(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 3 742 070 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.11.2020 Bulletin 2020/48

(21) Application number: **19741070.7**

(22) Date of filing: **18.01.2019**

(51) Int Cl.:
F25B 1/00 (2006.01) ***F25B 7/00*** (2006.01)
F25B 39/02 (2006.01) ***F25D 3/12*** (2006.01)

(86) International application number:
PCT/JP2019/001499

(87) International publication number:
WO 2019/142919 (25.07.2019 Gazette 2019/30)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **19.01.2018 JP 2018007071**

(71) Applicants:
- **The Doshisha**
Kyoto 602-8580 (JP)
- **MAYEKAWA MFG. CO., LTD.**
Tokyo 135-8482 (JP)

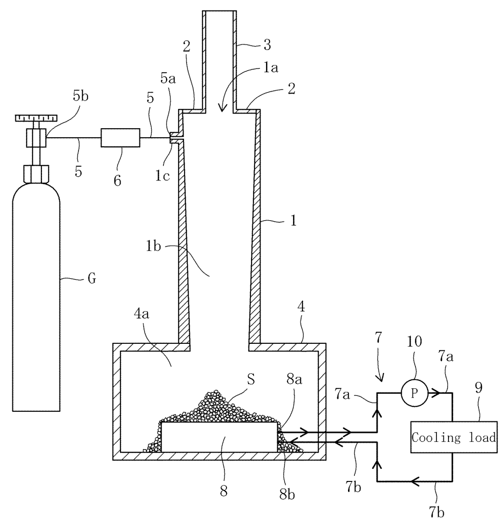
(72) Inventors:
- **YAMAGUCHI Hiroshi**
Kyotanabe-shi, Kyoto 610-0394 (JP)
- **YAMASAKI Haruhiko**
Kyotanabe-shi, Kyoto 610-0394 (JP)
- **NEKSAA Petter**
7030 Trondheim (NO)
- **HATTORI Kazuhiro**
Tokyo 135-8482 (JP)
- **KAMIMURA Takeshi**
Tokyo 135-8482 (JP)

(74) Representative: **Patent Boutique LLP**
10A Printing House Yard
Hackney Road
London E2 7PR (GB)

(54) **CYCLONE REFRIGERATION DEVICE, CYCLONE COOLNESS/HEAT RECOVERY UNIT, AND HEAT PUMP SYSTEM PROVIDED WITH SAID CYCLONE REFRIGERATION DEVICE OR CYCLONE COOLNESS/HEAT RECOVERY UNIT**

(57) A cyclone refrigeration device comprises a cylindrical portion 1, an exhaust pipe 3, a cooling portion 4 with a cavity 4a communicating with an interior space 1b of the cylindrical portion, a refrigerant inflow pipe 5 and a decompression unit 6. A liquid-phase refrigerant condensed under high pressure is supplied into the refrigerant inflow pipe and decompressed into a solid-gas two-phase refrigerant by the decompression unit, and the solid-gas two-phase refrigerant flows downward into the interior space of the cylindrical portion while forming a first vortex flow and separating into a solid-phase refrigerant and a gas-phase refrigerant. The solid-phase refrigerant deposits in the cavity and the gas-phase refrigerant forms a second vortex flow rising from the bottom of the cavity through the inside space of the first vortex flow to flow out through the exhaust pipe. A circulation pipeline for circulating fluid to be cooled 7a, 7b extends through the cavity. A heat exchanger 8 is provided in a portion of the circulation pipeline which is located within the cavity and exchanges heat between the solid-phase refrigerant Sand the fluid to be cooled. A pump 10 circulates the fluid to be cooled.

[Fig. 1]



EP 3 742 070 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a cyclone refrigeration device, a cyclone heat recovery unit and a heat pump system provided with such cyclone refrigeration device or cyclone heat recovery unit.

BACKGROUND ART

[0002] There are some refrigeration devices that uses carbon dioxide (CO_2) as refrigerant in the prior art.

[0003] This kind of refrigeration device comprises, for example, a compressor compressing CO_2 to saturation pressure or supercritical pressure at room temperature level, a condenser cooling and condensing the high pressure gas-phase CO_2 from the compressor, a CO_2 expansion device decompressing the condensed CO_2 to a pressure and temperature level below the triple point of CO_2 so as to transfer the condensed CO_2 into solid-gas two-phase CO_2 which is mixture of solid-phase CO_2 (dry ice) and gas-phase CO_2 (carbon dioxide gas), and a CO_2 sublimation means supplying heat due to sublimation of the solid-gas two-phase CO_2 to fluid to be cooled discharged from a cooling load and supplying the sublimated gas phase CO_2 to the compressor (see, for example, Patent Document 1).

[0004] The CO_2 sublimation means is a direct contact CO_2 sublimation device (see, Fig. 1 of Patent Document 1) or an indirect contact CO_2 sublimation device (see, Fig. 2 of Patent Document 1).

[0005] In the direct contact CO_2 sublimation device, the solid-gas two-phase CO_2 is ejected into the brine stored in a reservoir, and the solid-gas two-phase CO_2 is sublimated by heat of the brine, and the brine is cooled by this sublimation, and the cooled brine exchanges heat with the fluid to be cooled which is discharged from the cooling load.

[0006] In the indirect contact CO_2 sublimation device, the fluid to be cooled which is discharged from the cooling load flows into many cooling tubes arranged in parallel while the solid-gas two-phase CO_2 supplied from the CO_2 expansion device flows into a CO_2 passage provided between the cooling tubes, so that the solid-gas two-phase CO_2 is sublimated by heat of the fluid to be cooled in the cooling tubes and the fluid to be cooled is cooled to very low temperature by this sublimation.

[0007] However, according to this conventional refrigeration device, when the direct contact CO_2 sublimation device is used, solid-phase CO_2 deposits in the reservoir and accordingly a conduit draining the cooled fluid to be cooled from the reservoir is blocked, or the solid-phase CO_2 adheres to an exhaust nozzle for ejection of the solid-gas two-phase CO_2 into the reservoir and accordingly the exhaust nozzle is blocked, which sometimes hinders the operation of the refrigeration device. Also, when the indirect contact CO_2 sublimation device is used, the solid-phase CO_2 adheres to and deposits in the CO_2 passage and the CO_2 passage is blocked, which sometimes hinders the operation of the refrigeration device.

[0008] In addition, this refrigeration device uses the latent heat of the solid-phase CO_2 in the solid-gas two-phase state, but this refrigeration device has a drawback that the cooling capacity thereof is inferior to the case where the heat of sublimation of only the solid-phase CO_2 is used.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0009] Patent Document 1: JP 2004-308972 A

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0010] It is, therefore, an object of the present invention to provide refrigeration device that has a high cooling capacity and can be smoothly and continuously operated.

MEANS FOR SOLVING THE PROBLEMS

[0011] In order to achieve this object, the present invention provides a cyclone refrigeration device comprising: a cylindrical portion vertically extending and closed at a top end thereof; an exhaust pipe whose radius is smaller than the radius of the cylindrical portion connected coaxially to the top end of the cylindrical portion in fluid connection with an interior space of the cylindrical portion and extended upward from the top end of the cylindrical portion; a cooling portion connected to a bottom end of the cylindrical portion and provided with a cavity which communicates with the interior space of the cylindrical portion, the cylindrical portion having a refrigerant inlet at an upper portion of a side wall thereof; a refrigerant inflow pipe connected to the refrigerant inlet at one end thereof and receiving a supply of liquid-phase refrigerant compressed under high pressure at the other end thereof; and a first decompression unit provided in the refrigerant inflow pipe, wherein the liquid-phase refrigerant supplied to the refrigerant inflow pipe is decompressed to form solid-gas two-phase refrigerant by the first decompression unit, and the solid-gas two-phase refrigerant flows downward into the interior space of the cylindrical portion while forming a first vortex flow and separating into solid-phase refrigerant and gas-phase refrigerant, and the solid-phase refrigerant deposits in the cavity on the one hand and the gas-phase refrigerant forms a second vortex flow rising from the bottom of the cavity through an inside space of the first vortex flow to flow out of the exhaust pipe on the other hand, wherein the cyclone refrigeration device further comprises a circulation pipeline for fluid to be cooled extending through the cavity of the cooling portion, both ends of the circulation pipeline being connected to each other outside the cooling portion, the fluid to be cooled from a cooling load flowing in the circulation pipeline, a first heat exchanger provided in a portion of the circulation pipeline for fluid to be cooled which is located within the cavity, and a pump provided in the circulation pipeline for fluid to be cooled outside the cooling portion.

[0012] According to a preferred embodiment of the present invention, the first heat exchanger consists of a container made of heat conductor, the container having a fluid outlet and a fluid inlet and filled with the fluid to be cooled, wherein the circulation pipeline for fluid to be cooled consists of a discharge line for fluid to be cooled connected to the fluid outlet of the container at one end thereof and projecting from the container to the outside of the cooling portion through the cavity, and a supply line for fluid to be cooled connected to the fluid inlet of the container at one end thereof and projecting from the container to the outside of the cooling portion through the cavity, wherein the other end of the discharge line for fluid to be cooled and the other end of the supply line for fluid to be cooled are connected to each other through the cooling load, and the pump is provided in the discharge line for fluid to be cooled or the supply line for fluid to be cooled.

[0013] According to another preferred embodiment of the present invention, the cyclone refrigeration device further comprises a vortex flow control body arranged across the interior space of the cylindrical portion and the cavity of the cooling portion, the vortex flow control body having a columnar bottom portion, a frustoconical middle portion connecting to a top surface of the bottom portion and tapering upward from the bottom portion, and a columnar top portion connecting to a top surface of the middle portion and extending upward from the middle portion, wherein the vortex flow control body is provided with an axial through hole with circular cross section therein, the second vortex flow flowing into the through hole, the through hole spreading out toward the top surface of the vortex flow control body after tapering upward from the bottom surface of the vortex flow control body, wherein the vortex flow control body is supported coaxially to the cylindrical portion by the cooling portion and/or the cylindrical portion in a manner such that the bottom portion is located within the cavity and the middle portion across the cavity and the cylindrical portion and a certain space is formed under the bottom surface of the vortex control body.

[0014] According to further embodiment of the present invention, the interior space of the cylindrical portion is tapered downward.

[0015] According to further embodiment of the present invention, the refrigerant is carbon dioxide or water or ammonia.

[0016] In order to achieve this object, the present invention also provides a heat pump system comprising: the above cyclone refrigeration device; a refrigerant circulation pipe connecting an exit of the exhaust pipe of the cyclone refrigeration device and the other end of refrigerant inflow pipe; a first compressor provided in the refrigerant circulation pipe to compress the gas-phase refrigerant exhausted from the exhaust pipe of the cyclone refrigeration device; and a condenser arranged between the first compressor and the refrigerant inflow pipe of the cyclone refrigeration device in the refrigerant circulation pipe to condense the gas-phase refrigerant compressed by the first compressor into the liquid-phase refrigerant.

[0017] In order to achieve this object, the present invention also provides a cyclone heat recovery unit comprising: the above cyclone refrigeration device; a refrigerant circulation pipe connecting an exit of the exhaust pipe of the cyclone refrigeration device and the other end of refrigerant inflow pipe; a first compressor provided in the refrigerant circulation pipe to compress the gas-phase refrigerant exhausted from the exhaust pipe of the cyclone refrigeration device; first and second condensers provided in series downstream of the first compressor in the refrigerant circulation pipe so as to condense the gas-phase refrigerant compressed by the first compressor into the liquid-phase refrigerant; a second heat exchanger provided downstream of the first and second condensers in the refrigerant circulation pipe; a bypass line connecting a downstream side of the second heat exchanger and an upstream side of the first compressor in the refrigerant circulation pipe; a second decompression unit provided in the bypass line; an evaporator provided downstream of the second decompression unit in the bypass line; a first flow controller provided downstream of the connection point with an upstream end of the bypass line in the refrigerant circulation pipe; a second flow controller provided upstream of the second decompression unit in the bypass line; a third flow controller provided upstream of the connection point with a downstream end of the bypass line in the refrigerant circulation pipe; and a fourth flow controller provided downstream of the evaporator in the bypass line.

[0018] In order to achieve this object, the present invention further provides a cascade heat pump system comprising a low-temperature side cycle and a high-temperature side cycle, wherein the low-temperature side cycle consists of the above cyclone heat recovery unit, and the second heat exchanger of the cyclone heat recovery unit forms a low-temperature side heat exchanger of a cascade heat exchanger.

[0019] In the above cascade heat pump system, preferably, the high-temperature side cycle includes a high-temperature side heat exchanger pairing with the second heat exchanger of the cyclone heat recovery unit to form the cascade heat exchanger; a high-temperature side refrigerant circulation pipe extending between an exit and an entrance of the high-temperature side heat exchanger; a second compressor provided downstream of the high-temperature side heat exchanger in the high-temperature side refrigerant circulation pipe; third and fourth condensers provided in series downstream of the second compressor in the high-temperature side refrigerant circulation pipe; and a third decompression unit provided downstream of the third and fourth condensers in the high-temperature side refrigerant circulation pipe.

EFFECT OF THE INVENTION

[0020] According to the present invention, the liquid-phase refrigerant condensed under high pressure is decompressed into the solid-gas two-phase refrigerant, and the solid-gas two-phase refrigerant flows downward into the interior space of the cylindrical portion while forming the first vortex flow and separating into the solid-phase refrigerant and the gas-phase refrigerant. The solid-phase refrigerant deposits in the cavity of the cooling portion on the one hand and the gas-phase refrigerant forms a second vortex flow rising from the bottom of the cavity through the inside space of the first vortex flow to flow out through the exhaust pipe on the other hand. Thereby the solid-phase refrigerant is prevented from adhering to and depositing in a refrigerant flow passage to block the refrigerant flow passage during operation of the refrigeration device.

[0021] Also, a flow passage for the fluid to be cooled is separated from the solid-phase refrigerant by circulating the fluid to be cooled in the circulation pipeline for fluid to be cooled and exchanging heat between the fluid to be cooled and the solid-phase refrigerant deposited in the cavity, and accordingly, the solid-phase refrigerant is prevented from adhering to and depositing in a flow passage for the fluid to be cooled to block the flow passage for the fluid to be cooled during operation of the refrigeration device.

[0022] Thereby the smooth and stable continuous operation of the refrigeration device is achieved.

[0023] Furthermore, according to the present invention, only the solid-phase refrigerant separated from the solid-gas two-phase refrigerant exchanges heat with the fluid to be cooled so that all of the sublimation heat of the solid-phase refrigerant is supplied to the fluid to be cooled and can be used to cool the fluid to be cooled. Consequently, the cooling capacity of the refrigeration device is greatly improved, compared with the conventional refrigeration device using the latent heat of the solid-phase refrigerant in the solid-gas two-phase state.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

Fig. 1 is a front view schematically illustrating a configuration of a cyclone refrigeration device according to an embodiment of the present invention.

Fig. 2 is a view similar to Fig. 1 schematically illustrating a configuration of a cyclone refrigeration device according to another embodiment of the present invention.

Fig. 3 is a view schematically illustrating a configuration of a heat pump system into which the cyclone refrigeration device of Fig. 1 as an evaporator is incorporated.

Fig. 4 is a Mollier diagram of the heat pump system of Fig. 3 in which CO_2 as a refrigerant is used.

Fig. 5 is a Mollier diagram of a variation of the heat pump system of Fig. 3 in which the cyclone refrigeration device of Fig. 2 is provided instead of the cyclone refrigeration device of Fig. 1 and CO_2 as a refrigerant is used.

Fig. 6 is a Mollier diagram of a case in which a well-known evaporator is provided instead of the cyclone refrigeration device and CO_2 as a refrigerant is used in the heat pipe system shown in Fig. 3.

Fig. 7 is a view schematically illustrating a configuration of a cyclone heat recovery unit provided with the cyclone refrigeration device shown in Fig. 1.

Fig. 8 is a view schematically illustrating a configuration of a cascade heat pump system into which the cyclone heat recovery unit shown in Fig. 7 is incorporated as a low-temperature side cycle.

BEST MODE FOR CARRYING OUT THE INVENTION

[0025] A preferred embodiment of the present invention will be explained below with reference to accompanying drawings.

[0026] Fig. 1 is a front view schematically illustrating a configuration of a cyclone refrigeration device according to an embodiment of the present invention.

[0027] Referring to Fig. 1, the cyclone refrigeration device of the present invention comprises a cylindrical portion 1 extending vertically, an inner flange 2 provided at a top opening 1a of the cylindrical portion 1, an exhaust pipe 3 whose outer diameter corresponds to an opening diameter of the inner flange connected to the inner flange 2 at one end thereof in a manner such that the exhaust pipe protrudes upward from and coaxially with the top opening 1a of the cylindrical portion 1.

[0028] A structure of connecting the cylindrical portion 1 and the exhaust pipe 3 is not limited to this embodiment, and the connection may have any structure as long as the cylindrical portion vertically extends and is closed at a top end thereof and the exhaust pipe whose radius is smaller than the radius of the cylindrical portion is connected coaxially to the top end of the cylindrical portion and extended upward from the top end of the cylindrical portion.

[0029] Although, in this embodiment, an interior space 1b of the cylindrical portion 1 is tapered downward (the interior space 1b is formed so that inner diameter thereof gradually decreases downward), the inner diameter of the interior space 1b may be constant.

[0030] Also, a cooling portion 4 is connected to a bottom end of the cylindrical portion 1 and provided with a cavity 4a which communicates with the interior space 1b of the cylindrical portion 1.

[0031] The cylindrical portion 1 has a refrigerant inlet 1c at an upper portion of a side wall thereof. The refrigerant inlet 1c preferably extends tangentially to a cross section of the cylindrical portion 1.

[0032] A refrigerant inflow pipe 5 is connected to the refrigerant inlet 1c of the cylindrical portion 1 at one end 5a thereof. The refrigerant inflow pipe 5 receives supply of liquid-phase refrigerant condensed under high pressure at the other end 5b thereof. An expansion valve (decompression unit) 6 is provided in the refrigerant inflow pipe 5.

[0033] In this embodiment, a tank G as a supply source of liquid-phase refrigerant is connected to the other end 5b of the refrigerant inflow pipe 5.

[0034] Thus the liquid-phase refrigerant supplied to the refrigerant inflow pipe 5 is decompressed to form solid-gas two-phase refrigerant by the expansion valve 6, and the solid-gas two-phase refrigerant flows into the interior space 1b of the cylindrical portion 1 through the refrigerant inlet 1c and flows downward along an inner wall surface of the interior space 1b to form a first vortex flow.

[0035] In this case, the pressure outside the first vortex flow is greater than the pressure inside the first vortex flow, and this pressure difference between the outside and inside of the first vortex flow decreases from top to the bottom of the interior space 1b. Thereby the first vortex flow extends from the refrigerant inlet 1c of the cylindrical portion 1 to the cavity 4a of the cooling portion 4 and is maintained as it is.

[0036] The solid-gas two-phase refrigerant is separated from a solid-phase refrigerant S and a gas-phase refrigerant by the formation of the first vortex flow, and the solid-phase refrigerant S is deposited in the cavity 4a. On the other hand, the gas-phase refrigerant reaches the bottom of the cavity 4a, where the pressure difference between the outside and the inside of the first vortex flow is small so that the gas-phase refrigerant forms a second vortex flow rising through an inside space of the first vortex flow descending into the interior space 1b and flows out through the exhaust pipe 3.

[0037] In order to achieve this phase change of the refrigerant, it is required that the refrigerant used in the present invention can be maintained at pressure and temperature levels below the triple point thereof inside the refrigeration device. As a refrigerant satisfying this condition, for example, carbon dioxide (CO_2), water, ammonia and so on can be listed.

[0038] According to the present invention, the refrigeration device of the present invention also comprises a circulation pipeline for fluid to be cooled 7 extending through the cavity 4a of the cooling portion 4. Both ends of the circulation pipeline for fluid to be cooled 7 are connected to each other outside the cooling portion 4, and the fluid to be cooled from a cooling load 9 flows in the circulation pipeline for fluid to be cooled 7. A heat exchanger 8 is provided in a portion of the circulation pipeline for fluid to be cooled 7 which is located within the cavity 4. The heat exchanger 8 performs heat exchange between the solid-phase refrigerant deposited in the cavity 4a and the fluid to be cooled.

[0039] In this embodiment, the heat exchanger 8 consists of a container made of heat conductor, the container having a fluid outlet 8a and a fluid inlet 8b and filled with the fluid to be cooled.

[0040] In this case, antifreeze, ethanol and so on can be used as the fluid to be cooled, and the container (heat exchanger) 8 is preferably made of a metal such as aluminum that has high thermal conductivity and is not easily affected by corrosion by the fluid to be cooled.

[0041] The circulation pipeline for fluid to be cooled 7 consists of a discharge line for fluid to be cooled 7a connected to the fluid outlet 8a of the container (heat exchanger) 8 at one end thereof and projecting from the container 8 to the outside of the cooling portion 4 through the cavity 4a, and a supply line for fluid to be cooled 7b connected to the fluid inlet 8b of the container 8 at one end thereof and projecting from the container 8 to the outside of the cooling portion 4 through the cavity 4a.

[0042] The other end of the discharge line for fluid to be cooled 7a and the other end of the supply line for fluid to be cooled 7b are connected to each other through the cooling load 9.

[0043] According to the present invention, a pump 10 is provided in the discharge line for fluid to be cooled 7a or the supply line for fluid to be cooled 7b. The fluid to be cooled is circulated by the pump 10 in the order of the container (heat exchanger) 8 -> the discharge line for fluid to be cooled 7a -> the cooling load 9 -> the supply line for fluid to be cooled 7b -> the container (heat exchanger) 8.

[0044] Thus in the cyclone refrigeration device, liquid-phase refrigerant condensed under high pressure is decompressed to form solid-gas two-phase refrigerant, and the solid-gas two-phase refrigerant flows downward into the interior space 1a of the cylindrical portion 1 while forming the first vortex flow and separating into the solid-phase refrigerant S and the gas-phase refrigerant. The solid-phase refrigerant S deposits in the cavity 4a of the cooling portion 4 on the one hand and the gas-phase refrigerant forms a second vortex flow rising from the bottom of the cavity 4a through the inside space of the first vortex flow to flow out through the exhaust pipe 3 on the other hand.

[0045] Then the solid-phase refrigerant S deposited in the cavity 4a is sublimated by the heat of the fluid to be cooled which is filled in the container (heat exchanger) 8, and the sublimation heat is supplied to the fluid to be cooled so that the cooled fluid to be cooled is supplied to the cooling load 9 through the discharge line for fluid to be cooled 7a.

[0046] According to this configuration, the descending vortex flow (first vortex flow) of the solid-gas two-phase refrigerant is generated in the interior space 1b of the cylindrical portion 1 so that the solid-gas two-phase refrigerant is separated into the solid-phase refrigerant S and the gas-phase refrigerant. Then the solid-phase refrigerant S deposits in the cavity 4a of the cooling portion 4, while the gas-phase refrigerant flows upward through the inside space of the descending vortex flow (first vortex flow) to flow out through the exhaust pipe 3. Thereby the solid-phase refrigerant S is prevented from adhering to and depositing in a refrigerant flow passage to block the refrigerant flow passage during operation of the refrigeration device.

[0047] Furthermore, a flow passage for the fluid to be cooled is separated from the solid-phase refrigerant S by circulating the fluid to be cooled in the circulation pipeline for fluid to be cooled 7 and exchanging heat between the fluid to be cooled and the solid-phase refrigerant S deposited in the cavity 4a, and accordingly, the solid-phase refrigerant S is prevented from adhering to and depositing in a flow passage for the fluid to be cooled to block the flow passage for the fluid to be cooled during operation of the refrigeration device.

[0048] Thereby the smooth and stable continuous operation of the refrigeration device is achieved.

[0049] In addition, according to the present invention, only the solid-phase refrigerant S separated from the solid-gas two-phase refrigerant exchanges heat with the fluid to be cooled so that all of the sublimation heat of the solid-phase refrigerant S is supplied to the fluid to be cooled and can be used to cool the fluid to be cooled. Consequently, the cooling capacity of the refrigeration device is greatly improved, compared with the conventional refrigeration device using the latent heat of the solid-phase refrigerant in the solid-gas two-phase state.

[0050] Fig. 2 is a view similar to Fig. 1 schematically illustrating a configuration of a cyclone refrigeration device according to another embodiment of the present invention.

[0051] The embodiment of Fig. 2 differs from the embodiment of Fig. 1 only in that a structure for controlling the vortex flows is provided over the interior space 1b of the cylindrical portion 1 and the cavity 4a of the cooling portion 4. Therefore, in Fig. 2, the same structural elements as those shown in Fig. 1 are designated by the same reference numerals and the detailed description of them will be omitted in the following.

[0052] Referring to Fig. 2, in this embodiment, a vortex control body 11 is arranged across the interior space 1b of the cylindrical portion 1 and the cavity 4b of the cooling portion 4 and extends vertically.

[0053] The vortex flow control body 11 has a columnar bottom portion 11a, a frustoconical middle portion 11b connecting to a top surface of the bottom portion 11a and tapering upward from the bottom portion 11a, and a columnar top portion 11c connecting to a top surface of the middle portion 11b and extending upward from the middle portion 11b.

[0054] The vortex flow control body 11 is provided with an axial through hole 12 with circular cross section therein, and the second vortex flow flows into the through hole 12.

[0055] The through hole 12 tapers upward from a bottom surface 11e of the vortex flow control body 11 and then spreads out toward a top surface 11d of the vortex flow control body 11.

[0056] The through hole 12 functions as a diffuser.

[0057] The vortex flow control body 11 is supported coaxially to the cylindrical portion 1 by the cooling portion 4 and/or the cylindrical portion 1 through an appropriate support member (not shown) in a manner such that the bottom portion 11a is located within the cavity 4a and the middle portion 11b across the cavity 4a and the cylindrical portion 1 and a certain space is formed under the bottom surface 11e of the vortex control body 11.

[0058] The first vortex flow of the solid-gas two-phase refrigerant descending outside of the vortex control body 11 while the second vortex flow of the gas-phase refrigerant separated from the solid-gas two-phase refrigerant passes upward through the through hole 12 of the vortex flow control body 11 and pressurized by the diffuser function of the through hole during passage of the through hole.

[0059] According to this embodiment, the vortex flow control body 11 facilitates inward movement of the gas-phase refrigerant in the first vortex flow at the bottom of the interior space 1b and the cavity 4a and makes the second vortex flow of the gas-phase refrigerant more stable and stronger.

[0060] Thereby the collection efficiency of the solid-phase refrigerant S is higher than that of the embodiment shown in Fig. 1 and accordingly, the cooling capacity of the refrigeration device is improved.

[0061] Fig. 3 is a view schematically illustrating a configuration of a heat pump system into which the cyclone refrigeration device of Fig. 1 as an evaporator is incorporated. In Fig. 3, the same structural elements as those shown in Fig. 1 are designated by the same reference numerals and the detailed description of them will be omitted in the following.

[0062] Referring to Fig. 3, the heat pump system 16 comprises the cyclone refrigeration device shown in Fig. 1, and a refrigerant circulation pipe 15 connecting an exit of the exhaust pipe 3 of the cyclone refrigeration device and the other end 5b of refrigerant inflow pipe 5.

[0063] The heat pump system 16 further comprises a compressor 13 provided in the refrigerant circulation pipe 15 to compress the gas-phase refrigerant exhausted from the exhaust pipe 3 of the cyclone refrigeration device, and a condenser 14 arranged downstream of the compressor 13 in the refrigerant circulation pipe 15 to condense the gas-phase refrigerant compressed by the compressor 13 into the liquid-phase refrigerant.

[0064] Fig. 4 is a Mollier diagram of the heat pump system 16 when CO_2 is used as a refrigerant.

[0065] Next, the operation of the heat pump system 16 will be described with reference to Figs. 3 and 4.

[0066] A gas-phase CO_2 taken into the compressor 13 through the refrigerant circulation pipe 15 is compressed by the compressor 13 (D -> A in Fig. 4) to form high-pressure gas-phase CO_2, and the high-pressure gas-phase CO_2 is supplied to the condenser 14 through the refrigerant circulation pipe 15.

[0067] After that, in the condenser 14, the gas-phase CO_2 is cooled under high pressure to form a liquid-phase CO_2 (A -> B in Fig. 4), and the high-pressure liquid-phase CO_2 is supplied to the expansion valve 6 through the refrigerant inflow pipe 5.

[0068] The high-pressure liquid-phase CO_2 is expanded and decompressed by the expansion valve 6 to form a solid-gas two-phase CO_2 (B -> C in Fig. 4), and the solid-gas two-phase CO_2 flows into the interior space 1b of the cylindrical portion 1 of the evaporator (cyclone refrigeration device) through the refrigerant inlet 1c of the evaporator (cyclone refrigeration device).

[0069] The solid-gas two-phase CO_2 forms the first vortex flow descending into the interior space 1b and separates into a solid-phase CO_2 and a gas-phase CO_2 (C -> E (corresponding to a separation process of the solid-phase CO_2 from the solid-gas two-phase CO_2) and C -> D (corresponding to a separation process of the gas-phase CO_2 from the solid-gas two-phase CO_2) in Fig. 4) .

[0070] The solid-phase CO_2 deposits in the cavity 4a of the cooling portion 4 of the evaporator (cyclone refrigeration device) while the gas-phase CO_2 forms the second vortex flow rising through the inside space of the first vortex flow and is taken from the exhaust pipe 3 into the compressor 13 through the refrigerant circulation pipe 15.

[0071] The solid-phase CO_2 deposited in the cavity 4a of the evaporator (cyclone refrigeration device) is sublimated by the heat of the fluid to be cooled (E -> D in Fig. 4), and this sublimation heat is supplied to the fluid to be cooled.

[0072] Fig. 6 is a Mollier diagram of a case in which a well-known evaporator is provided instead of the cyclone refrigeration device of the present invention and CO_2 as a refrigerant is used.

[0073] In Fig. 6, D -> A corresponds to a compression process in the compressor 13, A -> B corresponds to a condensation process in the condenser 14, B -> C corresponds to an expansion process in the expansion valve (decompression unit), and C -> D corresponds to an evaporation process in the evaporator.

[0074] As is obvious from the comparison between the graph of Fig. 4 and the graph of Fig. 6, according to the heat pump system 16 of the present invention, the enthalpy obtained in the evaporation process in the evaporator (cyclone refrigeration device) is greatly increased compared to the conventional heat pump system.

[0075] This is due to the following:
In the conventional heat pump system, the heat exchange is done between a solid-gas two-phase CO_2 and fluid to be cooled so that the fluid to be cooled by the latent heat of the solid-phase CO_2 in the solid-gas two-phase state, and accordingly, heat of sublimation of the solid-phase CO_2 cannot be efficiently used to cool the fluid to be cooled. In contrast, according to the present invention, only the solid-phase CO_2 separated from the solid-gas two-phase CO_2 exchanges heat with the fluid to be cooled so that the heat of sublimation of the solid-phase CO_2 is supplied to the fluid to be cooled, and accordingly, all of the sublimation heat of the solid-phase CO_2 can be used to cool the fluid to be cooled.

[0076] Consequently, according to the heat pump system 16 of the present invention, the cooling capacity of the heat pump system is greatly increased.

[0077] Fig. 5 is a Mollier diagram of a variation of the heat pump system 16 of Fig. 3 in which the cyclone refrigeration device of Fig. 2 is provided instead of the cyclone refrigeration device of Fig. 1.

[0078] In Fig. 5, D -> A corresponds to a compression process in the compressor 13, A -> B corresponds to a condensation process in the condenser 14, B -> C corresponds to an expansion process in the expansion valve (decompression unit) 6, C -> E corresponds to a separation process of the solid-phase refrigerant from the solid-gas two-phase refrigerant S in the evaporator (cyclone refrigeration device), C -> D corresponds to a separation process of the gas-phase refrigerant from the solid-gas two-phase refrigerant in the evaporator (cyclone refrigeration device), and E -> D corresponds to an evaporation process of the solid-phase refrigerant S in the evaporator (cyclone refrigeration device).

[0079] As is obvious from the comparison between the graph of Fig. 5 and the graph of Fig. 4, in the embodiment of Fig. 5, the pressure value at the point D is higher than in the embodiment of Fig. 4.

[0080] This is due to the diffuser action of the through hole 12 of the vortex flow control body 11.

[0081] Thereby the effect that the suction pressure of the compressor 13 rises and the operating efficiency of the compressor 13 improves is obtained.

[0082] While a preferred embodiment of the present invention has been set forth for purposes of illustration, the foregoing description should not be deemed a limitation of the invention herein. Accordingly, various modifications, adaptations and alternatives may occur to one skilled in the art without departing from the spirit and the scope of the present invention.

[0083] For example, although one compressor is used alone in the compression process of CO_2 (D -> A) in the above embodiment, it is possible to provide a compressor composed of a low pressure compressor and a high pressure compressor which are connected in series, and an inter cooler arranged between the low pressure and high pressure compressors so as to compress CO_2 in two stages.

[0084] According to this configuration, a gas-phase CO_2 can be easily compressed to saturation or supercritical pressure.

[0085] Also, it is possible in the condensation process (A -> B) of CO_2 in the above embodiment to provide a cascade heat exchanger so as to cool and condense the high-pressure gas-phase CO_2 via the cascade heat exchanger.

[0086] According to this configuration, the cooling capacity of the condenser improves so that the high-pressure gas-phase CO_2 can be cooled to lower temperature in one stage.

[0087] Fig. 7 is a view schematically illustrating a configuration of a cyclone heat recovery unit provided with the cyclone refrigeration device shown in Fig. 1.

[0088] In Fig. 7, the same structural elements as those shown in Fig. 1 are designated by the same reference numerals and the detailed description of them will be omitted in the following.

[0089] Referring to Fig. 7, a cyclone heat recovery unit 17 of the present invention comprises the cyclone refrigeration device shown in Fig. 1, and a refrigerant circulation pipe 18 connecting an exit of the exhaust pipe 3 of the cyclone refrigeration device and the other end 5b of refrigerant inflow pipe 5.

[0090] A compressor 19 is provided in the refrigerant circulation pipe 18 so as to compress a gas-phase refrigerant exhausted from the exhaust pipe 3 of the cyclone refrigeration device, and first and second condensers 20, 21 are provided in series downstream of the compressor 19 in the refrigerant circulation pipe 18 so as to condense the gas-phase refrigerant compressed by the compressor 18 into a liquid-phase refrigerant.

[0091] Further, a heat exchanger 22 is provided downstream of the first and second condensers 20, 21 in the refrigerant circulation pipe 18.

[0092] A bypass line 23 is provided in the refrigerant circulation pipe 18 so as to connect a downstream side of the heat exchanger 22 and an upstream side of the compressor 18.

[0093] An expansion valve (decompression unit) 24 is provided in the bypass line 23 and an evaporator 25 is provided downstream of the expansion valve 24 in the bypass line 23.

[0094] A first flow controller 27 is provided downstream of the connection point 26 with an upstream end of the bypass line 23 in the refrigerant circulation pipe 18, and a second flow controller 28 is provided upstream of the expansion valve 24 in the bypass line 23.

[0095] A third flow controller 30a is provided upstream of the connection point 29 with a downstream end of the bypass line 23 in the refrigerant circulation pipe 18, and a fourth flow controller 30b is provided downstream of the evaporator 25 in the bypass line 23.

[0096] The third and fourth flow controllers 30a, 30b are primarily intended for pressure control.

[0097] That is to say, in this embodiment, when CO_2 is used as a refrigerant, the cyclone refrigeration device operates under the pressure condition below the triple point at which CO2 enters a solid-gas two-phase state while the evaporator 25 operates under the pressure condition above the triple point at which CO_2 enters a gas-liquid two-phase state and therefore, the third and fourth flow controllers 30a, 30b operate in such a way that the above pressure conditions are satisfied.

[0098] In this embodiment, the fluid to be cooled which exchanges heat with the solid-phase refrigerant S in the heat exchanger 8 of the cyclone refrigeration device is preferably low-temperature refrigerant (carbon dioxide, ethanol and helium and so on).

[0099] A lower temperature cold source can be obtained by using the low temperature refrigerant as fluid to be cooled.

[0100] In order to make the cyclone heat recovery unit 17 operate more stably, it is preferable to maintain the pressure in the cyclone refrigeration device at 1 MPa or less. This is easily achieved by sequence control of the compressor 19.

[0101] According to this embodiment, it is possible to divide some of the liquid-phase refrigerant flowing through the refrigerant circulation pipe 18 into the bypass line 23 so as to operate the cyclone refrigeration device and the evaporator 25 at the same time, or it is possible to stop the supply of the liquid-phase refrigerant to the bypass line 23 so as to operate only the cyclone refrigeration device, or it is possible to stop the supply of the liquid-phase refrigerant to the cyclone refrigeration device so as to operate only the evaporator 25.

[0102] Thereby the range of temperature of recoverable heat is wider than that of the embodiment shown in Fig. 1.

[0103] Fig. 8 is a view schematically illustrating a configuration of a cascade heat pump system into which the cyclone heat recovery unit shown in Fig. 7 is incorporated as a low-temperature side cycle.

[0104] In Fig. 8, the same structural elements as those shown in Fig. 7 are designated by the same reference numerals and the detailed description of them will be omitted in the following.

[0105] As shown in Fig. 8, a cascade heat pump system 31 comprises a low-temperature side cycle 32 and a high-temperature side cycle 33, and the low-temperature side cycle consists of the cyclone heat recovery unit 17 shown in Fig. 7.

[0106] In this case, the heat exchanger 22 of the cyclone heat recovery unit 17 forms a low-temperature side heat exchanger 35 of a cascade heat exchanger 34 of the cascade heat pump system 31.

[0107] The high-temperature side cycle 33 includes a high-temperature side heat exchanger 36 pairing with the low-temperature side heat exchanger 35 to form the cascade heat exchanger 34, a high-temperature side refrigerant circulation pipe 37 extending between an exit 36a and an entrance 36b of the high-temperature side heat exchanger 36, a compressor 38 provided downstream of the high-temperature side heat exchanger 36 in the high-temperature side refrigerant circulation pipe 37, third and fourth condensers 39, 40 provided in series downstream of the compressor 38 in the high-temperature side refrigerant circulation pipe 37, and an expansion valve (decompression unit) 41 provided downstream of the third and fourth condensers 39, 40 in the high-temperature side refrigerant circulation pipe 37.

DESCRIPTION OF REFERENCE NUMERALS

[0108]

1	Cylindrical portion
1a	Top opening
1b	Interior space
1c	Refrigerant inlet
2	Inner flange
3	Exhaust pipe
4	Cooling portion
4a	Cavity
5	Refrigerant inflow pipe
5a	One end
5b	The other end
6	Expansion valve (Decompression unit)
7	Circulation pipeline for liquid to be cooled
7a	Discharge line for fluid to be cooled
7b	Supply line for fluid to be cooled
8	Heat exchanger
8a	Fluid outlet
8b	Fluid inlet
9	Cooling load
10	Pump
11	Vortex flow control body
11a	Bottom portion
11b	Middle portion
11c	Top portion
11d	Top surface
11e	Bottom surface
12	Through hole
13	Compressor
14	Condenser
15	Refrigerant circulation pipe
16	Heat pump system
17	Cyclone heat recovery unit
18	Refrigerant circulation pipe
19	Compressor
20	First condenser
21	Second condenser
22	Heat exchanger
23	Bypass line
24	Expansion valve (Decompression unit)
25	Evaporator
26	Connection point
27	First flow controller
28	Second flow controller
29	Connection point
30a	Third flow controller
30b	Fourth flow controller
31	Cascade heat pump system
32	Low-temperature side cycle
33	High-temperature side cycle
34	Cascade heat exchanger
35	Low-temperature side heat exchanger
36	High-temperature side heat exchanger
36a	Exit
36b	Entrance
37	High-temperature side refrigerant circulation pipe
38	Compressor
39	Third condenser
40	Fourth condenser
41	Expansion valve (decompression unit)
S	Solid-phase refrigerant

Claims

1. A cyclone refrigeration device comprising:

a cylindrical portion vertically extending and closed at a top end thereof;
an exhaust pipe whose radius is smaller than the radius of the cylindrical portion connected coaxially to the top end of the cylindrical portion in fluid connection with an interior space of the cylindrical portion and extended upward from the top end of the cylindrical portion;
a cooling portion connected to a bottom end of the cylindrical portion and provided with a cavity which communicates with the interior space of the cylindrical portion,
the cylindrical portion having a refrigerant inlet at an upper portion of a side wall thereof;
a refrigerant inflow pipe connected to the refrigerant inlet at one end thereof and receiving a supply of liquid-phase refrigerant compressed under high pressure at the other end thereof; and
a first decompression unit provided in the refrigerant inflow pipe,
wherein the liquid-phase refrigerant supplied to the refrigerant inflow pipe is decompressed to form solid-gas two-phase refrigerant by the first decompression unit, and the solid-gas two-phase refrigerant flows downward into the interior space of the cylindrical portion while forming a first vortex flow and separating into solid-phase refrigerant and gas-phase refrigerant, and the solid-phase refrigerant deposits in the cavity on the one hand and the gas-phase refrigerant forms a second vortex flow rising from the bottom of the cavity through an inside space of the first vortex flow to flow out of the exhaust pipe on the other hand,
wherein the cyclone refrigeration device further comprises
a circulation pipeline for fluid to be cooled extending through the cavity of the cooling portion, both ends of the circulation pipeline being connected to each other outside the cooling portion, the fluid to be cooled from a cooling load flowing in the circulation pipeline,
a first heat exchanger provided in a portion of the circulation pipeline for fluid to be cooled which is located within the cavity, and

a pump provided in the circulation pipeline for fluid to be cooled outside the cooling portion.

2. The cyclone refrigeration device according to Claim 1, wherein the first heat exchanger consists of a container made of heat conductor, the container having a fluid outlet and a fluid inlet and filled with the fluid to be cooled,
wherein the circulation pipeline for fluid to be cooled consists of
a discharge line for fluid to be cooled connected to the fluid outlet of the container at one end thereof and projecting from the container to the outside of the cooling portion through the cavity, and
a supply line for fluid to be cooled connected to the fluid inlet of the container at one end thereof and projecting from the container to the outside of the cooling portion through the cavity,
wherein the other end of the discharge line for fluid to be cooled and the other end of the supply line for fluid to be cooled are connected to each other through the cooling load, and the pump is provided in the discharge line for fluid to be cooled or the supply line for fluid to be cooled.

3. The cyclone refrigeration device according to Claim 1, further comprising a vortex flow control body arranged across the interior space of the cylindrical portion and the cavity of the cooling portion and extended vertically, the vortex flow control body having a columnar bottom portion,
a frustoconical middle portion connecting to a top surface of the bottom portion and tapering upward from the bottom portion, and
a columnar top portion connecting to a top surface of the middle portion and extending upward from the middle portion,
wherein the vortex flow control body is provided with an axial through hole with circular cross section therein, the second vortex flow flowing into the through hole, the through hole spreading out toward the top surface of the vortex flow control body after tapering upward from the bottom surface of the vortex flow control body,
wherein the vortex flow control body is supported coaxially to the cylindrical portion by the cooling portion and/or the cylindrical portion in a manner such that the bottom portion is located within the cavity and the middle portion across the cavity and the cylindrical portion and a certain space is formed under the bottom surface of the vortex control body.

4. The cyclone refrigeration device according to Claim 1, wherein the interior space of the cylindrical portion is tapered downward.

5. The cyclone refrigeration device according to Claim 1, wherein the refrigerant is carbon dioxide or water or ammonia.

6. A heat pump system comprising:

the cyclone refrigeration device according to any one of Claims 1 to 5;
a refrigerant circulation pipe connecting an exit of the exhaust pipe of the cyclone refrigeration device and the other end of refrigerant inflow pipe;
a first compressor provided in the refrigerant circulation pipe to compress the gas-phase refrigerant exhausted from the exhaust pipe of the cyclone refrigeration device; and
a condenser arranged between the first compressor and the refrigerant inflow pipe of the cyclone refrigeration device in the refrigerant circulation pipe to condense the gas-phase refrigerant compressed by the first compressor into the liquid-phase refrigerant.

7. A cyclone heat recovery unit comprising:

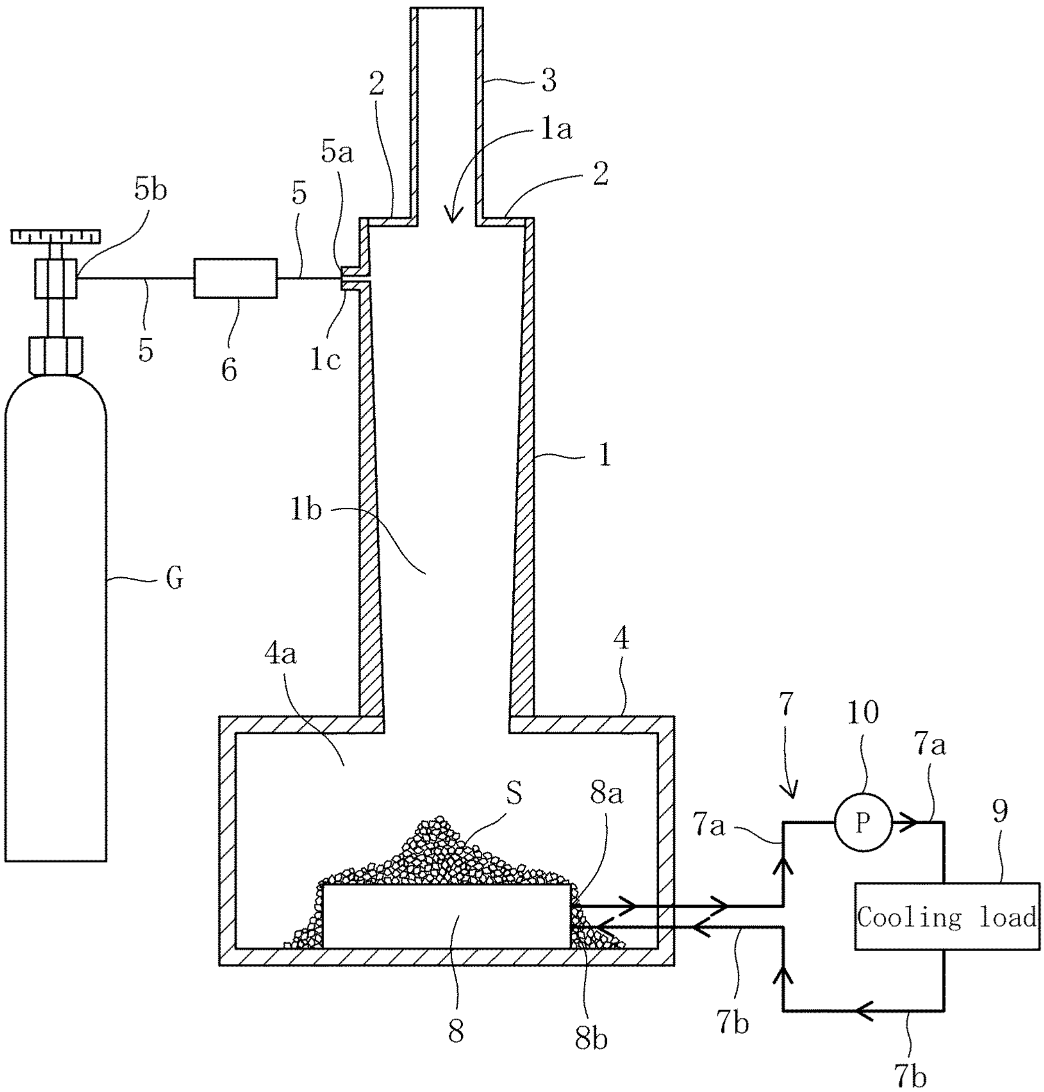
the cyclone refrigeration device according to any one of Claims 1 to 5;
a refrigerant circulation pipe connecting an exit of the exhaust pipe of the cyclone refrigeration device and the other end of refrigerant inflow pipe;
a first compressor provided in the refrigerant circulation pipe to compress the gas-phase refrigerant exhausted from the exhaust pipe of the cyclone refrigeration device;
first and second condensers provided in series downstream of the first compressor in the refrigerant circulation pipe so as to condense the gas-phase refrigerant compressed by the first compressor into the liquid-phase refrigerant;
a second heat exchanger provided downstream of the first and second condensers in the refrigerant circulation pipe;
a bypass line connecting a downstream side of the second heat exchanger and an upstream side of the first compressor in the refrigerant circulation pipe;
a second decompression unit provided in the bypass line;
an evaporator provided downstream of the second decompression unit in the bypass line;
a first flow controller provided downstream of the connection point with an upstream end of the bypass line in the refrigerant circulation pipe;
a second flow controller provided upstream of the second decompression unit in the bypass line;
a third flow controller provided upstream of the connection point with a downstream end of the bypass line in the refrigerant circulation pipe;

and
a fourth flow controller provided downstream of the evaporator in the bypass line.

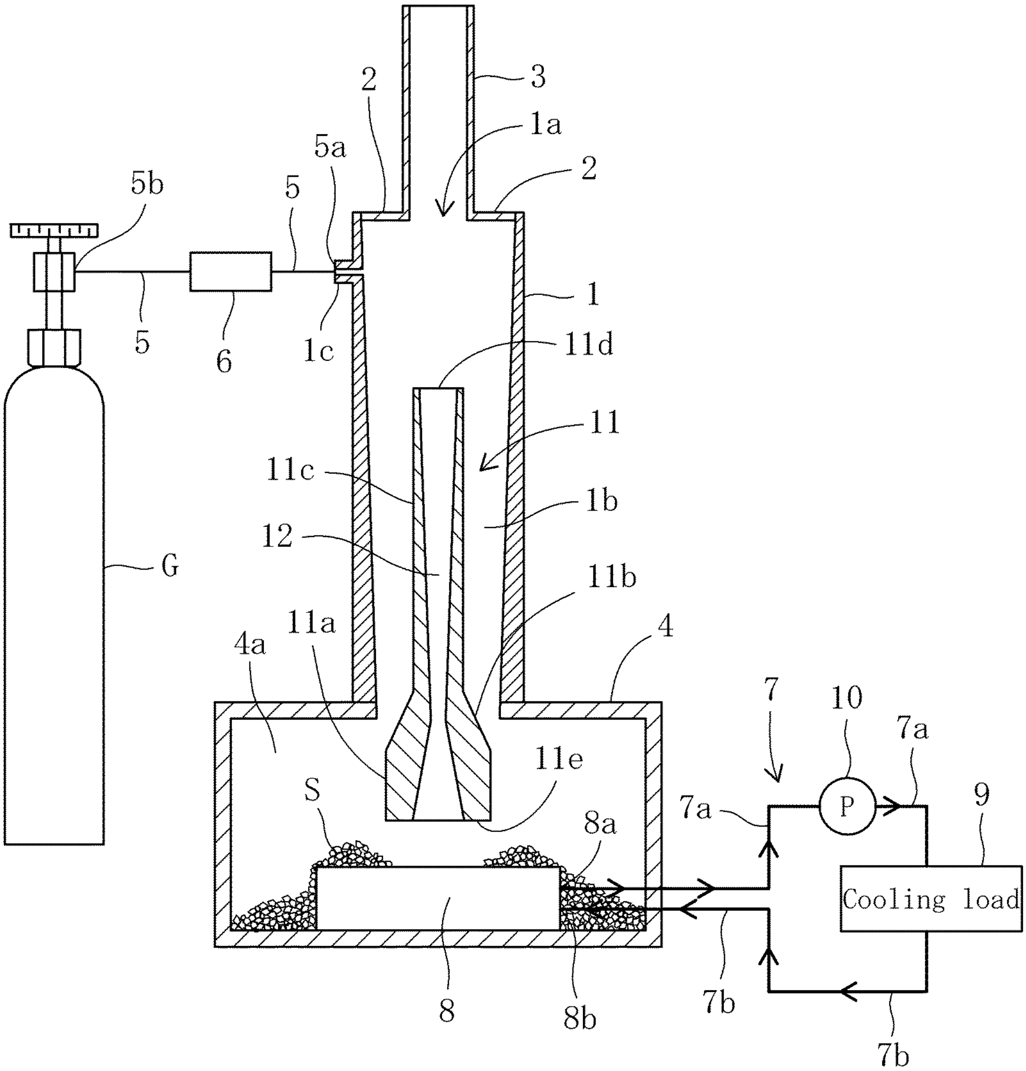
8. A cascade heat pump system comprising a low-temperature side cycle and a high-temperature side cycle,
wherein the low-temperature side cycle consists of the cyclone heat recovery unit according to Claim 7, and the second heat exchanger of the cyclone heat recovery unit forms a low-temperature side heat exchanger of a cascade heat exchanger.

9. The cascade heat pump system according to Claim 8, wherein the high-temperature side cycle includes
a high-temperature side heat exchanger pairing with the second heat exchanger of the cyclone heat recovery unit to form the cascade heat exchanger;
a high-temperature side refrigerant circulation pipe extending between an exit and an entrance of the high-temperature side heat exchanger;
a second compressor provided downstream of the high-temperature side heat exchanger in the high-temperature side refrigerant circulation pipe;
third and fourth condensers provided in series downstream of the second compressor in the high-temperature side refrigerant circulation pipe; and
a third decompression unit provided downstream of the third and fourth condensers in the high-temperature side refrigerant circulation pipe.

[Fig. 1]

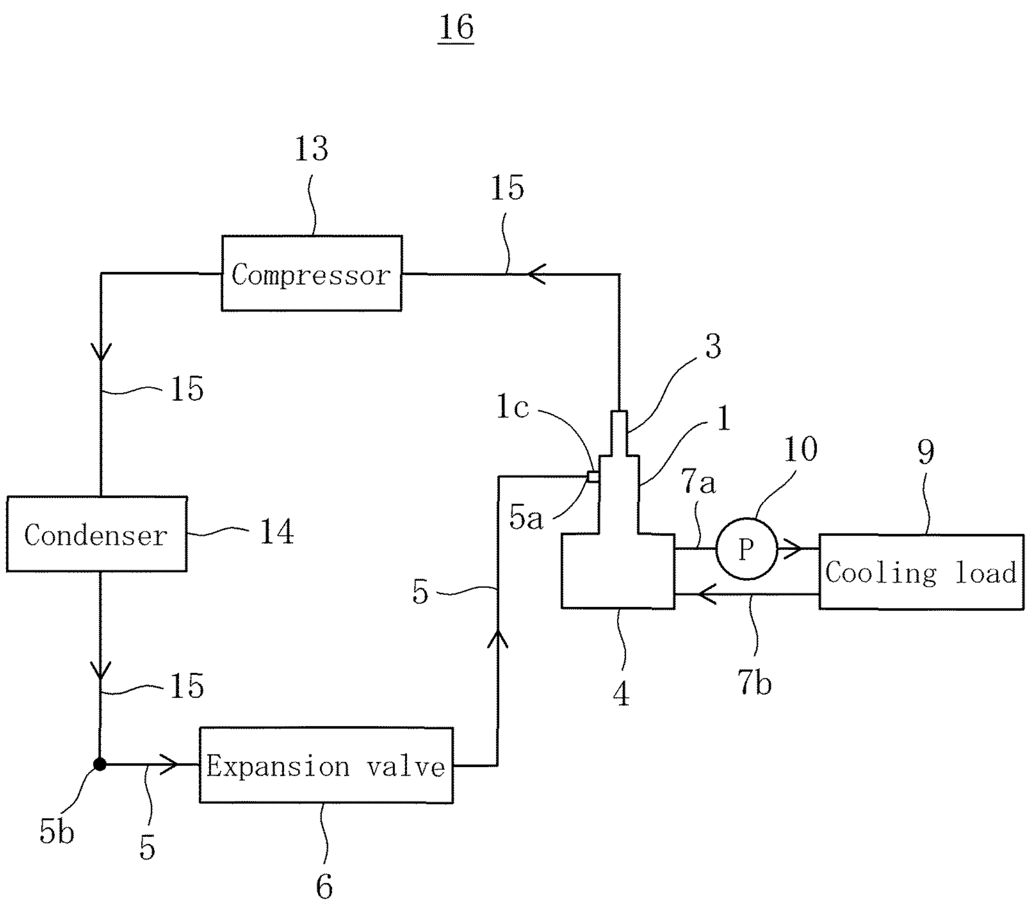

3
2
1a
5a
2
5b
5
5
6
1c
1
1b
G
4a
4
7
10
7a
S
8a
7a
P
9
Cooling load
8
8b
7b
7b

[Fig. 2]

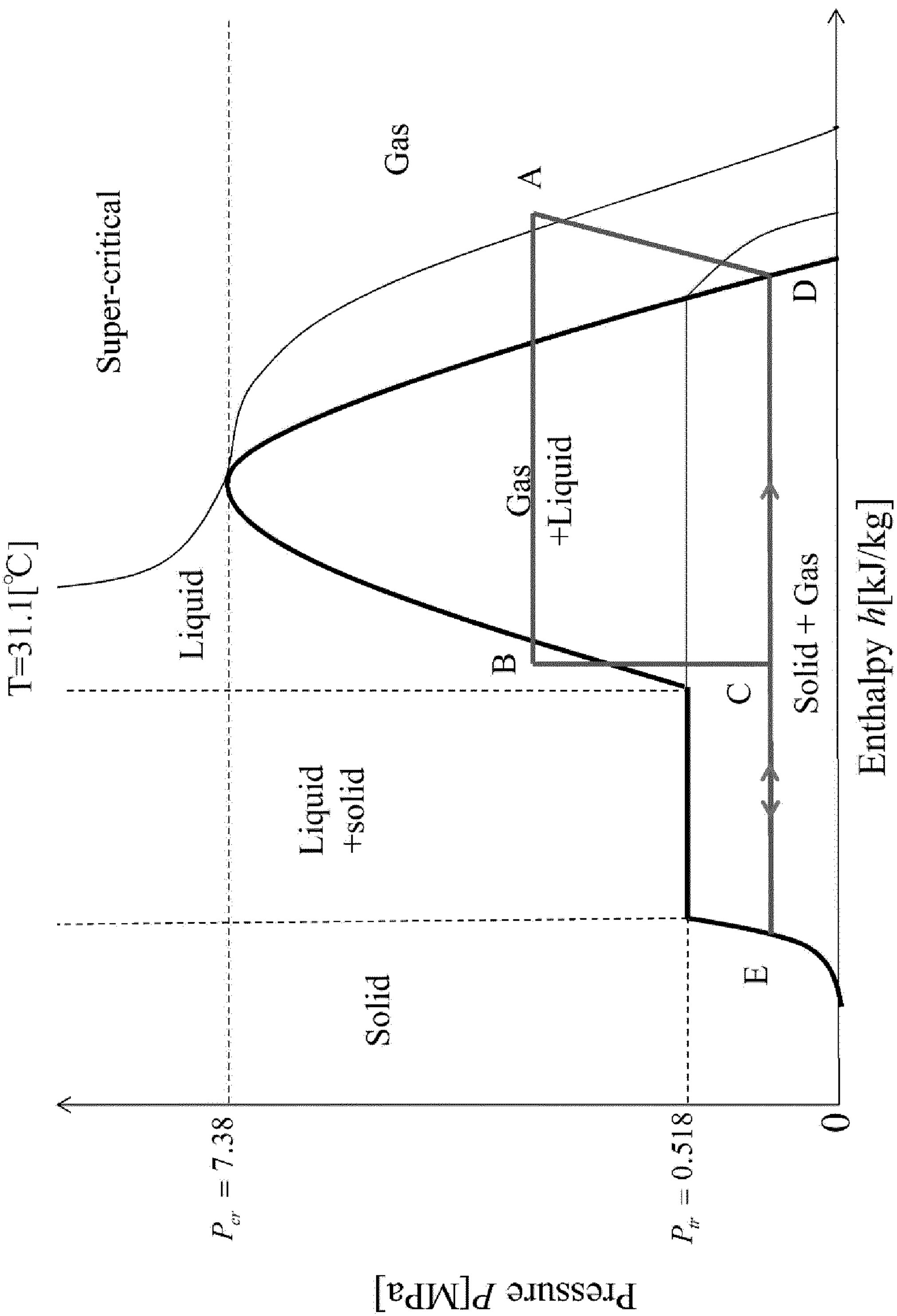


3
1a
2
2
5a
5b
5
5
6
1c
1
11d
11
11c
1b
12
G
11b
11a
4a
4
7
10
7a
11e
S
7a
P
9
8a
Cooling load
8
8b
7b
7b

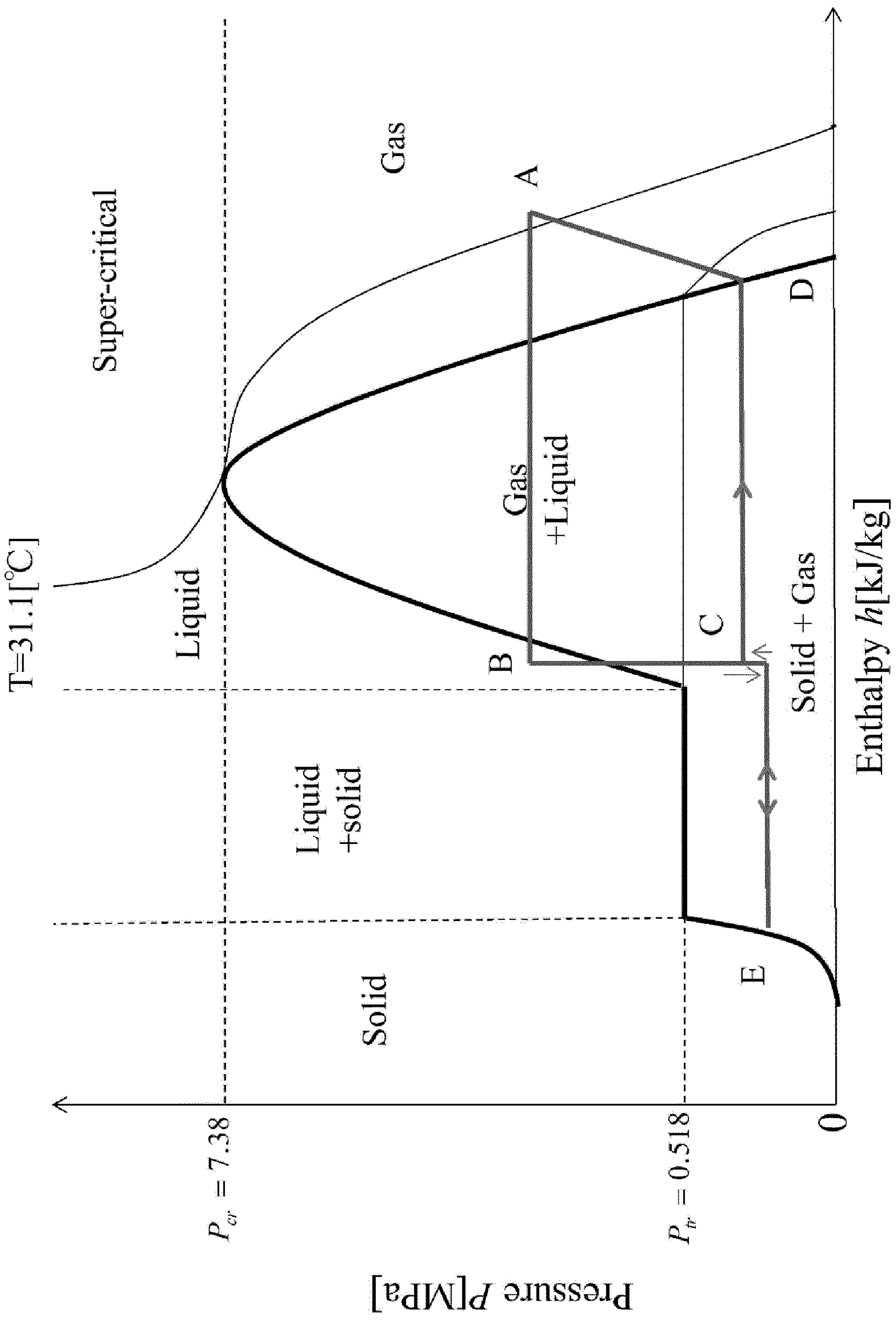
[Fig. 3]


16
13
Compressor
15
15
3
1c
1
10
9
7a
5a
Condenser
14
P
Cooling load
5
15
4
7b
Expansion valve
5b
5
6

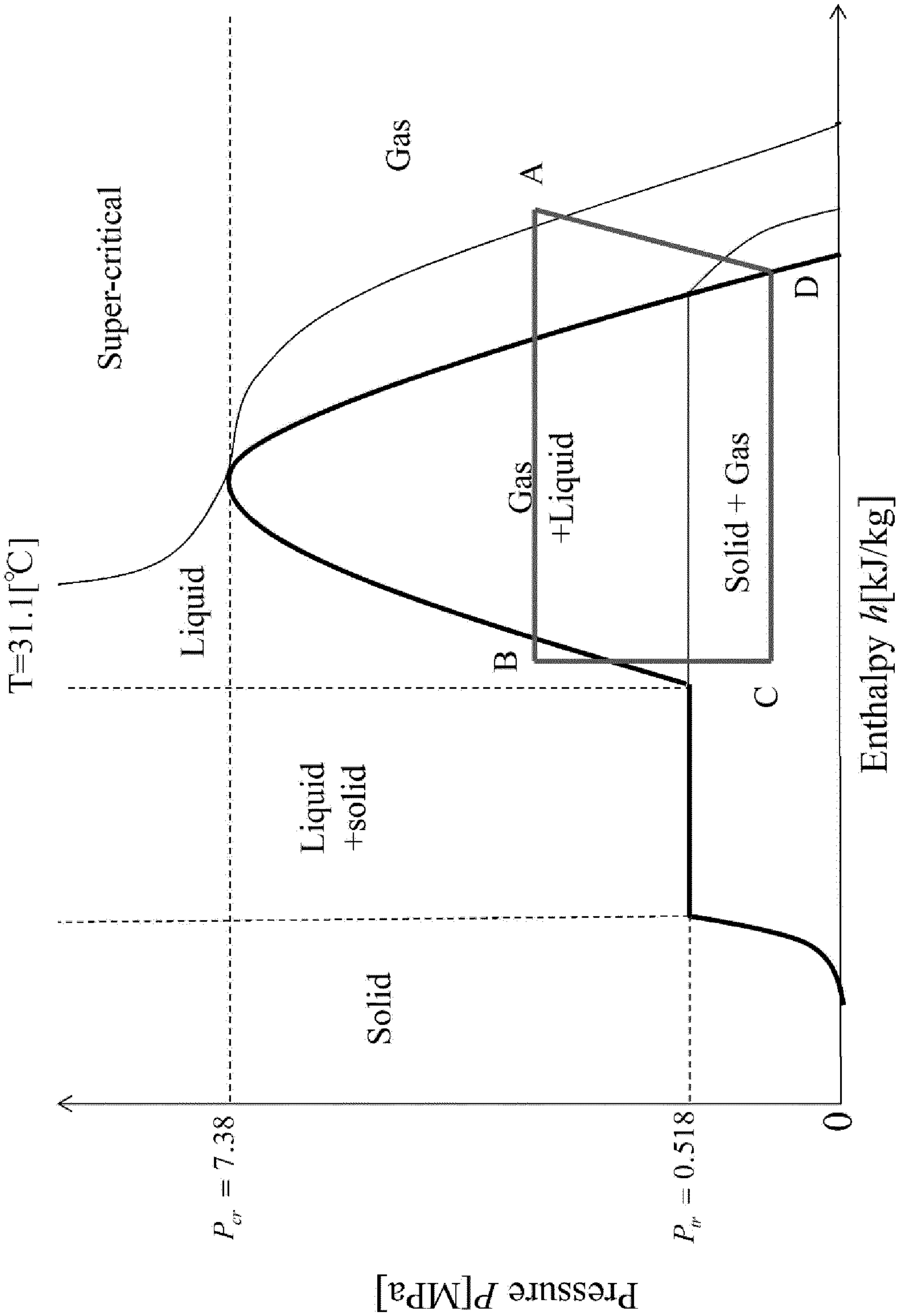
[Fig. 4]


T=31.1[°C]
Super-critical
Gas
A
Liquid
Gas
+Liquid
B
C
D
Liquid
+solid
Solid + Gas
Solid
E
Enthalpy h[kJ/kg]
Pressure P[MPa]
P_{cr} = 7.38
P_{tr} = 0.518
0

[Fig. 5]

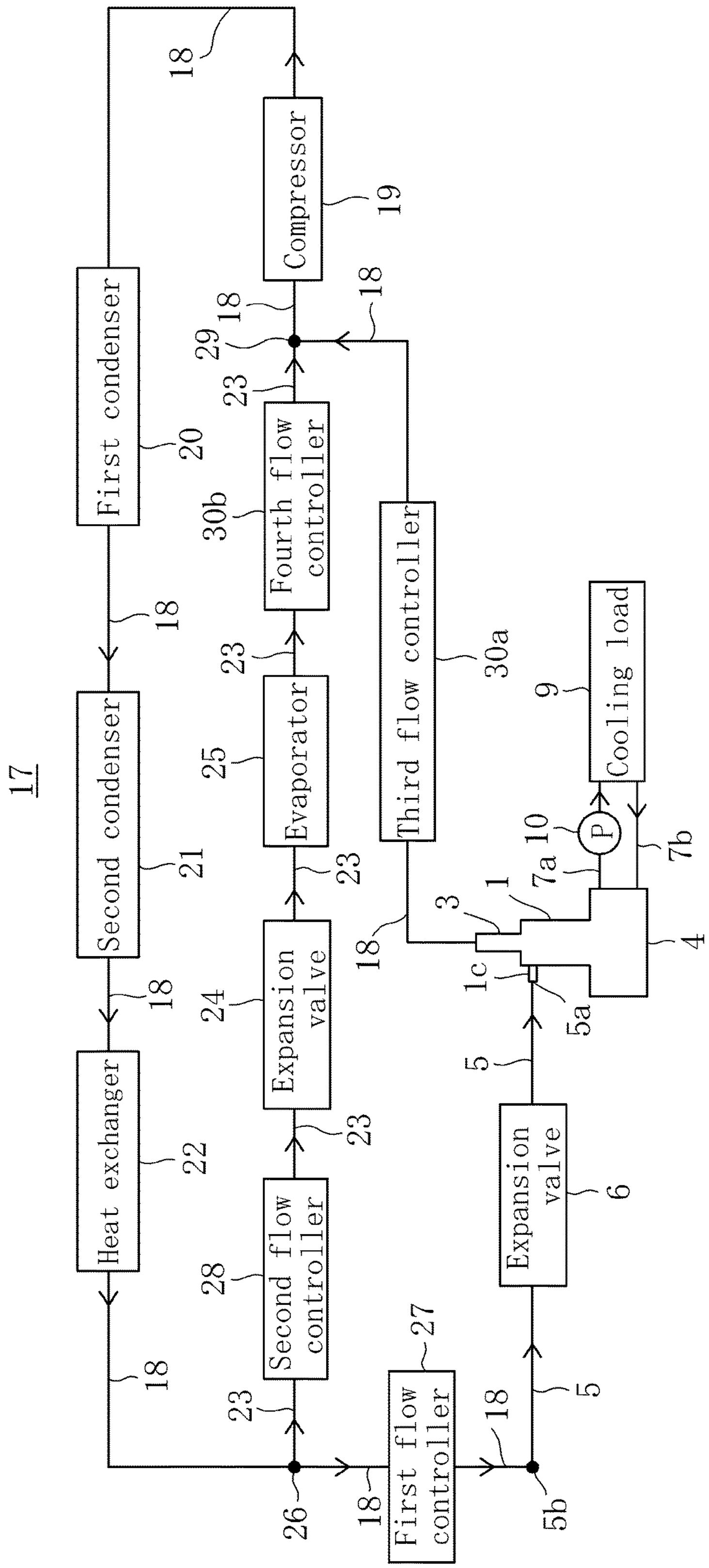

T=31.1[℃]
Super-critical
Gas
A
Gas
+Liquid
D
Liquid
B
C
Solid + Gas
Liquid
+solid
E
Solid
Enthalpy h[kJ/kg]
P_cr = 7.38
P_tr = 0.518
0
Pressure P[MPa]

[Fig. 6]

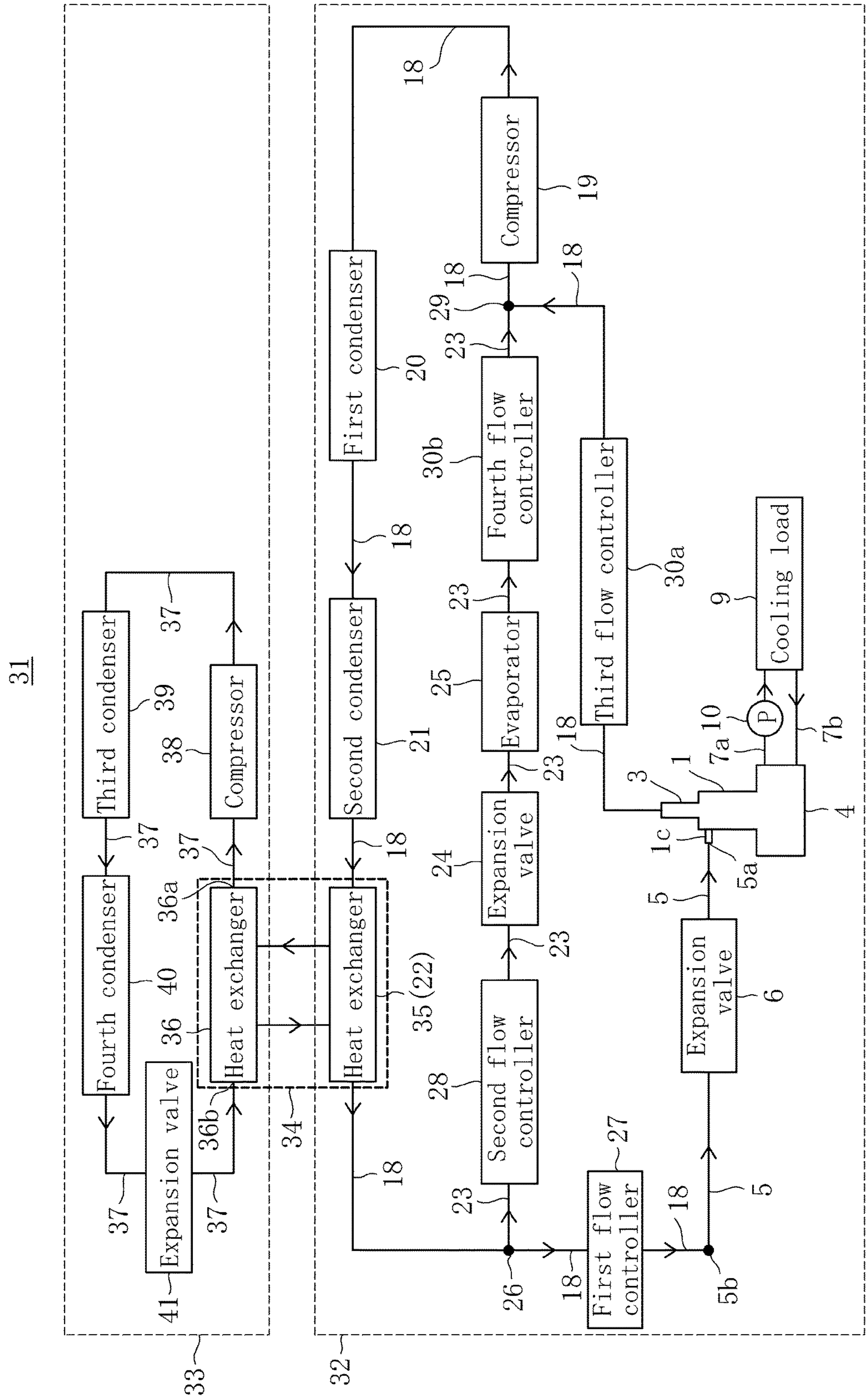


Pressure P[MPa]
Enthalpy h[kJ/kg]
$P_{cr} = 7.38$
$P_{tr} = 0.518$
0
T=31.1[°C]
Super-critical
Gas
Liquid
Gas
+Liquid
Liquid
+solid
Solid + Gas
Solid
A
B
C
D

[Fig. 7]


17
Compressor
19
First condenser
20
Second condenser
21
Heat exchanger
22
18
23
Expansion valve
24
Evaporator
25
26
First flow controller
27
Second flow controller
28
29
Third flow controller
30a
Fourth flow controller
30b
Cooling load
9
P
10
7a
7b
1
1c
3
4
5
5a
5b
Expansion valve
6

[Fig. 8]


31
Third condenser
39
37
Compressor
38
Fourth condenser
40
36a
36
Heat exchanger
Expansion valve
36b
41
33
34
First condenser
20
18
Second condenser
21
Heat exchanger
35(22)
26
32
Compressor
19
29
23
Fourth flow controller
30b
Evaporator
25
Expansion valve
24
Second flow controller
28
First flow controller
27
Third flow controller
30a
Cooling load
9
P
10
7a
7b
3
1
1c
4
5a
5
Expansion valve
6
5b

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/001499

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F25B1/00(2006.01)i, F25B7/00(2006.01)i, F25B39/02(2006.01)i, F25D3/12(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. F25B1/00, F25B7/00, F25B39/02, F25D3/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 145145/1974 (Laid-open No. 98359/1975) (L AIR LIQUIDE SOCIETE ANONYME POUR L ETUDE ET L EXPLOITA) 15 August 1975, specification, page 15, line 8 to page 17, line 14, page 19, line 19 to page 24, line 12, fig. 1-4 & FR 2253193 A1 & BE 822694 A & NL 7415776 A & IT 1025606 B	1-9
A	JP 11-30599 A (TOYO ENGINEERING WORKS, LTD.) 02 February 1999, paragraphs [0007]-[0014], fig. 1 (Family: none)	1-9
A	JP 2004-308972 A (MAYEKAWA MFG., CO., LTD.) 04 November 2004, paragraphs [0017]-[0031], fig. 1-2 (Family: none)	1-9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 March 2019 (02.03.2019)	02 April 2019 (02.04.2019)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2004308972 A **[0009]**