refrigeration device |
| 11 | compressor |
| 12 | compressor downstream-side heat exchanger |

13	external heat exchanger
13A	heat exchange unit
13B	casing
14	internal heat exchanger
14A	heat exchange unit
14B	casing
16	refrigerant circulation path
161	first pipe
162	second pipe
163	third pipe
164	fourth pipe
165	fifth pipe
18	motor
18A	drive shaft
21	expander
22	expander downstream-side heat exchanger
22A	heat exchange unit
22B	casing
22i	fluid inlet port
22e	fluid outlet port
30	cooling heat medium flow path
100	fluid circulation device
101U	upstream-side flow path
101D	downstream-side flow path
102	heater
103	pump
104	three-way valve
105	bypass flow path
Tr	secondary temperature control target
UD	up-down direction
Ax	axial direction
DD1, DD2	radial direction
PS	installation space
FS	flow path installation space
EU	heat exchange unit
CC	common casing

Claims

[Claim 1]

A refrigeration device comprising: a compressor; a compressor downstream-side heat exchanger; an expander; and an expander downstream-side heat exchanger, wherein

a natural refrigerant flowing out of the compressor passes through the compressor downstream-side heat exchanger, the expander, and the expander downstream-side heat exchanger in this order and then circulates to the compressor,

the compressor and the expander are coupled to each other by a drive shaft that is common to the compressor and the expander,

the compressor downstream-side heat exchanger cools the natural refrigerant flowing out of the compressor,

the expander downstream-side heat exchanger exchanges heat between the natural refrigerant flowing out of the expander and a temperature control target, and

the compressor downstream-side heat exchanger and the expander downstream-side heat exchanger are arranged to be aligned in a direction parallel to an axial direction of the drive shaft or on the axial direction.

[Claim 2]

The refrigeration device according to claim 1, wherein the compressor downstream-side heat exchanger includes an external heat exchanger that cools the natural refrigerant flowing out of the compressor with a heat medium different from the natural refrigerant, and an internal heat exchanger that cools the natural refrigerant flowing out of the compressor with the natural refrigerant received from the expander downstream-side heat exchanger, and at least one of the external heat exchanger and the internal heat exchanger, and the expander downstream-side heat exchanger are aligned in a direction parallel to an axial direction of the drive shaft or on the axial direction.

[Claim 3]

The refrigeration device according to claim 2, wherein the expander downstream-side heat exchanger and the internal heat exchanger are aligned in this order along a direction from the expander toward the compressor in the axial direction.

[Claim 4]

The refrigeration device according to claim 3, wherein at least a part of a range occupied by the compressor, the drive shaft, and the expander overlaps at least a part of a range occupied by the expander downstream-side heat exchanger and the internal heat exchanger in a radial direction of the drive shaft orthogonal to the axial direction.

[Claim 5]

The refrigeration device according to claim 4, wherein the expander, the drive shaft, and the expander are arranged between both ends in a direction parallel to the axial direction of a range occupied by the expander downstream-side heat exchanger and the internal heat exchanger.

[Claim 6]

The refrigeration device according to any one of claims 2 to 5, wherein the expander downstream-side heat exchanger, the internal heat exchanger, and the external heat exchanger are aligned in this order along a direction from the expander toward the compressor in the axial direction.

[Claim 7]

The refrigeration device according to claim 6, wherein the external heat exchanger, the internal heat exchanger, and the expander downstream-side heat exchanger are integrated.

[Claim 8]

The refrigeration device according to claim 2, wherein the internal heat exchanger and the expander downstream-side heat exchanger are integrated so as to be adjacent to each other, and

the internal heat exchanger and the external heat exchanger are integrated so as to be adjacent to each other in a direction orthogonal to a direction in which the internal heat exchanger and the expander downstream-side heat exchanger are adjacent to each other.

[Claim 9]

A heat exchanger unit comprising: a first external heat exchanger; an internal heat exchanger; and a second external heat exchanger, wherein

each of the first external heat exchanger, the internal heat exchanger, and the second external heat exchanger includes a heat exchange unit that enables heat exchange between fluids flowing through separate flow paths, and a casing that houses the heat exchange unit,

the casing of the first external heat exchanger, the casing of the internal heat exchanger, and the casing of the second external heat exchanger are integrated to form a common casing,

one of two fluid outlet ports of the heat exchange unit in the first external heat exchanger is connected to one of two fluid inlet ports of the heat exchange unit in the internal heat exchanger inside the common casing, and

one of two fluid outlet ports of the heat exchange unit in the second external heat exchanger is connected to the other of two fluid inlet ports of the heat exchange unit in the internal heat exchanger inside the common casing.

[Claim 10]

The heat exchanger unit according to claim 9, wherein the first external heat exchanger, the internal heat exchanger, and the second external heat exchanger are integrated so as to be linearly aligned in this order.

[Claim 11]

A cooling system comprising:

the refrigeration device according to claim 1; and

a fluid circulation device that is connected to the expander downstream-side heat exchanger and circulates a fluid as the temperature control target, the fluid being heat-exchanged with the natural refrigerant flowing out of the expander.