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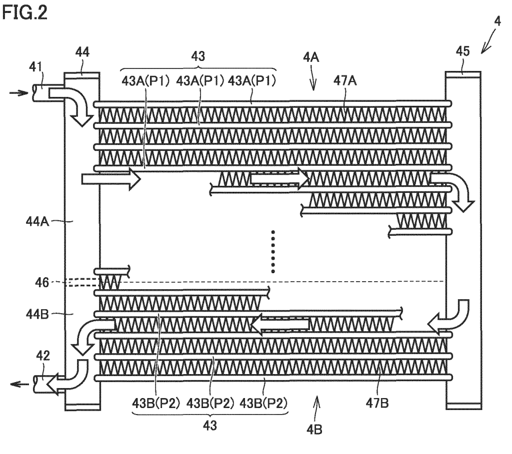
(54) REFRIGERATION CYCLE DEVICE

(57) The refrigeration cycle apparatus (100) includes a refrigerant circuit (10) which includes a compressor (1), a condenser (2), a supercooler (4), an expansion valve (5), and an evaporator (6), and circulates refrigerant in the order of the compressor, the condenser, the supercooler, the expansion valve, and the evaporator. The supercooler includes a plurality of refrigerant flow paths through which the refrigerant flows. The plurality of refrigerant flow paths includes a plurality of first refrigerant flow paths (P1) disposed at the most upstream side of the refrigerant circuit among the plurality of refrigerant flow paths, and a plurality of second refrigerant flow paths (P2) through which the refrigerant that has flowed through each of the plurality of first refrigerant flow paths flows. The total flow path cross-sectional area of the plurality of first refrigerant flow paths is greater than the total flow path cross-sectional area of the plurality of second refrigerant flow paths.

FIG.2



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND ART

[0002] There is known a refrigeration cycle apparatus which includes a supercooler for supercooling refrigerant condensed in a condenser (for example, see Japanese Patent Laying-Open No. 2018-091502 (PTL 1)). The supercooler includes a plurality of refrigerant flow paths through which the refrigerant flows. In the supercooler, the refrigerant flowing inside the plurality of refrigerant flow paths is supercooled by heat exchange with a heat medium (a cold source) flowing outside the plurality of refrigerant flow paths.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 2018-091502

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] As the refrigerant flows through the supercooler, a saturation temperature of the refrigerant decreases due to a pressure loss of the refrigerant. As a result, when the degree of supercooling of the refrigerant flowing into the supercooler is small, the refrigerant is converted into gas-liquid two-phase refrigerant as it flows through the supercooler.

[0005] Since the pressure loss of the gas-liquid two-phase refrigerant is greater than the pressure loss of the liquid-phase refrigerant, the saturation temperature of the gas-liquid two-phase refrigerant is likely to decrease lower than the saturation temperature of the liquid-phase refrigerant. Therefore, when the refrigerant is converted into the gas-liquid two-phase refrigerant as it flows through the supercooler, the temperature difference between the gas-liquid two-phase refrigerant and the heat medium (the cold source) decreases toward the downstream side of the plurality of refrigerant flow paths. In this case, the supercooler cannot supercool the refrigerant, and the refrigerant flows out from the supercooler as the gas-liquid two-phase refrigerant. Thus, as compared with the case where the liquid-phase refrigerant having a degree of supercooling flows through the expansion valve, the flow rate of the refrigerant expanded by the expansion valve is reduced, which deteriorates the capacity of the refrigeration cycle apparatus.

[0006] A main object of the present disclosure is to provide a refrigeration cycle apparatus which prevents the capacity thereof from being deteriorated by the conversion of refrigerant into gas-liquid two-phase refrigerant in a supercooler.

SOLUTION TO PROBLEM

[0007] The refrigeration cycle apparatus according to the present disclosure includes a refrigerant circuit which includes a compressor, a condenser, a supercooler, an expansion valve, and an evaporator, and circulates refrigerant in the order of the compressor, the condenser, the supercooler, the expansion valve, and the evaporator. The supercooler includes a plurality of refrigerant flow paths through which refrigerant flows. The plurality of refrigerant flow paths includes a plurality of first refrigerant flow paths disposed at the most upstream side of the refrigerant circuit among the plurality of refrigerant flow paths, and a plurality of second refrigerant flow paths through which the refrigerant that has flowed through each of the plurality of first refrigerant flow paths flows. The total flow path cross-sectional area of the plurality of first refrigerant flow paths is greater than the total flow path cross-sectional area of the plurality of second refrigerant flow paths.

ADVANTAGEOUS EFFECTS OF INVENTION

[0008] According to the present disclosure, it is possible to provide a refrigeration cycle apparatus which prevents the capacity thereof from being deteriorated by the conversion of refrigerant into gas-liquid two-phase refrigerant in a supercooler.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

Fig. 1 is a block diagram illustrating a refrigeration cycle apparatus according to a first embodiment;
Fig. 2 is a diagram illustrating an example supercooler of the refrigeration cycle apparatus according to the first embodiment;
Fig. 3 is a graph illustrating a change in the temperature of refrigerant flowing from a refrigerant inflow portion into a refrigerant outflow portion and a change in the saturation temperature of the refrigerant in the supercooler according to the first embodiment;
Fig. 4 is a block diagram illustrating a modification of the refrigeration cycle apparatus according to the first embodiment;
Fig. 5 is a block diagram illustrating another modification of the refrigeration cycle apparatus according to the first embodiment;
Fig. 6 is a block diagram illustrating yet another modification of the refrigeration cycle apparatus according to the first embodiment;

Fig. 7 is a block diagram illustrating a modification of the supercooler according to the first embodiment;
Fig. 8 is a block diagram illustrating a refrigeration cycle apparatus according to a second embodiment;
Fig. 9 is a block diagram illustrating a modification of the refrigeration cycle apparatus according to the second embodiment;
Fig. 10 is a graph illustrating a change in the temperature of the refrigerant flowing from a refrigerant inflow portion into a refrigerant outflow portion and a change in the saturation temperature of the refrigerant in a supercooler according to a comparative example.

DESCRIPTION OF EMBODIMENTS

[0010] Hereinafter, embodiments of the present invention will now be described with reference to the accompanying drawings. In the following drawings, the same or equivalent portions will be denoted by the same reference numerals, and the description thereof will not be repeated.

First Embodiment

<Configuration of Refrigeration Cycle Apparatus>

[0011] As illustrated in Fig. 1, a refrigeration cycle apparatus 100 according to a first embodiment includes a refrigerant circuit which includes a compressor 1, a condenser 2, a receiver 3, a supercooler 4, an expansion valve 5, and an evaporator 6, and circulates refrigerant. The refrigerant flows through the refrigerant circuit in the order of the compressor 1, the condenser 2, the receiver 3, the supercooler 4, the expansion valve 5, and the evaporator 6.

[0012] The compressor 1 sucks in the refrigerant evaporated by the evaporator 6, compresses the refrigerant, and discharges the compressed refrigerant. The compressor 1 is, for example, an inverter-controlled compressor capable of changing the capacity thereof by changing the operating frequency.

[0013] The refrigerant discharged from the compressor 1 is condensed in the condenser 2 by exchanging heat with a heat medium such as air. The refrigerant condensed in the condenser 2 is temporarily stored in the receiver 3 as a saturated liquid. Even when liquid-phase refrigerant having a degree of supercooling flows from the condenser 2 into the receiver 3, the liquid-phase refrigerant cools the vapor-phase refrigerant in the receiver 3, and thereby the degree of supercooling is lost. The receiver 3 has a refrigerant outlet 30 through which the refrigerant flows out. The refrigerant that flows out from the refrigerant outlet 30 of the receiver 3 and flows into the supercooler 4 is a saturated liquid having no degree of supercooling.

[0014] The refrigerant flowing out from the receiver 3 is supercooled in the supercooler 4 by exchanging heat with a heat medium (hereinafter referred to as a cold source) such as air. The supercooler 4 includes a refrigerant inflow portion 41 through which the refrigerant flows in, a refrigerant outflow portion 42 through which refrigerant flows out, and a plurality of refrigerant flow paths disposed between the refrigerant inflow portion 41 and the refrigerant outflow portion 42 for the refrigerant to flow through. The plurality of refrigerant flow paths are provided in such a manner that the refrigerant flowing through the plurality of refrigerant flow paths exchanges heat with a cold source flowing outside the plurality of refrigerant flow paths. The refrigerant flowing from the supercooler 4 into the expansion valve 5 is liquid-phase refrigerant having a degree of supercooling. The detailed configuration of the supercooler 4 will be described later.

[0015] The liquid-phase refrigerant which flowing out from the supercooler 4 and has a degree of supercooling is decompressed in the expansion valve 5 and is converted into a gas-liquid two-phase refrigerant. The expansion valve 5 may be replaced by any decompressing device such as a capillary tube capable of decompressing the refrigerant.

[0016] The refrigerant decompressed by the expansion valve 5 is evaporated in the evaporator 6 by exchanging heat with a heat medium such as air.

<Configuration of Supercooler>

[0017] As illustrated in Fig. 2, the supercooler 4 includes, for example, a single heat exchanger. The supercooler 4 is, for example, a parallel flow type (PFC) heat exchanger. The supercooler 4 includes a refrigerant inflow portion 41, a refrigerant outflow portion 42, a plurality of heat transfer tubes 43, a first header 44, and a second header 45.

[0018] The plurality of heat transfer tubes 43 are disposed in parallel to each other. The plurality of heat transfer tubes 43 includes a plurality of first heat transfer tubes 43A and a plurality of second heat transfer tubes 43B. The flow path cross-sectional area of each of the plurality of first heat transfer tubes 43A is equal to each other, for example. The flow path cross-sectional area of each of the plurality of second heat transfer tubes 43B is equal to each other, for example. The flow path cross-sectional area of each of the plurality of first heat transfer tubes 43A is equal to the flow path cross-sectional area of each of the plurality of second heat transfer tubes 43B, for example.

[0019] One end of each of the plurality of first heat transfer tubes 43A and one end of each of the plurality of second heat transfer tubes 43B are connected to the first header 44. The other end of each of the plurality of second heat transfer tubes 43B is connected to the second header 45. The length of each of the plurality of first heat transfer tubes 43A in the extending direction is equal to each other, for example. The length of each of the plurality of second heat transfer tubes 43B in the extending direction is equal to each other, for example. The length of each of the plurality of first heat transfer tubes 43A in the extending direction is equal to the length of each of the plurality of second heat transfer tubes 43B in the extending direction, for example.

[0020] The plurality of heat transfer tubes 43 are disposed in such a manner that the plurality of heat transfer tubes 43 extend in the horizontal direction and are separated from each other with an interval in the vertical direction, for example. The plurality of first heat transfer tubes 43A are disposed in such a manner that the plurality of first heat transfer tubes 43A are separated from each other with an interval in the vertical direction. The plurality of second heat transfer tubes 43B are disposed in such a manner that the plurality of second heat transfer tubes 43B are separated from each other with an interval in the vertical direction. The plurality of first heat transfer tubes 43A are disposed above the plurality of second heat transfer tubes 43B, for example. A first heat transfer tube 43A, which is disposed at the lowest position among the plurality of first heat transfer tubes 43A, is disposed above a second heat transfer tube 43B, which is disposed at the highest position among the plurality of second heat transfer tubes 43B.

[0021] Each of the plurality of refrigerant flow paths is formed inside a corresponding one of the plurality of heat transfer tubes 43. The air serving as a cold source flows outside the plurality of heat transfer tubes 43. The plurality of refrigerant flow paths are provided in such a manner that the refrigerant flowing inside the plurality of heat transfer tubes 43 exchanges heat with the cold source flowing outside the plurality of heat transfer tubes 43.

[0022] The plurality of refrigerant flow paths includes a plurality of first refrigerant flow paths P1, each of which is formed inside a corresponding one of the plurality of first heat transfer tubes 43A, and a plurality of second refrigerant flow paths P2, each of which is formed inside a corresponding one of the plurality of second heat transfer tubes 43B.

[0023] In other words, the plurality of refrigerant flow paths includes a plurality of first refrigerant flow paths P1 disposed at the most upstream side of the refrigerant circuit among the plurality of refrigerant flow paths, and a plurality of second refrigerant flow paths P2 through which the refrigerant that has flowed through each of the plurality of first refrigerant flow paths P1 flows. The flow path cross-sectional area of each of the plurality of first refrigerant flow paths P1 is equal to the flow path cross-sectional area of each of the plurality of second refrigerant flow paths P2.

[0024] An upstream end of each of the plurality of first refrigerant flow paths P1 is connected to the first header 44. A downstream end of each of the plurality of first refrigerant flow paths P1 is connected to the second header 45. The plurality of first refrigerant flow paths P1 are connected in parallel to each other between the first header 44 and the second header 45.

[0025] An upstream end of each of the plurality of second refrigerant flow paths P2 is connected to the second header 45. A downstream end of each of the plurality of second refrigerant flow paths P2 is connected to the first header 44. The plurality of second refrigerant flow paths P2 are connected in parallel to each other between the first header 44 and the second header 45. Each of the plurality of second refrigerant flow paths P2 is connected in series with each of the plurality of first refrigerant flow paths P 1.

[0026] The total flow path cross-sectional area of the plurality of first heat transfer tubes 43A is greater than the total flow path cross-sectional area of the plurality of second heat transfer tubes 43B. The number of the first heat transfer tubes 43A is greater than the number of the second heat transfer tubes 43B. In other words, the total flow path cross-sectional area of the plurality of first refrigerant flow paths P1 is greater than the total flow path cross-sectional area of the plurality of second refrigerant flow paths P2. The number of the plurality of first refrigerant flow paths P1 is greater than the number of the plurality of second refrigerant flow paths P2. Preferably, the total flow path cross-sectional area of the plurality of first refrigerant flow paths P1 is 1.4 times or more and 2 times or less as great as the total flow path cross-sectional area of the plurality of second refrigerant flow paths P2. Preferably, the number of the plurality of first refrigerant flow paths P1 is 1.4 times or more and 2 times or less as great as the number of the plurality of second refrigerant flow paths P2.

[0027] The first header 44 includes a first space 44A that is contiguous to the upstream end of each of the plurality of first refrigerant flow paths P1, a second space 44B that is contiguous to the downstream end of each of the plurality of second refrigerant flow paths P2, and a partition 46 that partitions the first space 44A and the second space 44B. The first space 44A is contiguous to the refrigerant inflow portion 41. The second space 44B is contiguous to the refrigerant outflow portion 42. The first space 44A and the second space 44B are formed inside the first header 44. The partition 46 is fixed inside the first header 44.

[0028] The second header 45 has an internal space that is contiguous to both the downstream end of each of the plurality of first refrigerant flow paths P1 and the upstream end of each of the plurality of second refrigerant flow paths P2.

[0029] The refrigerant flowing from the refrigerant inflow portion 41 into the first space 44A of the first header 44 is distributed to each of the plurality of first refrigerant flow paths P1. The refrigerant flowing through each of the plurality of first refrigerant flow paths P1 merges in the inner space of the second header 45, and then is distributed to each of the plurality of second refrigerant flow paths P2. The refrigerant flowing through each of the plurality of second refrigerant flow paths P2 merges in the second space 44B of the first header 44, and then flows out from the refrigerant outflow portion 42.

[0030] The supercooler 4 further includes a plurality of fins 47. Each of the fins 47 is a corrugate fin. Each of the fins 47 is connected to an outer peripheral surface of each of the heat transfer tubes 43. Each of the fins 47 faces the flow path of the cold source. The direction in which the cold source flows intersects the extending direction of each of the plurality of heat transfer tubes 43. Each of the fins 47 is disposed, for example, between two of the first heat transfer tubes 43A adjacent to each other in the vertical direction, or between two of the second heat transfer tubes 43B adjacent to each other in the vertical direction, or between a first heat transfer tube 43A disposed at the lowest position among the plurality of first heat transfer tubes 43A and a second heat transfer tube 43B disposed at the highest position among the plurality of second heat transfer tubes 43B.

[0031] The supercooler 4 includes a first heat exchange unit 4A which exchanges heat between the refrigerant flowing inside the plurality of first heat transfer tubes 43A and the cold source such as air flowing outside the plurality of first heat transfer tubes 43A, and a second heat exchange unit 4B which exchanges heat between the refrigerant flowing inside the plurality of second heat transfer tubes 43B and the cold source such as air flowing outside the plurality of second heat transfer tubes 43B. In the refrigerant circuit, the first heat exchange unit 4A is disposed upstream of the second heat exchange unit 4B and is connected in series with the second heat exchange unit 4B. Each of the first heat exchange unit 4A and the second heat exchange unit 4B is formed as a part of a single heat exchanger.

<Effects>

[0032] The effects of the refrigeration cycle apparatus 100 will be described on the basis of a comparison with comparative example 1 or 2. A refrigeration cycle apparatus according to comparative example 1 or 2 is different from the refrigeration cycle apparatus 100 only in that the refrigeration cycle apparatus according to comparative example 1 or 2 is provided with a supercooler in which the total flow path cross-sectional area of the refrigerant flow paths located at the upstream side (hereinafter referred to as the upstream refrigerant flow paths) is equal to the total flow path cross-sectional area of the refrigerant flow paths located at the downstream side (hereinafter referred to as the downstream refrigerant flow paths).

[0033] In the supercooler of comparative example 1, the total flow path cross-sectional area of the upstream refrigerant flow paths is equal to the total flow path cross-sectional area of the downstream refrigerant flow paths. The total flow path cross-sectional area of the downstream refrigerant flow paths of the supercooler of comparative example 1 is equal to the total flow path cross-sectional area of the plurality of second refrigerant flow paths P2 of the supercooler 4. The total flow path cross-sectional area of the upstream refrigerant flow paths of the supercooler of comparative example 1 is smaller than the total flow path cross-sectional area of the plurality of first refrigerant flow paths P1 of the supercooler 4. In other words, the pressure loss of the refrigerant in the plurality of first refrigerant flow paths P1 of the supercooler 4 is smaller than the pressure loss of the refrigerant in the upstream refrigerant flow path of the supercooler of comparative example 1.

[0034] In the supercooler of comparative example 2, the total flow path cross-sectional area of the upstream refrigerant flow paths is equal to the total flow path cross-sectional area of the downstream refrigerant flow paths. The total flow path cross-sectional area of the upstream refrigerant flow paths of the supercooler of comparative example 2 is equal to the total flow path cross-sectional area of the plurality of first refrigerant flow paths P1 of the supercooler 4. The total flow path cross-sectional area of the downstream refrigerant flow paths of the supercooler of comparative example 2 is greater than the total flow path cross-sectional area of the plurality of second refrigerant flow paths P2 of the supercooler 4. In other words, the flow velocity of the refrigerant flowing through the plurality of second refrigerant flow paths P2 of the supercooler 4 is higher than the flow velocity of the refrigerant flowing through the downstream refrigerant flow paths of the supercooler of comparative example 2.

[0035] Firstly, the supercooler 4 is compared with the supercooler of comparative example 1. Assume that the refrigerant flowing through the supercooler 4 has the same type, the same flow rate and the same saturation temperature as the refrigerant flowing through the supercooler of comparative example 1. In each of the supercooler 4 and the supercooler of comparative example 1, the refrigerant which is a saturated liquid having no degree of supercooling flows from the refrigerant inflow portion into the plurality of first refrigerant flow paths or the upstream refrigerant flow paths. In each of the supercooler 4 and the supercooler of comparative example 1, the refrigerant flows through the plurality of first refrigerant flow paths or the upstream refrigerant flow paths to exchange heat with the heat medium (the cold source). At the same time, when the refrigerant flows through the plurality of first refrigerant flow paths or the upstream refrigerant flow paths, a pressure loss occurs in the refrigerant. Since the saturation temperature of the refrigerant corresponds to the pressure of the refrigerant, the greater the pressure loss of the refrigerant is, the lower the saturation temperature of the refrigerant will be.

[0036] Fig. 3 is a graph illustrating a change in the temperature of the refrigerant flowing from the refrigerant inflow portion 41 into the refrigerant outflow portion 42 and a change in the saturation temperature of the refrigerant in the supercooler 4. Fig. 10 is a graph illustrating a change in the temperature of the refrigerant flowing from the refrigerant inflow portion into the refrigerant outflow portion and a change in the saturation temperature of the refrigerant in the supercooler of comparative example 1. In Figs. 3 and 10, a solid line indicates a change in the temperature of the refrigerant, and a dotted line indicates a change in the saturation temperature of the refrigerant.

[0037] As illustrated in Fig. 10, since the pressure loss of the refrigerant is relatively large as the refrigerant flows through the upstream refrigerant flow path of the supercooler of comparative example 1, the refrigerant is likely to be converted into gas-liquid two-phase refrigerant during the flowing. In other words, it is likely that the gas-liquid two-phase refrigerant flows in the downstream refrigerant flow path of the supercooler of comparative example 1.

[0038] The higher the dryness of the refrigerant is, the greater the pressure loss of the refrigerant will be. Therefore, the pressure loss of the gas-liquid two-phase refrigerant flowing through the downstream refrigerant flow path is greater than the pressure loss of the refrigerant flowing through the upstream refrigerant flow path before it is converted to the gas-liquid two-phase refrigerant. Thus, the saturation temperature of the gas-liquid two-phase refrigerant flowing through the downstream refrigerant flow path is likely to become lower than that of the refrigerant flowing through the upstream refrigerant flow path before it is converted to the gas-liquid two-phase refrigerant. Therefore, the temperature difference between the refrigerant flowing through the downstream refrigerant flow path and the heat medium (the cold source) is smaller than the temperature difference between the refrigerant flowing through the upstream refrigerant flow path and the heat medium, and becomes smaller as the refrigerant flows toward the refrigerant outflow portion. Therefore, in the supercooler of comparative example 1, the gas-liquid two-phase refrigerant flows out from the refrigerant outflow portion without being supercooled.

[0039] In other words, in the supercooler of comparative example 1, the refrigerant is likely to be converted into gas-liquid two-phase refrigerant, and the gas-liquid two-phase refrigerant flows out without being supercooled. In the refrigeration cycle apparatus according to comparative example 1, since the gas-liquid two-phase refrigerant flowing out from the supercooler flows into the expansion valve, the flow rate of the refrigerant expanded in the expansion valve is reduced as compared with the case where the liquid-phase refrigerant having a degree of supercooling flows into the expansion valve, and thereby, the capacity of the refrigeration cycle apparatus is deteriorated.

[0040] On the other hand, the total flow path cross-sectional area of the plurality of first refrigerant flow paths P1 of the supercooler 4 is greater than the total flow path cross-sectional area of the upstream refrigerant flow paths of the supercooler of comparative example 1. Therefore, as illustrated in Fig. 3, the pressure loss of the refrigerant as it flows through each first refrigerant flow path P1 of the supercooler 4 is smaller than the pressure loss of the refrigerant as it flows through the upstream refrigerant flow path of the supercooler of comparative example 1. As illustrated in Figs. 3 and 10, the amount of decrease in the saturation temperature of the refrigerant as it flows through each first refrigerant flow path P1 is smaller than the amount of decrease in the saturation temperature of the refrigerant as it flows through the upstream refrigerant flow path.

[0041] Thus, as compared with the case where the refrigerant flows through the upstream refrigerant flow path of comparative example 1, as the refrigerant flows through each first refrigerant flow path P1, the refrigerant is less likely to be converted into gas-liquid two-phase refrigerant, and thereby, the pressure loss of the refrigerant is smaller and the amount of decrease in the saturated temperature of the refrigerant is smaller. Therefore, as the refrigerant flows through each first refrigerant flow path P1, the refrigerant is sufficiently supercooled as compared with the case where the refrigerant flows through the upstream refrigerant flow path of comparative example 1. As a result, in the supercooler 4, the liquid-phase refrigerant having a degree of supercooling flows from each first refrigerant flow path P1 into each second refrigerant flow path P2. As illustrated in Fig. 10, for example, the temperature of the refrigerant flowing into each of the second refrigerant flow paths P2 may be lower than the saturation temperature of the refrigerant flowing out from the refrigerant outflow portion 42.

[0042] The total flow path cross-sectional area of the plurality of second refrigerant flow paths P2 of the supercooler 4 is equal to the total flow path cross-sectional area of the downstream refrigerant flow paths of the supercooler of comparative example 1. However, as described above, since the pressure loss of the liquid-phase refrigerant is smaller than the pressure loss of the gas-liquid two-phase refrigerant, as the liquid-phase refrigerant flows through the plurality of second refrigerant flow paths P2, the saturation temperature of the liquid-phase refrigerant is less likely to decrease lower than the saturation temperature of the gas-liquid two-phase refrigerant as the gas-liquid two-phase refrigerant flows through the downstream refrigerant flow path of comparative example 1. Therefore, in the supercooler 4, the liquid-phase refrigerant flowing into the plurality of second refrigerant flow paths P2 is not converted into the gas-liquid two-phase refrigerant, but flows out from the refrigerant outflow portion 42 while maintaining the degree of supercooling.

[0043] In other words, in the supercooler 4, the refrigerant is prevented from being converted into the gas-liquid two-phase refrigerant as it flows through each of the plurality of first refrigerant flow paths P1 and each of the plurality of second refrigerant flow paths P2, and thereby, the refrigerant having a degree of supercooling flows out from the refrigerant outflow portion 42. In the refrigeration cycle apparatus 100 including the supercooler 4, since the refrigerant flowing out from the supercooler 4 into the expansion valve 5 is liquid-phase refrigerant, the capacity of the refrigeration cycle apparatus 100 is improved as compared with the refrigeration cycle apparatus according to comparative example 1.

[0044] Since the total flow path cross-sectional area of the plurality of second refrigerant flow paths P2 is smaller than the total flow path cross-sectional area of the plurality of first refrigerant flow paths P1, the pressure loss of the refrigerant as it flows through each of the second refrigerant flow paths P2 is greater than the pressure loss of the refrigerant as it flows through each of the first refrigerant flow paths P1. Therefore, in the supercooler 4, the saturation temperature of the refrigerant as it flows through each of the second refrigerant flow paths P2 is smaller than the saturation temperature of the refrigerant as it flows through each of the first refrigerant flow paths P1. However, in the supercooler 4, since the degree of supercooling of the refrigerant flowing into each of the second refrigerant flow paths P2 can be made sufficiently large, it is possible to ensure the degree of supercooling of the refrigerant flowing out from the refrigerant outflow portion 42. As a result, in the refrigeration cycle apparatus 100 including the supercooler 4, since the refrigerant flowing out from the supercooler 4 into the expansion valve 5 is liquid-phase refrigerant, the capacity of the refrigeration cycle apparatus is prevented from being deteriorated by the gas-liquid two-phase refrigerant flowing into the expansion valve.

[0045] Next, the supercooler 4 is compared with the supercooler of comparative example 2. Assume that the refrigerant flowing through the supercooler 4 has the same type, the same flow rate and the same saturation temperature as the refrigerant flowing through the supercooler of comparative example 2. Similar to the refrigerant flowing through the plurality of first refrigerant flow paths P 1 of the supercooler 4, as the refrigerant flows through the upstream refrigerant flow path of the supercooler of comparative example 2, the refrigerant is sufficiently supercooled, and thereby, the liquid-phase refrigerant having a degree of supercooling flows into the downstream refrigerant flow path. However, since the total flow path cross-sectional area of the downstream refrigerant flow paths of comparative example 2 is greater than the total flow path cross-sectional area of the downstream refrigerant flow paths of comparative example 1, the flow velocity of the liquid-phase refrigerant flowing through the downstream refrigerant flow paths of comparative example 2 is slower than the flow velocity of the gas-liquid two-phase refrigerant flowing through the downstream refrigerant flow paths of comparative example 1. Since the heat transfer coefficient of the downstream refrigerant flow paths of comparative example 2 is low, it is difficult to encure the degree of supercooling of the refrigerant flowing out from the refrigerant outflow portion.

[0046] On the contrary, in the supercooler 4, the number of the second refrigerant flow paths P2 is smaller than the number of the first refrigerant flow paths P1, and is smaller than the number of the downstream refrigerant flow paths of comparative example 2. Therefore, the flow velocity of the refrigerant flowing through the plurality of second refrigerant flow paths P2 is higher than the flow velocity of the refrigerant flowing through the plurality of first refrigerant flow paths P1, and is higher than the flow velocity of the refrigerant flowing through the downstream refrigerant flow paths of comparative example 2. As a result, in the supercooler 4, the heat transfer coefficient in each of the second refrigerant flow paths P2 is sufficiently high, which makes it possible to ensure the degree of supercooling of the refrigerant flowing out from the refrigerant outflow portion 42. As a result, in the refrigeration cycle apparatus 100 including the supercooler 4, since the refrigerant flowing out from the supercooler 4 into the expansion valve 5 is liquid-phase refrigerant, the capacity of the refrigeration cycle apparatus is prevented from being deteriorated by the gas-liquid two-phase refrigerant flowing into the expansion valve.

<Modifications>

[0047] Figs. 4 to 6 are block diagrams, each of which illustrates a modification of the refrigeration cycle apparatus 100.

[0048] As illustrated in Fig. 4, the supercooler 4 may include two or more heat exchangers. Each of the first heat exchange unit 4A and the second heat exchange unit 4B may be a single heat exchanger. Since a refrigeration cycle apparatus 101 illustrated in Fig. 4 has substantially the same configuration as the refrigeration cycle apparatus 100, it can obtain the same effects as the refrigeration cycle apparatus 100.

[0049] It should be noted that each of the first heat exchange unit 4A and the second heat exchange unit 4B is not limited to a PFC type heat exchanger, and may be any heat exchanger. Each of the first heat exchange unit 4A and the second heat exchange unit 4B may be, for example, a heat exchanger including a plurality of heat transfer tubes 43 and a plurality of plate fins.

[0050] Further, each of the first heat exchange unit 4A and the second heat exchange unit 4B may be a plate heat exchanger including a plurality of heat transfer plates stacked on each other to replace the plurality of heat transfer tubes 43. In this case, the plurality of first refrigerant flow paths P1 are formed between two heat transfer plates adjacent to each other in the stacking direction of the plurality of heat transfer plates, and are alternately arranged with the flow paths of the plurality of cold sources in the stacking direction. Similarly, the plurality of second refrigerant flow paths P2 are formed between two heat transfer plates adjacent to each other in the stacking direction of the plurality of heat transfer plates, and are alternately arranged with the flow paths of the plurality of cold sources in the stacking direction.

[0051] As illustrated in Fig. 5, a refrigeration cycle apparatus 102 may further include an injection flow path 11. The injection flow path 11 includes an injection expansion valve 7. One end of the injection flow path 11 is connected to a refrigerant path located between the supercooler 4 and the expansion valve 5 in the refrigerant circuit 10. The other end of the injection flow path 11 is connected to an intermediate pressure port of the compressor 1.

[0052] As illustrated in Fig. 5, the supercooler 4 may be provided as an internal heat exchanger which exchanges heat between the refrigerant flowing between the receiver 3 and the expansion valve 5 and the refrigerant flowing between the injection expansion valve 7 and the compressor 1 in the injection flow path 11. In this case, each of the plurality of first refrigerant flow paths P 1 and the plurality of second refrigerant flow paths P2 is disposed downstream of the receiver 3 and upstream of the one end of the injection flow path 11 in the refrigerant circuit 10. The refrigerant flowing between the injection expansion valve 7 and the compressor 1 in the injection flow path 11 serves as a cold source.

[0053] The supercooler 4 illustrated in Fig. 5 includes, for example, a first heat exchange unit 4A and a second heat exchange unit 4B. Each of the first heat exchange unit 4A and the second heat exchange unit 4B is, for example, a plate heat exchanger as described above.

[0054] Since the refrigeration cycle apparatus 102 illustrated in Fig. 5 has substantially the same configuration as the refrigeration cycle apparatus 100, it can obtain the same effects as the refrigeration cycle apparatus 100.

[0055] As illustrated in Fig. 6, a refrigeration cycle apparatus 103 may further include a second refrigerant circuit 12. The second refrigerant circuit 12 circulates a refrigerant different from that circulated in the refrigerant circuit 10. The second refrigerant circuit 12 includes a second compressor 13, a second condenser 14, a second expansion valve 15, and a supercooler 4 that functions as an evaporator in the second refrigerant circuit 12. In the second refrigerant circuit 12, the refrigerant decompressed by the second expansion valve 15 serves as a cold source of the supercooler 4.

[0056] The supercooler 4 illustrated in Fig. 6 includes, for example, a first heat exchange unit 4A and a second heat exchange unit 4B. Each of the first heat exchange unit 4A and the second heat exchange unit 4B is, for example, a plate heat exchanger as described above.

[0057] Since the refrigeration cycle apparatus 103 illustrated in Fig. 6 has substantially the same configuration as the refrigeration cycle apparatus 100, it can obtain the same effects as the refrigeration cycle apparatus 100.

[0058] Fig. 7 is a diagram illustrating a modification of the supercooler 4. The supercooler 4 illustrated in Fig. 7 further includes a plurality of connection members 50, each of which connects a downstream end of each of two first refrigerant flow paths P1 to an upstream end of one second refrigerant flow path P2. In other words, in the supercooler 4 illustrated in Fig. 7, each of the plurality of first refrigerant flow paths P1 and each of the plurality of second refrigerant flow paths P2 are connected in series via the plurality of connection members 50 instead of the second header 45 illustrated in Fig. 2.

[0059] Each of the connection members 50 is provided as, for example, a branched pipe. Each of the connection members 50 may be provided in any means as long as it can connect a downstream end of each of at least two first refrigerant flow paths P1 to an upstream end of at least one second refrigerant flow path P2. The supercooler 4 may include at least one connection member 50.

Second Embodiment

[0060] As illustrated in Fig. 8, a refrigeration cycle apparatus 104 according to a second embodiment has substantially the same configuration as the refrigeration cycle apparatus 100 according to the first embodiment, but is different from the refrigeration cycle apparatus 100 in that the refrigerant circuit 10 of the refrigeration cycle apparatus 104 further includes a booster unit configured to boost the refrigerant flowing from the refrigerant outlet 30 of the receiver 3 into the refrigerant inflow portion 41 of the supercooler 4.

[0061] The refrigerant circuit 10 of the refrigeration cycle apparatus 104 illustrated in Fig. 8 includes a descending pipe line 10A as the booster unit. One end of the descending pipe line 10A is disposed at the upstream side of the refrigerant circuit 10, and the other end thereof is disposed at the downstream side of the refrigerant circuit 10. The one end of the descending pipe line 10A is disposed above the other end of the descending pipe line 10A.

[0062] In other words, the refrigeration cycle apparatus 104 differs from the refrigeration cycle apparatus 100 in that the refrigerant outlet 30 of the receiver 3 is disposed above the refrigerant inflow portion 41 of the supercooler 4.

[0063] Since the refrigeration cycle apparatus 104 has substantially the same configuration as the refrigeration cycle apparatus 100, it can obtain the same effects as the refrigeration cycle apparatus 100. Further, in the refrigeration cycle apparatus 104, the refrigerant flowing out from the refrigerant outlet 30 of the receiver 3 is boosted by the descending pipe line 10A, and then flows into the refrigerant inflow portion 41 of the supercooler 4. Therefore, the saturation temperature of the refrigerant flowing through the plurality of first refrigerant flow paths P1 in the refrigeration cycle apparatus 104 is higher than the saturation temperature of the refrigerant flowing through the plurality of first refrigerant flow paths P1 in the refrigeration cycle apparatus 100. As a result, the degree of supercooling of the refrigerant flowing out from the refrigerant outflow portion 42 in the refrigeration cycle apparatus 104 is further higher than the degree of supercooling of the refrigerant flowing out from the refrigerant outflow portion 42 in the refrigeration cycle apparatus 100. Therefore, it is more reliably to prevent the capacity of the refrigeration cycle apparatus 104 from being deteriorated by the conversion of refrigerant into gas-liquid two-phase refrigerant in the supercooler 4.

[0064] In the refrigeration cycle apparatus according to the second embodiment, the booster unit may have any configuration as long as it can boost the refrigerant flowing from the refrigerant outlet 30 of the receiver 3 into the refrigerant inflow portion 41 of the supercooler 4.

[0065] The refrigerant circuit 10 of a refrigeration cycle apparatus 105 illustrated in Fig. 9 includes a booster pump 8 as the booster unit. Similar to the descending pipe line 10A, the booster pump 8 boosts the refrigerant flowing from the refrigerant outlet 30 of the receiver 3 into the refrigerant inflow portion 41 of the supercooler 4. The booster pump 8 may have any configuration as long as it can boost the refrigerant that flows out from the refrigerant outlet 30 of the receiver 3 as a saturated liquid having no degree of supercooling, and it may be, for example, a reciprocating pump that includes a cylinder and a piston which reciprocates inside the cylinder.

[0066] As described above, since the refrigeration cycle apparatus 105 has substantially the same configuration as the refrigeration cycle apparatus 104, it can obtain the same effects as the refrigeration cycle apparatus 104.

[0067] The refrigerant circuit 10 of the refrigeration cycle apparatus 105 may further include a descending pipe line 10A as the booster unit. The booster pump 8 and the descending pipe line 10A are connected in series in the refrigerant circuit 10. The booster pump 8 is disposed, for example, on the downstream side of the descending pipe line 10A. The booster pump 8 may be disposed, for example, on the downstream side of the descending pipe line 10A.

[0068] The supercooler 4 of the refrigeration cycle apparatus 104 or 105 according to the second embodiment may have the same configuration as the supercooler 4 illustrated in Figs. 4 to 7. Further, the refrigerant circuit 10 in each of the refrigeration cycle apparatuses 100 to 105 according to the first or second embodiment may not include the receiver 3. In this case, since the liquid-phase refrigerant having a degree of supercooling can flow from the condenser 2 into the supercooler 4, it is more reliably to prevent the capacity from being deteriorated by the conversion of refrigerant into gas-liquid two-phase refrigerant in the supercooler 4 than the refrigeration cycle apparatuses 100 to 105 described above.

[0069] The supercooler 4 in each of the refrigeration cycle apparatuses 100 to 105 according to the first or second embodiment may include at least one second refrigerant flow path P2.

[0070] Although the embodiments of the present disclosure have been described above, the above-described embodiments may be modified in various ways. The scope of the present disclosure is not limited to the above-described embodiments. The scope of the present disclosure is defined by the claims, rather than the description above, and is intended to include any modifications within the meaning and scope equivalent to the claims.

REFERENCE SIGNS LIST

[0071] 1: compressor; 2: condenser; 3: receiver; 4: supercooler; 4A: first heat exchange unit; 4B: second heat exchange unit; 5: expansion valve; 6: evaporator; 7: injection expansion valve; 8: booster pump; 10: refrigerant circuit; 10A: descending pipe line; 11: injection flow path; 12: second refrigerant circuit; 13: second compressor; 14: second condenser; 15: second expansion valve; 30: refrigerant outlet; 41: refrigerant inflow portion; 42: refrigerant outflow portion; 43: heat transfer tube; 43A: first heat transfer tube; 43B: second heat transfer tube; 44: first header; 44A: first space; 44B: second space; 45: second header; 46: partition; 47: fin; 50: connection member; 100, 101, 102, 103, 104, 105: refrigeration cycle apparatus

Claims

1. A refrigeration cycle apparatus comprising:

a refrigerant circuit which includes a compressor, a condenser, a supercooler, an expansion valve, and an evaporator, and circulates refrigerant in the order of the compressor, the condenser, the supercooler, the expansion valve, and the evaporator,
wherein the supercooler includes a plurality of refrigerant flow paths through which the refrigerant flows,
the plurality of refrigerant flow paths includes a plurality of first refrigerant flow paths disposed at the most upstream side of the refrigerant circuit among the plurality of refrigerant flow paths, and at least one second refrigerant flow path through which the refrigerant that has flowed through each of the plurality of first refrigerant flow paths flows, and
a total flow path cross-sectional area of the plurality of first refrigerant flow paths is greater than a total flow path cross-sectional area of the at least one second refrigerant flow path.

2. The refrigeration cycle apparatus according to claim 1, wherein

the refrigerant circuit further includes a receiver that is disposed between the condenser and the supercooler so as to store the refrigerant condensed in the condenser,
the receiver includes a refrigerant outlet through which the refrigerant flows out, and
each of the plurality of first refrigerant flow paths is disposed lower than the refrigerant outlet of the receiver.

3. The refrigeration cycle apparatus according to claim 2, wherein

the refrigerant circuit further includes a booster unit that is disposed between the receiver and the supercooler so as to boost the refrigerant flowing out from the receiver, and
the refrigerant boosted by the booster unit flows

into each of the plurality of first refrigerant flow paths.

4. The refrigeration cycle apparatus according to any one of claims 1 to 3, wherein

the at least one second refrigerant flow path includes a plurality of second refrigerant flow paths,
the supercooler further includes:

a first header to which an upstream end of each of the plurality of first refrigerant flow paths and a downstream end of each of the plurality of second refrigerant flow paths are connected; and
a second header to which a downstream end of each of the plurality of first refrigerant flow paths and an upstream end of each of the plurality of second refrigerant flow paths are connected,

the first header includes:

a first space that is contiguous to the upstream end of each of the plurality of first refrigerant flow paths;
a second space that is contiguous to the downstream end of each of the plurality of second refrigerant flow paths; and
a partition that partitions the first space and the second space.

5. The refrigeration cycle apparatus according to any one of claims 1 to 3, wherein

the supercooler further includes at least one connection member that connects a downstream end of each of the plurality of first refrigerant flow paths and an upstream end of the at least one second refrigerant flow path, and
a total flow path cross-sectional area of the plurality of first refrigerant flow paths connected to the at least one connection member is greater than a total flow path cross-sectional area of the at least one second refrigerant flow path connected to the at least one connection member.

6. The refrigeration cycle apparatus according to any one of claims 1 to 3, wherein

the supercooler includes a first supercooling section that includes the plurality of first refrigerant flow paths and a second supercooling section that includes the at least one second refrigerant flow path, and
the first supercooling section is separated from the second supercooling section.

7. The refrigeration cycle apparatus according to any one of claims 1 to 6, wherein
the number of the plurality of first refrigerant flow paths is greater than the number of the at least one second refrigerant flow path.

FIG.1

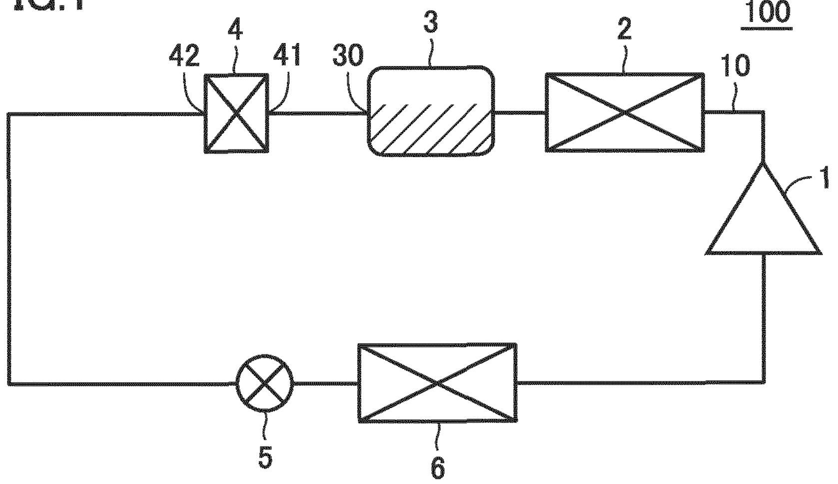
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FIG.2

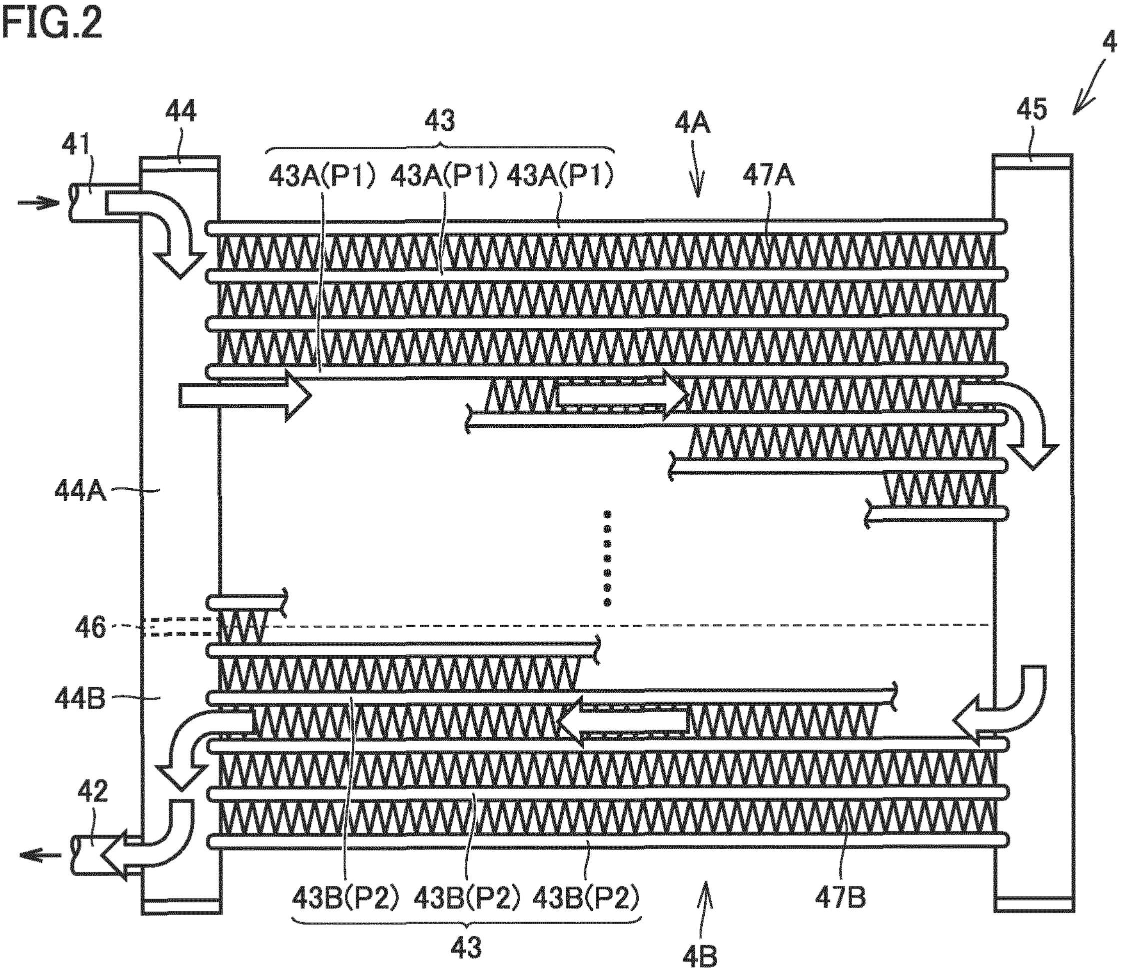
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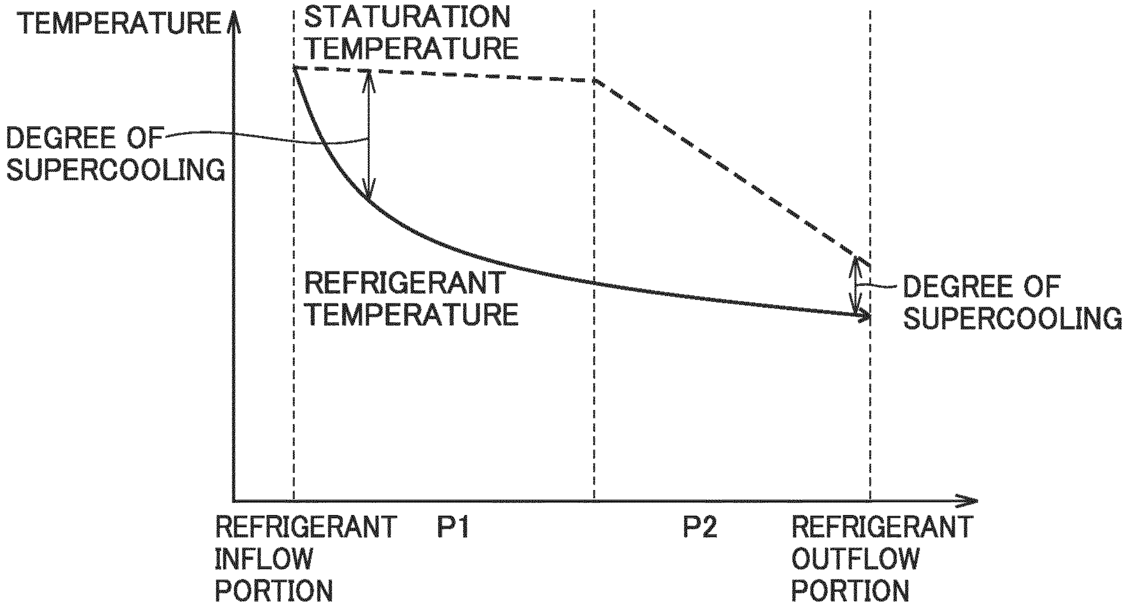
FIG.3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DEGREE OF SUPERCOOLING
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DEGREE OF SUPERCOOLING
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P1
P2
REFRIGERANT OUTFLOW PORTION

FIG.4

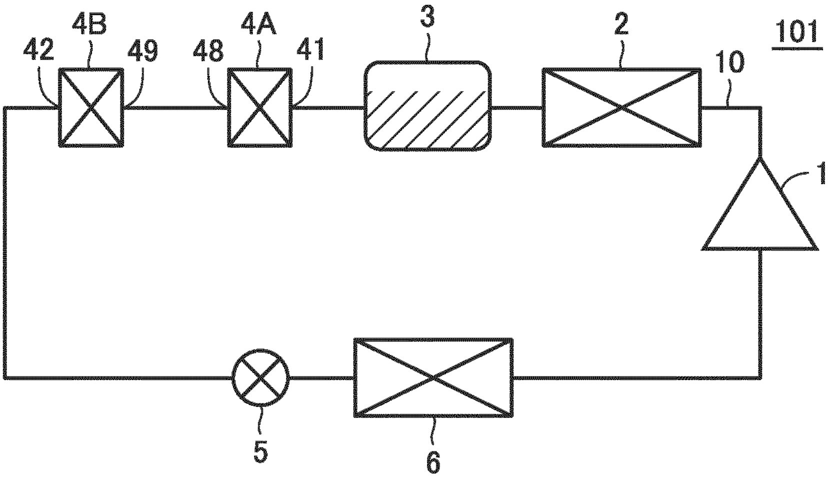
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FIG.5

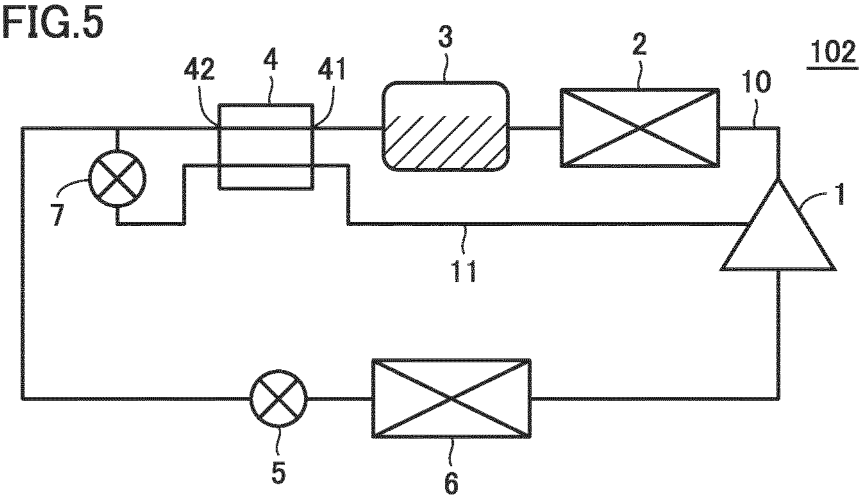

FIG.6

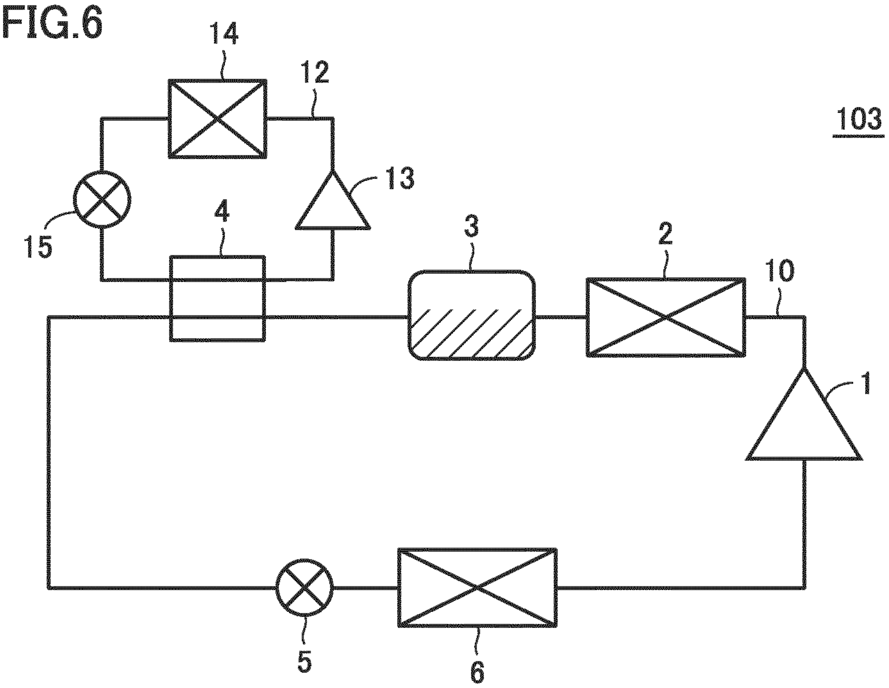

FIG.7

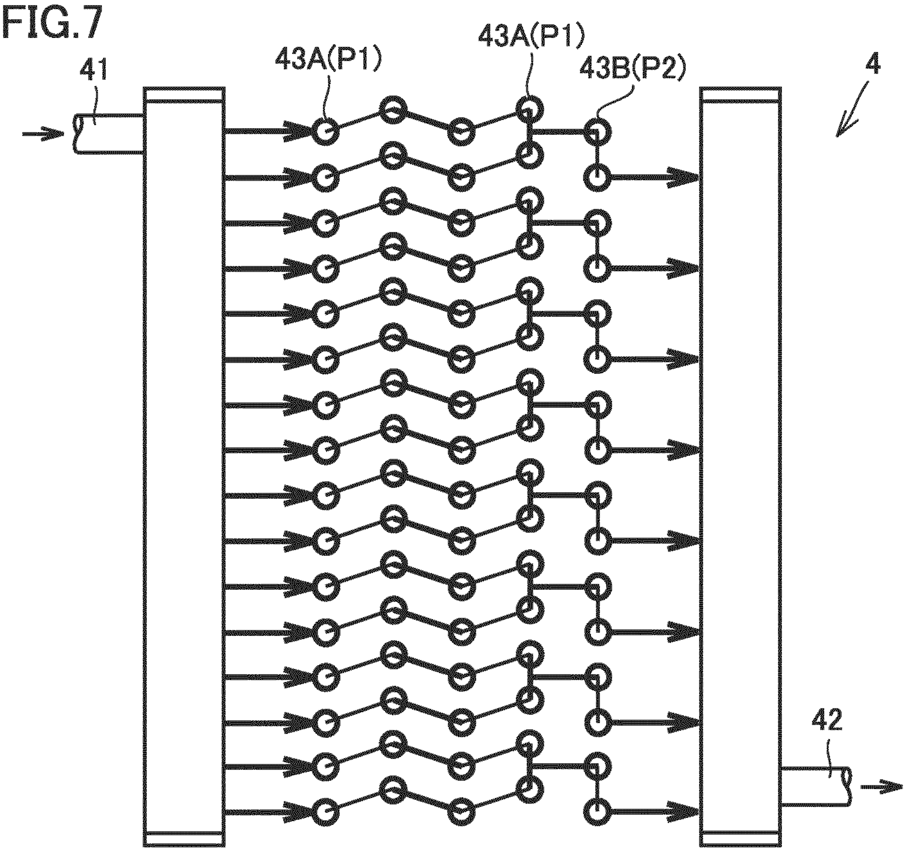

FIG.8

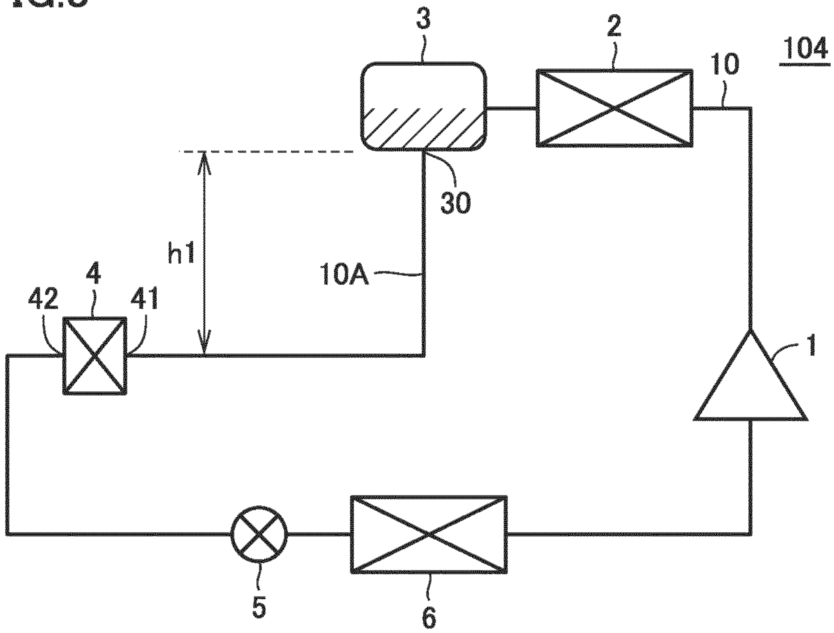

FIG.9

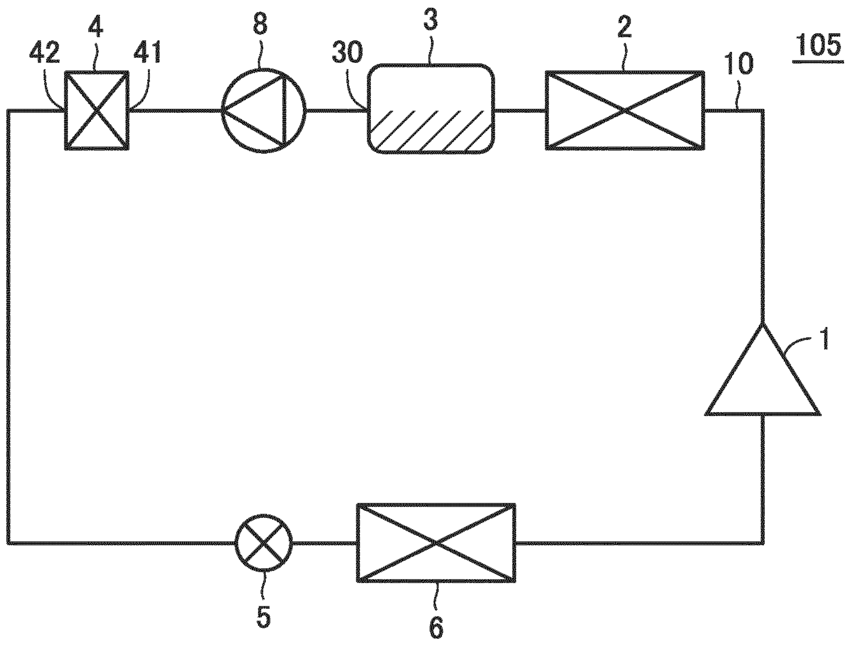
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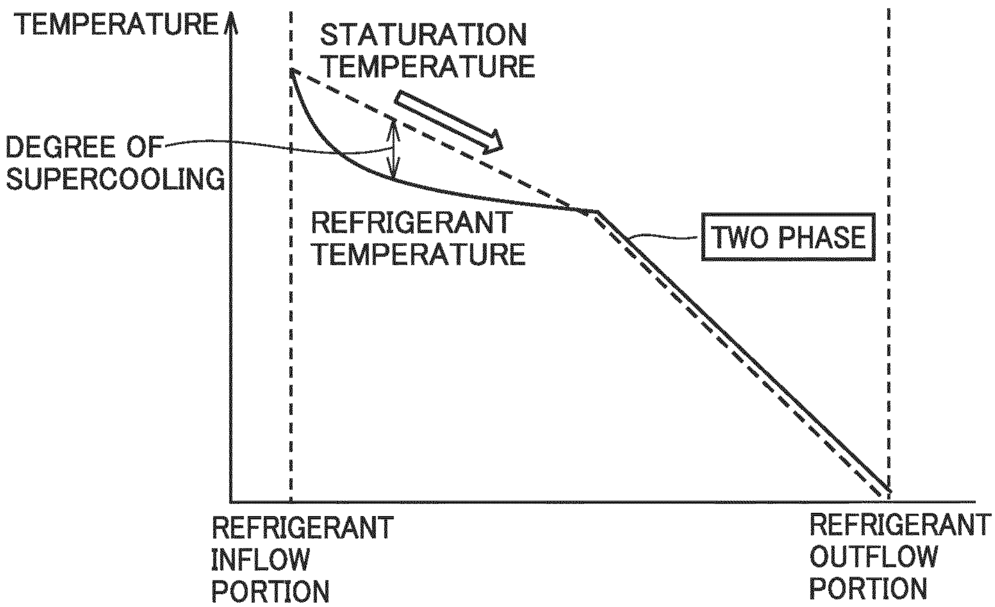
FIG.10


TEMPERATURE
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DEGREE OF SUPERCOOLING
REFRIGERANT TEMPERATURE
TWO PHASE
REFRIGERANT INFLOW PORTION
REFRIGERANT OUTFLOW PORTION

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2020/023429

A. CLASSIFICATION OF SUBJECT MATTER
F25B 40/02(2006.01)i
FI: F25B40/02 Z

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)
F25B40/02

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	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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 2020-16339 A (ECORA TECH CO., LTD.) 30 January 2020 (2020-01-30) fig. 1, 6-7, paragraphs [0021]-[0026]	1, 4-7
Y	JP 2009-236404 A (DENSO CORP.) 15 October 2009 (2009-10-15) fig. 1-2, paragraphs [0068]-[0069]	1, 4-7
A	JP 2019-163867 A (NTT FACILITIES, INC.) 26 September 2019 (2019-09-26) entire text, all drawings	1-7
A	US 2001/0037650 A1 (SCHEUFLER, Fred G.) 08 November 2001 (2001-11-08) entire text, all drawings	1-7
A	JP 2006-343039 A (KOBE STEEL, LTD.) 21 December 2006 (2006-12-21) entire text, all drawings	1-7
A	WO 2012/098912 A1 (DAIKIN INDUSTRIES, LTD.) 26 July 2012 (2012-07-26) entire text, all drawings	1-7

☒ 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
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- "P" document published prior to the international filing date but later than the priority date claimed
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 August 2020 (05.08.2020)	01 September 2020 (01.09.2020)

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

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2020/023429

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 2005-106329 A (SANDEN CORP.) 21 April 2005 (2005-04-21) entire text, all drawings	1-7

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/023429

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2020-16339 A	30 Jan. 2020	(Family: none)	
JP 2009-236404 A	15 Oct. 2009	US 2009/0241573 A1 fig. 1-2, paragraphs [0079]-[0080] CN 101545690 A	
JP 2019-163867 A	26 Sep. 2019	(Family: none)	
US 2001/0037650 A1	08 Nov. 2001	(Family: none)	
JP 2006-343039 A	21 Dec. 2006	(Family: none)	
WO 2012/098912 A1	26 Jul. 2012	US 2013/0292098 A1 entire text, all drawings EP 2667134 A1 CN 103339457 A KR 10-2013-0129265 A	
JP 2005-106329 A	21 Apr. 2005	CN 1616905 A entire text, all drawings	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2018091502 A **[0002] [0003]**