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(54) HEAT EXCHANGER

(75) Inventors: **Hirokazu Fujino**, Osaka (JP); **Shun Yoshioka**, Osaka (JP); **Takashi Doi**, Shiga (JP); **Masaaki Kitazawa**, Shiga (JP); **Haruo Nakata**, Osaka (JP)

Correspondence Address:
GLOBAL IP COUNSELORS, LLP
1233 20TH STREET, NW, SUITE 700
WASHINGTON, DC 20036-2680 (US)

(73) Assignee: **DAIKIN INDUSTRIES, LTD.**, Osaka-shi, Osaka (JP)

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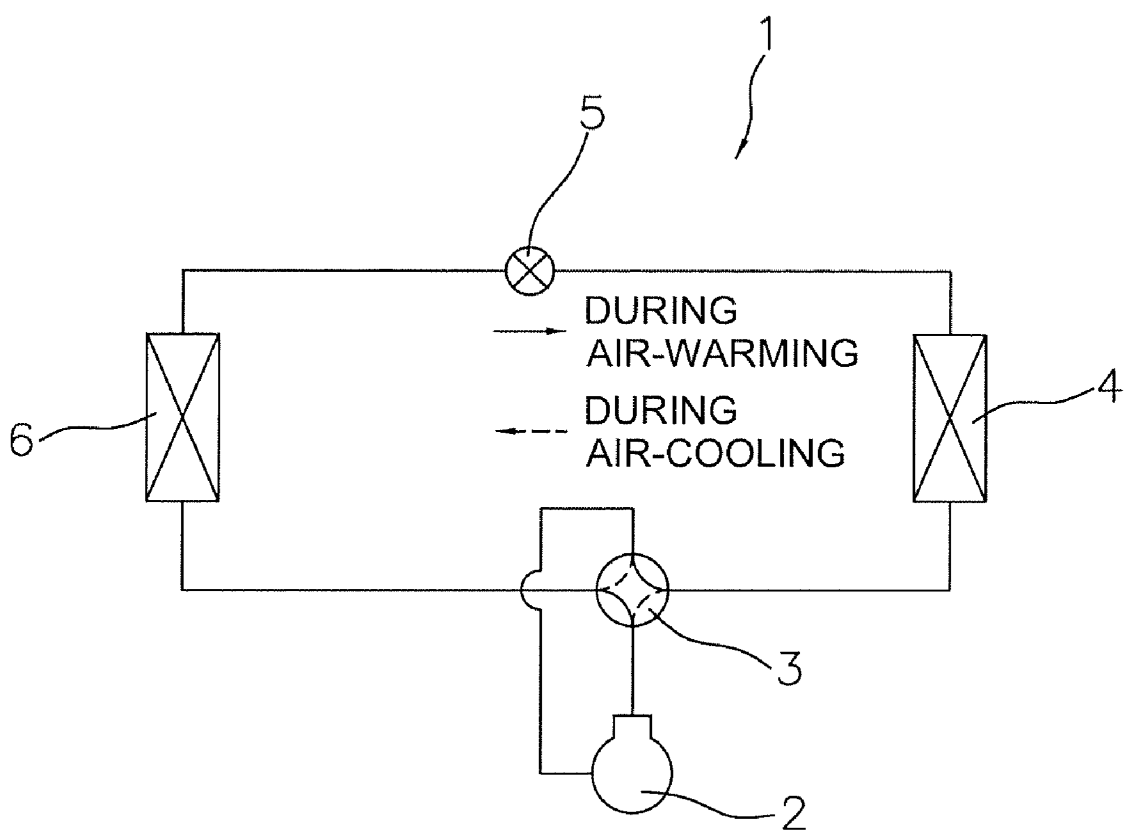
(57) ABSTRACT

A heat exchanger includes heat transfer tubes forming one or more refrigerant passages, and a plurality of plate-shaped fins aligned and stacked at a predetermined spacing with the heat transfer tubes passing through in a substantially perpendicular manner. A relationship between a center-to-center distance S between an adjacent pair of heat transfer tubes and an outside diameter D of the heat transfer tubes is $2.5<S/D<3.5$. The center-to-center distance S is measured substantially perpendicularly to the adjacent pair of heat transfer tubes. A relationship between a length L of the one or more refrigerant passages and the outside diameter D of the heat transfer tubes is $0.28\times D^{1.17}<L<1.10\times D^{1.17}$. The heat exchanger is preferably for a refrigerant circuit using either a single refrigerant or a mixed refrigerant including the single refrigerant. The single refrigerant includes an organic compound having a molecular formula $C_3H_mF_n$ (where m=1 to 5, n=1 to 5, and m+n=6) and a molecular structure with one double bond.



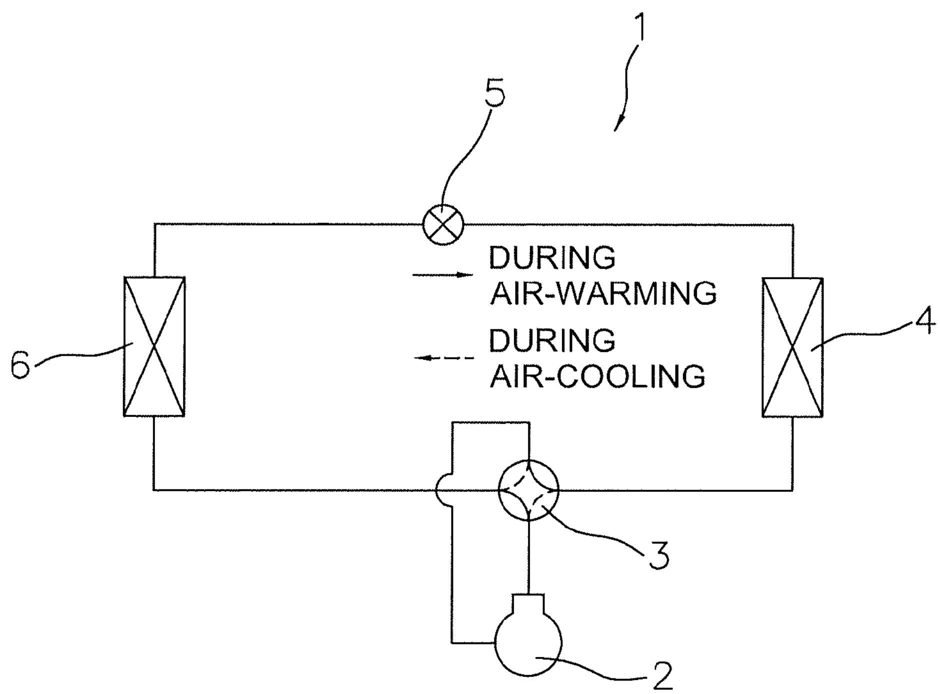

1
5
DURING
AIR-WARMING
DURING
AIR-COOLING
6
4
3
2

FIG. 1

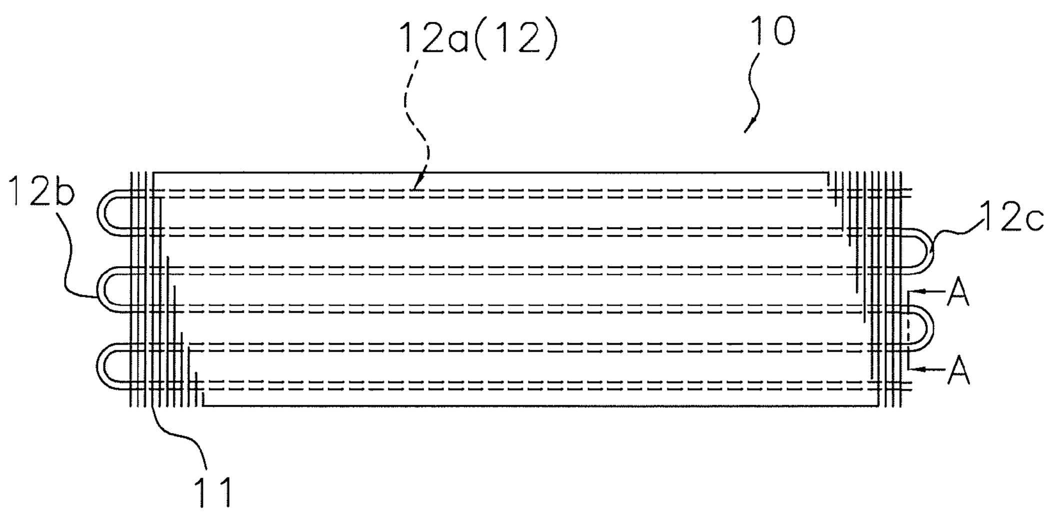

12a(12)
10
12b
12c
A
A
11

FIG. 2

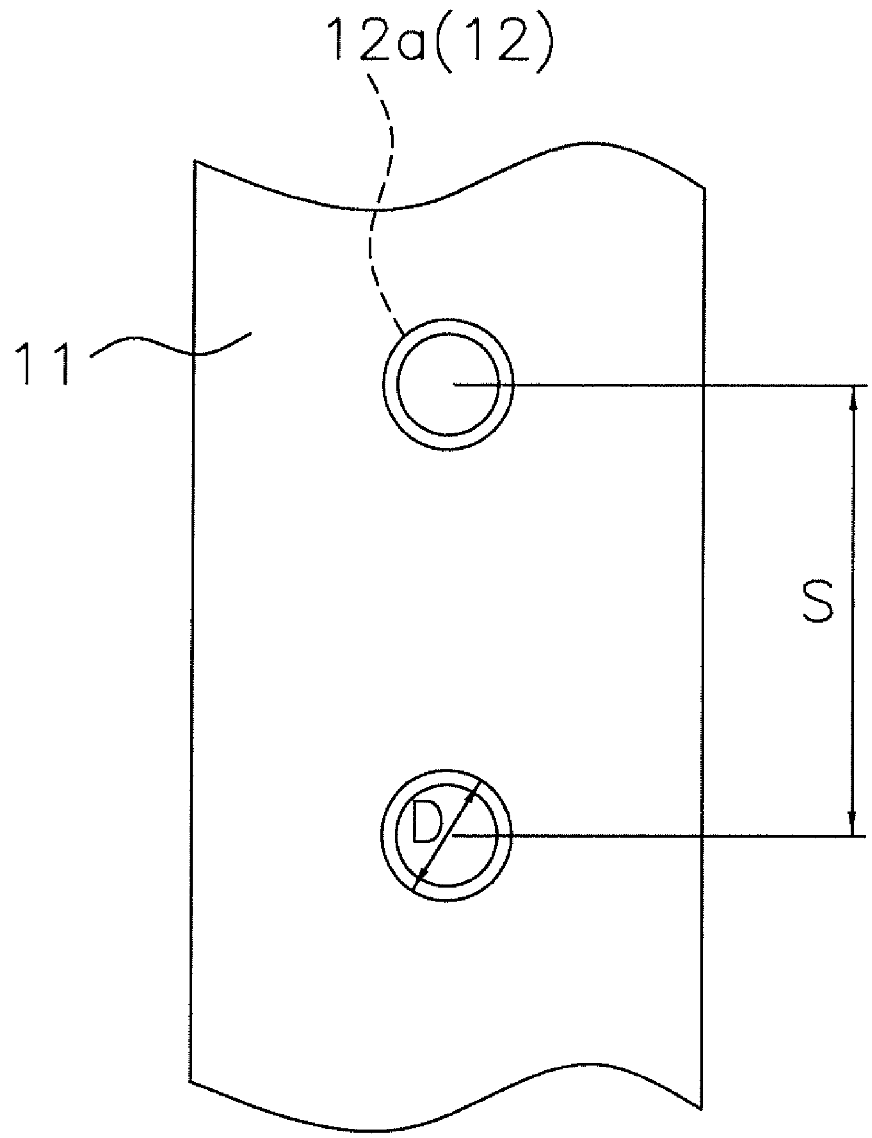


FIG. 3

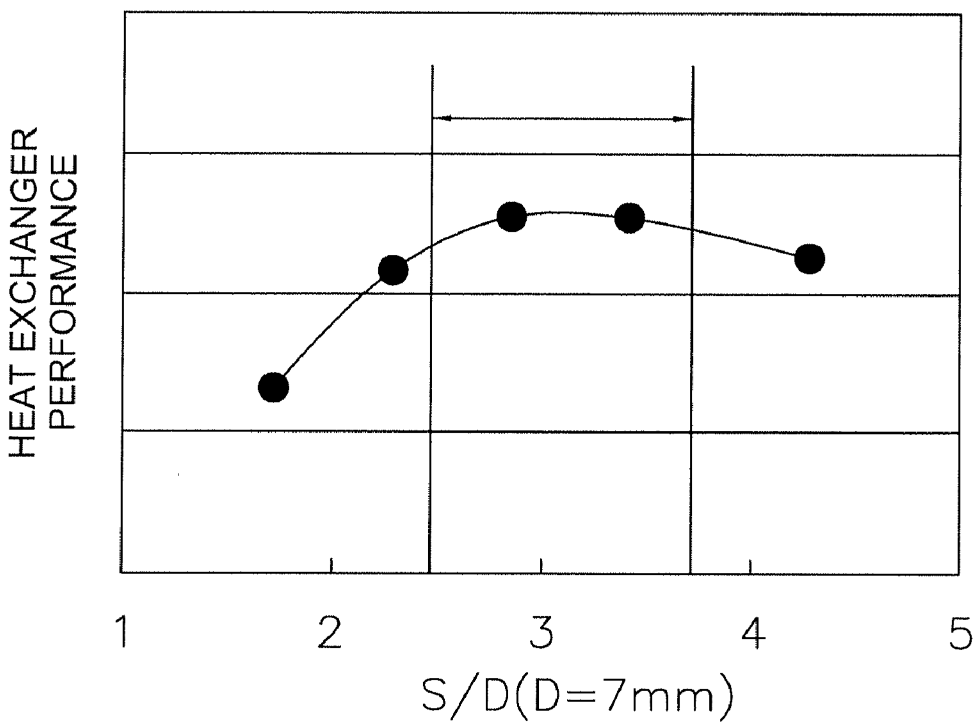


FIG. 4

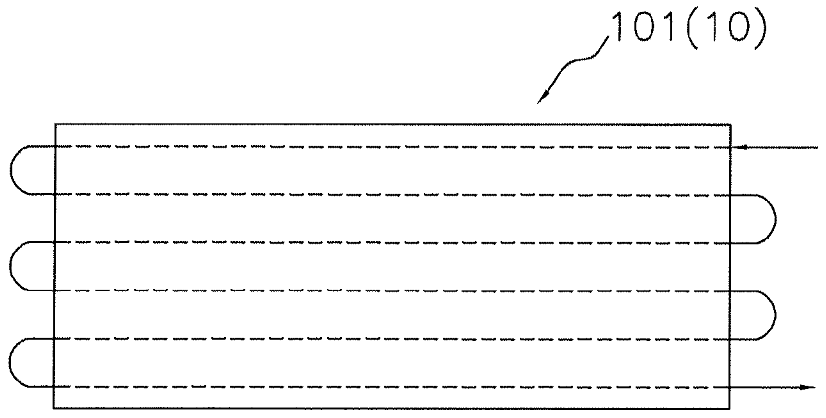


FIG. 5 (a)

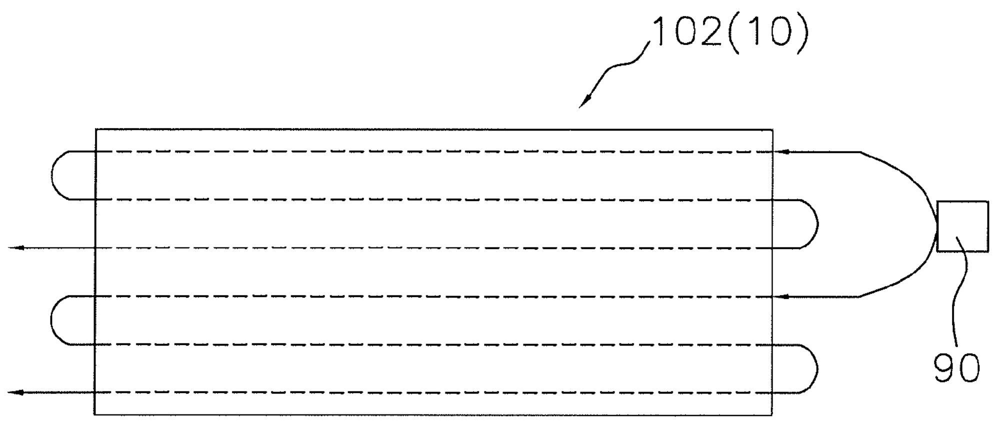


FIG. 5 (b)

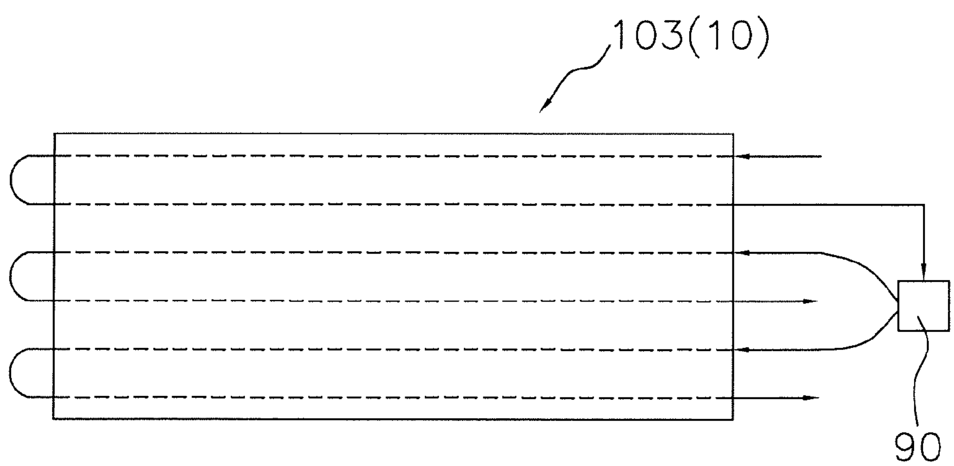


FIG. 5 (c)

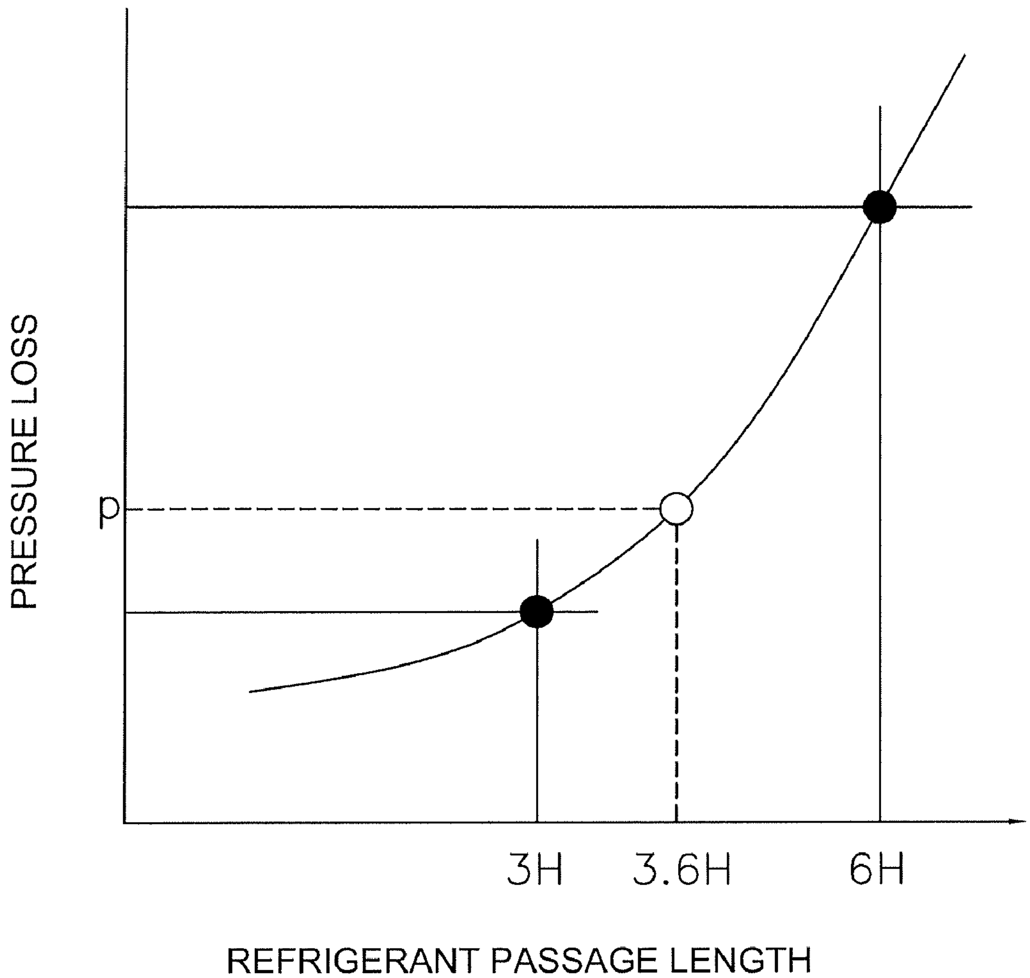


FIG. 6

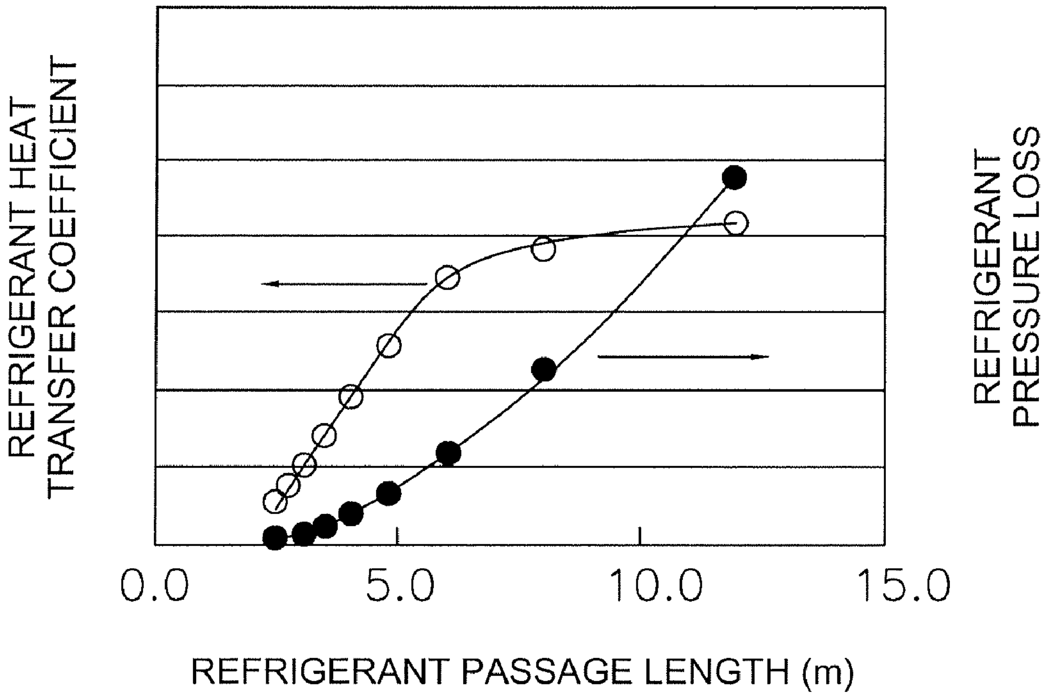

REFRIGERANT HEAT TRANSFER COEFFICIENT
REFRIGERANT PRESSURE LOSS
0.0
5.0
10.0
15.0
REFRIGERANT PASSAGE LENGTH (m)

FIG. 7

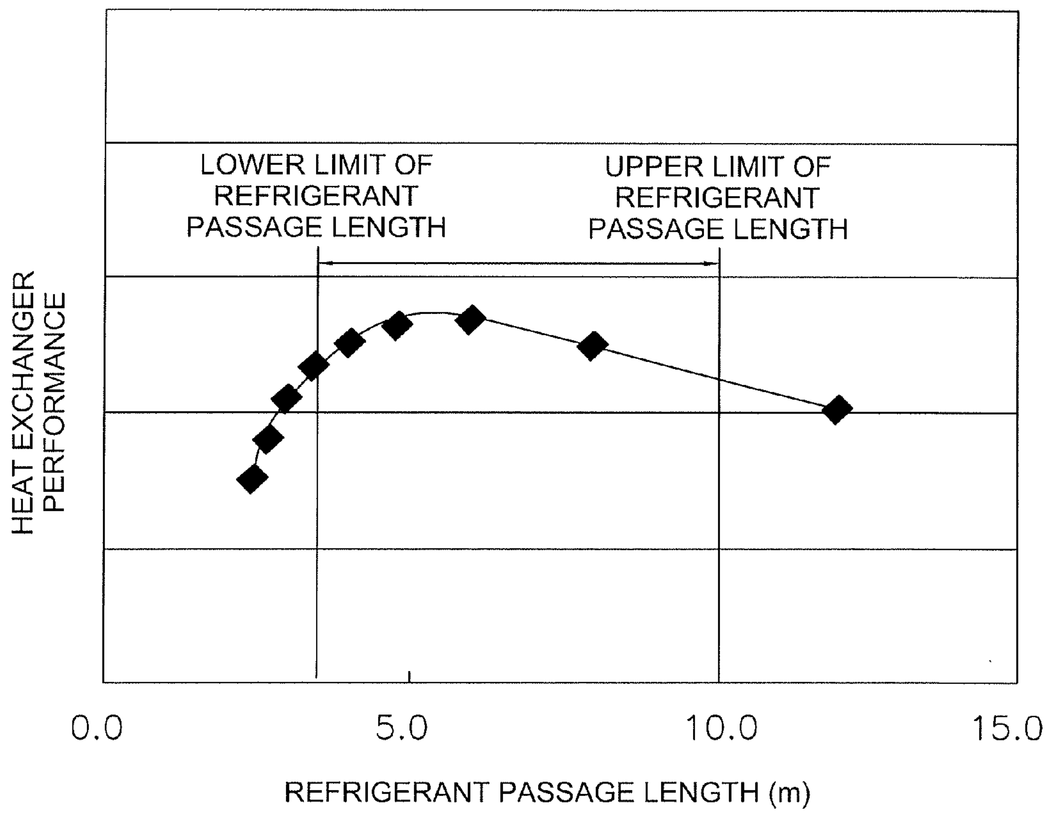

LOWER LIMIT OF REFRIGERANT PASSAGE LENGTH
UPPER LIMIT OF REFRIGERANT PASSAGE LENGTH
HEAT EXCHANGER PERFORMANCE
0.0
5.0
10.0
15.0
REFRIGERANT PASSAGE LENGTH (m)

FIG. 8

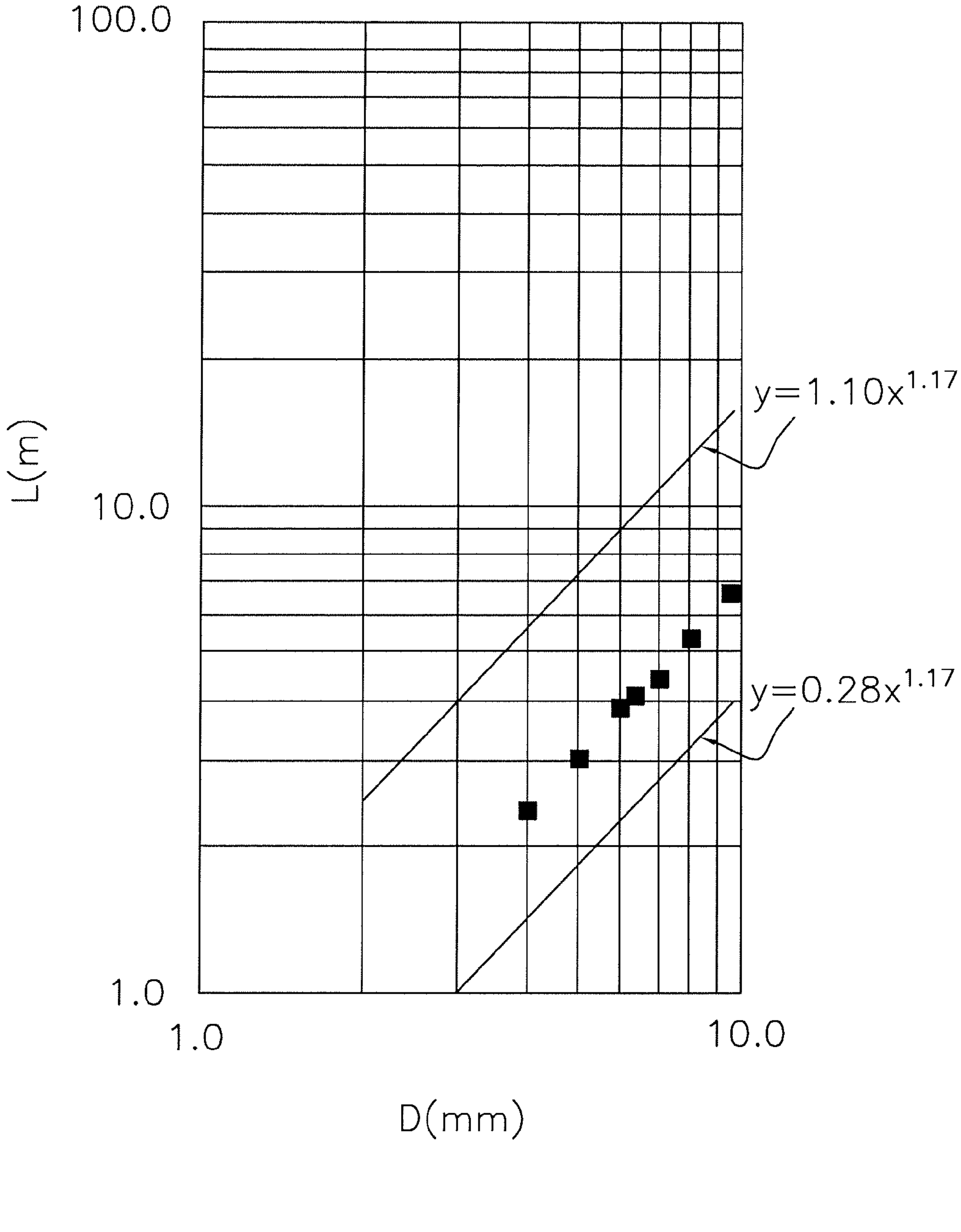


FIG. 9

HEAT EXCHANGER

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.

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

DISCLOSURE OF THE INVENTION

Technical Problem

[0004] 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

[0005] 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 $0.28\times D^{1.17}<L<1.10\times D^{1.17}$.

[0006] 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.

[0007] 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.

[0008] 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.

[0009] 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.

[0010] 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.

[0011] 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.

[0012] 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

[0013] 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

[0014] FIG. **1** is a refrigerant circuit of an air-conditioning apparatus.

[0015] FIG. **2** is a front view of a heat exchanger according to an embodiment of the present invention.

[0016] FIG. **3** is a cross-sectional view of the heat exchanger when divided along line A-A in FIG. **2**.

[0017] 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.

[0018] 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.

[0019] FIG. **6** is a graph showing the relationship between refrigerant passage length and pressure loss.

[0020] 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.

[0021] FIG. **8** is a graph showing the refrigerant passage length and the heat exchanger performance when D=7 mm.

[0022] FIG. **9** is a graph in which the refrigerant passage length L is plotted relative to the heat transfer tube outside diameter D.

[0023] 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

[0024] **4** Outdoor heat exchanger

[0025] **6** Indoor heat exchanger

[0026] **10** Heat exchanger

[0027] **11** Plate-shaped fin

[0028] **12** Heat-transfer tube

BEST MODE FOR CARRYING OUT THE INVENTION

Refrigerant Circuit

[0029] 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.

[0030] 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

[0031] 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 **12***a* inserted through the through-holes of the fins **11**, and first U-shaped tubes **12***b* and second U-shaped tubes **12***c* connecting the ends of adjacent straight tubes **12***a* to each other. The straight tubes **12***a* and the first U-shaped tubes **12***b* are formed integrally, and the second U-shaped tubes **12***c* are connected to the ends of the straight tubes **12***a* by welding or another method after the straight tubes **12***a* 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)

[0032] 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 **12***a* 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.

[0033] 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.

[0034] 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)

[0035] 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.

[0036] 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 6 H.

[0037] 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 3 H, which is half that of the 1-pass heat exchanger **101**.

[0038] 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.

[0039] 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 3.6 H. 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.

[0040] 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 $1/K=1/ha+R/hr$, using the air heat transfer coefficient ha, the refrigerant heat transfer coefficient hr, and the inside-outside heat transfer surface area ratio R.

[0041] 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 hr 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.

[0042] When the number of refrigerant passages is increased 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 hr decreases and the heat exchanger performance Q decreases.

[0043] 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.

[0044] 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.

[0045] 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)

[0046] 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.

[0047] 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)

[0048] 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.

[0049] 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.

[0050] 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, $CH_2F\text{-}CF_3$), HFC-143a (1,1,1-trifluoroethane, CH_3CF_3), HFC-152a (1,1-difluoroethane, $CHF_2\text{-}CH_3$), HFC-161 (fluoroethane, $CH_3\text{-}CH_2F$), HFC-227ea (1,1,1,2,3,3,3-heptafluoropropane, $CF_3\text{-}CHF\text{-}CF_3$), HFC-236ea (1,1,1,2,3,3-hexafluoropropane, $CF_3\text{-}CHF\text{-}CHF_2$), HFC-236fa (1,1,1,3,3,3-hexafluoroethane, $CF_3\text{-}CH_2\text{-}CF_3$), and HFC-365mfc (1,1,1,3,3-pentafluorobutane, $CF_3\text{-}CH_2CF_2\text{-}CH_3$).

[0051] 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.

[0052] Specifically, the mixed refrigerant may contain any one of the reference refrigerants listed above, and any one of the following: methane (CH_4), ethane ($CH_3\text{-}CH_3$), propane ($CH_3\text{-}CH_2\text{-}CH_3$), propene ($CH_3{-}CH{=}CH_2$), butane ($CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_3$), isobutane ($CH_3\text{-}CH(CH_3)\text{-}CH_3$), pentane, ($CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$), 2-methylbutane ($CH_3\text{-}CH(CH_3)\text{-}CH_2\text{-}CH_3$), and cyclopentane (cyclo-C_5H_{10}).

[0053] The mixed refrigerant may also contain any one of the reference refrigerants listed above, and any one of the following: dimethyl ether ($CH_3\text{-}O\text{-}CH_3$), bis-trifluoromethyl-sulfide ($CF_3\text{-}S\text{-}CF_3$), carbon dioxide ($CO_2$), and helium (He).

[0054] 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

[0055] 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 $C_3H_mF_n$ (wherein m=1 to 5, n=1 to 5, and m+n=6) and whose molecular structure has one double bond. The heat exchanger **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

[0056] As described above, the present invention is effective in a heat exchanger of a refrigerant circuit which uses a low-pressure refrigerant.

1. A heat exchanger of a refrigerant circuit using a refrigerant, which is either a single refrigerant or a mixed refrigerant including the single refrigerant, the single refrigerant including an organic compound having a molecular formula expressed as $C_3H_mF_n$ (wherein m=1 to 5, n=1 to 5, and m+n=6) and a molecular structure with one double bond, the heat exchanger comprising:

a plurality of heat transfer tubes forming one or more refrigerant passages configured to allow the refrigerant to flow therethrough; and

a plurality of plate-shaped fins aligned and stacked at a predetermined spacing with the heat transfer tubes passing therethrough in a substantially perpendicular manner,

a relationship between a center-to-center distance S between an adjacent pair of the heat transfer tubes and an outside diameter D of the heat transfer tubes is $2.5<S/D<3.5$, where the center-to-center distance S is measured in a direction substantially perpendicular to the adjacent pair of the heat transfer tubes, and

a relationship between a length L of the one or more refrigerant passages and the outside diameter D of the heat transfer tubes is $0.28\times D^{1.17}<L<1.10\times D^{1.17}$.

2. The heat exchanger according to claim **1**, wherein

the single refrigerant includes 2,3,3,3-tetrafluoro-1-propene.

3. The heat exchanger according to claim **1**, wherein

the refrigerant circuit uses the mixed refrigerant, and the mixed refrigerant includes 2,3,3,3-tetrafluoro-1-propene and difluoromethane.

4. The heat exchanger according to claim **1**, wherein

the refrigerant circuit uses the mixed refrigerant, and the mixed refrigerant includes 2,3,3,3-tetrafluoro-1-propene and pentafluoroethane.

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