



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

(43) Date of publication:
24.03.2021 Bulletin 2021/12

(51) Int Cl.:
F25B 39/04 ^(2006.01) **F25B 13/00** ^(2006.01)
F28F 1/40 ^(2006.01) **F28F 13/08** ^(2006.01)

(21) Application number: **18918977.2**

(86) International application number:
PCT/JP2018/018766

(22) Date of filing: **15.05.2018**

(87) International publication number:
WO 2019/220541 (21.11.2019 Gazette 2019/47)

(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

- **TANAKA, Kosuke**
Tokyo 1008310 (JP)
- **FUJITA, Kunihiro**
Tokyo 1008310 (JP)
- **ABE, Takafumi**
Tokyo 1008310 (JP)

(71) Applicant: **Mitsubishi Electric Corporation**
Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

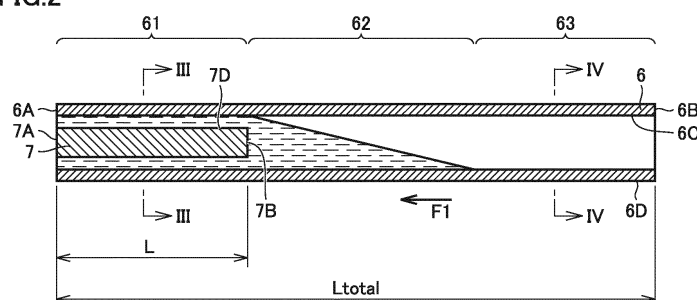
(72) Inventors:
• **ISHIYAMA, Hiroki**
Tokyo 1008310 (JP)

(54) **REFRIGERATION CYCLE DEVICE**

(57) Provided is a refrigeration cycle apparatus with improved period efficiency, when compared with a conventional refrigeration cycle apparatus. The refrigeration cycle apparatus (100) includes a refrigerant circuit which includes a compressor (1), a first heat exchanger (3), and a second heat exchanger (4), and through which refrigerant circulates. The refrigerant circuit is provided to be switchable between a first state in which the first heat exchanger (3) acts as a condenser and the second heat exchanger (4) acts as an evaporator and a second state in which the second heat exchanger (4) acts as a condenser and the first heat exchanger (3) acts as an evaporator.

The first heat exchanger (3) includes a first heat transfer tube (6) inside which the refrigerant flows. The first heat transfer tube (6) has a first tube portion (61) located downstream of an intermediate position in a flowing direction of the refrigerant when the first heat exchanger acts as a condenser. The first heat exchanger (3) further includes a first inner member (7) arranged inside the first tube portion (61). In the first state and the second state, an inner diameter D_1 and an equivalent diameter M_1 of the first tube portion (61) satisfy a relational expression $D_i/2.5 < M_1 < D_1/1.5$.

FIG.2



Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration cycle apparatus including a first heat exchanger and a second heat exchanger, and in particular to a refrigeration cycle apparatus provided to be switchable between a first state in which a first heat exchanger acts as a condenser and a second heat exchanger acts as an evaporator and a second state in which the second heat exchanger acts as a condenser and the first heat exchanger acts as an evaporator.

BACKGROUND ART

[0002] Refrigerant circulating through a refrigeration cycle apparatus condenses from a gas single-phase state through a gas-liquid two-phase state to a liquid single-phase state in the course of flowing from one end to the other end of a heat transfer tube of a condenser. Further, the refrigerant evaporates from a gas-liquid two-phase state to a gas single-phase state in the course of flowing from one end to the other end of a heat transfer tube of an evaporator.

[0003] When the heat transfer tube of the condenser has a uniform configuration between the one end and the other end thereof, heat transfer performance between the refrigerant flowing inside the heat transfer tube and a heat medium such as air flowing outside the heat transfer tube (hereinafter referred to as in-tube heat transfer performance) changes according to the position in a direction in which the heat transfer tube extends. The in-tube heat transfer performance in a first portion located on a downstream side including the other end of the heat transfer tube of the condenser is lower than the in-tube heat transfer performance in a second portion located upstream of the first portion and located downstream of the one end. This is because the flow velocity of the refrigerant in the liquid single-phase state flowing through the first portion of the condenser is lower than the flow velocity of the refrigerant in the gas-liquid two-phase state flowing through the second portion of the condenser.

[0004] Japanese Patent Laying-Open No. 2000-55509 (PTL 1) discloses a heat exchanger including an insertion body provided inside a heat transfer tube on a refrigerant outlet side when the heat exchanger acts as a condenser, in order to improve in-tube heat transfer performance in a portion located on a downstream side of a heat transfer tube of the condenser, and improve heat exchanger performance in an operation state in which the heat exchanger acts as the condenser.

CITATION LIST

PATENT LITERATURE

- 5 **[0005]** PTL 1: Japanese Patent Laying-Open No. 2000-55509

SUMMARY OF INVENTION

10 TECHNICAL PROBLEM

- [0006]** However, when the above heat exchanger acts as an evaporator, refrigerant in a gas-liquid two-phase state or a gas single-phase state flows inside the heat transfer tube in which the insertion body is inserted. Accordingly, when the above heat exchanger acts as an evaporator, the pressure loss of the refrigerant flowing through a portion in which the insertion body is inserted in the heat transfer tube is significantly larger than the pressure loss of the refrigerant flowing through a portion in which the insertion body is not inserted in the heat transfer tube. Accordingly, the heat exchanger performance when the above heat exchanger acts as an evaporator is significantly lower than the heat exchanger performance when a heat exchanger not provided with the above insertion body acts as an evaporator. As a result, it has been difficult to improve period efficiency in a refrigeration cycle apparatus provided to be switchable between an operation state in which the above heat exchanger acts as a condenser and an operation state in which the above heat exchanger acts as an evaporator.
- [0007]** A main object of the present invention is to provide a refrigeration cycle apparatus with improved period efficiency, when compared with a refrigeration cycle apparatus as described above.

SOLUTION TO PROBLEM

- [0008]** A refrigeration cycle apparatus in accordance with the present invention includes a refrigerant circuit which includes a compressor, a flow path switching valve, a first heat exchanger, a second heat exchanger, and a decompression unit, and through which refrigerant circulates. The refrigerant circuit is provided to be switchable between a first state in which the first heat exchanger acts as a condenser and the second heat exchanger acts as an evaporator and a second state in which the second heat exchanger acts as a condenser and the first heat exchanger acts as an evaporator. The first heat exchanger and the second heat exchanger each include a heat transfer tube inside which the refrigerant flows. The heat transfer tube has a first tube portion located downstream of an intermediate position of a first heat transfer tube in a flowing direction of the refrigerant when the first heat exchanger acts as a condenser. The first heat exchanger further includes a first inner member arranged inside the first tube portion. In the first state and the second state, an inner diameter D_1 of the first tube portion and an equiv-

alent diameter M_1 calculated from the following relational expression (1) satisfy the following relational expression (2):

$$M_1 = 4 \times A_1/S_1 \dots (1);$$

and

$$D_1/2.5 < M_1 < D_1/1.5 \dots (2),$$

where A_1 is a flow path cross sectional area of the first tube portion, and S_1 is a wetted perimeter of the first tube portion.

ADVANTAGEOUS EFFECTS OF INVENTION

[0009] Since the first heat exchanger in the refrigeration cycle apparatus of the present invention includes the first tube portion in which equivalent diameter M satisfies the above relational expression (2), the first heat exchanger exhibits a high heat exchange performance when it acts as a condenser. Further, since the first heat exchanger includes the first tube portion in which equivalent diameter M satisfies the above relational expression (2), the first heat exchanger exhibits a high heat exchange performance when it acts as an evaporator, when compared with a conventional heat exchanger including a heat transfer tube in which an equivalent diameter does not satisfy the above relational expression (2). As a result, according to the present invention, it is possible to provide a refrigeration cycle apparatus with improved period efficiency, when compared with a refrigeration cycle apparatus including the conventional heat exchanger including the heat transfer tube in which the equivalent diameter does not satisfy the above relational expression (2).

BRIEF DESCRIPTION OF DRAWINGS

[0010]

Fig. 1 is a schematic configuration diagram of a refrigeration cycle apparatus in accordance with a first embodiment.

Fig. 2 is a schematic cross sectional view of a heat transfer tube of a first heat exchanger when the refrigeration cycle apparatus in accordance with the first embodiment is in a first state.

Fig. 3 is a schematic cross sectional view seen from arrows III-III in Fig. 2.

Fig. 4 is a schematic cross sectional view seen from arrows IV-IV in Fig. 2.

Fig. 5 is a graph showing the relation between the period efficiency of the first heat exchanger and the equivalent diameter of a first tube portion of the first

heat exchanger in the refrigeration cycle apparatus in accordance with the first embodiment.

Fig. 6 is a graph showing the relation between the circulation amount of refrigerant and the equivalent diameter of the first tube portion of the first heat exchanger in the refrigeration cycle apparatus in accordance with the first embodiment.

Fig. 7 is a schematic cross sectional view of a heat transfer tube of a first heat exchanger when a refrigeration cycle apparatus in accordance with a third embodiment is in the first state.

Fig. 8 is a schematic cross sectional view seen from arrows VIII-VIII in Fig. 7.

Fig. 9 is a schematic cross sectional view of the heat transfer tube of the first heat exchanger when the refrigeration cycle apparatus in accordance with the third embodiment is in a second state.

Fig. 10 is a schematic cross sectional view seen from arrows X-X in Fig. 9.

Fig. 11 is a schematic cross sectional view of a heat transfer tube of a first heat exchanger when a refrigeration cycle apparatus in accordance with a fourth embodiment is in the first state.

Fig. 12 is a schematic cross sectional view seen from arrows XII-XII in Fig. 11.

Fig. 13 is a schematic cross sectional view of the heat transfer tube of the first heat exchanger when the refrigeration cycle apparatus in accordance with the fourth embodiment is in the second state.

Fig. 14 is a schematic cross sectional view seen from arrows XIV-XIV in Fig. 13.

Fig. 15 is a schematic cross sectional view of a heat transfer tube of a first heat exchanger when a refrigeration cycle apparatus in accordance with a fifth embodiment is in the first state.

Fig. 16 is a schematic cross sectional view seen from arrows XVI-XVI in Fig. 15.

Fig. 17 is a flowchart when the refrigeration cycle apparatus in accordance with the fifth embodiment is intermittently operated.

Fig. 18(a) is a graph showing the relation between operation time and compressor frequency when the refrigeration cycle apparatus in accordance with the fifth embodiment is intermittently operated, and Fig. 18(b) is a graph showing the relation between operation time and indoor temperature when the refrigeration cycle apparatus in accordance with the fifth embodiment is intermittently operated.

Fig. 19 is a schematic cross sectional view of a heat transfer tube of a first heat exchanger when a refrigeration cycle apparatus in accordance with a sixth embodiment is in the first state.

Fig. 20 is a schematic cross sectional view seen from arrows XX-XX in Fig. 19.

Fig. 21 is a schematic cross sectional view of a heat transfer tube of a first heat exchanger when a refrigeration cycle apparatus in accordance with a seventh embodiment is in the first state.

Fig. 22 is a schematic cross sectional view seen from arrows XXII-XXII in Fig. 21.

Fig. 23 is a schematic cross sectional view of a heat transfer tube of the first heat exchanger when a variation of the refrigeration cycle apparatus in accordance with the first embodiment is in the first state.

Fig. 24 is a schematic cross sectional view seen from arrows XXIV-XXIV in Fig. 23.

DESCRIPTION OF EMBODIMENTS

[0011] Hereinafter, embodiments of the present invention will be described with reference to the drawings. It should be noted that, in the drawings below, identical or corresponding parts will be designated by the same reference numerals, and the description thereof will not be repeated.

First Embodiment

configuration of Refrigeration Cycle Apparatus>

[0012] As shown in Fig. 1, a refrigeration cycle apparatus 100 in accordance with a first embodiment includes a refrigerant circuit which includes a compressor 1, a four-way valve 2 serving as a flow path switching valve, a first heat exchanger 3, a second heat exchanger 4, and a decompression unit 5, and through which refrigerant circulates. Refrigeration cycle apparatus 100 is provided to be switchable between a first state in which first heat exchanger 3 acts as a condenser and second heat exchanger 4 acts as an evaporator and a second state in which first heat exchanger 3 acts as an evaporator and second heat exchanger 4 acts as a condenser, by means of four-way valve 2. In the first state, the refrigerant flows through compressor 1, first heat exchanger 3, decompression unit 5, and second heat exchanger 4 in order, along a direction F1. In the second state, the refrigerant flows through compressor 1, second heat exchanger 4, decompression unit 5, and first heat exchanger 3 in order, along a direction F2. First heat exchanger 3 is an indoor heat exchanger placed inside a room, for example. Second heat exchanger 4 is an outdoor heat exchanger placed outside the room, for example. In this case, the first state is achieved during heating operation, and the second state is achieved during cooling operation.

[0013] As shown in Fig. 1, first heat exchanger 3 has a plurality of first heat transfer tubes 6 inside which the refrigerant flows, and is intended to perform heat exchange between the refrigerant flowing inside first heat transfer tubes 6 and a heat medium such as air, for example, flowing outside first heat transfer tubes 6. First heat exchanger 3 includes a heat exchange unit 30 including the plurality of first heat transfer tubes 6 and a fin not shown, a distributor 31, and a distributor 32. Each of the plurality of first heat transfer tubes 6 of first heat exchanger 3 has a mutually equal configuration, for example.

[0014] As shown in Figs. 1 and 2, each of the plurality of first heat transfer tubes 6 of first heat exchanger 3 has a first end portion 6A and a second end portion 6B provided with refrigerant inlet and outlet. First end portion 6A of each of the plurality of first heat transfer tubes 6 is connected with distributor 31. Second end portion 6B of each of the plurality of first heat transfer tubes 6 is connected with distributor 32. Further, each of the plurality of first heat transfer tubes 6 has an inner circumferential surface 6C and an outer circumferential surface 6D. In first heat exchanger 3, the refrigerant flows through a region surrounded by inner circumferential surface 6C of each first heat transfer tube 6. In the first state, the refrigerant condenses from a gas single-phase state through a gas-liquid two-phase state to a liquid single-phase state in the course of flowing from second end portion 6B to first end portion 6A of each of the plurality of first heat transfer tubes 6. In the second state, the refrigerant evaporates from a gas-liquid two-phase state to a gas single-phase state in the course of flowing from first end portion 6A to second end portion 6B of each of the plurality of first heat transfer tubes 6.

[0015] As shown in Fig. 2, each of the plurality of first heat transfer tubes 6 of first heat exchanger 3 can be divided into a third tube portion 63 located upstream of an intermediate position of first heat transfer tube 6 in flowing direction F1 of the refrigerant in the first state, a fourth tube portion 62 including the intermediate position and located downstream of third tube portion 63 in direction F1, and a first tube portion 61 located downstream of fourth tube portion 62 in direction F1. First tube portion 61 is located downstream of the intermediate position of first heat transfer tube 6 in direction F1. Flowing direction F1 of the refrigerant inside first heat transfer tube 6 extends along an axis line direction of first heat transfer tube 6. The axis line direction of first heat transfer tube 6 may extend linearly, or may meander. A material constituting first heat transfer tube 6 includes copper (Cu), for example.

[0016] First heat exchanger 3 includes a plurality of first inner members 7, for example. Each first inner member 7 is arranged inside each first tube portion 61. Each first inner member 7 has a mutually equal configuration, for example.

[0017] As shown in Fig. 2, first inner member 7 has a third end portion 7A and a fourth end portion 7B. Third end portion 7A of first inner member 7 is arranged at a position closer to first end portion 6A of first heat transfer tube 6 than fourth end portion 7B. An end portion of first tube portion 61 located closer to fourth tube portion 62 is a portion arranged on a cross section perpendicular to the axis line direction of first heat transfer tube 6, on which fourth end portion 7B of first inner member 7 is also arranged.

[0018] As shown in Fig. 2, first inner member 7 has an outer circumferential surface 7D. At least a portion of outer circumferential surface 7D is arranged to face inner circumferential surface 6C of first tube portion 61 with a

space therebetween. The refrigerant flowing through first tube portion 61 flows through a region sandwiched between inner circumferential surface 6C of first tube portion 61 and outer circumferential surface 7D of first inner member 7. Inside first tube portion 61, only one refrigerant flow path is arranged, for example. On a cross section perpendicular to the axis line direction, a shape formed by outer circumferential surface 7D of first inner member 7 is similar to a shape formed by inner circumferential surface 6C of first heat transfer tube 6, for example. The shape formed by outer circumferential surface 7D of first inner member 7 and the shape formed by inner circumferential surface 6C of first heat transfer tube 6 are circular, for example.

[0019] On the cross section perpendicular to the axis line direction, the following relational expression (5) is satisfied, where E_1 is a length of the outer circumferential surface of first inner member 7, E_2 is a length of the inner circumferential surface of first heat transfer tube 6, and S is a wetted perimeter of first tube portion 61. On the cross section perpendicular to the axis line direction, the above relational expression (1) is satisfied, where D_1 is an inner diameter of first tube portion 61, A_1 is a flow path cross sectional area of first tube portion 61, and M_1 is an equivalent diameter of first tube portion 61.

$$S_1 = E_1 + E_2 \dots (5)$$

[0020] As shown in Fig. 3, equivalent diameter M_1 of first tube portion 61 satisfies the following relational expression (6) in the first state and the second state. Preferably, equivalent diameter M_1 of first tube portion 61 satisfies the above relational expression (2) in the first state and the second state.

$$D_1/2.5 < M_1 \dots (6)$$

[0021] As shown in Fig. 2, first tube portion 61 includes a portion through which the liquid phase refrigerant flows when refrigeration cycle apparatus 100 is in the first state. First tube portion 61 includes a portion through which for example the gas-liquid two-phase refrigerant flows when refrigeration cycle apparatus 100 is in the second state. Fourth tube portion 62 includes a portion through which the gas-liquid two-phase refrigerant flows when refrigeration cycle apparatus 100 is in the first state. Third tube portion 63 includes a portion through which the gas phase refrigerant flows when refrigeration cycle apparatus 100 is in the first state. It should be noted that Fig. 2 schematically shows the refrigerant in order to describe the change of state thereof.

For example, Fig. 2 merely shows that the refrigerant inside fourth tube portion 62 is in the gas-liquid two-phase state, and Fig. 2 does not show a mixed state and a flowing state of a liquid phase portion and a gas phase portion

of the refrigerant in the gas-liquid two-phase state.

[0022] A length L_1 of first inner member 7 in the axis line direction of the first tube portion is less than or equal to half of a length L_2 of first heat transfer tube 6. Length L_2 of first heat transfer tube 6 is a length between first end portion 6A and second end portion 6B of first heat transfer tube 6 along the axis line direction.

[0023] Positional deviation of first inner member 7 with respect to first tube portion 61 of first heat transfer tube 6 in the axis line direction is restricted by an arbitrary configuration. For example, when the axis line direction of first heat transfer tube 6 meanders and first heat transfer tube 6 has a bent portion not shown, first tube portion 61 is located downstream of the bent portion in flowing direction F1. For example, a boundary portion between first tube portion 61 and fourth tube portion 62 of first heat transfer tube 6 is provided to be continuous to the bent portion. With such a configuration, first inner member 7 is positioned between the bent portion and first end portion 6A in the axis line direction.

[0024] A material constituting first inner member 7 may be any material. For example, it is a material having a corrosion resistance with respect to the refrigerant which is equal to that of the material constituting first heat transfer tube 6, and includes at least one selected from the group consisting of copper (Cu), rubber, and plastic, for example.

<Function and Effect>

[0025] Refrigeration cycle apparatus 100 includes the refrigerant circuit which includes compressor 1, four-way valve 2, first heat exchanger 3, second heat exchanger 4, and decompression unit 5, and through which the refrigerant circulates. The refrigerant circuit is provided to be switchable between the first state in which first heat exchanger 3 acts as a condenser and second heat exchanger 4 acts as an evaporator and the second state in which second heat exchanger 4 acts as a condenser and first heat exchanger 3 acts as an evaporator. First heat exchanger 3 includes first heat transfer tube 6 inside which the refrigerant flows. First heat transfer tube 6 has first tube portion 61 located downstream of the intermediate position of first heat transfer tube 6 in the flowing direction of the refrigerant when first heat exchanger 3 acts as a condenser. First heat exchanger 3 further includes first inner member 7 arranged inside first tube portion 61. In the first state and the second state, inner diameter D_1 of first tube portion 61 and equivalent diameter M_1 calculated from the following relational expression (1) satisfy the following relational expression (2):

$$M_1 = 4 \times A_1/S_1 \dots (1);$$

and

$$D_1/2.5 < M_1 < D_1/1.5 \dots (2),$$

where A_1 is the flow path cross sectional area of first tube portion 61, and S_1 is the wetted perimeter of first tube portion 61.

[0026] As described above, when refrigeration cycle apparatus 100 is in the first state, the refrigerant condenses in the course of flowing through third tube portion 63, fourth tube portion 62, and first tube portion 61 of first heat transfer tube 6 of first heat exchanger 3 in order, and changes from the gas single-phase state through the gas-liquid two-phase state to the liquid single-phase state. On the other hand, when refrigeration cycle apparatus 100 is in the second state, the refrigerant evaporates in the course of flowing through first tube portion 61, fourth tube portion 62, and third tube portion 63 of first heat transfer tube 6 of first heat exchanger 3 in order, and changes from the gas-liquid two-phase state to the gas single-phase state. That is, the refrigerant flowing through first tube portion 61 is mainly in the liquid single-phase state in the first state, and is mainly in the gas-liquid two-phase state in the second state. In addition, in the first state and the second state, the refrigerant in the liquid single-phase state flows through only first tube portion 61 and rarely flows through fourth tube portion 62 and third tube portion 63 of first heat transfer tube 6.

[0027] Since first inner member 7 is arranged inside first tube portion 61 of first heat transfer tube 6, flow path cross sectional area A of first tube portion 61 is smaller than flow path cross sectional areas of fourth tube portion 62 and third tube portion 63 of first heat transfer tube 6 inside which first inner member 7 is not arranged. Accordingly, the flow velocity of the refrigerant in the liquid single-phase state when it flows through first tube portion 61 is faster than the flow velocity of the refrigerant in the liquid single-phase state when it flows through a conventional heat transfer tube in which first inner member 7 is not arranged. As a result, the in-tube heat transfer performance of first tube portion 61 in the first state is higher than the in-tube heat transfer performance of the conventional heat transfer tube in which first inner member 7 is not arranged.

[0028] In addition, the heat exchanger provided with the insertion body described in PTL 1 does not satisfy the above relational expression (2). Specifically, as shown in Fig. 9 of PTL 1, an equivalent diameter M_r and an inner diameter D_r of the portion in which the insertion body is inserted satisfy a relational expression $M_r < D_r/2.5$.

[0029] In contrast, since equivalent diameter M of first tube portion 61 satisfies the above relational expression (2), the period efficiency of first heat exchanger 3 in refrigeration cycle apparatus 100 is improved, when compared with the heat exchanger in PTL1 which does not satisfy the above relational expression (2). Fig. 5 is a graph showing the relation between equivalent diameter

M of first tube portion 61 and the heat exchange performance of first heat exchanger 3 in the first state (a line segment A in Fig. 5), the heat exchange performance of first heat exchanger 3 in the second state (a line segment B in Fig. 5), and the period efficiency of first heat exchanger 3 (a line segment C in Fig. 5). The axis of abscissas in Fig. 5 represents equivalent diameter M of first tube portion 61, and the axis of ordinates in Fig. 5 represents the heat exchange performance and the period efficiency of first heat exchanger 3.

[0030] As shown in Fig. 5, in a case where equivalent diameter M_1 of first tube portion 61 is less than or equal to $D_1/2.5$, the period efficiency of first heat exchanger 3 is significantly decreased, when compared with a case where equivalent diameter M_1 of first tube portion 61 is more than $D_1/2.5$.

[0031] Referring to line segment B in Fig. 5, in the case where equivalent diameter M_1 of first tube portion 61 is less than or equal to $D_1/2.5$, the pressure loss of the refrigerant in the gas-liquid two-phase state flowing through first tube portion 61 in the second state is significantly increased, and the heat exchange performance of first heat exchanger 3 in the second state is significantly decreased, when compared with the case where equivalent diameter M_1 of first tube portion 61 is more than $D_1/2.5$. On the other hand, referring to line segment A in Fig. 5, in the case where equivalent diameter M_1 of first tube portion 61 is less than or equal to $D_1/2.5$, the velocity of the refrigerant in the liquid single-phase state flowing through first tube portion 61 in the first state is not significantly increased, and thus the heat exchange performance of first heat exchanger 3 in the first state is not significantly improved, when compared with the case where equivalent diameter M_1 of first tube portion 61 is more than $D_1/2.5$. Due to the above reason, the period efficiency of first heat exchanger 3 in which equivalent diameter M_1 of first tube portion 61 is more than $D_1/2.5$ is significantly improved, when compared with the period efficiency of the heat exchanger in PTL 1 in which equivalent diameter M_r in the heat transfer tube having inner diameter D_r is less than $D_r/2.5$.

[0032] In addition, as shown in Fig. 5, in a case where equivalent diameter M_1 of first tube portion 61 is more than or equal to $D_1/1.5$, the period efficiency of first heat exchanger 3 is not fully improved, when compared with a case where equivalent diameter M_1 of first tube portion 61 is less than $D_1/1.5$. In the case where equivalent diameter M_1 of first tube portion 61 is more than or equal to $D_1/1.5$, the pressure loss of the refrigerant in the gas-liquid two-phase state flowing through first tube portion 61 in the second state is suppressed, when compared with the case where equivalent diameter M_1 of first tube portion 61 is less than $D_1/1.5$. However, in the case where equivalent diameter M_1 of first tube portion 61 is more than or equal to $D_1/1.5$, the velocity of the refrigerant in the liquid single-phase state flowing through first tube portion 61 in the first state is not fully increased, and thus the heat exchange performance of first heat exchanger

3 in the first state is not fully significantly improved, when compared with the case where equivalent diameter M_1 of first tube portion 61 is less than $D_i/1.5$.

Due to the above reason, the period efficiency of first heat exchanger 3 in which equivalent diameter M_1 of first tube portion 61 is less than $D_i/1.5$ is significantly improved, when compared with the case where equivalent diameter M_1 of first tube portion 61 is more than or equal to $D_i/1.5$.

[0033] In addition, as shown in Fig. 6, since equivalent diameter M_1 of first tube portion 61 is more than $D_i/2.5$ in refrigeration cycle apparatus 100, the amount of refrigerant enclosed in the refrigerant circuit can be reduced, when compared with the case where equivalent diameter M_1 of first tube portion 61 is less than or equal to $D_i/2.5$. A surface area of the outer circumferential surface of first inner member 7 in the case where equivalent diameter M_1 of first tube portion 61 is more than $D_i/2.5$ is smaller than a surface area of the outer circumferential surface of first inner member 7 in the case where equivalent diameter M_1 of first tube portion 61 is less than or equal to $D_i/2.5$. Accordingly, the amount of refrigerant remaining inside first tube portion 61 in which equivalent diameter M_1 is more than $D_i/2.5$ is smaller than the amount of refrigerant remaining inside first tube portion 61 in which equivalent diameter M_1 is less than or equal to $D_i/2.5$. As a result, the amount of refrigerant enclosed in the refrigerant circuit of refrigeration cycle apparatus 100 can be reduced, when compared with that in PTL 1 in which equivalent diameter M_r in the heat transfer tube having inner diameter D_r is less than $D_r/2.5$. It should be noted that, when refrigerant and oil circulate through the refrigerant circuit of refrigeration cycle apparatus 100, the amount of oil enclosed in the refrigerant circuit can also be reduced, when compared with that in PTL 1, due to the same reason as that for the refrigerant.

[0034] In addition, in refrigeration cycle apparatus 100, only one refrigerant flow path is arranged inside first tube portion 61. When a plurality of refrigerant flow paths are arranged inside first tube portion 61, the refrigerant is distributed to the plurality of refrigerant flow paths. In this case, depending on the distribution ratio between the plurality of refrigerant flow paths, the in-tube heat transfer performance of first heat transfer tube 6 in the second state is deteriorated. Accordingly, the distribution ratio between the plurality of refrigerant flow paths should be set so as not to deteriorate the in-tube heat transfer performance of first heat transfer tube 6 in the second state in which the refrigerant in the gas-liquid two-phase state flows through first tube portion 61. In contrast, in refrigeration cycle apparatus 100, deterioration of in-tube heat transfer performance due to the distribution ratio described above is not caused.

[0035] It should be noted that, in the heat exchanger in PTL 1, a plurality of refrigerant flow paths divided by a plurality of projections are arranged, and when the heat exchanger acts as an evaporator, the refrigerant in the gas-liquid two-phase state flows around the insertion

body. However, in the heat exchanger in PTL 1, the distribution ratio of the refrigerant in the gas-liquid two-phase state is not taken into consideration. Accordingly, heat exchange performance in a case where first heat exchanger 3 acts as an evaporator is improved, when compared with that of the heat exchanger in PTL 1.

Second Embodiment

[0036] A refrigeration cycle apparatus in accordance with a second embodiment has basically the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment, and differs therefrom in that length L_1 of first inner member 7 (see Fig. 6) in the axis line direction of first tube portion 61 is defined to be less than $1/3$ of length L_2 of first heat transfer tube 6 (see Fig. 6).

[0037] When length L_1 of first inner member 7 is more than or equal to $1/3$ of length L_2 of first heat transfer tube 6, a portion in which the refrigerant in the liquid single-phase state flows in first heat transfer tube 6 can be restricted within first tube portion 61. On the other hand, in this case, the refrigerant in the gas-liquid two-phase state flows upstream of first tube portion 61 in the first state, which may increase pressure loss.

[0038] Since length L_1 of first inner member 7 is less than $1/3$ of length L_2 of first heat transfer tube 6 in the refrigeration cycle apparatus in accordance with the second embodiment, such a configuration suppresses an increase in pressure loss associated with the refrigerant in the gas-liquid two-phase state flowing through first tube portion 61 in the first state.

[0039] In addition, since the refrigeration cycle apparatus in accordance with the second embodiment has the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment except for the above configuration, it can exhibit the same effect as that of refrigeration cycle apparatus 100.

Third Embodiment

[0040] As shown in Figs. 7 to 10, a refrigeration cycle apparatus in accordance with a third embodiment has basically the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment, and differs therefrom in that it includes a first inner member 71 instead of first inner member 7. First inner member 71 differs from first inner member 7 in that a thermal expansion coefficient of a material constituting first inner member 71 is higher than a thermal expansion coefficient of the material constituting first heat transfer tube 6.

[0041] In the first state, first inner member 71 thermally expands, when compared with first heat transfer tube 6. Further, a temperature of the liquid single-phase refrigerant flowing through first tube portion 61 in the first state (hereinafter referred to as a first temperature) is higher than a temperature of the gas-liquid two-phase refrigerant

ant flowing through first tube portion 61 in the second state (hereinafter referred to as a second temperature). Accordingly, first inner member 71 in the first state thermally expands, when compared with first inner member 71 in the second state. As a result, in the refrigeration cycle apparatus in accordance with the third embodiment, flow path cross sectional area A of first tube portion 61 of first heat transfer tube 6 in the first state is smaller than flow path cross sectional area A of first tube portion 61 of first heat transfer tube 6 in the second state.

[0042] That is, both an equivalent diameter M_3 of first tube portion 61 of first heat transfer tube 6 in the first state and an equivalent diameter M_4 of first tube portion 61 of first heat transfer tube 6 in the second state satisfy the above relational expression (2) as with equivalent diameter M_1 , and equivalent diameter M_3 is smaller than equivalent diameter M_4 . That is, the refrigeration cycle apparatus in accordance with the third embodiment satisfies the following relational expression (7):

$$D_1/2.5 < M_3 < M_4 < D_1/1.5 \dots (7).$$

[0043] As described above, in the refrigeration cycle apparatus in accordance with the third embodiment, equivalent diameter M_3 of first tube portion 61 of first heat transfer tube 6 when first heat exchanger 3 acts as a condenser is smaller than equivalent diameter M_4 of first tube portion 61 of first heat transfer tube 6 when first heat exchanger 3 acts as an evaporator. Accordingly, the period efficiency of the refrigeration cycle apparatus in accordance with the third embodiment is improved, when compared with the period efficiency of refrigeration cycle apparatus 100 in accordance with the first embodiment.

[0044] For example, when first inner member 71 is designed such that equivalent diameter M_1 in the first state is equal to that of refrigeration cycle apparatus 100, equivalent diameter M_2 in the second state is smaller than that of refrigeration cycle apparatus 100. In first heat exchanger 3 including such first inner member 71, the pressure loss in first tube portion 61 in the second state is decreased, and thus heat exchange performance is improved, when compared with first heat exchanger 3 including first inner member 7.

[0045] In addition, when first inner member 71 is designed such that equivalent diameter M_4 in the second state is equal to that of refrigeration cycle apparatus 100, equivalent diameter M_1 in the first state is larger than that of refrigeration cycle apparatus 100. In first heat exchanger 3 including such first inner member 71, the velocity of the refrigerant in the liquid single-phase state in the first state is increased, and thus heat exchange performance is improved, when compared with first heat exchanger 3 including first inner member 7.

[0046] In addition, since the refrigeration cycle apparatus in accordance with the third embodiment has the same configuration as that of refrigeration cycle appara-

tus 100 in accordance with the first embodiment except for the above configuration, it can exhibit the same effect as that of refrigeration cycle apparatus 100. It should be noted that the refrigeration cycle apparatus in accordance with the third embodiment may have the same configuration as that of the refrigeration cycle apparatus in accordance with the second embodiment except for the above configuration.

10 Fourth Embodiment

[0047] As shown in Figs. 11 to 14, a refrigeration cycle apparatus in accordance with a fourth embodiment has basically the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment, and differs therefrom in that it includes a first inner member 72 instead of first inner member 7. First inner member 72 differs from first inner member 7 in that a material constituting first inner member 72 includes a shape memory alloy.

[0048] First inner member 72 is provided to be deformed between the first state and the second state. First inner member 72 is deformed such that flow path cross sectional area A of first tube portion 61 of first heat transfer tube 6 in the first state is smaller than flow path cross sectional area A of first tube portion 61 of first heat transfer tube 6 in the second state. That is, both equivalent diameter M_3 of first tube portion 61 of first heat transfer tube 6 in the first state and equivalent diameter M_4 of first tube portion 61 of first heat transfer tube 6 in the second state satisfy the above relational expression (2) as with equivalent diameter M_1 , and equivalent diameter M_3 is smaller than equivalent diameter M_4 .

[0049] The temperature of the liquid single-phase refrigerant flowing through first tube portion 61 in the first state (hereinafter referred to as the first temperature) is higher than the temperature of the gas-liquid two-phase refrigerant flowing through first tube portion 61 in the second state (hereinafter referred to as the second temperature).

[0050] The transition temperature of the shape memory alloy constituting first inner member 72 is less than or equal to the first temperature and more than the second temperature. When the temperature of first inner member 72 is less than the transition temperature, first inner member 72 is deformed under the pressure of the refrigerant in the gas-liquid two-phase state in the second state, for example. When the temperature of first inner member 72 is more than or equal to the transition temperature, first inner member 72 is restored from the deformed state.

[0051] Such a refrigeration cycle apparatus in accordance with the fourth embodiment satisfies the following relational expression (7), as with the refrigeration cycle apparatus in accordance with the third embodiment:

$$D_1/2.5 < M_3 < M_4 < D_1/1.5 \dots (7).$$

[0052] As described above, in the refrigeration cycle apparatus in accordance with the fourth embodiment, equivalent diameter M_1 of first tube portion 61 of first heat transfer tube 6 when first heat exchanger 3 acts as a condenser is smaller than equivalent diameter M_2 of first tube portion 61 of first heat transfer tube 6 when first heat exchanger 3 acts as an evaporator. Accordingly, the period efficiency of the refrigeration cycle apparatus in accordance with the fourth embodiment is improved, when compared with the period efficiency of refrigeration cycle apparatus 100 in accordance with the first embodiment.

[0053] For example, when first inner member 72 is designed such that equivalent diameter M_1 in the first state is equal to that of refrigeration cycle apparatus 100, equivalent diameter M_2 in the second state is smaller than that of refrigeration cycle apparatus 100. In first heat exchanger 3 including such first inner member 72, the pressure loss in first tube portion 61 in the second state is decreased, and thus heat exchange performance is improved, when compared with first heat exchanger 3 including first inner member 7.

[0054] In addition, when first inner member 72 is designed such that equivalent diameter M_2 in the second state is equal to that of refrigeration cycle apparatus 100, equivalent diameter M_1 in the first state is larger than that of refrigeration cycle apparatus 100. In first heat exchanger 3 including such first inner member 72, the velocity of the refrigerant in the liquid single-phase state in the first state is increased, and thus heat exchange performance is improved, when compared with first heat exchanger 3 including first inner member 7.

[0055] In addition, since the refrigeration cycle apparatus in accordance with the fourth embodiment has the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment except for the above configuration, it can exhibit the same effect as that of refrigeration cycle apparatus 100. It should be noted that the refrigeration cycle apparatus in accordance with the fourth embodiment may have the same configuration as that of the refrigeration cycle apparatus in accordance with the second embodiment except for the above configuration.

Fifth Embodiment

[0056] As shown in Figs. 15 and 16, a refrigeration cycle apparatus in accordance with a fifth embodiment has basically the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment, and differs therefrom in that it includes a first inner member 73 instead of first inner member 7. First inner member 73 differs from first inner member 7 in that a specific heat of a material constituting first inner member 73 is higher than a specific heat of the material consti-

tuting first heat transfer tube 6.

[0057] The material constituting first inner member 73 includes aluminum (Al), for example. A heat capacity of first inner member 73 is larger than a heat capacity of first tube portion 61, for example. First inner member 73 may be constituted of a single material, or may be constituted of a plurality of materials. The material constituting first inner member 73 may include a material having a specific heat equal to that of the material constituting first heat transfer tube 6, and a material having a specific heat higher than that of that material. The material constituting first inner member 73 may include copper (Cu), and any material having a specific heat higher than that of Cu, for example. In addition, first inner member 73 may be constituted by an external member provided with an internal space partitioned from the outside, and a filling member which fills the internal space. In this case, a material constituting the external member includes Cu, and a material constituting the filling member may include any material having a specific heat higher than that of Cu, for example, at least one of oil and water.

[0058] As shown in Figs. 17, 18(a) and 18(b), the refrigeration cycle apparatus in accordance with the fifth embodiment is provided such that it can perform intermittent operation in the first state. The intermittent operation is operation that alternately switches between a state where compressor 1 is driven and a state where compressor 1 is stopped. In the following, an example of a control flow for the intermittent operation in the first state is described, taking a case where the refrigeration cycle apparatus performs heating operation as the first state, as an example.

[0059] When the intermittent operation is started in the refrigeration cycle apparatus in accordance with the fifth embodiment, compressor 1 is driven and the first state is maintained until the indoor temperature becomes equal to or higher than a target set temperature, for example. Thereafter, when it is confirmed that the indoor temperature becomes equal to or higher than the target set temperature, compressor 1 is stopped, and circulation of the refrigerant through the refrigerant circuit is also stopped. On this occasion, when a heat medium that exchanges heat with the refrigerant in first heat exchanger 3 is air or the like, a fan for supplying the air to first heat exchanger 3 is driven continuously. In addition, when the heat medium is a brine or the like, a pump for supplying the brine to first heat exchanger 3 is driven continuously. Stop time of compressor 1 is counted. The fan or the pump is driven until the stop time of compressor 1 becomes equal to or longer than a set time. Thereafter, when it is confirmed that the stop time of compressor 1 becomes equal to or longer than the set time, the fan or the pump is stopped. Thereafter, when it is confirmed that the indoor temperature becomes lower than the target set temperature, driving of compressor 1 and the fan or the pump is resumed.

[0060] When such intermittent operation is performed, the frequency of compressor 1 is controlled as shown in

Fig. 18(a). In addition, as a result of such intermittent operation, the indoor temperature changes as shown in Fig. 18(b). In Figs. 18(a) and 18(b), a line segment D indicates the state of the intermittent operation in the refrigeration cycle apparatus in accordance with the fifth embodiment, and a line segment E indicates the state of the intermittent operation in a conventional refrigeration cycle apparatus in which driving of a compressor and a fan or a pump is stopped simultaneously when it is confirmed that the indoor temperature becomes equal to or higher than the target set temperature.

[0061] As shown in Figs. 18(a) and 18(b), in the refrigeration cycle apparatus in accordance with the fifth embodiment, although the number of times of operation of compressor 1 is reduced, a decrease in the indoor temperature is suppressed, when compared with the conventional refrigeration cycle apparatus. In the conventional refrigeration cycle apparatus, the amount of heat of a heat transfer tube of an indoor heat exchanger and the amount of heat of refrigerant remaining inside the heat transfer tube as the driving of the compressor is stopped are lost relatively quickly, due to heat exchange with a heat medium existing outside the heat transfer tube. As a result, the indoor temperature after the driving of the compressor is stopped decreases relatively quickly to lower than the target set temperature.

[0062] In contrast, in the refrigeration cycle apparatus in accordance with the fifth embodiment, while compressor 1 is driven, a portion of the amount of heat of the refrigerant flowing through first tube portion 61 is accumulated in first inner member 73. Accordingly, even when the driving of compressor 1 is stopped, first heat transfer tube 6 and the refrigerant remaining inside first heat transfer tube 6 can receive supply of the amount of heat from first inner member 73. Thereby, in the refrigeration cycle apparatus in accordance with the fifth embodiment, a decrease in the indoor temperature during the intermittent operation proceeds slowly, and thus comfortableness during the intermittent operation is improved, when compared with the conventional refrigeration cycle apparatus.

[0063] Further, in the refrigeration cycle apparatus in accordance with the fifth embodiment, the stop time of compressor 1 can be increased, and thus the number of times of driving of compressor 1 within a predetermined time can be reduced, when compared with the conventional refrigeration cycle apparatus. As a result, the refrigeration cycle apparatus in accordance with the fifth embodiment can reduce power consumption, and further can reduce load on compressor 1, and thus has a high reliability, when compared with the conventional refrigeration cycle apparatus.

[0064] In addition, since the refrigeration cycle apparatus in accordance with the fifth embodiment has the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment except for the above configuration, it can exhibit the same effect as that of refrigeration cycle apparatus 100. It should be

noted that the refrigeration cycle apparatus in accordance with the fifth embodiment may have the same configuration as that of any of the refrigeration cycle apparatuses in accordance with the second to fourth embodiments except for the above configuration.

Sixth Embodiment

[0065] As shown in Figs. 19 and 20, a refrigeration cycle apparatus in accordance with a sixth embodiment has basically the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment, and differs therefrom in that first tube portion 61 has a plurality of protrusions 64 protruding with respect to inner circumferential surface 6C that faces outer circumferential surface 7D of first inner member 7.

[0066] The plurality of protrusions 64 extend along the axis line direction. Each of the plurality of protrusions 64 has a fifth end portion 64A located closer to first end portion 6A, and a sixth end portion 64B located closer to second end portion 6B, in the axis line direction. Sixth end portion 64B and fourth end portion 7B of first inner member 7 are arranged on the same cross section perpendicular to the axis line direction.

[0067] The plurality of protrusions 64 are arranged to be spaced from each other in a circumferential direction with respect to the axis line direction. The number of protrusions 64 arranged to be spaced from each other in the circumferential direction may be any number that is two or more, and is five, for example. Each of the plurality of protrusions 64 has a mutually equal configuration, for example. The plurality of protrusions 64 are fixed to first tube portion 61. A material constituting the plurality of protrusions 64 may be any material. For example, it is a material having a corrosion resistance with respect to the refrigerant which is equal to that of the material constituting first heat transfer tube 6, and includes at least one selected from the group consisting of copper (Cu), rubber, and plastic, for example.

[0068] The plurality of protrusions 64 are in contact with outer circumferential surface 7D of first inner member 7. The plurality of protrusions 64 are provided to maintain a state where outer circumferential surface 7D and inner circumferential surface 6C of first tube portion 61 are arranged with a space therebetween. The plurality of protrusions 64 are provided such that first tube portion 61 and first inner member 7 are coaxially arranged. In other words, the plurality of protrusions 64 are provided such that an axis line of first tube portion 61 matches an axis line of first inner member 7. Positional deviation of first inner member 7 with respect to first tube portion 61 in a direction perpendicular to the axis line direction is suppressed by the plurality of protrusions 64. Positional deviation of first inner member 7 with respect to first tube portion 61 in the axis line direction, for example, is also suppressed by the plurality of protrusions 64.

[0069] In order to suppress a decrease in the heat exchange performance of first heat exchanger 3 associated

with the refrigerant in the gas-liquid two-phase state flowing through first tube portion 61 in the second state being distributed by the plurality of protrusions 64, the distribution ratio of the refrigerant in the gas-liquid two-phase state distributed by the plurality of protrusions 64 is designed as appropriate.

[0070] A cross sectional area perpendicular to the axis line direction of the plurality of protrusions 64, that is, a total value of cross sectional areas perpendicular to the axis line direction of respective protrusions 64, is less than a cross sectional area perpendicular to the axis line direction of first inner member 7.

[0071] Such a refrigeration cycle apparatus in accordance with the sixth embodiment satisfies the above relational expression (2), as with the refrigeration cycle apparatus in accordance with the first embodiment. It should be noted that, when comparison is made between first tube portion 61 in accordance with the sixth embodiment and first tube portion 61 in accordance with the first embodiment having equal inner diameter D_1 and including first inner member 7 having an equal configuration, flow path cross sectional area A of first tube portion 61 in accordance with the sixth embodiment is smaller than flow path cross sectional area A of first tube portion 61 in accordance with the first embodiment, and thus equivalent diameter M_1 of first tube portion 61 in accordance with the sixth embodiment is smaller than equivalent diameter M_1 of first tube portion 61 in accordance with the first embodiment.

[0072] In the refrigeration cycle apparatus in accordance with the sixth embodiment, since the plurality of protrusions 64 maintain the state where outer circumferential surface 7D and inner circumferential surface 6C of first tube portion 61 are arranged with a space therebetween, vibration of first inner member 7 due to pulsation of the refrigerant is suppressed. As a result, in the refrigeration cycle apparatus in accordance with the sixth embodiment, occurrence of noise associated with the vibration of first inner member 7 is suppressed, and comfortableness is improved, when compared with refrigeration cycle apparatus 100 in accordance with the first embodiment.

[0073] In addition, since the plurality of protrusions 64 prevent contact between outer circumferential surface 7D of first inner member 7 and inner circumferential surface 6C of first tube portion 61, a decrease in heat transfer area in inner circumferential surface 6C of first tube portion 61 is suppressed.

[0074] In addition, since the refrigeration cycle apparatus in accordance with the sixth embodiment has the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment except for the above configuration, it can exhibit the same effect as that of refrigeration cycle apparatus 100. It should be noted that the refrigeration cycle apparatus in accordance with the sixth embodiment may have the same configuration as that of any of the refrigeration cycle apparatuses in accordance with the second to fifth embodi-

ments except for the above configuration.

[0075] As shown in Figs. 19 and 20, inner circumferential surface 6C of first tube portion 61 may be provided with a plurality of groove portions. The plurality of groove portions are arranged to be spaced from each other in the circumferential direction. Between two groove portions adjacent in the circumferential direction, each of a plurality of minute protrusions 65 or the plurality of protrusions 64 provided to protrude with respect to bottom portions of the groove portions is arranged. That is, each protrusion 64 is arranged between two groove portions adjacent in the circumferential direction. In a cross section perpendicular to the axis line direction, a tip of each minute protrusion 65 has an intersection at which two curved surfaces intersect to form an acute angle therebetween, for example. The height of each protrusion 64 with respect to inner circumferential surface 6C is higher than the height of each minute protrusion 65 with respect to inner circumferential surface 6C. The number of minute protrusions 65 arranged to be spaced from each other in the circumferential direction may be any number that is two or more, and is more than the number of the plurality of protrusions 64, for example. Each of the plurality of minute protrusions 65 has a mutually equal configuration, for example.

[0076] In a case where first tube portion 61 is provided with the plurality of minute protrusions 65 as described above, the heat transfer area in inner circumferential surface 6C of first tube portion 61 is increased, and thus the heat exchange performance of first heat exchanger 3 is improved, when compared with a case where first tube portion 61 is not provided with the plurality of minute protrusions 65.

Seventh Embodiment

[0077] As shown in Figs. 21 and 22, a refrigeration cycle apparatus in accordance with a seventh embodiment has basically the same configuration as that of the refrigeration cycle apparatus in accordance with the sixth embodiment, and differs therefrom in that the plurality of protrusions 64 are arranged to be spaced from each other in the axis line direction. That is, the plurality of protrusions 64 are arranged to be spaced from each other in the circumferential direction with respect to the axis line direction, and are also arranged to be spaced from each other in the axis line direction.

[0078] The number of protrusions 64 arranged to be spaced from each other in the axis line direction may be any number that is two or more, and is three, for example. Each of the plurality of protrusions 64 has a mutually equal configuration, for example.

[0079] Such a refrigeration cycle apparatus in accordance with the seventh embodiment satisfies the above relational expression (2), as with the refrigeration cycle apparatus in accordance with the first embodiment.

[0080] In the refrigeration cycle apparatus in accordance with the seventh embodiment, since the plurality of

protrusions 64 are arranged to be spaced from each other in the axis line direction, occurrence of pressure loss resulting from the plurality of protrusions 64 is suppressed, when compared with the refrigeration cycle apparatus in accordance with the sixth embodiment. As a result, in the refrigeration cycle apparatus in accordance with the seventh embodiment, the heat exchange performance of first heat exchanger 3 in the second state is improved, and period efficiency is improved, when compared with the refrigeration cycle apparatus in accordance with the sixth embodiment.

[0081] In addition, since the refrigeration cycle apparatus in accordance with the seventh embodiment has the same configuration as that of refrigeration cycle apparatus 100 in accordance with the first embodiment except for the above configuration, it can exhibit the same effect as that of refrigeration cycle apparatus 100. It should be noted that the refrigeration cycle apparatus in accordance with the seventh embodiment may have the same configuration as that of any of the refrigeration cycle apparatuses in accordance with the second to fifth embodiments except for the above configuration.

<Variation>

[0082] Although first heat exchanger 3 includes first inner member 7, 71, 72, or 73 in the refrigeration cycle apparatuses in accordance with the first to seventh embodiments, second heat exchanger 4 may also include a second inner member having the same configuration as that of any of first inner members 7, 71, 72, and 73. It should be noted that Fig. 23 shows a configuration in which second heat exchanger 4 includes a second inner member 9 having the same configuration as that of first inner member 7.

[0083] As shown in Figs. 23 and 24, second heat exchanger 4 has a plurality of second heat transfer tubes 8 having the same configuration as that of first heat transfer tubes 6 of first heat exchanger 3. Each of second heat transfer tubes 8 can be divided into a fifth tube portion 83 located upstream of an intermediate position of second heat transfer tube 8 in flowing direction F2 of the refrigerant in the second state, a sixth tube portion 82 including the intermediate position of second heat transfer tube 8 and located downstream of fifth tube portion 83 in direction F2, and a second tube portion 81 located downstream of sixth tube portion 82 in direction F2. Second tube portion 81 of the second heat transfer tube is a portion located downstream of the intermediate position of second heat transfer tube 8 in flowing direction F2 of the refrigerant when second heat exchanger 4 acts as a condenser. Second tube portion 81 of the second heat transfer tube corresponds to first tube portion 61 of first heat transfer tube 6, sixth tube portion 82 of second heat transfer tube 8 corresponds to fourth tube portion 62 of first heat transfer tube 6, and fifth tube portion 83 of second heat transfer tube 8 corresponds to third tube portion 63 of first heat transfer tube 6. Second tube portion 81

of second heat transfer tube 8 includes a portion through which the liquid phase refrigerant flows when the refrigeration cycle apparatus is in the second state. Second tube portion 81 of second heat transfer tube 8 includes a portion through which for example the gas-liquid two-phase refrigerant flows when the refrigeration cycle apparatus is in the first state.

[0084] When second heat exchanger 4 includes a plurality of second inner members 9, each second inner member 9 is arranged inside second tube portion 81 of each second heat transfer tube 8. In this case, an equivalent diameter M_2 of second tube portion 81 of second heat transfer tube 8 is calculated from the following relational expression (3), as with equivalent diameter M_1 of first tube portion 61 of first heat transfer tube 6:

$$M_2 = 4 \times A_2 / S_2 \dots (3),$$

where A_2 is a flow path cross sectional area of second tube portion 81, and S_2 is a wetted perimeter of second tube portion 81.

[0085] Further, equivalent diameter M_2 and an inner diameter D_2 of second tube portion 81 satisfy the following relational expression (4) in the first state and the second state:

$$D_2 / 2.5 < M_2 < D_2 / 1.5 \dots (4).$$

[0086] In addition, the heat exchange performance of such second heat exchanger 4 in the second state is indicated by line segment A in Fig. 5, the heat exchange performance of second heat exchanger 4 in the first state is indicated by line segment B in Fig. 5, and the period efficiency of second heat exchanger 4 is indicated by line segment C in Fig. 5.

[0087] Accordingly, the in-tube heat transfer performance of second tube portion 81 of second heat transfer tube 8 in the second state is higher than that in a case where second inner member 9 is not arranged. In addition, the period efficiency of second heat exchanger 4 as described above is higher than the period efficiency of a heat exchanger provided with an insertion body which does not satisfy the above relational expression (4). In addition, the second inner member may have the same configuration as that of first inner member 71, 72, or 73.

[0088] In addition, first inner member 7, 71, 72, or 73 may be arranged inside at least one first tube portion 61 of the plurality of first heat transfer tubes 6 of first heat exchanger 3. Second inner member 9 may be arranged inside at least one second tube portion 81 of the plurality of second heat transfer tubes 8 of second heat exchanger 4.

[0089] Although the embodiments of the present invention have been described above, it is also possible to modify the embodiments described above in various

manners. In addition, the scope of the present invention is not limited to the embodiments described above. The scope of the present invention is defined by the scope of the claims, and is intended to include any modifications within the scope and meaning equivalent to the scope of the claims.

REFERENCE SIGNS LIST

[0090] 1: compressor; 2: four-way valve; 3: first heat exchanger; 4: second heat exchanger; 5: decompression unit; 6: first heat transfer tube; 6A: first end portion; 6B: second end portion; 6C: inner circumferential surface; 6D, 7D: outer circumferential surface; 7, 71, 72, 73: first inner member; 7A: third end portion; 7B: fourth end portion; 8: second heat transfer tube; 9: second inner member; 30: heat exchange unit; 31, 32: distributor; 61: first tube portion; 62: fourth tube portion; 63: third tube portion; 64: protrusion; 64A: fifth end portion; 64B: sixth end portion; 65: minute protrusion; 81: second tube portion; 82: sixth tube portion; 83: fifth tube portion; 100: refrigeration cycle apparatus.

Claims

1. A refrigeration cycle apparatus comprising a refrigerant circuit which includes a compressor, a flow path switching valve, a first heat exchanger, a second heat exchanger, and a decompression unit, and through which refrigerant circulates, the refrigerant circuit being provided to be switchable between a first state in which the first heat exchanger acts as a condenser and the second heat exchanger acts as an evaporator and a second state in which the second heat exchanger acts as a condenser and the first heat exchanger acts as an evaporator, the first heat exchanger including a first heat transfer tube inside which the refrigerant flows, the first heat transfer tube having a first tube portion located downstream of an intermediate position of the first heat transfer tube in a flowing direction of the refrigerant in the first state, the first heat exchanger further including a first inner member arranged inside the first tube portion, in the first state and the second state, an equivalent diameter M_1 calculated from a following relational expression (1) and an inner diameter D_1 of the first tube portion satisfying a following relational expression (2):

$$M_1 = 4 \times A_1/S_1 \dots (1);$$

and

$$D_1/2.5 < M_1 < D_1/1.5 \dots (2),$$

where A_1 is a flow path cross sectional area of the first tube portion, and S_1 is a wetted perimeter of the first tube portion.

2. The refrigeration cycle apparatus according to claim 1, wherein a length of the first inner member in an axis line direction of the first tube portion is less than 1/3 of a length of the first heat transfer tube.
3. The refrigeration cycle apparatus according to claim 1 or 2, wherein a thermal expansion coefficient of a material constituting the first inner member is higher than a thermal expansion coefficient of a material constituting the first heat transfer tube, and the equivalent diameter in the first state is smaller than the equivalent diameter in the second state.
4. The refrigeration cycle apparatus according to claim 1 or 2, wherein a material constituting the first inner member includes a shape memory alloy, and the equivalent diameter when the first heat exchanger acts as the condenser is smaller than the equivalent diameter in the second state.
5. The refrigeration cycle apparatus according to any one of claims 1 to 4, wherein a specific heat of a material constituting the first inner member is higher than a specific heat of a material constituting the first heat transfer tube.
6. The refrigeration cycle apparatus according to any one of claims 1 to 5, wherein the first tube portion has a plurality of protrusions protruding with respect to an inner circumferential surface that faces an outer circumferential surface of the first inner member, and the plurality of protrusions are in contact with the outer circumferential surface.
7. The refrigeration cycle apparatus according to claim 6, wherein the plurality of protrusions are arranged to be spaced from each other in a circumferential direction with respect to an axis line of the first tube portion.
8. The refrigeration cycle apparatus according to any one of claims 1 to 7, wherein the second heat exchanger includes a second heat transfer tube inside which the refrigerant flows, the second heat transfer tube has a second tube

portion located downstream of an intermediate position of the second heat transfer tube in a flowing direction of the refrigerant in the second state, the second heat exchanger further includes a second inner member arranged inside the second tube portion of the second heat transfer tube, in the first state and the second state, an inner diameter D_2 of the second tube portion and an equivalent diameter M_2 calculated from a following relational expression (3) satisfy a following relational expression (4):

$$M_2 = 4 \times A_2 / S_2 \dots (3);$$

and

$$D_2 / 2.5 < M_2 < D_2 / 1.5 \dots (4),$$

where A_2 is a flow path cross sectional area of the second tube portion, and S_2 is a wetted perimeter of the second tube portion.

FIG. 1

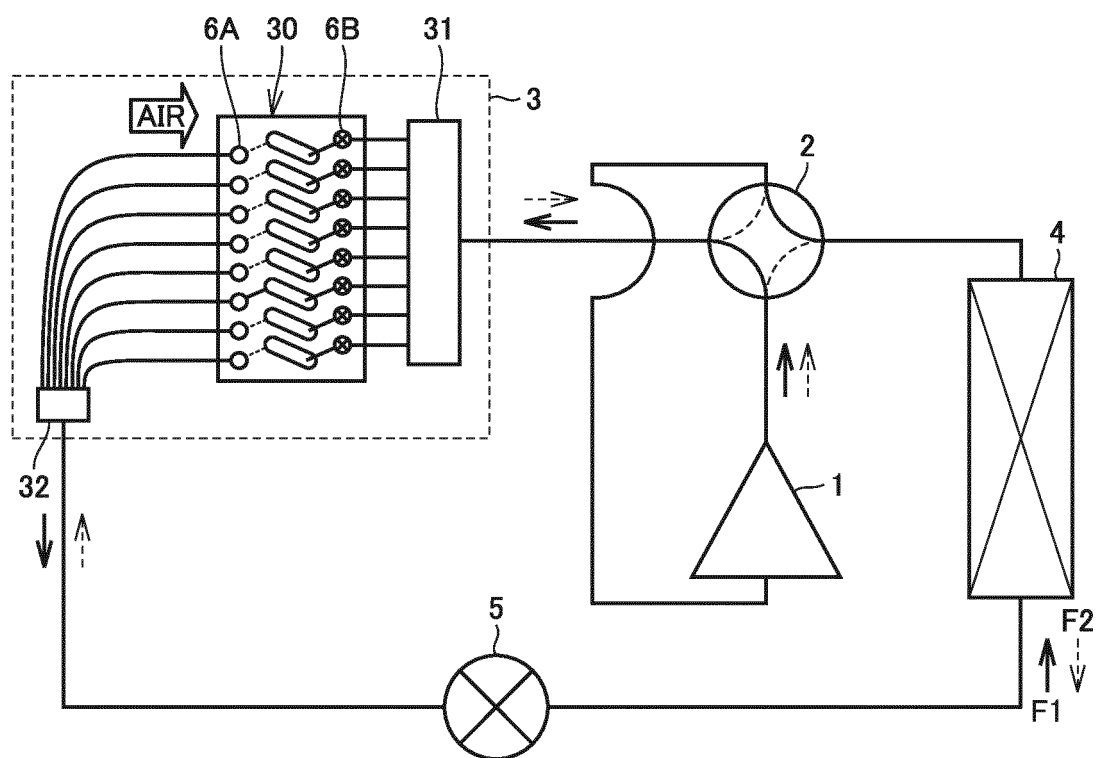


FIG.2

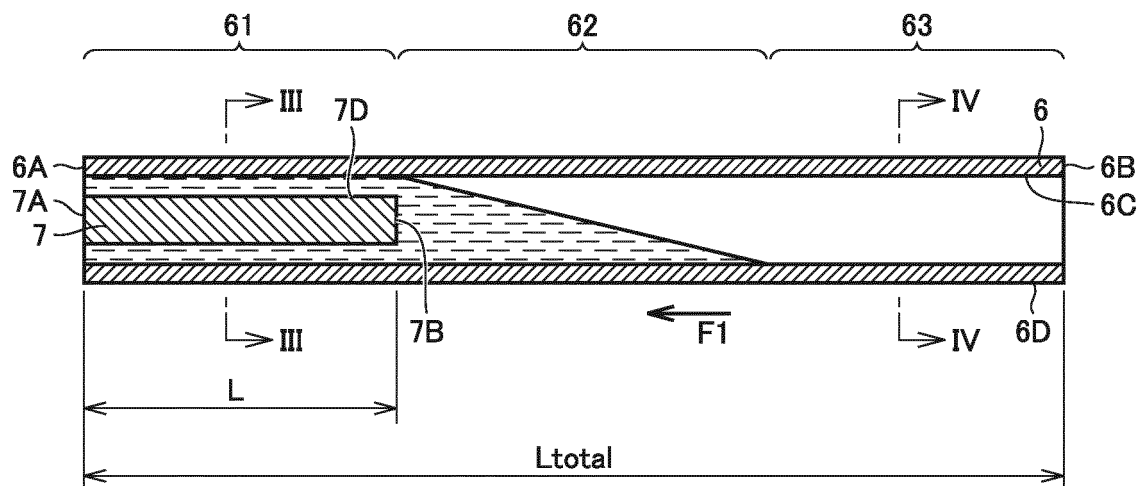


FIG.3

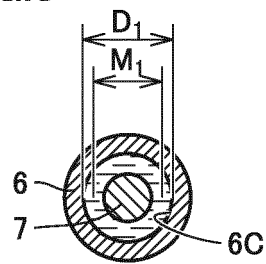


FIG.4

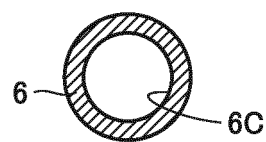


FIG.5

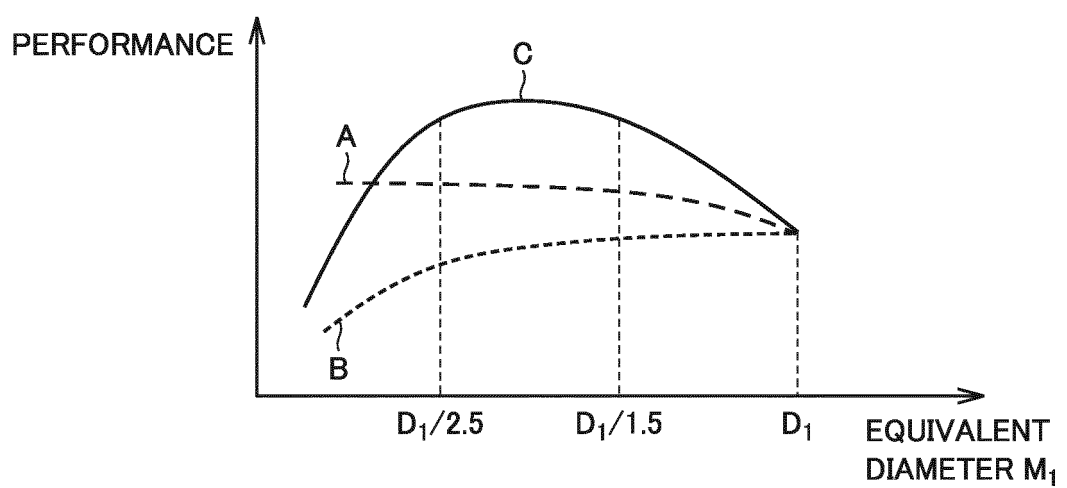


FIG.6

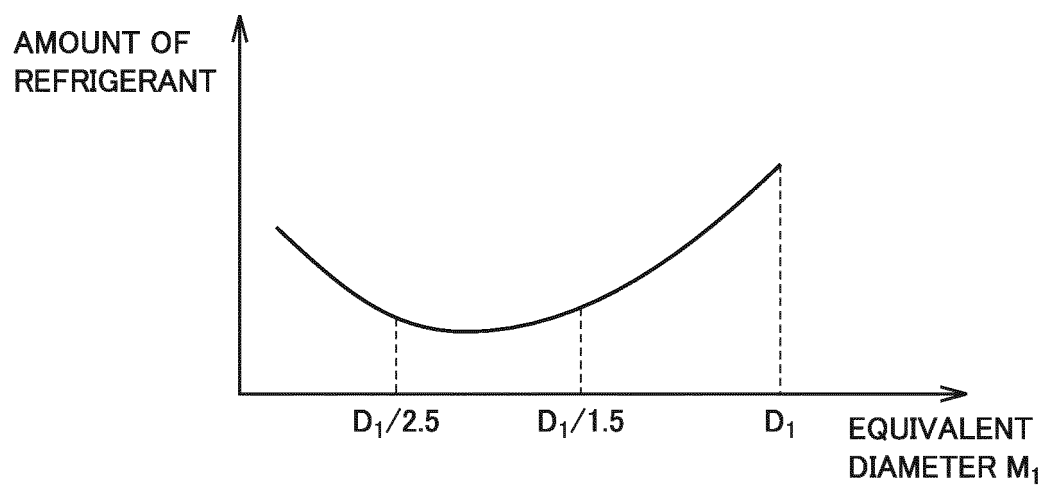


FIG.7

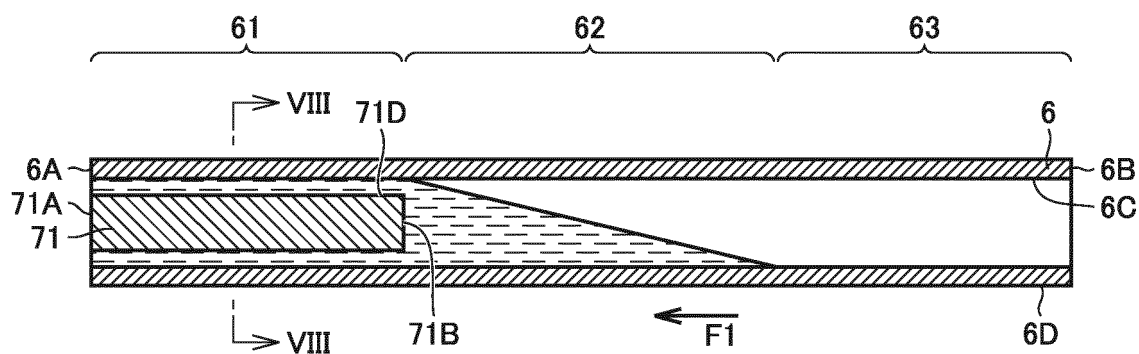


FIG.8

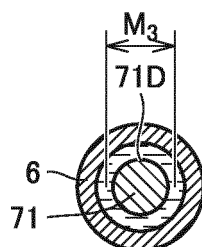


FIG.9

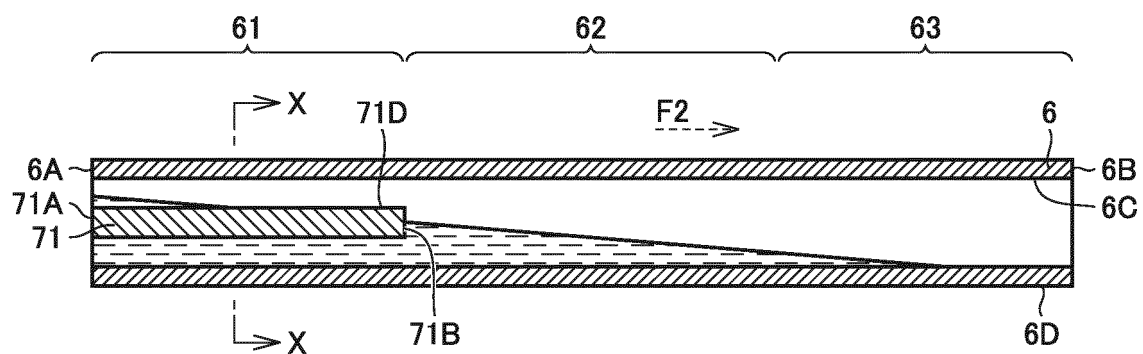


FIG.10

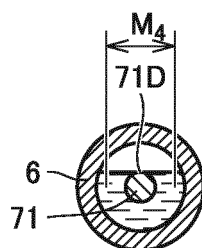


FIG.11

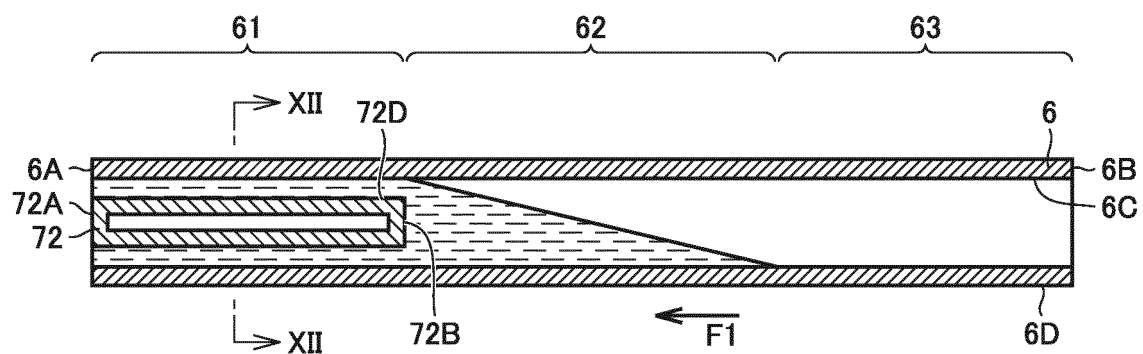


FIG.12

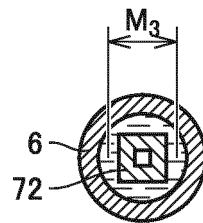


FIG.13

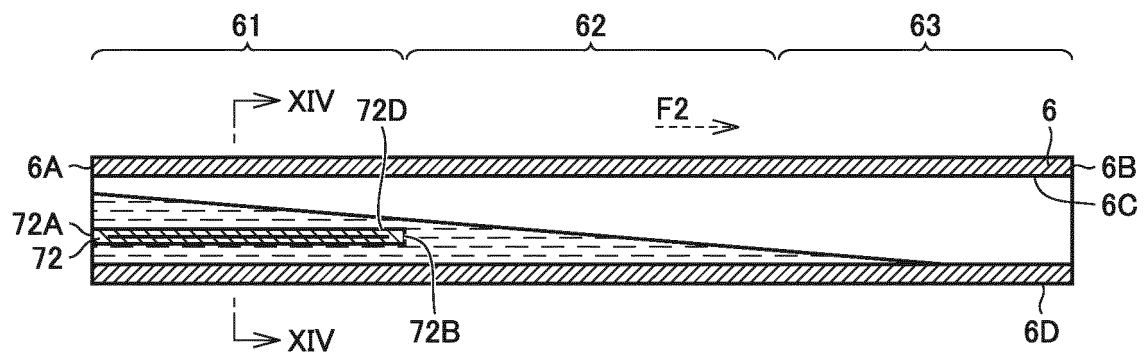


FIG.14

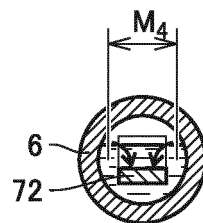


FIG.15

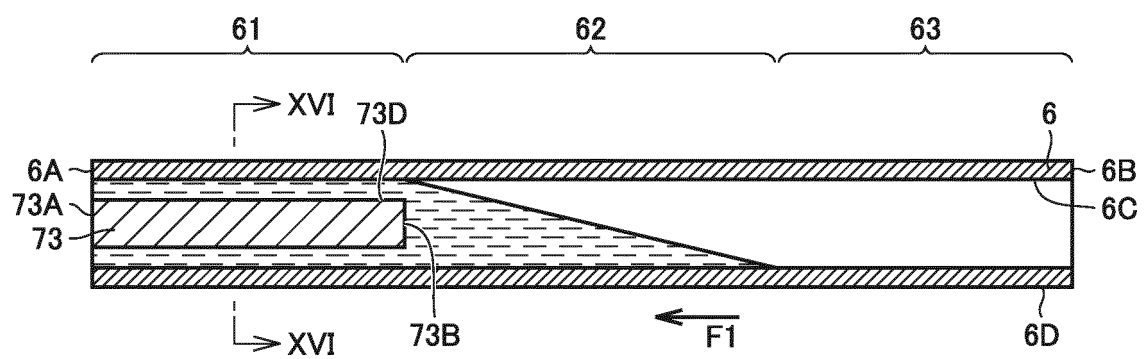


FIG.16

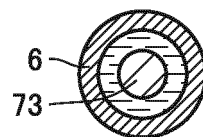


FIG.17

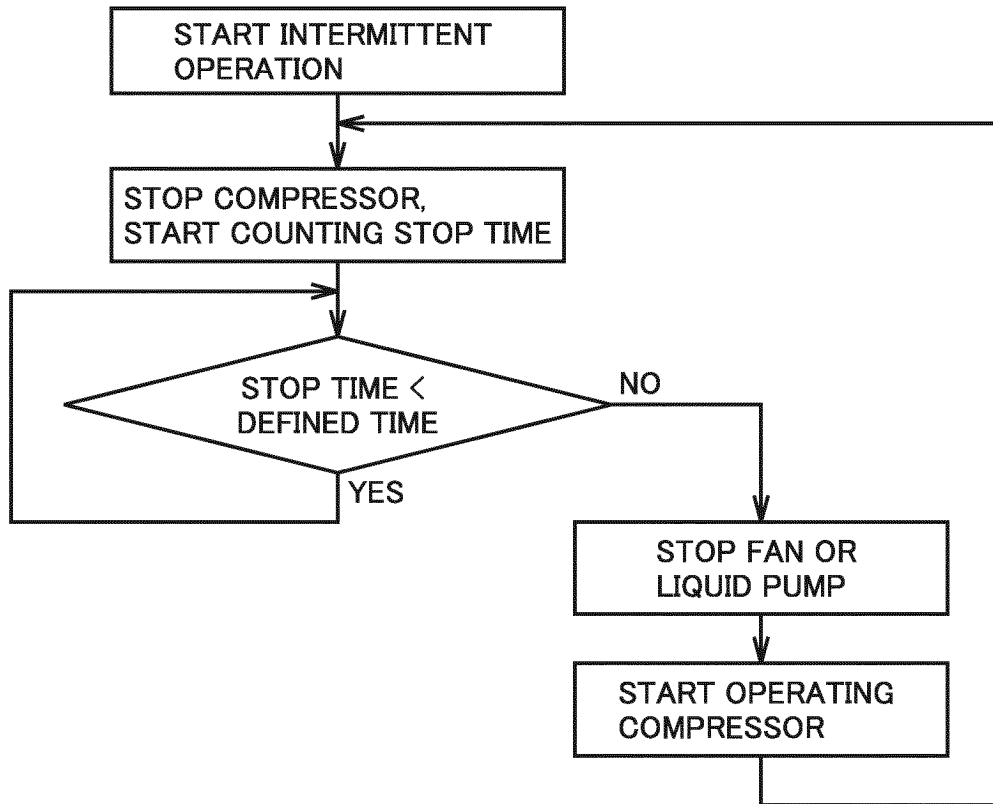


FIG.18

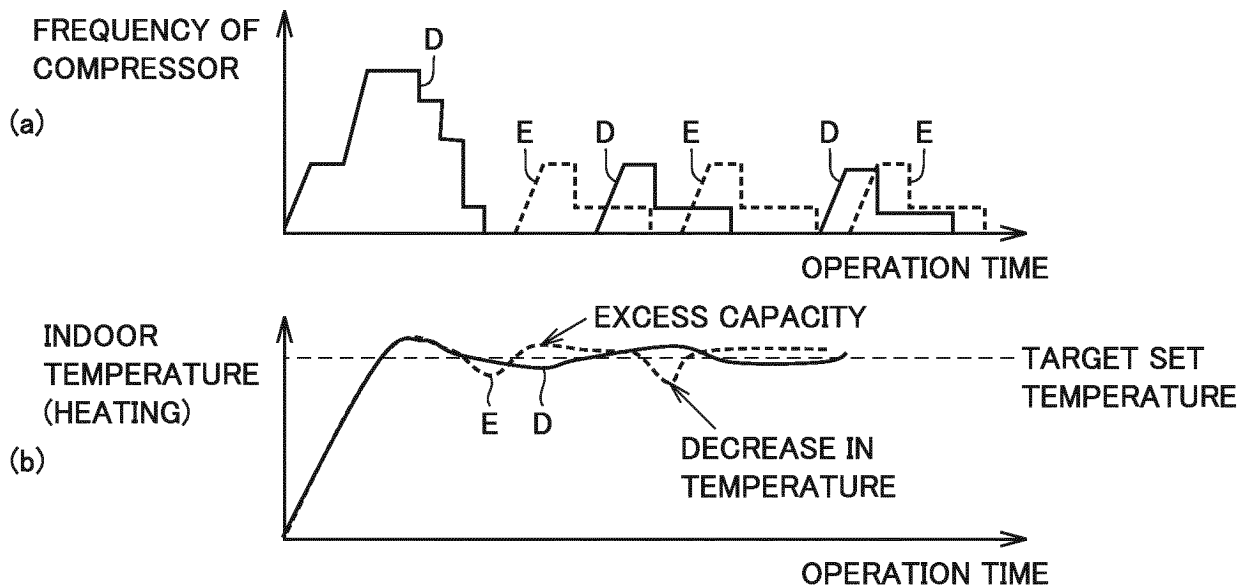


FIG.19

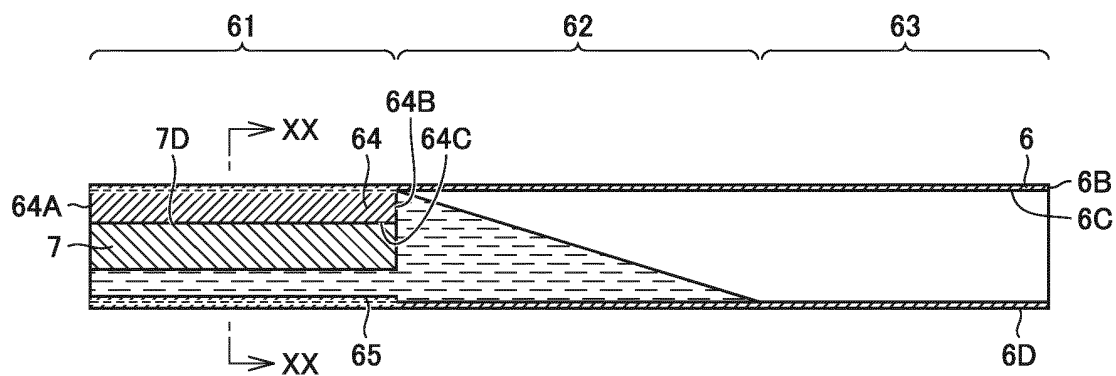


FIG.20

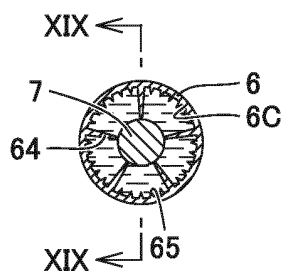


FIG.21

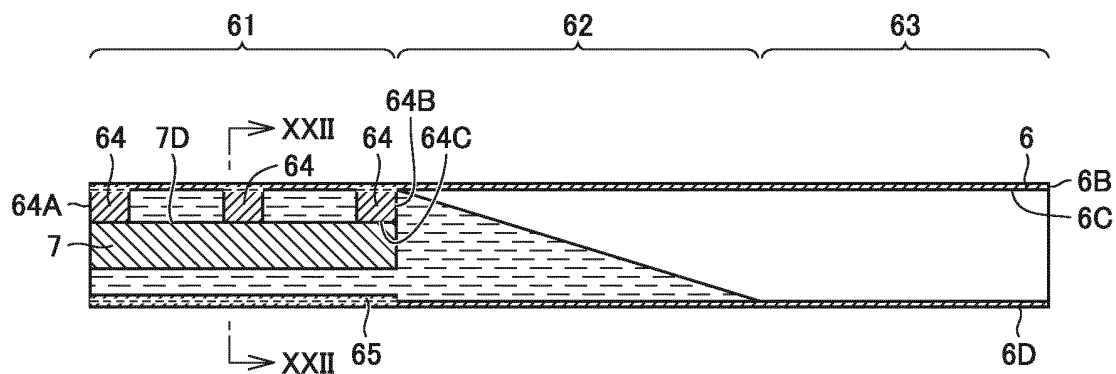


FIG.22

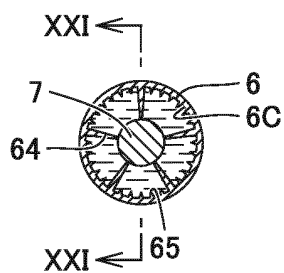


FIG.23

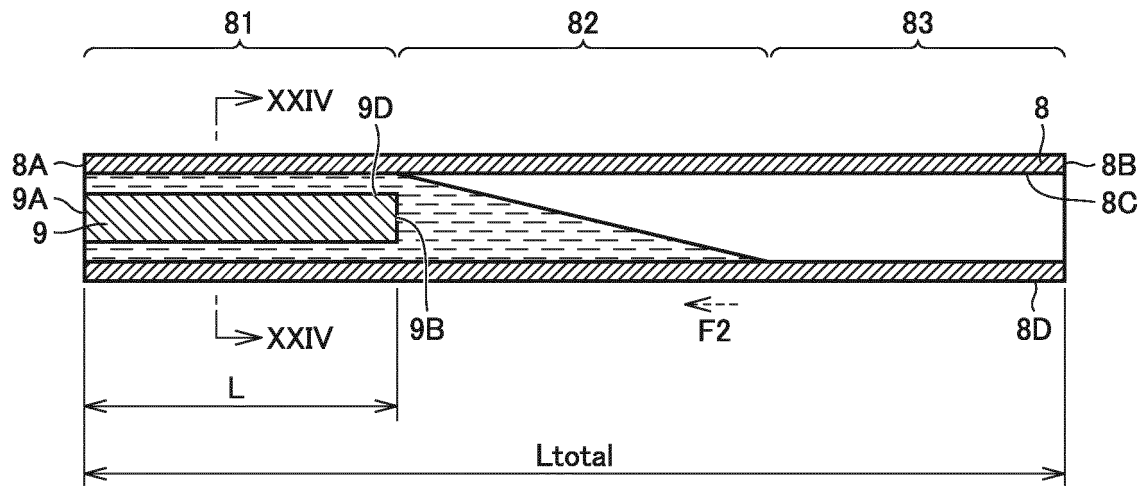
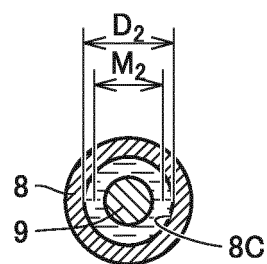


FIG.24



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/018766

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F25B39/04 (2006.01) i, F25B13/00 (2006.01) i, F28F1/40 (2006.01) i,
F28F13/05 (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)

Int. Cl. F25B39/04, F25B13/00, F28F1/40, F28F13/08

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 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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 A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 099298/1974 (Laid-open No. 027361/1976) (TOKYO SHIBAURA ELECTRIC CO., LTD.) 27 February 1976, description, page 2, line 11 to page 3, line 15, fig. 1-5 (Family: none)	1-3, 5-8 4
Y A	JP 2000-039283 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 08 February 2000, paragraphs [0001], [0015]-[0019], fig. 1 & US 2001/0003309 A1, paragraphs [0001], [0089]-[0097], fig. 1	1-3, 5-8 4



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

"I"

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
26.07.2018

Date of mailing of the international search report
07.08.2018

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/018766

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 11-257800 A (SANYO ELECTRIC CO., LTD.) 24 September 1999, paragraphs [0031]-[0038], fig. 1 (Family: none)	1-3, 5-8
Y	JP 2007-024419 A (MITSUBISHI ELECTRIC CORP.) 01 February 2007, paragraphs [0012], [0013], fig. 2 (Family: none)	1-3, 5-8
Y	JP 2000-055509 A (TOSHIBA CORP.) 25 February 2000, paragraph [0025], fig. 14 (Family: none)	3, 5
Y	JP 2004-279025 A (SUMITOMO LIGHT METAL INDUSTRIES, LTD.) 07 October 2004, paragraphs [0002], [0024], fig. 1 (Family: none)	3, 5
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 006256/1983 (Laid-open No. 113681/1984) (MITSUBISHI HEAVY INDUSTRIES, LTD.) 01 August 1984, description, page 2, lines 8-16, fig. 1 (Family: none)	6-7
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 165207/1984 (Laid-open No. 081573/1986) (TOSHIBA CORP.) 30 May 1986, description, page 2, line 17 to page 3, line 5, fig. 13, 14 (Family: none)	6-7
A	JP 2011-106770 A (PANASONIC CORP.) 02 June 2011, entire text, all drawings (Family: none)	1-8
A	JP 2006-052864 A (TOSHIBA CARRIER CORP.) 23 February 2006, entire text, all drawings (Family: none)	1-8
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 193095/1986 (Laid-open No. 104878/1988) (ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.) 07 July 1988, entire text, all drawings (Family: none)	1-8

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/018766
--

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 59-077273 A (HITACHI, LTD.) 02 May 1984, entire text, all drawings (Family: none)	1-8

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2000055509 A [0004] [0005]