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

(11) EP 2 317 251 A1

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

(43) Date of publication:
04.05.2011 Bulletin 2011/18

(21) Application number: **08809387.7**

(22) Date of filing: **27.08.2008**

(51) Int Cl.:
F25B 1/10 *(2006.01)* ***F25B 1/00*** *(2006.01)*
F25B 5/04 *(2006.01)*

(86) International application number:
PCT/JP2008/065308

(87) International publication number:
WO 2010/023737 (04.03.2010 Gazette 2010/09)

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

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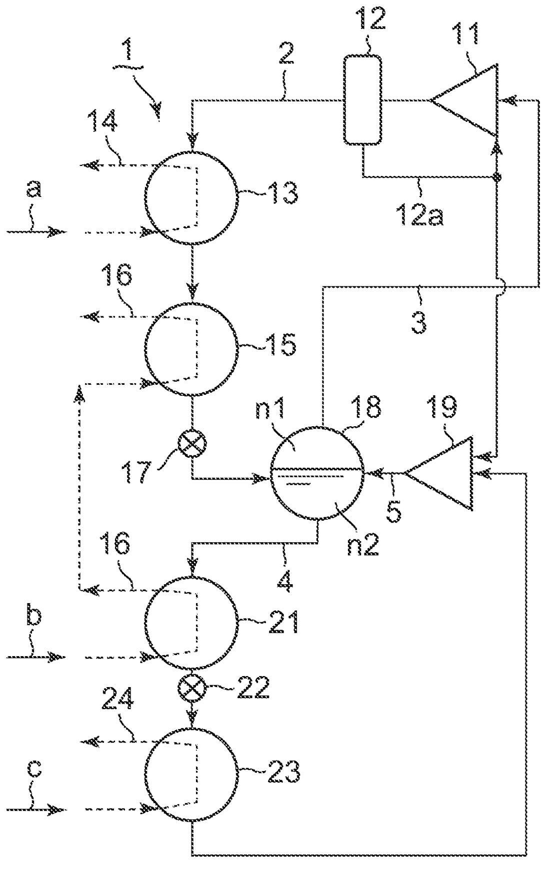
(54) TWO-STAGE COMPRESSOR HEAT PUMP CYCLING APPARATUS

(57) A two-stage compression heat pump cycle device using NH_3 heat as a heat carrier, wherein three kinds of heat carriers in a higher temperature range, a medium temperature range and a lower temperature range can be extracted at the same time while stabilizing extraction of the high-temperature heat-transfer medium. The following configuration is employed for the device. A first heat carrier line (14) is provided in a condenser (13) to generate the high-temperature heat-transfer medium through latent heat exchange of a first heat-transfer medium a with a gaseous heat-transfer medium (NH_3) n_1 in the condenser, while a second a heat carrier line (16) is provided in an evaporator (23) to generate the low-temperature heat transfer media through latent heat exchange of second heat-transfer medium c with a liquid heat-transfer medium (NH_3) n2 in the evaporator. Further, a first sub-cooling device (15) is interposed between the condenser (13) and an intermediate cooler (18), while a second sub-cooling device (21) is interposed between the intermediate cooler and the evaporator (23), and a third heat carrier line (16) is provided in series with the first sub-cooling device (15) via the second sub-cooling device (21) to generate the medium-temperature heat-transfer medium through sensible heat exchange of third heat-transfer medium b with the liquid heat-transfer medium in the first and second sub-cooling devices.

Fig. 1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a device configuring a heat pump cycle in which a two-stage compressor including a low stage compression part and high stage compression part is provided, the heat pump cycle making use of NH_3 as a main circuit heat transfer medium; whereby, three kinds of heat extracting (or supplying) circuits for extracting (or supplying) heat from the main circuit toward the outside of the main circuit are provided; the temperature of the heat carrier at the outlet of each heat extracting (or supplying) circuit is in a higher temperature range (60 to 75 °C), a medium temperature range (40 to 60°C), or a lower temperature range (-15 to 10°C) ; the heat extracting at each heat exchanging part can be performed at the same time, and the refrigeration capacity as well as the coefficient of performance is enhanced in comparison with the conventional level.

Background of the Invention

[0002] Patent Reference 1 (JP2000-249413A) discloses a two-stage compression refrigerating device according to the conventional technology; the explanation as to the configuration thereof is now given. A refrigerating device 010 depicted in Fig. 7 is used as a business use refrigerator, a household refrigerator, an ice plant, a refrigerator for a showcase and so on. A refrigerant circuit 020 configures a two-stage compression heat pump cycle having a main circuit 02M provided with a high stage compressor 021H and a low stage compressor 021L. Further, the two-stage compression heat pump cycle is provided with an intermediate cooler 022 so that the temperature of the refrigerant gas emitted by the low stage compressor is reduced.

[0003] In other words, in the two-stage compression heat pump cycle, the gas discharge side of the low stage compressor 021L is connected to the intermediate cooler 022 via a refrigerant piping 023; the intermediate cooler 022 is connected to the high stage compressor 021H via the refrigerant piping 023. Further, the discharge side of the high stage compressor 021H is connected to a heat exchanger (a heat source side heat exchanger) 024. The heat exchanger 024 may be, for instance, an air-cooled condenser, and heat exchange is performed between the outdoor open-air and the main circuit refrigerant so that the refrigerant is condensed; hereby, a heat carrier other than the outdoor open-air may be used as a heat transfer medium absorbing heat from the refrigerant in the main circuit; namely, the heat carrier other than the outdoor open-air is warmed while passing through a pipe for the heat carrier in the heat exchanger 024.

[0004] From the heat exchanger (a heat source side heat exchanger) 024, a heat exchanging part 022a in the intermediate cooler 022, an expansion valve 025, a heat exchanger (a cooled object side heat exchanger) 026 are connected in the sequential order in series via the refrigerant piping 023. Further, the heat exchanger 026 is, for instance, configured so that the heat exchange between the air in a refrigerated warehouse and the refrigerant in the refrigerant piping 023 is performed at the heat exchanger 026; thereby, the refrigerant evaporates so as to cool the air in the warehouse. In addition, the heat exchanger (a to-be-cooled object side heat exchanger) 026 is connected to the gas inlet side of the low stage compressor 021L the refrigerant piping 023 so that the evaporated refrigerant is guided to the low stage compressor 021L.

[0005] The passage of the refrigerant at the outlet of the heat exchanger (the heat source side heat exchanger) 024 is branched out into a branched passage 030 from the main circuit of the refrigerant; the branched passage 030 is provided with an auxiliary expansion valve 031 on the downstream side of the heat exchanger 024, on a part way of the branched passage 030; the refrigerant outlet side of the auxiliary expansion valve 031 is connected to the intermediate cooler 022 via the branched passage 030.
The refrigerant in a liquid state streams through the branched passage 030 from the auxiliary expansion valve 031 into the intermediate cooler 022; thereby, the refrigerant streaming into the intermediate cooler 022 through the branched passage 030 evaporates so as to super-cools (sub-cools) the liquid state refrigerant in the main circuit 02M and cools the refrigerant gas discharged by the low stage compressor 021L and guided into the intermediate cooler 022 through the refrigerant piping 023.

[0006] The cooling workings (or working processes) of the two-stage compression refrigerating-device are now explained based on a Mollier chart of Fig. 8. In the first place, the low refrigerant gas in a state of the point A in Fig. 8 is sucked into the low stage compressor 021L and discharged from the compressor 021L; the discharged gas streams, via the refrigerant piping 023, into the intermediate cooler 022 where the gas from the compressor 021L is cooled by the refrigerant from the branched passage 030, as is described later.

[0007] In the second place, the cooled gas in a state of the point C of Fig. 8 streams into the high stage compressor 021H where the gas is compressed up to a state of the point D. Further, the gas sucked by the compressor 021H is discharged from the compressor 021H and streams into the heat exchanger (a heat source side heat exchanger) 024; thereby, heat exchange is performed between the gas streaming into the heat exchanger 024 and another heat carrier that absorbs heat from the gas. The gas streaming into the heat exchanger 024 is cooled in the heat exchanger 024 so that the state of the gas reaches a state of the point E (in a liquid state) and the gas is condensed.

[0008] The condensed liquid refrigerant at a high streams into two passages: one is the main circuit 02M and the other is the branched passage 030. The pressure of the liquid refrigerant streaming through the branched passage 030 is reduced at the auxiliary expansion valve 031 to a state of the point F, and the liquid refrigerant streams into the intermediate cooler 022. On the other hand, the liquid refrigerant passing through the main circuit 02M streams through the heat exchanging part 022a in the intermediate cooler 022. In the intermediate cooler 022, the liquid refrigerant passing through the branched passage 030 evaporates so as to cool the refrigerant gas discharged by the low stage compressor 021L (the state of the refrigerant in the main circuit changes from point B to the point C in the intermediate cooler 022) as well as cools the liquid refrigerant passing through the heat exchanging part 022a in the intermediate cooler 022 (the state of the refrigerant in the main circuit changes from point E to the point G in the intermediate cooler 022).

[0009] On the other hand, the refrigerant gas that evaporates in the intermediate cooler 022 joins, at a state of the point C, the refrigerant gas that is discharged by the low stage compressor 021L and streams into the intermediate cooler 022; then, the confluence refrigerant gas streams through the refrigerant piping 023 and is sucked into the high stage compressor 021H. On the other hand, the pressure (at a state of the point G) of the liquid refrigerant at the heat exchanging part 022a in the main circuit 02M is reduced to the pressure at a state of the point H, just on the downstream side of the expansion valve 025; then, the liquid refrigerant from the expansion valve 025 enters the heat exchanger (a to-be-cooled object side heat exchanger) 026 where heat exchange is performed between the liquid refrigerant and a heat carrier such as the air inside the refrigerated warehouse; and, the liquid refrigerant evaporates so as to absorb the heat from the air inside the ice warehouse. After the evaporated refrigerant leaves the heat exchanger 026, the state of the refrigerant returns back to the state of the point A; thus, the refrigerant gas sucked into the low stage compressor 021L.

[0010] As described thus far, in removing heat from the heat transfer medium in the higher temperature range or the medium temperature range, the heat carrier (of the heat removing side) is warmed-up mainly by the sensible heat or the latent heat of the gas (heat transfer medium) discharged by a compressor that configures the heat pump cycle; according to this conventional approach, the heat removal from the heat amount (the enthalpy drop from the gas phase to the condensed liquid phase) of the heat transfer medium is performed in two processes, namely, in a process of the higher temperature process (B to C) and a process of the medium temperature process (E to G) . When it is taken into consideration that the heat removal in the higher temperature process is performed mainly by use of the sensible heat of the heat-transfer medium, the heat amount that can be removed in the higher temperature process is at most 20% level of the total heat amount (the enthalpy drop from the gas phase to the condensed liquid phase) of the heat transfer medium.

[0011] Further, in the heat exchanger (on the heat source side), the heat exchange is performed in a counter flow heat exchanger regarding the refrigerant gas flow and the heat removal carrier; thus, in a case where the temperature of the discharged gas is low according to the operation condition of the refrigerant cycle, sufficient heat transfer cannot be performed; accordingly, the heat exchange amount may remain under the to-be-exchanged amount. In other words, it may be difficult that the heat carrier sufficiently removes heat from the refrigerant gas in the higher temperature range.

[0012] It is conventionally disclosed to the public that, in a heat pump cycle device in which CO_2 is used as a refrigerant, the heat removing heat carrier which temperature at the outlet of the heat exchanger can be as high as the level of 90 °C, under a condition that the pressure of the refrigerant gas (CO_2) discharged by the compressor is more than or equal to the pressure at the CO_2 transcritical point; namely, the compressor is operated so as to realize a transcritical state regarding the working gas.

However, when the operated heat cycle with CO_2 includes a transcritical state thereof, the pressure of the transcritical state becomes as high as 10 to 12 MPa; accordingly, it is required that the compressor be provided with a pressure resistant structure so as to be operated under such a high pressure. Further, in such a case where an after-burning (an additional heating) regarding the working medium of the heat cycle including a transcritical state is performed, the COP (coefficient of performance) of the heat cycle is deteriorated and the degree of freedom regarding the operation of the compressor is reduced.

SUMMARY OF THE INVENTION

Subjects to be solved

[0013] In view of the above-described background, the present invention aims at providing a two-stage compression heat pump cycle device; whereby, a stable and high temperature condition regarding the heat transfer medium can be achieved; three heat extracting (or supplying) heat-exchangers for extracting (or supplying) heat from the main circuit toward the heat extracting (or supplying) side circuits can be simultaneously realized so that the outlet temperature of the heat carrier at each heat exchanger outlet exists in a higher temperature range, a medium temperature range, and a lower temperature range; the COP (coefficient of performance) of the heat cycle can be enhanced; and, the degree of freedom regarding the operation of the heat pump cycle can be enhanced.

Means to solve the Subjects

[0014] In order to reach the goals of the subjects, the present invention discloses a two-stage compression heat pump cycle device using NH_3 as a heat-transfer medium in the heat pump cycle, the device being provided with a two-stage compressor unit comprising a high stage compressor and a low stage compressor and an intermediate cooler being arranged between the high stage compressor and the low stage compressor on a part way of a line through which the heat-transfer medium streams from the discharge side of the low stage compressor to the inlet side of the high stage compressor; the heat-transfer medium in a gas state (the medium which is) discharged from the high stage compressor reaches a condenser where the heat-transfer medium is condensed into a liquid state, and the liquid heat-transfer medium enters the intermediate cooler so that heat exchange between the liquid heat-transfer medium and the gaseous heat-transfer medium discharged by the low stage compressor is performed; the heat-transfer medium in the intermediate cooler proceeds to an evaporator where the medium evaporates into a gas state; the heat-transfer medium gasified in the evaporator returns back to the gas inhaling side of the low stage compressor so that the heat pump cycle as a circulatory cycle is formed; wherein,

a first heat carrier line in which a first heat carrier streams is provided so that the first heat carrier line passes through the condenser where the latent heat of the heat-transfer medium is absorbed by the first heat carrier, the temperature of the first heat carrier at the outlet of the condenser being in a higher temperature range;

a second heat carrier line in which a second heat carrier streams is provided so that the second heat carrier line passes through the evaporator where the latent heat of the heat-transfer medium is supplied by the second heat carrier, the temperature of the second heat carrier at the outlet of the evaporator being in a lower temperature range;

a first sub-cooling device is provided on a part way of a line through which the heat-transfer medium streams, between the condenser and the intermediate cooler;

a second sub-cooling device is provided on a part way of a line through which the heat-transfer medium streams, between the intermediate cooler and the evaporator;

a third heat carrier line in which a third heat carrier streams is provided so that the third heat carrier line passes through the second sub-cooling device and the first sub-cooling device in order, the third heat carrier line connecting the sub-cooling devices in a series arrangement; at each of the sub-cooling devices, the sensible heat of the heat-transfer medium is absorbed by the third heat carrier, the temperature of the third heat carrier at the outlet of the evaporator being in a medium temperature range.

[0015] In the device according to the present invention, NH_3 is used as a heat-transfer medium in the heat pump cycle (i.e. in the main circuit); the reasons (or advantageous points of NH_3) are that: NH_3 is friendly to the earth environment; the heat transfer coefficient as well as the heat absorbing effect is great; the COP in a case where NH_3 is used can be kept high; the price of NH_3 in a unit weight is sufficiently cheap. Further, in addition to the enhanced COP regarding the heat pump cycle, there is another advantage that the heat pump cycle device can dispense with a high pressure resistant structure, and the easy operation of the device can be achieved, as the maximum pressure appearing in the heat pump cycle using NH_3 is as low as the level of 4 MPa in comparison with the heat pump cycle using CO_2 and no special pressure resistant structure for the high stage compressor is required.

Further, since the heat pump cycle using NH_3 does not include a transcritical states (i.e. high states) therein apart from the heat pump cycle using CO_2, the COP is not deteriorated even when an after-burning (an additional heating) regarding the working medium of the heat cycle is performed. Thus, the degree of freedom regarding the operation of the heat pump cycle device is not reduced.

[0016] Further, the condensation temperature in the condenser can be within a range of 65 to 80°C; the intermediate temperature in the intermediate cooler can be within a range 20 to 40°C; the evaporation temperature in the evaporator can be within a range of -20 to 10 °C. In addition, in a case where NH_3 is used as a heat-transfer medium in the heat pump cycle, the temperature of the medium at the discharge side of the high stage compressor can be kept sufficiently high; and, in the condenser, the heat carrier in the heat extracting circuit can stably absorb the heat (including the latent heat) of the heat-transfer medium in the main circuit.

[0017] The heat extracting from the heat-transfer medium in the main circuit to the heat carrier (the third heat carrier, i.e. the intermediate temperature heat carrier) in the heat extracting circuit is performed in the first sub-cooling device and the second sub-cooling device; namely, the third heat carrier line (passage) in which a third heat carrier streams is provided so that the third heat carrier line passes through the second sub-cooling device and the first sub-cooling device in order, the third heat carrier line connecting the sub-cooling devices in a series arrangement; in the first sub-cooling device and the second sub-cooling device, heat exchange between the third heat carrier and the heat-transfer medium is performed, the third heat carrier absorbing the sensible heat of the heat-transfer medium in a counter flow arrangement regarding the main circuit and the heat carrier line. In this way, the temperature of the heat carrier at the outlet of the first sub-cooling device can be within a range of 40 to 60°C.

[0018] Further, in the first sub-cooling device and the second sub-cooling device, the heat-transfer medium in the main circuit is sub-cooled; thus, the heat transferred to the heat-transfer medium from the (second) heat carrier streaming through the (second) heat carrier line is increased; in particular, in comparison with the conventional technology, the heat exchange increase brought by the heat exchange in the second sub-cooling device relates to the COP increase regarding the heat pump cycle device.

[0019] Further, the degree of sub-cooling regarding the liquid heat-transfer medium is enhanced while the liquid heat-transfer medium is sub-cooled in the second sub-cooling device and the first sub-cooling device; accordingly, the degree of dryness regarding the heat-transfer medium in the medium temperature range can be reduced. As a result, the amount of flash gas by which the heat-transfer medium cools the medium itself can be reduced. Therefore, the amount of the flow rate regarding the gaseous heat-transfer medium streaming in the intermediate pressure range can be reduced; thus, the cycle work needed in the intermediate pressure range can be reduced. Hence, the power consumption of the high stage compressor and the low stage compressor can be reduced. Moreover, the heat absorbing performance in the evaporator can be enhanced; thus, the COP of the heat pump cycle device can be improved, and the stable high temperature at the discharge side of the high stage compressor can be realized.

[0020] In addition, the heat absorbed by the first heat carrier in the high temperature range can be used for, for instance, a heat supplying application or a heating system in which a heat carrier is warmed from a level of 60 °C to a level of 70°C; the heat absorbed by the first heat carrier can be used for a heat source of an adsorption refrigerator. Further, the heat absorbed by the first heat carrier can be used for a hot-water supply, whereby heat-exchange is performed between the to-be-heated water and the first heat carrier via brine heat transfer medium. Moreover, the heat absorbed by the third heat carrier in the medium temperature range can be used for a hot-water supply, for instance, whereby water is heated-up from a level of 15°C to a level of 55 °C; or , the heat absorbed by the third heat carrier can be used for heating-up the boiler feed water.

[0021] In addition, the heat absorbed by the second heat carrier in the low temperature range can be made use of in the processes in cooling systems; or, the heat absorbed by the second heat carrier can be used for an indirect system for supplying brine (e.g. CO_2 brine), the indirect system comprising a combination of a low pressure liquid receiving device and an evaporator; or, the heat absorbed by the second heat carrier can be used for a NH_3-CO_2 brine liquid pump refrigeration system in which an evaporator works as a cascade condenser that liquefies CO_2 refrigerant, the liquefied CO_2 refrigerant being circulated by a liquid pump.

[0022] A preferable embodiment according to the present invention is the two-stage compression heat pump cycle device, the device comprising:

a first expansion valve on a part way of a line through which the heat-transfer medium streams, between the first sub-cooling device and the intermediate cooler;
a second expansion valve on a part way of a line through which the heat-transfer medium streams, between the second sub-cooling device and the evaporator.
Thus, the two-stage compression heat pump cycle device can be realized;
thereby, an intermediate pressure range other than the high pressure range and the low pressure range can be formed so that the heat pump cycle device is configured.

[0023] In a case where the condensation temperature regarding the discharge gas discharged by the high stage compressor reaches a level of 80°C, the discharge pressure of the compressor reaches around a level of 4 MPa; the pressure level is high enough to install a countermeasure against the NH_3 gas leakage. Hence, another preferable embodiment according to the present invention is the two-stage compression heat pump cycle device, the device further comprising:

a hermetic type motor or an encapsulated IPM (interior permanent magnet) motor that drives at least the high stage compressor out of the high stage compressor and the low stage compressor; thereby, the winding of the stator is made of aluminium wire.

In this way, the motor that drives the high stage compressor can be protected against the corrosion due to the attack of NH_3 heat-transfer medium; further, the NH_3 heat-transfer medium can be prevented from leaking outside of the device.

[0024] Another preferable embodiment according to the present invention is the two-stage compression heat pump cycle device, the two-stage compressor unit being a single compressor unit comprising the high stage compressor and the low stage compressor.
In this way, the two-stage compressor unit can be compactly configured; the space where the heat pump cycle device is installed can be reduced; and, the power needed to drive the compressors can be reduced. Further, when the hermetic type motor and the single compressor unit are combined into an integrated configuration, the combination can be synergistic.

[0025] Another preferable embodiment according to the present invention is the two-stage compression heat pump cycle device, the device further comprising an oil separator for separating the oil contained in the heat-transfer medium discharged from the high stage compressor, whereby the oil separator is arranged on the downstream side of the high stage compressor so that the heat-transfer medium NH_3 is pre-cooled by the condenser before the heat-transfer medium enters the oil mist separator.

In this way, the high temperature heat-transfer medium of NH_3 gas discharged from the high stage compressor is once cooled in the condenser, before the heat-transfer medium enters the oil mist separator; thus, the separation elements of the separator can be prevented from being deteriorated. Further, the viscosity of the oil mist that enters the gaseous heat-transfer medium is reduced while the gaseous medium is cooled; thus, the separation of the lube-oil from the gaseous medium can be effective. In addition, since the heat-transfer medium discharged from the high stage compressor is guided into the separator after the medium is pre-cooled, the volume of the gaseous heat-transfer medium passing through the separation elements of the separator 12 can be reduced; thus, an appropriate velocity of flow of the gaseous heat-transfer medium passing through the separation elements can be achieved.

[0026] Another preferable embodiment according to the present invention is the two-stage compression heat pump cycle device, the oil separator comprising an oil separator element for separating the oil contained in the heat-transfer medium so that the oil separator element surrounds, in a saccate space, the mixed fluid of the oil and the heat-transfer medium the mixed fluid which enters the saccate space through an opening; whereby, the oil separator element comprising 3 layers-filter elements in order from the inner side to the outer side, namely:

a rough separation pre-filter element through which rough oil particles in the mixed fluid is separated;
a regular separation filter element that is provided with material being full of fine holes with which a fine mesh size structure is formed so that even fine oil mist is separated from the mixed fluid;
an oil scattering prevention filter element that is provided with a plenty of slots through which the gaseous heat-transfer medium can pass so that the oil scattering prevention filter element prevents the oil mist captured by the regular separation filter element from scattering again.

[0027] The temperature of the heat-transfer medium NH_3 discharged from the high stage compressor reaches 100°C or more; on the other hand, as described above, the oil separator is provided with the rough separation pre-filter element through which rough oil particles in the mixed fluid is separated, inside of the regular separation filter element that is provided with material being full of fine holes with which a fine mesh size structure; thus, scales in the main circuit or large size particles of the oil mist can be captured by the rough separation pre-filter element; in this way, the regular separation filter element (i.e. filter element body) can endure the condition of the temperature up to 150°C. Moreover, the oil separator is provided with the oil scattering prevention filter element outside of the regular separation filter element; thus, the oil mist once separated and captured can be prevented from scattering again; accordingly, the oil mist separation performance can be enhanced.

[0028] Another preferable embodiment according to the present invention is the two-stage compression heat pump cycle device; thereby the lube-oil used for the two-stage compressors is indissoluble with the NH_3 refrigerant, namely the heat-transfer medium.
In this way, the oil mist separation performance can be further enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The present invention will now be described in greater detail with reference to the preferred embodiments of the invention and the accompanying drawings, wherein:

Fig. 1 shows, a schematic diagram of a heat pump cycle device according to a first embodiment of the present invention;
Fig. 2 shows a Mollier chart according to the first embodiment of the present invention;
Fig. 3 shows a perspective view of a hermetic type motor, a part of the motor being cut so that the inside of the motor is seen;
Fig. 4 shows an illustrative view of a compressor unit used for the first embodiment of the present invention;
Fig. 5 shows a longitudinal cross-section as well as an elevation view of an oil separator used in the first embodiment of the present invention;
Fig. 6 shows a schematic diagram in part regarding a heat pump cycle device according to a second embodiment of the present invention;
Fig. 7 shows a schematic diagram of a two-stage compression refrigerator according to the conventional technology;
Fig. 8 shows a Mollier chart regarding the two-stage compression refrigerator according to the conventional technology.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] Hereafter, the present invention will be described in detail with reference to the embodiments shown in the figures. However, the dimensions, materials, shape, the relative placement and so on of a component described in these embodiments shall not be construed as limiting the scope of the invention thereto, unless especially specific mention is made.

[0031] The first embodiment according to the present invention is now explained based on Figs. 1 to 5; Fig. 1 shows, a schematic diagram of a heat pump cycle device according to the first embodiment of the present invention, the heat transfer medium NH_3 being used in the heat pump cycle device. As shown in Fig. 1, the gas-discharged side of a high stage compressor 11 is connected to a heat-transfer medium piping 2 on which an oil separator 12 is provided; the oil separator 12 separates the oil content included in the gas heat-transfer medium, the oil content being derived from the lube oil used for the compressor 11; the separated lube-oil is returned back to the gas inlet side of the high stage compressor 11 or a low stage compressor 19 that is described later, via a return line 12a of the separated lube-oil. Incidentally, the lube-oil used in this embodiment is, for instance, naphthenic mineral oil or alkylbenzene oil (a synthetic oil), each oil being not compatible with the heat-transfer medium NH_3.

[0032] On a part way of the heat-transfer medium piping 2 on the downstream side of the oil separator 12, a condenser 13 is provided; the condenser 13 is connected to a heat carrier line 14 through which high temperature heat carrier (the first heat carrier) is taken-out outward so that heat exchange between the heat carrier and the gaseous heat-transfer medium NH_3 is performed; thus, the latent heat in the gas-to-liquid phase change regarding the heat-transfer medium NH_3 is indirectly (i.e. without mixing) absorbed into the heat carrier "a" (the first heat carrier) streaming through the heat carrier line 14; thereby, the heat carrier "a" is heated-up, whereas the heat-transfer medium is cooled-down and liquefied.

[0033] On a part way of the heat-transfer medium piping 2 on the downstream side of the condenser 13, a first sub-cooling device 15 is provided; the first sub-cooling device 15 is connected to a heat carrier line 16 through which the medium temperature heat carrier "b" (the third heat carrier) is taken-out outward so that heat exchange between the heat carrier (the heat carrier for removing heat in the medium temperature range) and the liquefied heat-transfer medium NH_3 is performed; thus, the sensible heat in the liquid phase of the heat-transfer medium NH_3 is absorbed into the heat carrier "b" streaming through the heat carrier line 16; thereby, the heat carrier "b" is heated-up, whereas the heat-transfer medium is sub-cooled. On a part way of the heat-transfer medium piping 2 on the downstream side of the first sub-cooling device 15, a first expansion valve 17 is provided; after being depressurized while passing through the first expansion valve 17, the heat-transfer medium reaches the intermediate cooler 18.

[0034] On the other hand, the gaseous heat-transfer medium NH_3 is supplied to the intermediate cooler 18 from the low stage compressor 19 through a heat-transfer medium piping 5 connected to the gas discharge side thereof. A part of the liquid heat-transfer medium depressurized through the first expansion valve 17 evaporates in the intermediate cooler 18 so as to absorb the heat of the gaseous heat-transfer medium (NH_3) supplied into the intermediate cooler 18 through the heat-transfer medium piping 5. Further, the gaseous heat-transfer medium (NH_3) n_1 in the intermediate cooler 18 is guided toward the high stage compressor 11 through a heat-transfer medium piping 3; the liquid heat-transfer medium (NH_3) n_2 in the intermediate cooler 18 proceeds to a second sub-cooling device 21 through a heat-transfer medium piping 4.

[0035] An upstream end of a heat carrier line 16 is connected to the second sub-cooling device 21 in which, at first, the heat exchange between the heat carrier "b" (the third heat carrier) for removing heat in the medium temperature range and the liquid heat-transfer medium is performed so that the heat carrier "b" is preheated; on the other hand, the liquid heat-transfer medium is further sub-cooled so that the degree of sub-cooling as to the liquid heat-transfer medium is enhanced. In this way, the heat carrier line 16 of the heat carrier "b" for removing heat from the liquid heat-transfer medium in the medium temperature range is provided so that the line 16 passes through the second sub-cooling device 21 and the first sub-cooling device 15 in a series arrangement; thus, after the heat carrier for removing heat in the medium temperature range is preheated in the second sub-cooling device 21, the heat carrier (the third heat carrier) is further heated-up in the first sub-cooling device 15.

[0036] On a part way of the heat-transfer medium piping 4 on the downstream side of the second sub-cooling device 21, a second expansion valve 22 is provided; the pressure of the liquid heat-transfer medium is further reduced while passing through the second expansion valve 22; then the depressurized heat-transfer medium reaches an evaporator 23. The evaporator 23 is connected to a heat carrier line 24 through which the lower temperature heat carrier "c" is taken-out outward so that heat exchange between the heat carrier (the second heat carrier, namely, the heat carrier for removing heat in the lower temperature range) and the heat-transfer medium NH_3 in the liquid-to-gas phase change is performed; thus, the heat corresponding to the latent heat is removed from the heat carrier "c", whereas the heat-transfer medium is heated up by the heat, and the heat-transfer medium evaporates. Further, the evaporated heat-transfer medium in a gas state reaches the lower stage compressor 19 where the heat-transfer medium gas is compressed. On the other hand, the heat carrier "c" (the second heat carrier) is cooled in the evaporator 23 and delivered toward a device to use the cold.
In the above-explanation, the second expansion valve 22 is installed between the second sub-cooling device 21 and the evaporator 23; however, the second expansion valve 22 may be installed between the intermediate cooler 18 and the second sub-cooling device 21, as is described in "SUMMARY

OF THE INVENTION."

[0037] In addition, in this embodiment, the rotating shaft of the high stage compressor 11 and the rotating shaft of the low stage compressor 19 are connected to each other in a series arrangement so that a single compressor unit of a two-stage compressor is formed; each of the high stage compressor 11 and the low stage compressor 19 is a reciprocating compressor. The piston of the high stage compressor 11 and the piston of the low stage compressor 19 are connected to a common crankshaft via the connecting rod corresponding to each piston; each compressor is driven by the common crankshaft.

[0038] In the next place, the workings as to the heat pump cycle device 1 according to this embodiment are now explained by use of a Mollier chart in Fig. 2. In Fig. 2, each of the symbols A to H without or with a dash mark denotes a point in response to a state of the heat-transfer medium in the heat pump cycle process; the symbol without a dash mark in Fig. 2 corresponds to the same symbol in Fig. 8 (a Mollier chart) that explains the workings as to the two-stage compression refrigerating device 010 of Fig. 7 according to the conventional technology. The workings as to the device 010 are already explained by use of the Mollier chart of in Fig. 8.

In addition, the workings along the processes (that start from the point A and end at the point E, passing on the points A, B, C, D and E) in the heat pump cycle device 1 according to this embodiment are the same as the workings along the processes in the two-stage compression refrigerating device 010 according to the conventional technology.

[0039] The low refrigerant gas in a state of the point A in Fig. 2 is sucked into the low stage compressor 19 and compressed to a state of the point B; the compressed gas (the heat-transfer medium) discharged by the compressor 19 streams into the intermediate cooler 18 where the gas is cooled by the liquid heat-transfer medium that streams into the intermediate cooler 18 through the heat-transfer medium piping 2 so that the gaseous heat-transfer medium reaches a state of the point C

[0040] The gaseous heat-transfer medium (NH_3) n_1 in the intermediate cooler 18 is guided toward the high stage compressor 11 where the heat-transfer medium (NH_3) is compressed to a state of the point D; the heat-transfer medium (NH_3) discharged from the high stage compressor 11 enters the condenser 13 so as to be cooled and condensed to a state of the point E. after passing through the condenser 13, the heat-transfer medium in a liquid state proceeds to the first sub-cooling device 15 where the heat-transfer medium is further cooled so as to reach a sub-cooled state of point E'. After passing through the first sub-cooling device 15, the liquid heat-transfer medium is depressurized while passing through the first expansion valve 17; then, the heat-transfer medium reaches the intermediate cooler 18; thereby, the heat-transfer medium reaches a state of the point F'.

[0041] A part of the liquid heat-transfer medium depressurized through the first expansion valve 17 evaporates in the intermediate cooler 18 so as to absorb the heat of the gaseous heat-transfer medium (NH_3) supplied into the intermediate cooler 18 through the heat-transfer medium piping 5; in the

Mollier chart of Fig. 2, the evaporation process regarding the part (to be evaporated) of the liquid heat-transfer medium corresponds to the process from the point F' to the point C. Then, the gaseous heat-transfer medium (the evaporated gas and the gas from the low stage compressor) in the intermediate cooler 18 is guided toward the high stage compressor 11.

On the other hand, the remaining part n_2 of the liquid heat-transfer medium in the intermediate cooler 18 proceeds to the second sub-cooling device 21; whereby, the liquid heat-transfer medium is cooled by the heat carrier "b" for removing heat in the medium temperature range; the cooling process regarding the liquid heat-transfer medium corresponds to the process from the point F' to the point G' in the Mollier chart of Fig. 2.

After passing through the second sub-cooling device 21, the liquid heat-transfer medium is depressurized while passing through the second expansion valve 22; the depressurizing process corresponds to the process from the point G' to the point H'. Subsequently, the liquid heat-transfer medium evaporates in the evaporator 23 so as to take the evaporating latent heat from the heat carrier "c" for removing heat in the lower temperature range; the evaporating process corresponds to the process from the point H' to the point A. Then, the low stage compressor 19 again compresses the heat-transfer medium gasified through the evaporation; the compression process corresponds to the process from the point A to the point B.

[0042] In this embodiment, NH_3 is used as the heat-transfer medium; however, NH_3 is inflammable (combustible) and poisonous. Thus, it is necessary to prevent NH_3 gas from leaking outside of the compressor. In a case where the condensation temperature regarding the discharge gas discharged by the high stage compressor 11 reaches a level of 80°C, the discharge pressure of the compressor 11 reaches around a level of 4 MPa; the pressure level is high enough to install a countermeasure against the NH_3 gas leakage. Hence, a hermetic type motor for driving the high stage compressor 11 is usually used. Based on Fig. 3, the structure of the hermetic type motor is hereafter explained.

[0043] A hermetic type motor 30 (as depicted in Fig. 3) is coupled with a crankshaft 52 (cf. Fig.4) for driving at least one piston of the high stage compressor 11 as well as the low stage compressor 19; thus, the compressors 11 and 19 are driven. For instance, the hermetic type motor 30 is a three-phase induction motor, being provided with a pressure resistant sealed casing 31 of a substantially cylindrical shape; a rotating shaft 33 is rotation-freely supported by sealed ball bearings 32 installed in the casing 31; an end (on the right side of Fig. 3) of the rotating shaft 33 protrudes toward the outside of the casing, and the rotating shaft 33 is coupled with the crankshaft of the high stage compressor 11 as well as the low stage compressor 19.

[0044] On the inner periphery side of the casing 31, a flame 31a is provided; inside of the flame 31a, a stator 35 is arranged so as to surround a rotator 34 that is fitted to the rotating shaft 33. The stator 35 is equipped with a winding 36; a terminal box 37 is fitted on the casing 31; the winding 36 communicates with thermal relays 39, electromagnetic contactors 41, circuit breakers 42 and a three-phase current power source 43, through wiring 38 that is extended from the winding 36 at the terminal box 37. The hermetic type motor 30 is driven by the electric power transferred through the power supply system as described above.

[0045] As shown in Fig. 4, a compressor (unit) 50 used for the heat pump cycle device 1 according to this embodiment is configured with the high stage compressor 11 and the low stage compressor 19 as if the two compressors form a multi-cylinder reciprocating machine. In a crankcase 51 of the compressor unit, at least one piston of the high stage compressor 11 as well as the low stage compressor 19 is connected to the crankshaft 52 common to both the compressors, via a connecting rod corresponding to each piston (not shown) of each compressor.

[0046] Between the crankcase 51 and the casing 31 of the hermetic type motor 30, a coupling casing 54 is provided so that the compressor unit 50 and the hermetic type motor 30 is integrated into one unit, completely under a gas-tight sealing condition. The rotating shaft 33 of the hermetic type motor 30 is coupled with the crankshaft 52 via a coupling 53 that is arranged inside of the coupling casing 54.

[0047] When the hermetic type motor 30 is operated, the rotation thereof is transferred to the crankshaft 52 of the compressor unit 50; thus, the high stage compressor 11 as well as the low stage compressor 19 is operated. Incidentally, the casing 31 is provided with an inlet hole (not shown) and a discharge hole (not shown) regarding the heat-transfer medium NH_3; a part of the heat-transfer medium NH_3 is supplied to the inside of the casing 31 of the motor 30, so as to cool the hermetic type motor 30.

[0048] In relation to Fig. 3, the rotator 34 is manufactured by die-casting aluminium material, whereas the stator 35 is made of, for example, magnetic steel plate (e.g. JIS C2522). Insulation coating is applied on the surface of the magnetic steel plate used for the stator. The winding is made of aluminium wire of high purity, the surface of the wire being covered with PFA (perfluoro alkoxyfluoro plastic) that is a kind of fluorocarbon resin. The conductivity of aluminium wire is lower than that of copper wire, whereas aluminium wire is not subject to corrosion caused by NH_3 gas. Further, the aluminium wire of the winding is coated with PFA that is excellent in insulation properties, tracking properties as to aluminium thermal deformation, anti-crack properties, and anti-heat deterioration properties; thus, high durability of the aluminium wire against NH_3 gas can be maintained.

[0049] In addition, the hermetic type motor may be an IPM (interior permanent magnet) motor other than the three-phase induction motor; in a case of the IPM motor, permanent magnets are embedded in the rotator; thereby, the stator is arranged so as to surround the rotator. When the IPM motor is used, the efficiency of the motor driving the compressor unit 50 can be enhanced and the compressor unit 50 can be made compact; moreover, the optimal control regarding the driving motor can be realized by introducing speed control such as what-they-call IPM speed control.

Incidentally, Patent Reference (now made public with the number JP2004-56990) which application was submitted by the present applicant prior to the present application discloses the detailed configuration in a case where the hermetic type motor or the IPM motor is applied; in either of the motors, the aluminium wire is used for the winding. The entire contents of Patent Reference JP2004-56990 are hereby incorporated by reference.

[0050] In the next place, the configuration of the oil separator 12 is explained based on Fig. 5. As shown in Fig. 5, an inlet opening 10a is provided in a partition 10 of the separator 12 so that the mixed fluid "d" including the heat-transfer medium NH_3 and the lube-oil streams into the separator through the inlet opening 10a; at the lower part of the inlet opening 10a, the oil separator 12 is fitted; the oil separator 12 comprises an upper cover 122 having an opening 122a at the center of the upper cover 122, an oil separator element 123 forming a cylindrical shape (a saccate space), and a lower cover 124; whereby, the lower cover 124 is supported by a large-diameter end part 121a of a cylindrical shape that is screwed in the lower end part of a shaft 121 which is vertically installed along a center axis of the oil separator; thus, the oil separator 12 is fitted to the inlet opening 10a of the partition 10 of the separator 12.

[0051] The oil separator element 123 is provided with an opening on the upper side of the element; the mixed fluid "d" that has streamed into the inside of the separator through the opening passes through a rough separation element 125 from the inside thereof toward the outside thereof; namely, the mixed fluid "d" passes through (the rough meshes of) the rough separation element 125 along the direction (from inside to the outside) of the arrows in Fig. 5. In this way, the contaminations are separated from the mixed fluid. Further, the oil separator element 123 comprises a 3-layer-structure; from the inner side to the outer side, the layers are the rough separation element 125, a regular separation element 126, and an oil scattering prevention element 127. On the outer periphery side of the regular separation element 126, a support member 128 for supporting the regular separation element 126 is provided; on the outer periphery side of the oil scattering prevention element 127, a guard member 129 for protecting the oil scattering prevention element 127 is provided. The rough separation element 125 is configured with a rough-meshed metal wire sieve, and the element 125 separates oil mists and contaminations of large particle size from the mixed fluid "d."

[0052] The regular separation element 126 is made of porous spongy material such as glass wool, the material being full of fine holes with which a fine mesh size structure is formed; at the regular separation element 126, oil mist of even a fine particle size is separated from the mixed fluid. The oil scattering prevention element 127 is provided with a plenty of slots through which the gaseous heat-transfer medium can pass; the oil scattering prevention element 127 prevents the oil mist captured by the regular separation element 126 from scattering again. With the above-described configuration of the oil separator element 123, the oil mist which particle sizes are as fine as micron levels can be separated; further, thanks to the installation of the rough separation element 125, the apprehension that the regular separation element is damaged by the contaminations can be relieved.

[0053] According to this embodiment as described above, the heat-transfer medium NH_3 having excellent heat-transfer properties is used in the heat pump cycle; thereby, the temperature of the refrigerant (the heat-transfer medium NH_3) discharged by the high stage compressor 11 reaches 100°C or more, and the condensation temperature in the condenser 13 is within a range of 65 to 80°C. Further, the condenser 13 is connected to the heat carrier line 14 through which the high temperature heat carrier (the first heat carrier) is taken-out outward so that heat exchange between the heat carrier and the gaseous heat-transfer medium NH_3 is performed; incidentally, the condenser forms a counter flow heat exchanger; thus, the latent heat in the gas-to-liquid phase change regarding the heat-transfer medium NH_3 is indirectly (i.e. without mixing) absorbed into the heat carrier "a" streaming through the heat carrier line 14; thereby, the heat carrier "a" (the first heat carrier) is heated-up, whereas the heat-transfer medium is cooled-down and liquefied; the heat absorbed by the heat carrier corresponds to the enthalpy change of the heat-transfer medium from the point D to the point E in Fig. 2. In this way, the temperature of the heat carrier "a" at the outlet side of the condenser 13 can reach a level of 60 to 75°C.

[0054] Taking into consideration that, in the intermediate cooler 18, the temperature of the heat-transfer medium NH_3 is within a range 20 to 40°C, attention is paid to the heat carrier line 16 through which the medium temperature heat carrier "b" (the third heat carrier) is taken-out outward. The heat carrier line 16 is arranged so that it passes through the second sub-cooling device 21 and the first sub-cooling device 15 in a series arrangement; the heat carrier "b" absorbs the sensible heat of the liquid heat-transfer medium NH_3 in the second sub-cooling device 21 and the first sub-cooling device 15; the heat absorbed by the heat carrier "b" corresponds to the enthalpy change of the heat-transfer medium from the point E to the point G' in Fig. 2. On the other hand, it is also taken into consideration that the temperature of the liquid heat-transfer medium at the outlet of the condenser 13 is at least 60°C. Accordingly, the temperature of the medium temperature heat carrier "b" at the outlet of the first sub-cooling device 15 is within a range of 40 to 60°C. For instance, in a case where the temperature of the condensed liquid heat-transfer medium at the outlet of the condenser 13 is 60°C, the temperature of the heat carrier "b" can be at the level of 55°C.

[0055] Further, in the evaporator 23, the heat carrier line 24 is arranged so that it passes through the evaporator 23; whereby, the heat carrier "c" (the second heat carrier) for removing heat in the lower temperature range absorbs the minus-heat from (i.e. gives heat to) the heat-transfer medium; the heat (warming the heat-transfer medium) corresponds to the enthalpy change of the heat-transfer medium from the point H' to the point A in Fig. 2. In this way, the temperature of the heat carrier "c" at the outlet of the evaporator 23 can be within a range of -15 to 10°C.

[0056] The heat carrier line 16 of the medium temperature heat carrier "b" sub-cools the heat-transfer medium in the second sub-cooling device 21 and the first sub-cooling device 15; thus, as shown in Fig. 2, the refrigerant effect increases by Δh in comparison with the conventional refrigerant device. In other words, the evaporating latent heat of the heat-transfer medium in the evaporator 23 can be increased.

[0057] A further explanation regarding the increase Δh is hereby given. As for the liquid the heat-transfer medium in the intermediate cooler 18 in which the temperature of the heat-transfer medium is, for example, 40°C, the enthalpy thereof is 145.6 kcal/kg; when the heat-transfer medium is subsequently sub-cooled to 15°C in the second sub-cooling device 21, the corresponding enthalpy becomes 117.8 kcal/kg; accordingly, the increase in the refrigerant effect becomes Δh = 14506-11708 = 27.8 kcal/kg. The increase Δh corresponds to approximately 10% of the evaporating latent heat of the liquid heat-transfer medium in the case where the medium is heated-up from -20 to 10°C in the evaporator 23. Therefore, it can be estimated that the maximum increase in the refrigerant effect is approximately 10%.

[0058] Further, the degree of sub-cooling regarding the liquid heat-transfer medium is enhanced while the liquid heat-transfer medium is sub-cooled in the second sub-cooling device 21 and the first sub-cooling device 15; accordingly, the degree of dryness regarding the heat-transfer medium in the medium temperature range can be reduced. As a result, the amount of flash gas by which the heat-transfer medium cools the medium itself can be reduced. Therefore, the amount of the flow rate regarding the gaseous heat-transfer medium streaming in the intermediate pressure range (i.e. the intermediate range between the high stage and the low stage) can be reduced; thus, the cycle work needed in the intermediate pressure range can be reduced. Hence, the power consumption of the high stage compressor 11 and the low stage compressor 19 can be reduced. Moreover, the heat absorbing performance in the evaporator 23 is enhanced; thus, the COP of the heat pump cycle device 1 can be improved, and the stable high temperature at the discharge side of the high stage compressor 11 can be achieved.

[0059] Further, the heat-transfer medium NH_3 is used; and, apart from the case where CO_2 is used as a heat-transfer medium, the high pressure in the heat pump cycle is as low as the level of 4 MPa; thus, no special pressure resistant structure for the high stage compressor is required, and the compressor can be easily operated.

Moreover, the level of the high pressure in the heat pump cycle is lower than the transcritical pressure regarding NH_3; therefore, even when the additional heating is performed so that a higher maximum temperature is reached, the reduction of COP can be evaded. In this way, an advantage in relation to the degree of freedom as to the operation of the heat pump cycle device can be obtained.

[0060] Further, a reciprocating type compressor is used for the high stage compressor 11 in the compressor unit 50; in the case of reciprocating type compressor, the discharged gaseous heat-transfer medium discharged by the compressor does not include a plenty of lube-oil; thus, it becomes easier to achieve a necessary flow rate as well as a higher max-temperature regarding the heat-transfer medium circulating in the heat pump cycle. Incidentally, in a case of a screw compressor, the discharged gaseous heat-transfer medium includes a plenty of lube-oil; thus, it is difficult to maintain a sufficient flow rate as well as a higher max-temperature.

[0061] Further, in this embodiment, the hermetic type motor 30 as a driving means of the compressor unit is provided; the winding 36 of the stator 35 in the hermetic type motor 30 is made of aluminium wire; the compressor unit forms a sealed structure so that the heat-transfer medium NH_3 does not leak outside of the compressor unit; accordingly, the inflammable (combustible) , poisonous and highly corrosive NH_3 gas can be prevented from leaking outside; and the driving motor of the compressor unit 50 can be free from the corrosion attack caused by NH_3 gas.

[0062] cf. [0036] Further, in this embodiment, each of the high stage compressor 11 and the low stage compressor 19 is a reciprocating compressor; the rotating (driving) shaft of the high stage compressor 11 and the rotating (driving) shaft of the low stage compressor 19 forms a common crankshaft 52 so that the crankshaft is driven by the driving motor; thus, a single compressor unit of a two-stage compressor is formed. Hence, the installation space regarding the heat pump cycle unit 1 can be reduced; and, the driving power to drive the high stage compressor 11 and the low stage compressor 19 can be reduced.

[0063] Further, in this embodiment, the oil separator 12 configured as shown in Fig. 5 is provided on the downstream side of the gas outlet regarding the high stage compressor 11; thus, the lube-oil that intrudes into the gaseous heat-transfer medium discharged from the high stage compressor 11 can be separated with high accuracy; further, since the lube-oil that is indissoluble with the heat-transfer medium NH_3 is used, the lube-oil even of a micron size particle can be separated.

[0064] In the next place, a second embodiment according to the present invention is explained based on Fig. 6; in the second embodiment as shown in Fig. 6, the heat pump cycle device is provided with: a heat-transfer medium piping 2a that guides the gaseous heat-transfer medium discharged from the high stage compressor 11 into the condenser 13; and, a heat-transfer medium piping 2b that guides the refrigerant (the heat-transfer medium) which sensible heat is absorbed in the condenser 13, into the oil separator 12. Incidentally, it is noted that the heat-transfer medium being guided through the heat-transfer medium piping 2b is in a gas state.

The configuration in this second embodiment other than the hereby-described configuration is the same as the configuration in the first embodiment; the explanation regarding the same configuration is not repeated.

[0065] In this second embodiment, the gaseous heat-transfer medium of a high temperature discharged from the high stage compressor 11 is once guided into the condenser 13; whereby, heat exchange between the heat-transfer medium (in the line 2b) and the heat carrier "a" (the first heat carrier in the line 14) for removing heat in a higher temperature range is performed, the heat exchange being performed in the condenser 13 that forms a counter flow heat exchanger (namely, the lines 14 and 2b are in a counter flow arrangement so that a part of the sensible heat of the heat-transfer medium is transferred to the heat carrier "a"). In this way, the heat-transfer medium is pre-cooled before the medium is guided into the oil separator 12. The temperature of the heat-transfer medium NH_3 discharged from the high stage compressor 11 reaches 100°C or more; the heat-transfer medium of that high temperature is not directly guided into the separator 12, but the heat-transfer medium enters the separator 12 after being pre-cooled to a temperature level of 100°C or less. In this way, the separation elements of the separator 12 can be prevented from being deteriorated by the high temperature of the heat-transfer medium discharged from the high stage compressor.

[0066] Further, since the heat-transfer medium discharged from the high stage compressor is guided into the separator 12 after the medium is pre-cooled, the volume of the gaseous heat-transfer medium passing through the separation elements of the separator 12 can be reduced; thus, an appropriate velocity of flow of the gaseous heat-transfer medium passing through the separation elements can be achieved. It is needless to say that the effects obtained by the first embodiment are also obtained by this second embodiment.

Industrial Applicability

[0067] According to the present invention, a two-stage compression heat pump cycle device using NH_3 as a heat-transfer medium in the heat pump cycle can be realized; whereby, , a stable and high temperature condition regarding the heat transfer medium discharged by the high stage compressor can be achieved; three heat extracting (or supplying) heat- exchangers for extracting (or supplying) heat from the main circuit toward the heat extracting (or supplying) side circuits can be simultaneously realized so that the outlet temperature of the heat carrier at each heat exchanger outlet exists in a higher temperature range, a medium temperature range, and a lower temperature range; the COP (coefficient of performance) of the heat cycle can be enhanced; and, the degree of freedom regarding the operation of the heat pump cycle can be enhanced.

Claims

1. A two-stage compression heat pump cycle device using NH_3 as a heat-transfer medium in the heat pump cycle, the device comprising a two-stage compressor unit having a high stage compressor, a low stage compressor and an intermediate cooler being arranged between the high stage compressor and the low stage compressor, and the liquid heat-transfer medium being passed through a condenser discharged from the high stage compressor and then enters the intermediate cooler so that heat exchange between the liquid heat-transfer medium and the gaseous heat-transfer medium discharged by the low stage compressor is performed; the heat-transfer medium in the intermediate cooler proceeds to an evaporator where the medium evaporates into a gas state; the heat-transfer medium gasified in the evaporator returns back to the gas inhaling side of the low stage compressor so that the heat pump cycle as a circulatory cycle is formed; wherein,
a first heat carrier line in which a first heat carrier streams is provided so that the first heat carrier line passes through the condenser where the latent heat of the gaseous heat-transfer medium is absorbed the first heat carrier so as to produce high temperature heat carrier;
a second heat carrier line in which a second heat carrier streams is provided so that the second heat carrier line passes through the evaporator where the latent heat of the liquid heat-transfer medium is supplied by the second heat carrier so as to produce low temperature heat carrier;
a first sub-cooling device is arranged between the condenser and the intermediate cooler;
a second sub-cooling device is arranged between the intermediate cooler and the evaporator; and
a third heat carrier line in which a third heat carrier streams is provided so that the third heat carrier line passes through the second sub-cooling device and the first sub-cooling device in this order, the third heat carrier line connecting the first sub-cooling device and the second sub-cooling device in a series arrangement, at each of the first and second sub-cooling device, the sensible heat of the liquid heat-transfer medium is absorbed by the third heat carrier so as to produce a medium heat temperature heat carrier.

2. The two-stage compression heat pump cycle device according to claim 1, the device, comprising:

a first expansion valve arranged between the first sub-cooling device and the intermediate cooler;
a second expansion valve arranged between the second sub-cooling device and the evaporator.

3. The two-stage compression heat pump cycle device according to claim 1 or 2, the device further comprising:

One of a hermetic type motor and an encapsulated IPM motor that use aluminum wire as a winding wire to drive at least the high stage compressor out of the high stage compressor and the low stage compressor.

4. The two-stage compression heat pump cycle device according to claim 1 or 2, wherein the two-stage compressor unit includes a single compressor unit in which the high stage compressor and the low stage compressor are connected in series.

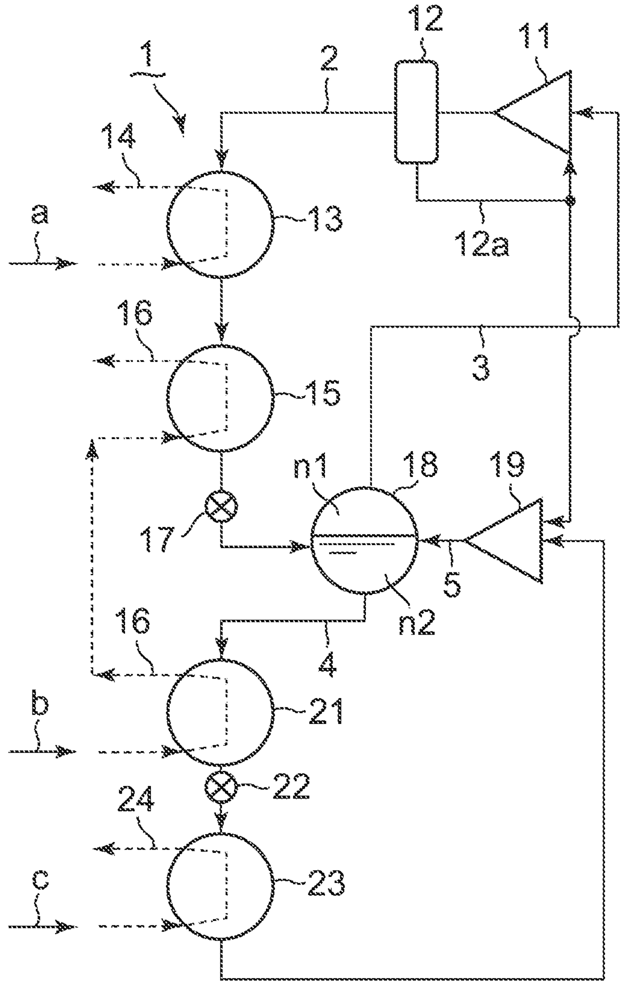
5. The two-stage compression heat pump cycle device according to claim 1 or 2, further comprising an oil separator for separating oil contained in the heat-transfer medium discharged from the high stage compressor, whereby the oil separator being arranged on a downstream side of the high stage compressor so that the heat-transfer medium is precooled by the condenser before the heat-transfer medium enters the oil separator.

6. The two-stage compression heat pump cycle device according to claim 5, wherein the oil separator includes an oil separator element for separating the oil contained in the heat-transfer medium so that the oil separator element surrounds an inflow opening through which the mixed fluid of the oil and the heat-transfer medium enters; whereby, the oil separator element comprising three layer-filter elements in order from the inner side to the outer side, namely:

a rough separation pre-filter element through which rough oil particles in the mixed fluid is separated;
a regular separation filter element that is provided with material being full of fine holes with which a fine mesh size structure is formed so that even fine oil mist is separated from the mixed fluid;
an oil scattering prevention filter element that is provided with a plenty of slots through which the gaseous heat-transfer medium can pass so that the oil scattering prevention filter element prevents the oil mist captured by the regular separation filter element from scattering again.

7. The two-stage compression heat pump cycle device according to claim 5 or 6, wherein the lube-oil used for the two-stage compressors is indissoluble with the NH_3 refrigerant.

Fig. 1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2
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11
14
a
13
12a
16
15
3
n1
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19
17
5
n2
16
4
b
21
22
24
c
23

Fig. 2

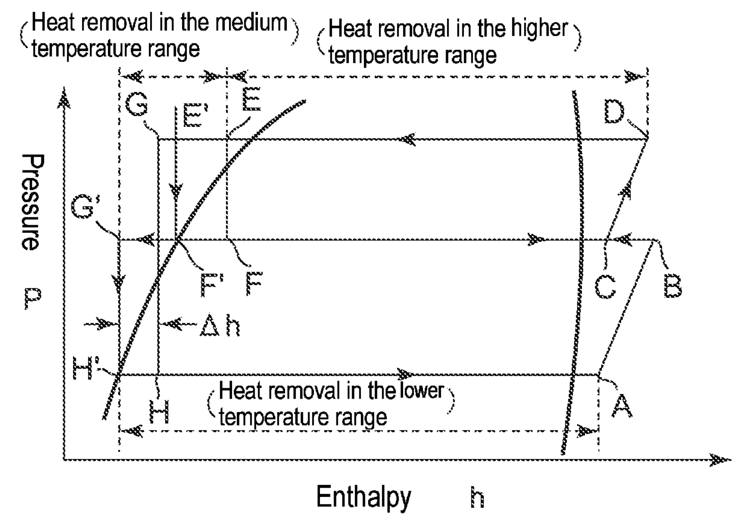

Heat removal in the medium temperature range
Heat removal in the higher temperature range
G
E'
E
D
G'
F'
F
C
B
Δh
H'
H
A
Heat removal in the lower temperature range
Pressure P
Enthalpy h

Fig. 3

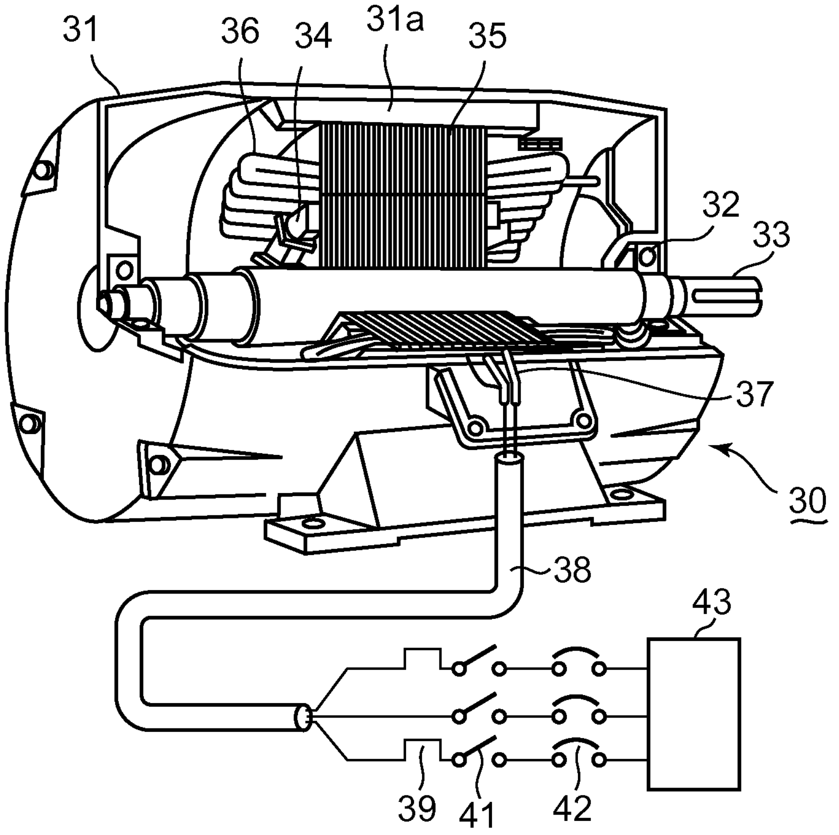


Fig. 4

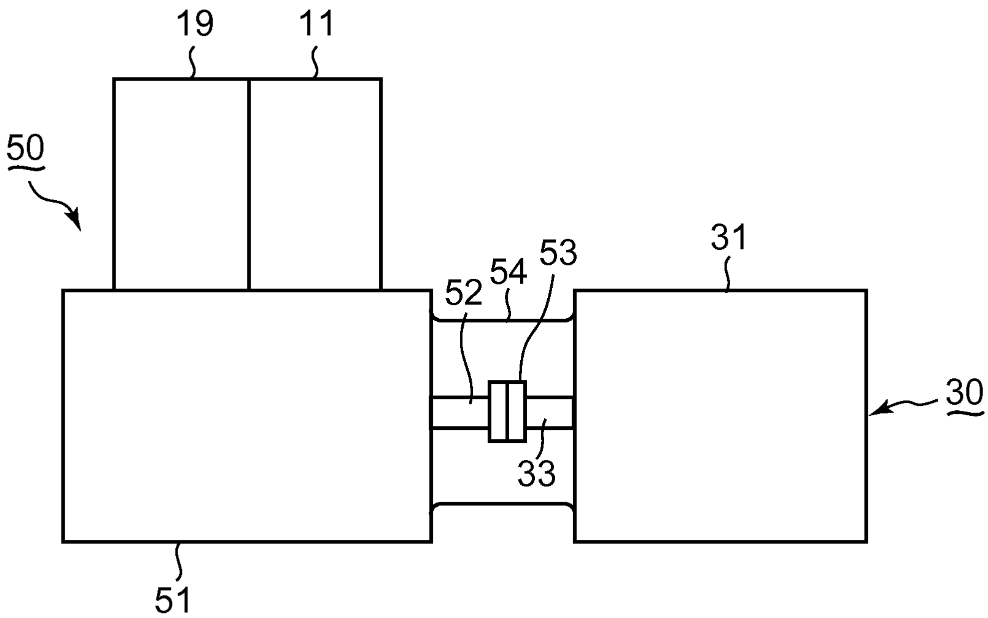
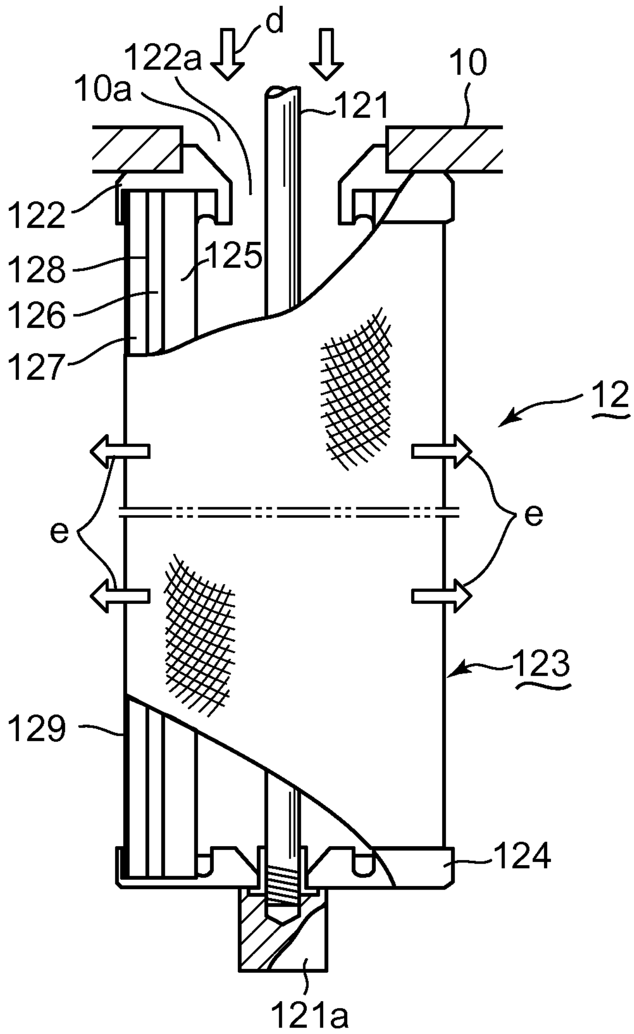


Fig. 5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125
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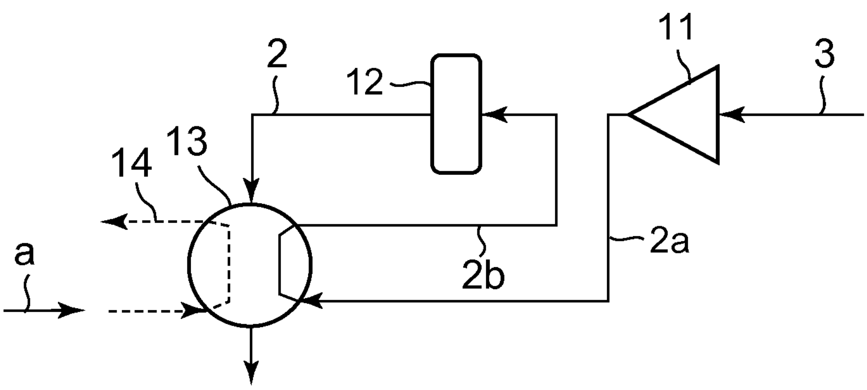
127
12
e
e
123
129
124
121a

Fig. 6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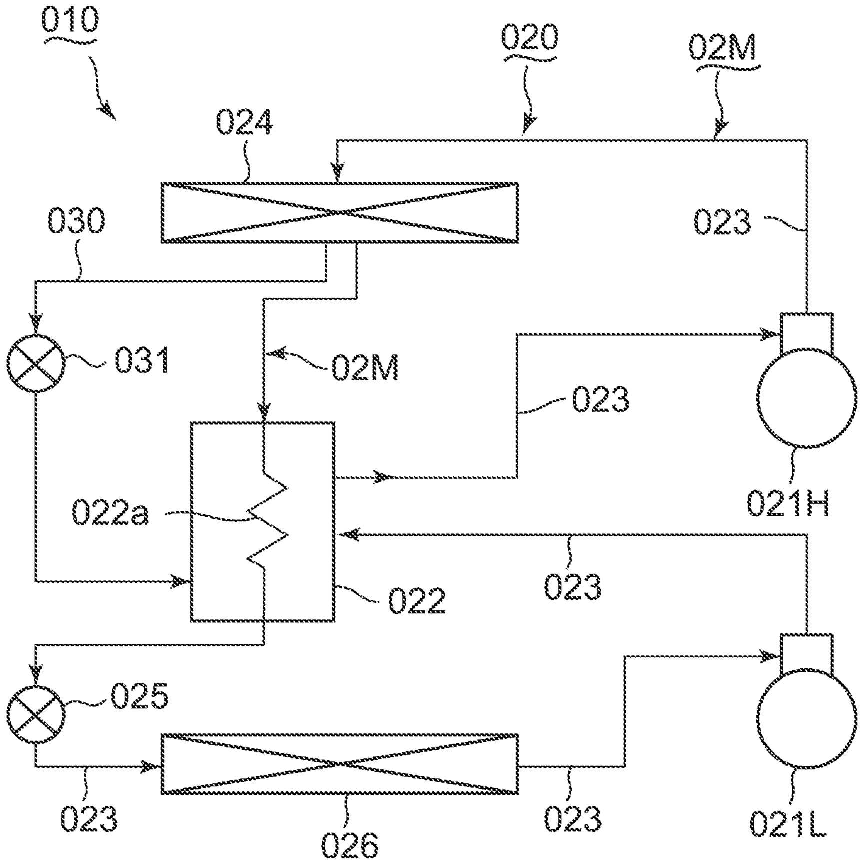
13
14
2a
a
2b

Fig. 7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026
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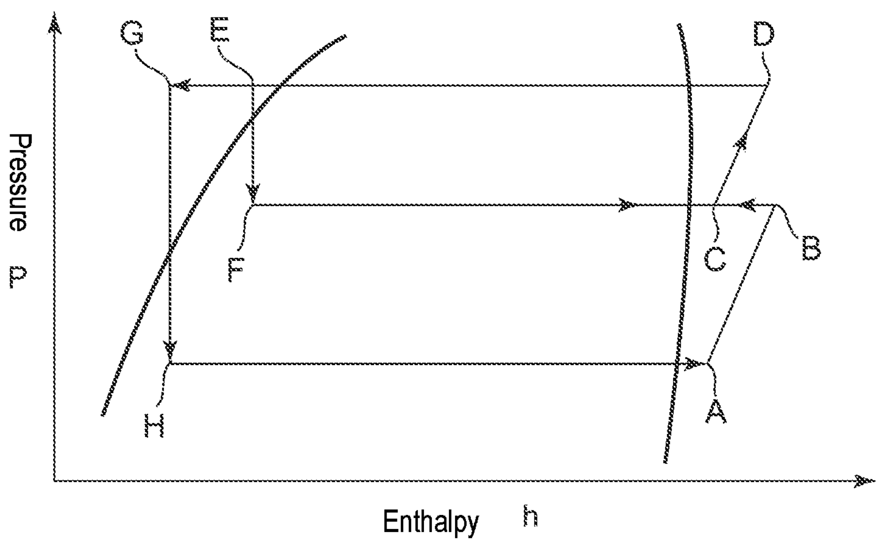
021L

Fig. 8


G
E
D
Pressure P
F
C
B
H
A
Enthalpy h

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/065308

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/10(2006.01)i, *F25B1/00*(2006.01)i, *F25B5/04*(2006.01)i

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)
F25B1/10, F25B1/00, F25B5/04

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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.
Y	JP 58-145859 A (Hitachi, Ltd.), 31 August, 1983 (31.08.83), Claims; page 1, lower left column, line 14 to page 2, lower right column, line 20; Figs. 1 to 4 (Family: none)	1-7
Y	JP 57-31767 A (Hitachi, Ltd.), 20 February, 1982 (20.02.82), Claims; page 1, lower left column, line 12 to page 2, lower right column, line 14; Figs. 1 to 2 (Family: none)	1-7

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

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-220351 A (Hitachi, Ltd.), 24 August, 2006 (24.08.06), Par. Nos. [0014] to [0019]; Fig. 3 & CN 1818506 A	1-7
Y	JP 2004-56990 A (Mayekawa Mfg., Co., Ltd.), 19 February, 2004 (19.02.04), Claims; Par. Nos. [0001] to [0059]; Figs. 1 to 8 (Family: none)	1-7
Y	JP 5-245321 A (Nippon Muki Co., Ltd.), 24 September, 1993 (24.09.93), Claims; Par. Nos. [0001] to [0029]; Figs. 1 to 3 (Family: none)	6-7
A	JP 2000-249413 A (Daikin Industries, Ltd.), 14 September, 2000 (14.09.00), Full text; all drawings (Family: none)	1-7

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Patent documents cited in the description

- JP 2000249413 A **[0002]**
- JP 2004056990 A **[0049]**