



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

(43) Date of publication:
29.12.2010 Bulletin 2010/52

(51) Int Cl.:
F28F 1/32 (2006.01) F25B 1/00 (2006.01)

(21) Application number: **09722156.8**

(86) International application number:
PCT/JP2009/054999

(22) Date of filing: **16.03.2009**

(87) International publication number:
WO 2009/116478 (24.09.2009 Gazette 2009/39)

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

- **YOSHIOKA, Shun**
Sakai-shi
Osaka 591-8511 (JP)
- **DOI, Takashi**
Kusatsu-shi
Shiga 525-8526 (JP)
- **KITAZAWA, Masaaki**
Kusatsu-shi
Shiga 525-8526 (JP)
- **NAKATA, Haruo**
Sakai-shi
Osaka 591-8511 (JP)

(30) Priority: **18.03.2008 JP 2008070356**

(71) Applicant: **Daikin Industries, Ltd.**
Osaka 530-8323 (JP)

(72) Inventors:
• **FUJINO, Hirokazu**
Sakai-shi
Osaka 591-8511 (JP)

(74) Representative: **HOFFMANN EITLE**
Patent- und Rechtsanwälte
Arabellastraße 4
81925 München (DE)

(54) **HEAT EXCHANGER**

(57) The present invention provides a heat exchanger suitable for a refrigerant circuit in which a single refrigerant or a mixed refrigerant containing the single refrigerant is used, the single refrigerant composed of a refrigerant whose molecular formula is expressed as $C_3H_mF_n$ (wherein $m = 1$ to 5 , $n = 1$ to 5 , and $m + n = 6$) and whose molecular structure has one double bond. In a heat exchanger (10), the relationship between the center-to-center distance S between heat transfer tubes that are adjacent in the vertical direction and an outside diameter D of the heat transfer tubes is $2.5 < S/D < 3.5$, the relationship between the length L of a refrigerant passage and the outside diameter D of the heat transfer tubes is $0.28 \times D^{1.17} < L < 1.10 \times D^{1.17}$, and an outdoor heat exchanger (4) and an indoor heat exchanger (6) are designed based on the above relational expressions.

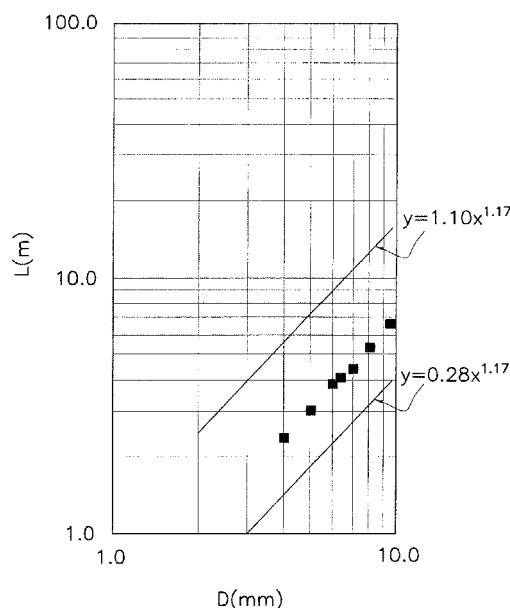


FIG. 9

Description

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger, and particularly relates to a heat exchanger suited to a refrigerant circuit which uses a low-pressure refrigerant.

BACKGROUND ART

[0002] From a standpoint of protecting the global environment, there is demand that refrigerants used in refrigerant circuits of air-conditioning apparatuses have low global warming potential and do not contribute to damaging the ozone layer. Refrigerants that comply with these requirements are actually being developed (for example, see Patent Document 1).

[0003] The refrigerant disclosed in Patent Document 1 ($C_3H_mF_n$) has the characteristics of a comparatively high theoretical COP and a low global warming potential. However, since this refrigerant is a so-called low-pressure refrigerant having a comparatively high boiling point, there is a possibility of the input of the compressor increasing and the operating efficiency being reduced due to the effect of pressure loss in the heat exchanger.

[0004] <Patent Document 1> Japanese Laid-open Patent Application No. 4-110388

DISCLOSURE OF THE INVENTION

<Technical Problem>

[0005] An object of the invention is to provide a heat exchanger suited to a refrigerant circuit which uses either a single refrigerant or a mixed refrigerant including the single refrigerant, which is composed of a refrigerant whose molecular formula is expressed as $C_3H_mF_n$ (wherein $m = 1$ to 5 , $n = 1$ to 5 , and $m + n = 6$) and whose molecular structure has one double bond.

<Solution to Problem>

[0006] A heat exchanger according to a first aspect of the present invention is a heat exchanger of a refrigerant circuit in which either a single refrigerant or a mixed refrigerant including the single refrigerant is employed, the single refrigerant comprising an organic compound whose molecular formula is expressed as $C_3H_mF_n$ (wherein $m = 1$ to 5 , $n = 1$ to 5 , and $m + n = 6$) and whose molecular structure has one double bond, the heat exchanger comprising a plurality of heat transfer tubes and a plurality of plate-shaped fins. The heat transfer tubes form one or a plurality of refrigerant passages for allowing the refrigerant to flow therethrough. The plate-shaped fins are aligned so as to be stacked at a predetermined spacing, and the plurality of heat transfer tubes pass through the fins in a substantially vertical manner. The

relationship between the center-to-center distance S between heat transfer tubes that are adjacent in the vertical direction and the outside diameter D of the heat transfer tubes is $2.5 < S/D < 3.5$, and the relationship between the length L of the refrigerant passages and the outside diameter D of the heat transfer tubes is $0.28 \times D^{1.17} < L < 1.10 \times D^{1.17}$.

[0007] Since the refrigerant is a low-pressure refrigerant, the refrigerant is susceptible to the effect of pressure loss inside the heat transfer tubes, but in this heat exchanger, the effect of pressure loss on the refrigerant inside the heat transfer tubes can be kept to a minimum by applying the relationship between the refrigerant passage length L , the outside diameter D of the heat transfer tubes and the center-to-center distance S between heat transfer tubes to the above relational expressions.

[0008] The heat exchanger according to a second aspect of the present invention is the heat exchanger according to the first aspect of the present invention, wherein the refrigerant is either a single refrigerant comprising 2,3,3,3-tetrafluoro-1-propene or a mixed refrigerant containing the single refrigerant.

[0009] Since either the single refrigerant composed of 2,3,3,3-tetrafluoro-1-propene or the mixed refrigerant containing the single refrigerant is a low-pressure refrigerant, the refrigerant is susceptible to the effect of pressure loss inside the heat transfer tubes, but in this heat exchanger, the effect of pressure loss on the refrigerant inside the heat transfer tubes can be kept to a minimum by applying the relationship between the refrigerant passage length L , the outside diameter D of the heat transfer tubes and the center-to-center distance S between heat transfer tubes to the above relational expressions.

[0010] The heat exchanger according to a third aspect of the present invention is the heat exchanger according to the first aspect of the present invention, wherein the refrigerant is a mixed refrigerant comprising 2,3,3,3-tetrafluoro-1-propene and difluoromethane.

[0011] Since the mixed refrigerant containing 2,3,3,3-tetrafluoro-1-propene and difluoromethane is a low-pressure refrigerant, the refrigerant is susceptible to the effect of pressure loss inside the heat transfer tubes, but in this heat exchanger, the effect of pressure loss on the refrigerant inside the heat transfer tubes can be kept to a minimum by applying the relationship between the refrigerant passage length L , the outside diameter D of the heat transfer tubes and the center-to-center distance S between heat transfer tubes to the above relational expressions.

[0012] The heat exchanger according to a fourth aspect of the present invention is the heat exchanger according to the first aspect of the present invention, wherein the refrigerant is a mixed refrigerant comprising 2,3,3,3-tetrafluoro-1-propene and pentafluoroethane.

[0013] Since the mixed refrigerant containing 2,3,3,3-tetrafluoro-1-propene and pentafluoroethane is a low-pressure refrigerant, the refrigerant is susceptible to the effect of pressure loss inside the heat transfer tubes, but

in this heat exchanger, the effect of pressure loss on the refrigerant inside the heat transfer tubes can be kept to a minimum by applying the relationship between the refrigerant passage length L, the outside diameter D of the heat transfer tubes and the center-to-center distance S between heat transfer tubes to the above relational expressions.

<Advantageous Effects of Invention>

[0014] In the heat exchanger according to any of the first, second, third, and fourth aspects of the present invention, the effect of pressure loss on the refrigerant inside the heat transfer tubes can be kept to a minimum by applying the relationship between the refrigerant passage length L, the outside diameter D of the heat transfer tubes and the center-to-center distance S between heat transfer tubes to the above relational expressions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 is a refrigerant circuit of an air-conditioning apparatus.

FIG. 2 is a front view of a heat exchanger according to an embodiment of the present invention.

FIG. 3 is a cross-sectional view of the heat exchanger when divided along line A-A in FIG. 2.

FIG. 4 is a graph showing the relationship between S/D and the heat exchanger performance when the air blower power is constant and D = 7 mm.

FIG 5(a) is a schematic view of the heat exchanger of FIG. 2 when the heat exchanger has one refrigerant passage; (b) is a schematic view of the heat exchanger of FIG. 2 when the heat exchanger has two refrigerant passages; and (c) is a schematic view of the heat exchanger of FIG. 2 when the refrigerant passage of the heat exchanger branches in two half-way through.

FIG. 6 is a graph showing the relationship between refrigerant passage length and pressure loss.

FIG. 7 is a graph showing the relationship of the refrigerant passage length to the refrigerant heat transfer coefficient as well as to the pressure loss when D = 7 mm.

FIG. 8 is a graph showing the refrigerant passage length and the heat exchanger performance when D = 7 mm.

FIG. 9 is a graph in which the refrigerant passage length L is plotted relative to the heat transfer tube outside diameter D.

FIG. 10 is a composition table of refrigerants used in the refrigerant circuit containing the heat exchanger according to the present embodiment.

EXPLANATION OF THE REFERENCE NUMERALS

[0016]

- 4 Outdoor heat exchanger
- 6 Indoor heat exchanger
- 10 Heat exchanger
- 11 Plate-shaped fin
- 12 Heat-transfer tube

BEST MODE FOR CARRYING OUT THE INVENTION

<Refrigerant Circuit>

- [0017]** FIG. 1 is a refrigerant circuit of an air-conditioning apparatus. The air-conditioning apparatus 1 has a refrigeration circuit in which a compressor 2, a four-way switching valve 3, an outdoor heat exchanger 4, an expansion valve 5, and an indoor heat exchanger 6 are connected by a refrigerant pipe. In FIG 1, the solid-line and dashed-line arrows indicate directions of refrigerant flow, and in the air-conditioning apparatus 1, it is possible to switch between an air-warming operation and an air-cooling operation by switching the direction of refrigerant flow via the four-way switching valve 3. During the air-cooling operation, the outdoor heat exchanger 4 serves as a condenser and the indoor heat exchanger 6 serves as an evaporator. During the air-warming operation, the outdoor heat exchanger 4 serves as an evaporator and the indoor heat exchanger 6 serves as a condenser.

- [0018]** The refrigerant circuit is filled with a mixed refrigerant composed of the two organic compounds HFO-1234yf (2, 3, 3, 3-tetrafluoro-1-propene) and HFC-32 (difluoromethane). The refrigerant used in the present embodiment is a mixed refrigerant composed of 78.2 mass% of HFO-1234yf and 21.8 mass% of HFC-32. The chemical formula of HFO-1234yf is expressed as CF_3CFCH_2 , and the chemical formula of HFC-32 is expressed as CH_2F_2 .

<Structure of Heat Exchanger>

- [0019]** FIG 2 is a front view of a heat exchanger according to an embodiment of the present invention. In FIG. 2, the heat exchanger 10 is a cross-fin type heat exchanger, and is a basic model of the outdoor heat exchanger 4 and the indoor heat exchanger 6 shown in FIG. 1. The heat exchanger 10 comprises fins 11 and heat transfer tubes 12. The fins 11 are thin flat plates made of aluminum, and a plurality of through-holes are formed in each fin 11. The heat transfer tubes 12 are composed of straight tubes 12a inserted through the through-holes of the fins 11, and first U-shaped tubes 12b and second U-shaped tubes 12c connecting the ends of adjacent straight tubes 12a to each other. The straight tubes 12a and the first U-shaped tubes 12b are formed integrally, and the second U-shaped tubes 12c are connected to the ends of the straight tubes 12a by

welding or another method after the straight tubes 12a have been inserted through the through-holes of the fins 11.

(Relationship of Outside Diameters of Heat Transfer Tubes and Center-to-center Distance to Heat Exchanger Performance)

[0020] FIG. 3 is a cross-sectional view of a heat exchanger when divided along line A-A in FIG. 2. In FIG. 3, the outside diameter of the straight tubes 12a is D, and the distance between the centers of heat transfer tubes 12 that are adjacent in a vertical direction is S. Generally, the smaller the center-to-center distance S, the more improved the fin efficiency, but the greater the airflow resistance. Conversely, the greater the center-to-center distance S, the poorer the fin efficiency, but the lesser the airflow resistance. The term "fin efficiency" refers to the ratio between the actual quantity of heat radiated from the combined heat transfer surfaces of the fins, and the quantity of heat radiated when the combined heat transfer surfaces of the fins are assumed to be equal in temperature to the refrigerant.

[0021] When the center-to-center distance S is constant, the greater the tube outside diameter D, the more improved the fin efficiency, but the greater the airflow resistance. Conversely, the smaller the tube outside diameter D, the poorer the fin efficiency, but the lesser the airflow resistance. In other words, between the tube outside diameter D and the center-to-center distance S, there exists an optimal condition for improving the heat exchanger performance.

[0022] FIG. 4 is a graph showing the relationship between S/D and the heat exchanger performance when the air blower power is constant and D = 7 mm. In FIG. 4, the heat exchanger performance exhibits a high value in a range of $2.5 < S/D < 3.5$, and outside of this range the heat exchanger performance decreases. In other words, FIG. 4 indicates that with the outdoor heat exchanger 4 and the indoor heat exchanger 6 of the refrigerant circuit which uses a mixed refrigerant of HFO-1234yf and HFC-32, the optimal heat exchanger performance is obtained when the relationship between the outside diameter D and the center-to-center distance S is $2.5 < S/D < 3.5$.

(Relationship Between Refrigerant Passage Length of Heat Exchanger and Heat Exchanger Performance)

[0023] FIG. 5(a) is a schematic view of the heat exchanger of FIG. 2 when the heat exchanger has one refrigerant passage, (b) is a schematic view of the heat exchanger of FIG. 2 when the heat exchanger has two refrigerant passages, and (c) is a schematic view of the heat exchanger of FIG. 2 when the refrigerant passage of the heat exchanger branches in two halfway through.

[0024] In FIG. 5(a), the heat exchanger 10 has one refrigerant passage and is therefore referred to as a 1-

pass heat exchanger 101. In cases in which the heat exchanger 10 has six heat transfer tubes 12 and the length of one heat transfer tube 12 is denoted as H, the refrigerant passage length of the 1-pass heat exchanger 101 is approximately 6H.

[0025] In FIG. 5(b), the heat exchanger 10 has two refrigerant passages formed by a flow diverter 90 and is therefore referred to as a 2-pass heat exchanger 102. The refrigerant passage length of the 2-pass heat exchanger 102 is equivalent to approximately 3H, which is half that of the 1-pass heat exchanger 101.

[0026] In FIG. 5(c), the heat exchanger 10 is referred to as a 1-2 pass heat exchanger 103 because one refrigerant passage branches via the flow diverter 90 into two refrigerant passages partway therealong. Since the 1-2 pass heat exchanger 103 has both a shared refrigerant passage and independent refrigerant passages, the refrigerant passage length cannot be calculated in a simple manner. In view of this, the actual pressure loss of the 1-2 pass heat exchanger 103 is found, a determination is made as to what the length would be of a refrigerant passage having an equivalent pressure loss if there was only one refrigerant passage, and the value thereof is used as the refrigerant passage length.

[0027] FIG. 6 is a graph showing the relationship between refrigerant passage length and pressure loss. For example, when the refrigerant pressure loss in the 1-2 pass heat exchanger 103 of FIG. 5(c) is p, according to the graph, the refrigerant passage length is 3.6H. Thus, the 1-pass heat exchanger 101, the 2-pass heat exchanger 102, and the 1-2 pass heat exchanger 103 whose refrigerant passage lengths differ can be created from a single heat exchanger 10 as a reference. In other words, the refrigerant passage length can be set by varying the quantity of refrigerant passages.

[0028] Next, the relationship between refrigerant passage length and heat exchanger performance will be described. To be clear the heat exchanger performance Q is expressed by the equation $Q = KA \times dT$, using the heat reflux rate K, the heat transfer surface area A, and the temperature difference dT between the air and the refrigerant. The reflux rate K is the inverse of the combined resistance of the heat resistance of the air and the heat resistance of the refrigerant. The combined resistance 1/K is expressed by the equation $1/K = 1/h_a + R/h_r$, using the air heat transfer coefficient h_a , the refrigerant heat transfer coefficient h_r , and the inside-outside heat transfer surface area ratio R.

[0029] When the number of refrigerant passages is reduced and the refrigerant passage length is increased, the quantity of refrigerant flowing through one refrigerant passage increases and the refrigerant heat transfer coefficient h_r improves, but since the evaporation temperature in the heat exchanger inlet increases due to the increase in pressure loss, the temperature difference dT between the air and the refrigerant decreases, and the heat exchanger performance Q decreases.

[0030] When the number of refrigerant passages is in-

creased and the refrigerant passage length is reduced, the pressure loss decreases, the evaporation temperature in the heat exchanger inlet decreases, and the temperature difference dT between the air and the refrigerant increases, but since the quantity of refrigerant flowing through one refrigerant passage decreases, the refrigerant heat transfer coefficient h_r decreases and the heat exchanger performance Q decreases.

[0031] In other words, the outdoor heat exchanger 4 and the indoor heat exchanger 6 of the refrigerant circuit which uses a mixed refrigerant of HFO-1234yf and HFC-32 cannot be substituted with an outdoor heat exchanger and an indoor heat exchanger corresponding to conventional refrigerant (for example, 410A refrigerant), and in order to achieve the optimal heat exchanger performance, the heat exchanger must be designed after clarifying the relationship between the heat transfer tube outside diameter D and the refrigerant passage length L .

[0032] FIG. 7 is a graph showing the relationship of the refrigerant passage length to the refrigerant heat transfer coefficient as well as to the pressure loss when $D = 7$ mm, and FIG. 8 is a graph showing the refrigerant passage length and the heat exchanger performance when $D = 7$ mm. As FIG. 7 shows, the shorter the refrigerant passage length, the smaller the pressure loss, but the lower the refrigerant heat transfer coefficient as well. As a result, the heat exchanger performance also decreases due to the decrease in the refrigerant heat transfer coefficient, as shown in FIG. 8. When the refrigerant passage length is increased, the heat exchanger performance peaks at first, but thereafter falls. In other words, FIG. 8 indicates that there is a refrigerant passage length suited to the heat transfer tube outside diameter.

[0033] FIG. 9 is a graph in which the refrigerant passage length L is plotted relative to the heat transfer tube outside diameter D . In FIG. 9, the square black points indicate the optimal refrigerant passage length corresponding to the heat transfer tube outside diameter, where the lower limit of the refrigerant passage length corresponding to the heat transfer tube outside diameter lies on the line $y = 0.28x^{1.17}$, and the upper limit lies on the line $y = 1.10x^{1.17}$. In other words, it is indicated that with the outdoor heat exchanger 4 and the indoor heat exchanger 6 of the refrigerant circuit which uses a mixed refrigerant of HFO-1234yf and HFC-32, the optimal heat exchanger performance is obtained by setting the refrigerant passage length L in a range of $0.28 \times D^{1.17} < L < 1.10 \times D^{1.17}$.

<Refrigerant Used in Refrigerant Circuit>

(Single Refrigerant)

[0034] In the embodiment described above, a mixed refrigerant composed of two organic compounds HFO-1234yf and HFC-32 is used as the refrigerant, but the refrigerant is not limited to this option alone. For example, FIG. 10 is a composition table of refrigerants used in the

refrigerant circuit containing the heat exchanger according to the present embodiment, and a single refrigerant composed of an organic compound whose molecular formula is expressed as $C_3H_mF_n$ (wherein $m = 1$ to 5, $n = 1$ to 5, and $m + n = 6$) and whose molecular structure has one double bond, such as HFO-1234yf, may be used.

[0035] Specifically, possible examples as shown in the upper row of FIG. 10 include HFO-1225ye (1,2,3,3,3-pentafluoro-1-propene, chemical formula: $CF_3-CF=CHF$), HFO-1234ze (1,3,3,3-tetrafluoro-1-propene, chemical formula: $CF_3-CH=CHF$), HFO-1234ye (1,2,3,3-tetrafluoro-1-propene, chemical formula: $CHF_2-CF=CHF$), HFO-1243zf (3,3,3-trifluoro-1-propene, chemical formula: $CF_3-CH=CH_2$, or 1,2,2-trifluoro-1-propene, chemical formula: $CH_3-CF=CF_2$), 2-fluoro-1-propene (chemical formula: $CH_3-CF=CH_2$), and the like. For the sake of convenience in the description, these single refrigerants are classified as reference refrigerants.

(Mixed Refrigerant)

[0036] Another option is to use a mixed refrigerant composed of any one of the reference refrigerants listed above and any one of the second components shown in FIG. 10. For example, the mixed refrigerant may contain 22 mass% of HFC-32. Furthermore, the percentage of HFC-32 is preferably 6 mass% or more and 30 mass% or less, more preferably 13 mass% or more and 23 mass% or less, and even more preferably 21 mass% or more and 23 mass% or less.

[0037] The mixed refrigerant may also contain any one of the reference refrigerants listed above and 10 mass% or more of HFC-125 (pentafluoroethane, CF_3-CHF_2), and furthermore, the percentage of HFC-125 is preferably 10 mass% or more and 20 mass% or less.

[0038] The mixed refrigerant may contain any one of the reference refrigerants listed above, and any one of the following: HFC-134 (1,1,2,2-tetrafluoroethane, CHF_2-CHF_2), HFC-134a (1,1,1,2-tetrafluoroethane, CH_2F-CF_3), HFC-143a (1,1,1-trifluoroethane, CH_3CF_3), HFC-152a (1,1-difluoroethane, CHF_2-CH_3), HFC-161 (fluoroethane, CH_3-CH_2F), HFC-227ea (1,1,1,2,3,3,3-heptafluoropropane, $CF_3-CHF-CF_3$), HFC-236ea (1,1,1,2,3,3-hexafluoropropane, $CF_3-CHF-CHF_2$), HFC-236fa (1,1,1,3,3,3-hexafluoroethane, $CF_3-CH_2-CF_3$), and HFC-365mfc (1,1,1,3,3-pentafluorobutane, $CF_3-CH_2CF_2-CH_3$).

[0039] The mixed refrigerant described above is a mixed refrigerant containing any one of the reference refrigerants listed above and an HFC-based refrigerant, but is not limited to these options alone, and may also be a mixed refrigerant containing any one of the reference refrigerants listed above and a hydrocarbon-based refrigerant.

[0040] Specifically, the mixed refrigerant may contain any one of the reference refrigerants listed above, and any one of the following: methane (CH_4), ethane (CH_3-CH_3), propane ($CH_3-CH_2-CH_3$), propene (CH_3-

CH=CH₂), butane (CH₃-CH₂-CH₂-CH₃), isobutane (CH₃-CH(CH₃)-CH₃), pentane, (CH₃-CH₂-CH₂-CH₂-CH₃), 2-methylbutane (CH₃-CH(CH₃)-CH₂-CH₃), and cyclopentane (cyclo-C₅H₁₀).

[0041] The mixed refrigerant may also contain any one of the reference refrigerants listed above, and any one of the following: dimethyl ether (CH₃-O-CH₃), bis-trifluoromethylsulfide (CF₃-S-CF₃), carbon dioxide (CO₂), and helium (He).

[0042] In the embodiment described above, a mixed refrigerant composed of two refrigerants HFO-1234yf and HFC-32 is used as the refrigerant, but a mixed refrigerant composed of any one of the reference refrigerants listed above and any two of the second components listed above may also be used. For example, a mixed refrigerant composed of 52 mass% of HFO-1234yf, 23 mass% of HFC-32, and 25 mass% of HFC-125 is preferred.

<Characteristics>

[0043] The heat exchanger 10 is used as a heat exchanger of a refrigerant circuit which uses either a single refrigerant or a mixed refrigerant including the single refrigerant, which is composed of an organic compound whose molecular formula is expressed as C₃H_mF_n (wherein m = 1 to 5, n = 1 to 5, and m + n = 6) and whose molecular structure has one double bond. The heat exchanger 10 comprises a plurality of heat transfer tubes 12 and a plurality of plate-shaped fins 11. The heat transfer tubes 12 form one or a plurality of refrigerant passages for allowing the refrigerant to flow through. The plate-shaped fins 11 are disposed substantially parallel to the direction of air flow and the plurality of heat transfer tubes pass through the fins in a substantially vertical manner. The relationship between the center-to-center distance S between heat transfer tubes that are adjacent in a vertical direction and the outside diameter D of the heat transfer tubes is $2.5 < S/D < 3.5$, and the relationship between the refrigerant passage length L and the outside diameter D of the heat transfer tubes is $0.28 \times D^{1.17} < L < 1.10 \times D^{1.17}$. As a result, the effect of refrigerant pressure loss inside the heat transfer tubes is kept to a minimum. The specific refrigerant used is either a single refrigerant composed of 2,3,3,3-tetrafluoro-1-propene, a mixed refrigerant containing the single refrigerant, a mixed refrigerant containing 2,3,3,3-tetrafluoro-1-propene and difluoromethane, or a mixed refrigerant containing 2,3,3,3-tetrafluoro-1-propene and pentafluoroethane.

INDUSTRIAL APPLICABILITY

[0044] As described above, the present invention is effective in a heat exchanger of a refrigerant circuit which uses a low-pressure refrigerant.

Claims

1. A heat exchanger (4, 6, 10) of a refrigerant circuit in which either a single refrigerant or a mixed refrigerant including the single refrigerant is employed, the single refrigerant comprising an organic compound whose molecular formula is expressed as C₃H_mF_n (wherein m = 1 to 5, n = 1 to 5, and m + n = 6) and whose molecular structure has one double bond, the heat exchanger comprising:

a plurality of heat transfer tubes (12) which form one or a plurality of refrigerant passages for allowing the refrigerant to flow therethrough; and a plurality of plate-shaped fins (11) aligned to be stacked at a predetermined spacing through which the heat transfer tubes (12) pass through in a substantially vertical manner; wherein the relationship between a center-to-center distance S between the heat transfer tubes (12) that are adjacent in the vertical direction and an outside diameter D of the heat transfer tubes (12) is

$$2.5 < S/D < 3.5;$$

and the relationship between the length L of the refrigerant passages and the outside diameter D of the heat transfer tubes (12) is

$$0.28 \times D^{1.17} < L < 1.10 \times D^{1.17}.$$

2. The heat exchanger (4, 6, 10) according to claim 1, wherein the refrigerant is either a single refrigerant comprising 2,3,3,3-tetrafluoro-1-propene or a mixed refrigerant containing the single refrigerant.
3. The heat exchanger (4, 6, 10) according to claim 1, wherein the refrigerant is a mixed refrigerant comprising 2,3,3,3-tetrafluoro-1-propene and difluoromethane.
4. The heat exchanger (4, 6, 10) according to claim 1, wherein the refrigerant is a mixed refrigerant comprising 2,3,3,3-tetrafluoro-1-propene and pentafluoroethane.

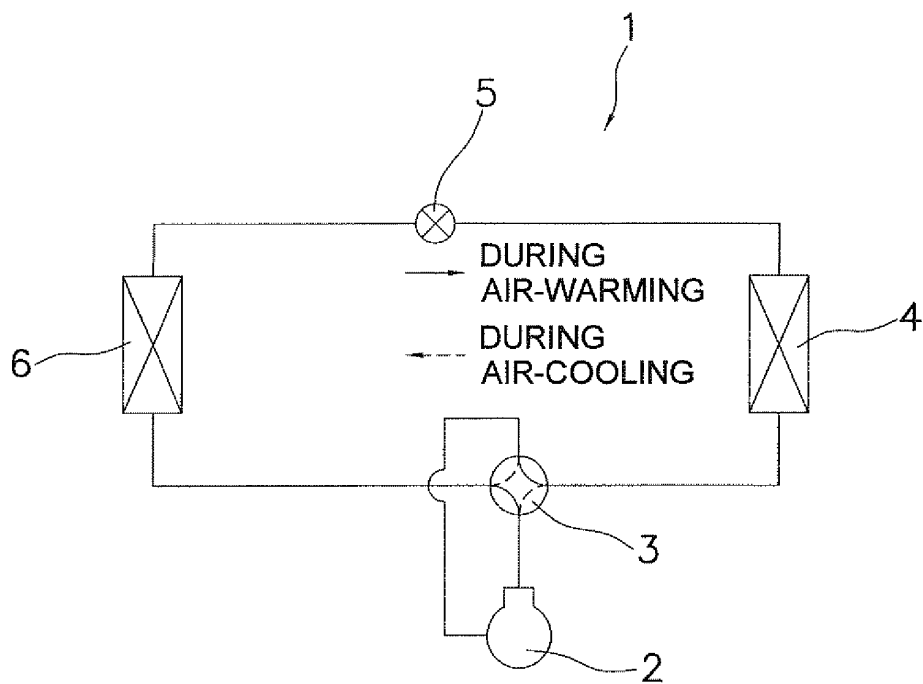


FIG. 1

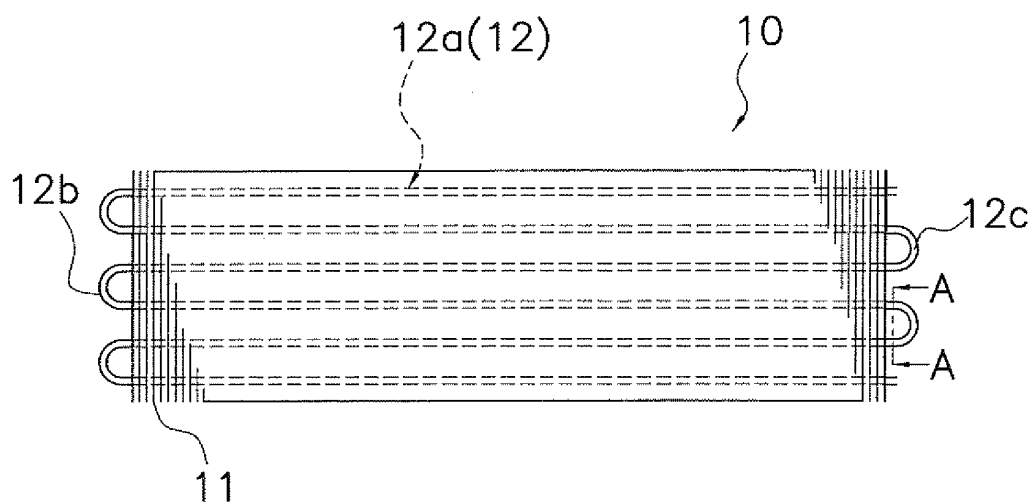


FIG. 2

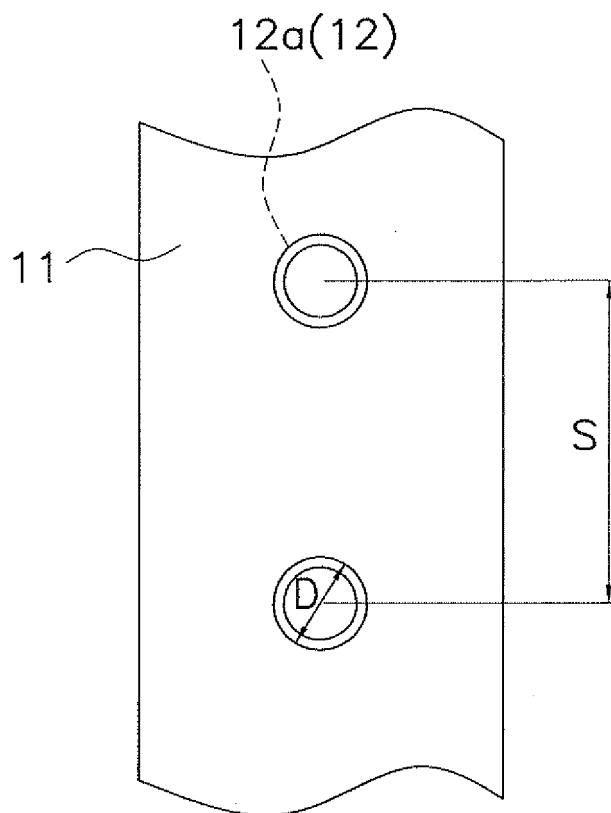


FIG. 3

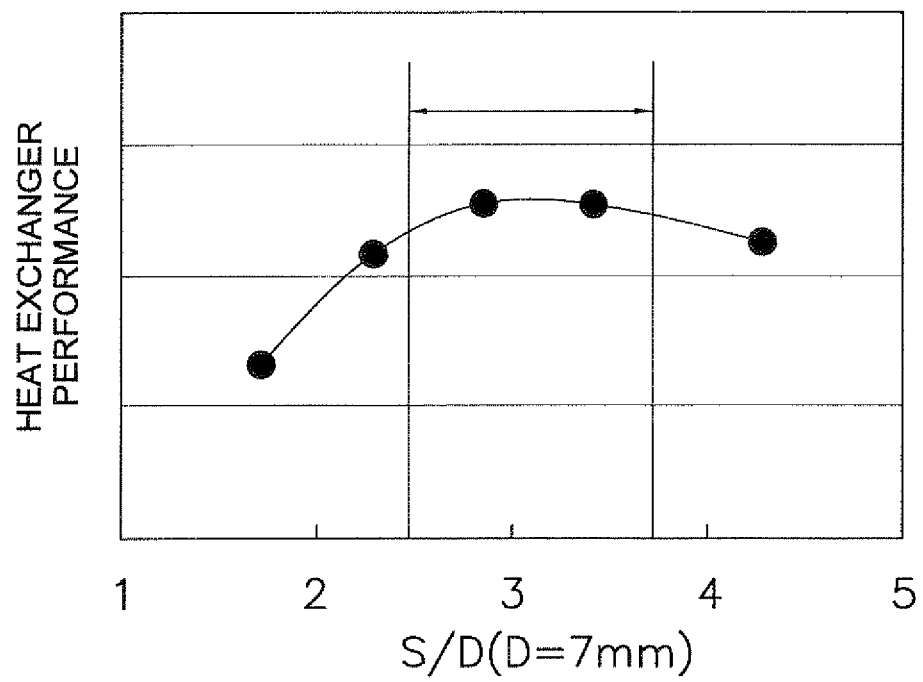


FIG. 4

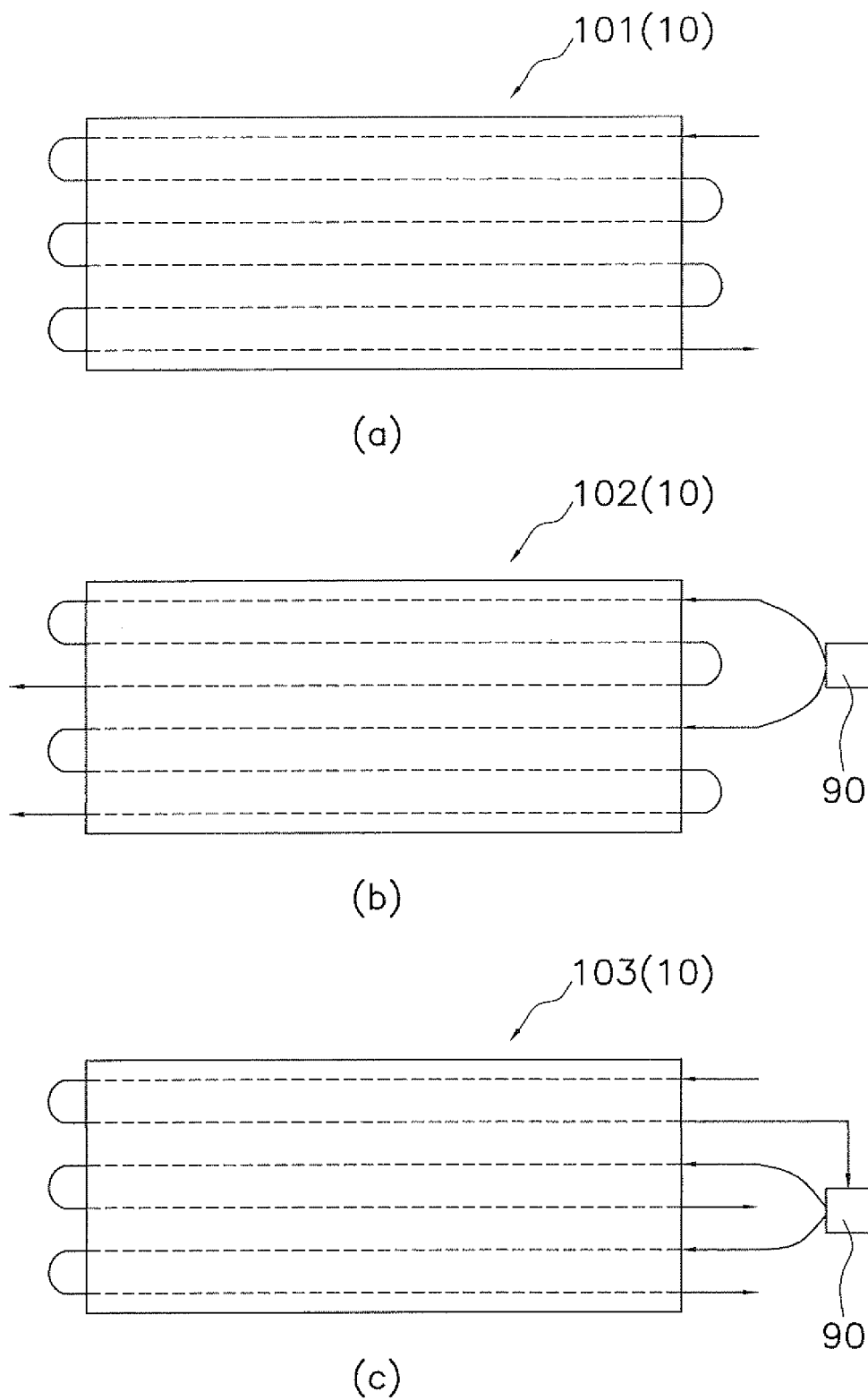


FIG. 5

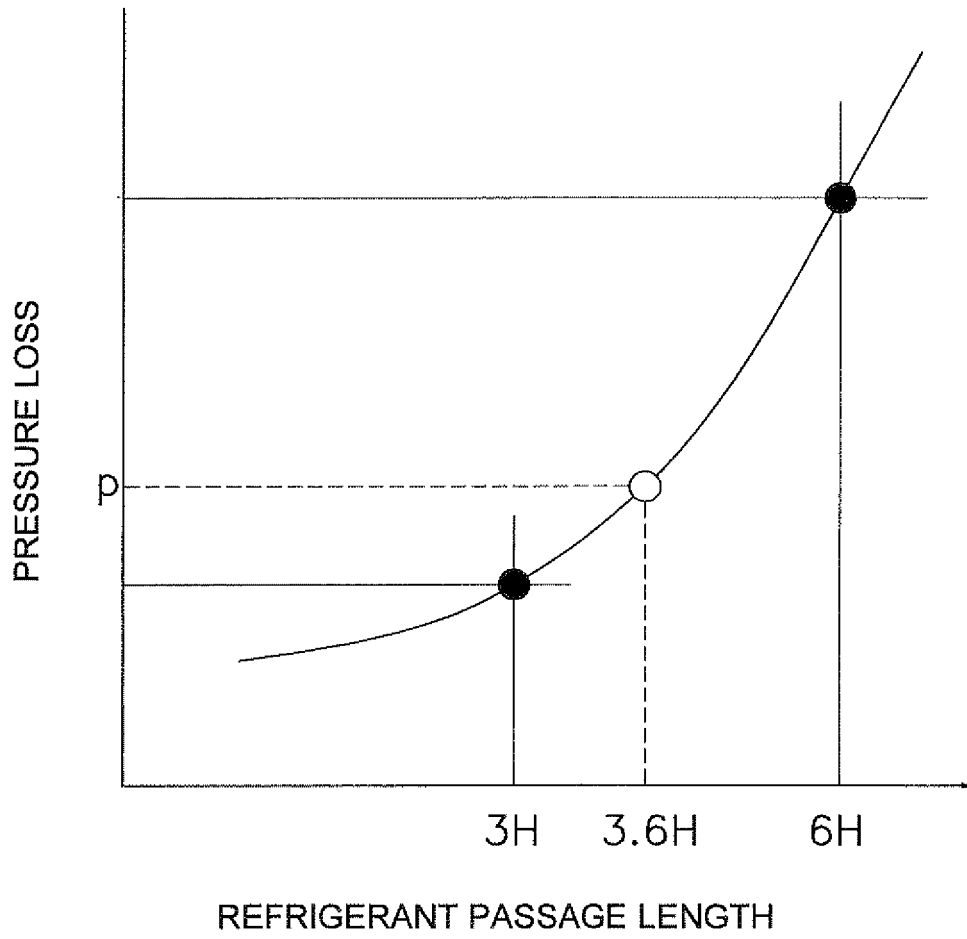


FIG. 6

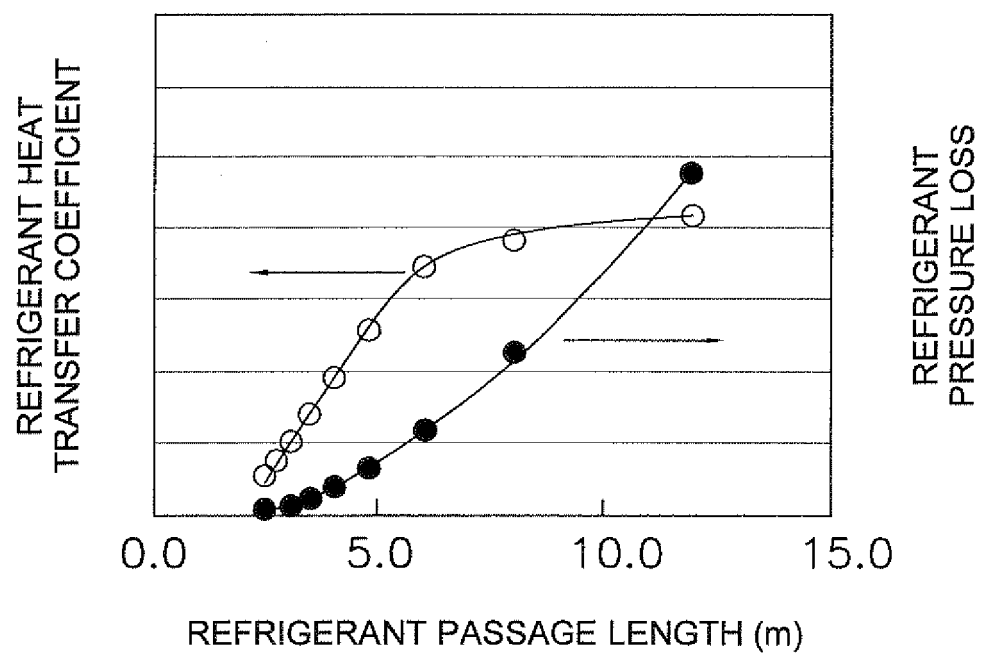


FIG. 7

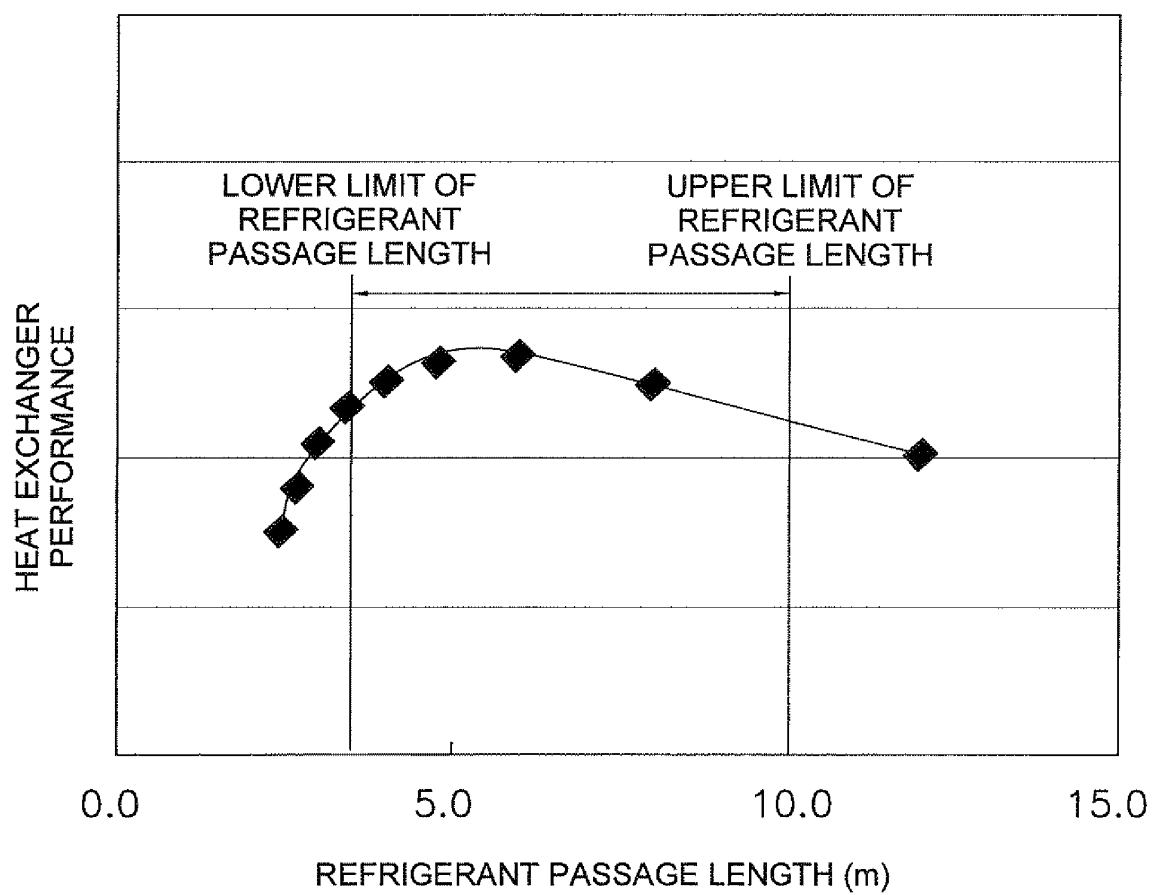


FIG. 8

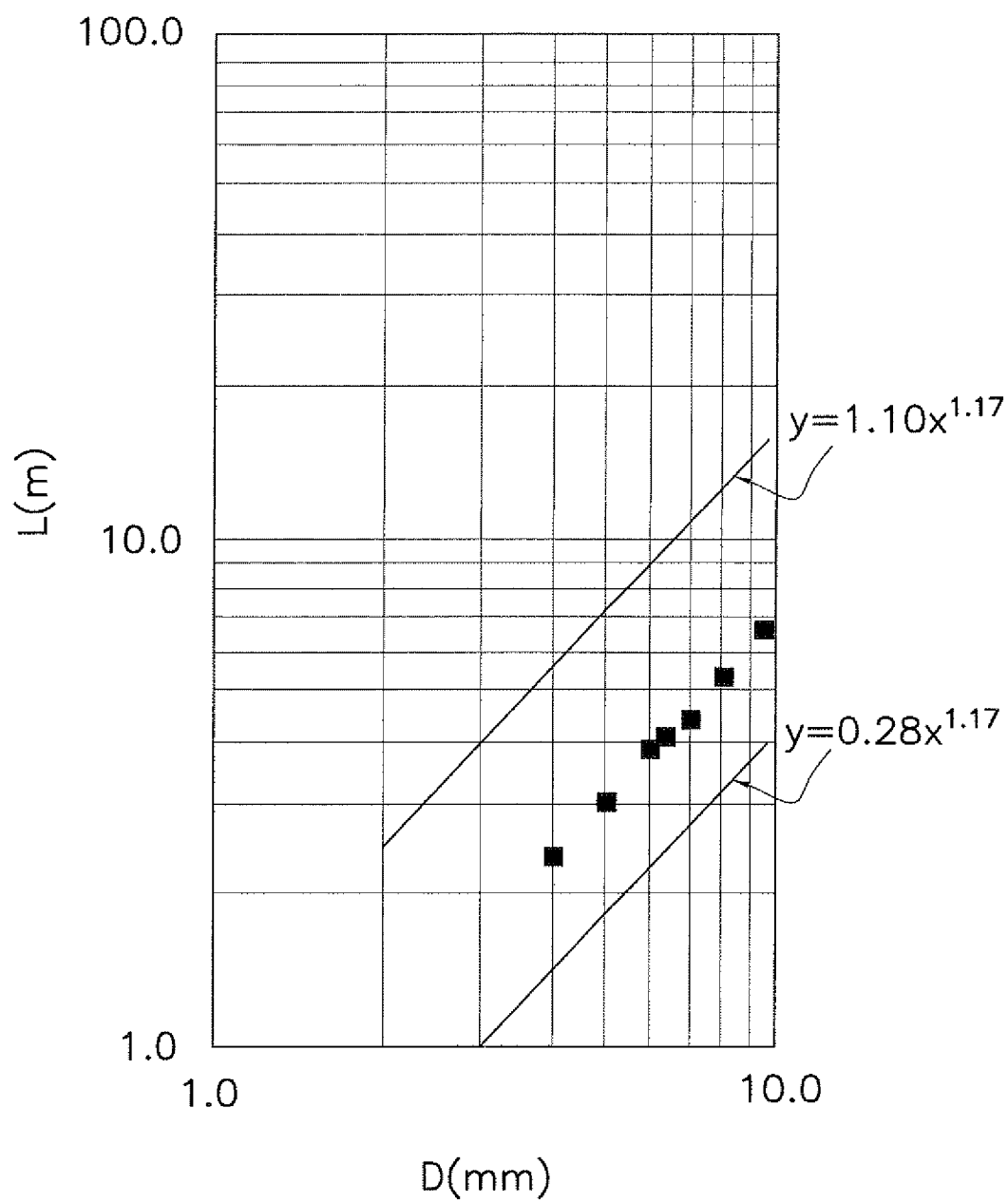


FIG. 9

	Refrigerant Type	Symbol	Material Name	Chemical Formula
Reference Refrigerant	C3HmFn	HFO-1225 based	1,2,3,3,3-pentafluoropropene	CF ₃ -CF=CHF
		HFO-1234 based		
		HFO-1234yf	2,3,3,3-tetrafluoro-1-propene	CF ₃ -CF=CH ₂
		HFO-1234ze	1,3,3,3-tetrafluoro-1-propene	CF ₃ -CH=CHF
		HFO-1234ye	1,2,3,3-tetrafluoro-1-propene	CHF ₂ -CF=CHF
		HFO-1243 based		
		HFO-1243zf	3,3,3-trifluoro-1-propene	CF ₃ -CHCH ₂
			1,2,2-trifluoro-1-propene	CH ₃ -CF=CF ₂
		HFO-1261 based		
			2-fluoro-1-propene	CH ₃ -CF=CH ₂
Second Component	HFC based	HFC-32	difluoromethane	CH ₂ F ₂
		HFC-125	pentafluoroethane	CF ₃ -CHF ₂
		HFC-134	1,1,2,2-tetrafluoroethane	CHF ₂ -CHF ₂
		HFC-134a	1,1,1,2-tetrafluoroethane	CH ₂ F-CF ₃
		HFC-143a	1,1,1-trifluoroethane	CH ₃ -CF ₃
		HFC-152a	1,1,-difluoroethane	CHF ₂ -CH ₃
		HFC-161	fluoroethane	CH ₃ -CH ₂ F
		HFC-227ea	1,1,1,2,3,3,3-heptafluoropropane	CF ₃ -CHF-CF ₃
		HFC-236ea	1,1,1,2,3,3-hexafluoropropane	CF ₃ -CHF-CHF ₂
		HFC-236fa	1,1,1,3,3,3-hexafluoroethane	CF ₃ -CH ₂ -CF ₃
		HFC-365mfc	1,1,1,3,3-pentafluorobutane	CF ₃ -CH ₂ -CF ₂ -CH ₃
	Hydrocarbon-based		methane	CH ₄
			ethane	CH ₃ -CH ₃
		R290	propane	CH ₃ -CH ₂ -CH ₃
			propene	CH ₃ -CH=CH ₂
		R600	butane	CH ₃ -CH ₂ -CH ₂ -CH ₃
		R600a	isobutane	CH ₃ -CH(CH ₃)-CH ₃
			pentane	CH ₃ -CH ₂ -CH ₂ -CH ₂ -CH ₃
			2-methylbutane	CH ₃ -CH(CH ₃)-CH ₂ -CH ₃
			cyclopentane	cyclo-C ₅ H ₁₀
	Ether	DME	dimethyl ether	CH ₃ -O-CH ₃
	Other		bis-trifluoromethyl-sulfide	CF ₃ -S-CF ₃
		R744	carbon dioxide	CO ₂
			helium	He

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/054999

A. CLASSIFICATION OF SUBJECT MATTER

F28F1/32(2006.01) i, F25B1/00(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)

F28F1/32, F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 4-110388 A (Daikin Industries, Ltd.), 10 April, 1992 (10.04.92), Full text; all drawings (Family: none)	1-4
Y	JP 63-3188 A (Matsushita Refrigeration Co.), 08 January, 1988 (08.01.88), Full text; all drawings (Family: none)	1-4
Y	JP 2003-343942 A (Denso Corp.), 03 December, 2003 (03.12.03), Par. Nos. [0011] to [0029]; Figs. 1 to 8 (Family: none)	1-4

☒ 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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
27 April, 2009 (27.04.09)Date of mailing of the international search report
19 May, 2009 (19.05.09)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/054999

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-512426 A (Honeywell International Inc.), 13 April, 2006 (13.04.06), Full text; particularly, Par. Nos. [0023], [0046] & JP 2006-503961 A & JP 2007-510039 A & JP 2007-535611 A & US 2004/0089839 A1 & US 2004/0119047 A1 & US 2004/0127383 A1 & US 2004/0256594 A1 & US 2007/0010592 A1 & US 2007/0069175 A1 & US 2007/0290177 A1 & US 2008/0098755 A1 & US 2008/0125505 A1 & US 2008/0125506 A1 & US 2008/0166305 A1 & US 2008/0171652 A1 & US 2008/0207788 A1 & US 2008/0292564 A1 & US 2008/0099190 A1 & US 2007/0007488 A1 & US 2008/0121837 A1 & US 2008/0135800 A1 & EP 1563032 A & EP 1578883 A & EP 1725628 A & EP 2009075 A & EP 1716216 A & WO 2004/037913 A2 & WO 2004/037752 A2 & WO 2005/042663 A1 & WO 2005/105947 A2 & WO 2009/009413 A & CA 2503421 A & BR 315633 A & KR 10-2005-0055787 A & CN 1732243 A & TW 291492 B & ZA 200504236 A & KR 10-2006-0103324 A & CN 1898353 A & CA 2557873 A & KR 10-2007-0004654 A & BRA PI0508245 & CN 101014680 A & SG 139767 A & AR 50327 A & ES 2306635 T	2-4
Y	WO 2007/002625 A2 (HONEY INTERNATIONAL INC.), 04 January, 2007 (04.01.07), Full text; particularly, page 11, line 8 to page 12, line 20 & JP 2008-544072 A & JP 2008-546892 A & US 2007/0007488 A1 & US 2008/0098755 A1 & US 2008/0099190 A1 & US 2008/0166305 A1 & US 2008/0171652 A1 & US 2008/0292564 A1 & US 2008/0121837 A1 & EP 1893714 A & EP 1893715 A & WO 2007/002703 A2 & WO 2009/009413 A & CA 2612986 A & CA 2613090 A & KR 10-2008-0033292 A & KR 10-2008-0025748 A & CN 101248153 A & CN 101283071 A	2-4

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

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 4110388 A [0004]