



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

(43) Date of publication:
18.05.2016 Bulletin 2016/20

(51) Int Cl.:
F28D 1/053 ^(2006.01) **F25B 5/02** ^(2006.01)
F25B 39/02 ^(2006.01)

(21) Application number: **14823375.2**

(86) International application number:
PCT/JP2014/068203

(22) Date of filing: **08.07.2014**

(87) International publication number:
WO 2015/005352 (15.01.2015 Gazette 2015/02)

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

- **MATSUDA, Takuya**
Tokyo 100-8310 (JP)
- **OKAZAKI, Takashi**
Tokyo 100-8310 (JP)
- **MOCHIZUKI, Atsushi**
Tokyo 102-0073 (JP)

(30) Priority: **08.07.2013 PCT/JP2013/068677**

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

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

(72) Inventors:
• **ISHIBASHI, Akira**
Tokyo 100-8310 (JP)

(54) **HEAT EXCHANGER, AND HEAT PUMP DEVICE**

(57) A heat exchanger according to the present invention includes a plurality of thin-plate members 1 spaced apart from one another, fluid flowing through the space, a flow channel formed in each of the plurality of thin-plate members 1, a medium flowing through the flow channel, the medium exchanging heat with the fluid, and a pair of headers each connecting ends of a corresponding one of two sides of the plurality of thin-plate members. The plurality of thin-plate members 1 satisfy a relationship of $3 \leq F_p/F_t \leq 21$, where F_p denotes a pitch of the plurality of thin-plate members 1 adjacent to one another, and F_t denotes a thickness of each of the plurality of thin-plate members 1.

FIG. 2

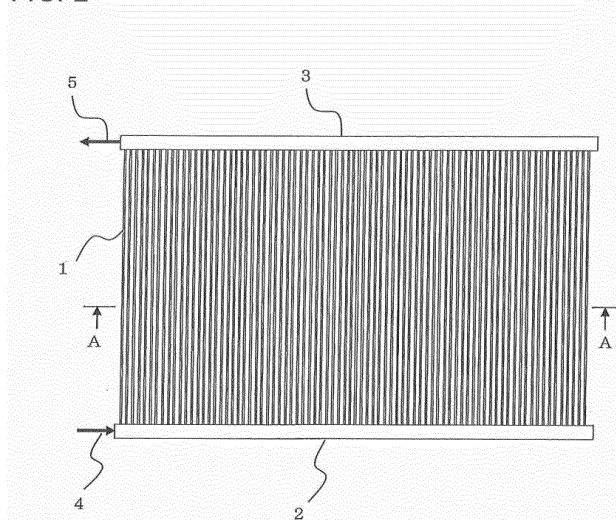
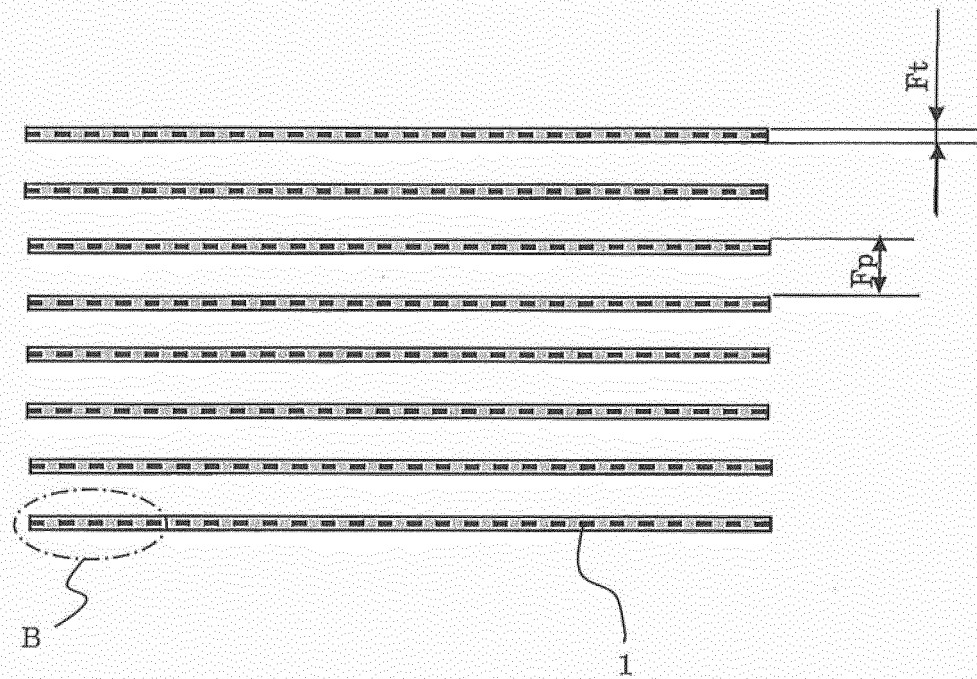


FIG. 3



Description

Technical Field

[0001] The present invention relates to a heat exchanger and a heat pump apparatus including the heat exchanger.

Background Art

[0002] A plate-fin heat exchanger, a conventional heat exchanger has, for example, a pair of headers, a plurality of multi-channel heat-exchanger tubes, and fins. The headers are spaced apart from each other. One of the headers connects ends of one side of the multi-channel heat-exchanger tubes, and the other of the headers connects ends of the other side of the multi-channel heat-exchanger tubes. The fins are thin-plate members for promoting heat exchange coupled between the plurality of multi-channel heat-exchanger tubes.

[0003] Another conventional heat exchanger has a pair of headers and a plurality of fins. The headers are spaced apart from each other. One of the headers connects ends of one side of the fins, which are thin-plate members, and the other of the headers connects ends of the other side of the thin-plate members. Flow channels are formed in each of the plurality of thin-plate members (see Patent Literature 1, for example).

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2008-528943 (Abstract)

Summary of Invention

Technical Problem

[0005] In the above technology disclosed by Patent Literature 1, the thickness and the intervals of the plurality of thin-plate members are not considered.

[0006] Hence, there is a problem in that the thickness and the intervals of the plurality of thin-plate members may be inappropriate, thus lowering the heat exchangeability of the heat exchanger.

[0007] For example, if the thickness of the thin-plate members is made too large, although the channel area increases, the draft resistance applied to air passing through each space between adjacent ones of the plurality of thin-plate members increases, thus lowering the heat exchangeability. In contrast, if the thickness of the thin-plate members is reduced, the draft resistance applied to air passing through each space between adjacent ones of the thin-plate members is reduced. Instead, the channel area is reduced, thus lowering the heat exchangeability.

[0008] In view of the above problem, the present invention provides a heat exchanger and a heat pump apparatus that exhibits improved heat exchangeability. Solution to Problem

[0009] A heat exchanger according to the present invention includes a plurality of thin-plate members spaced apart from one another, fluid flowing through the space, a flow channel formed in each of the plurality of thin-plate members, a medium flowing through the flow channel, the medium exchanging heat with the fluid, and a pair of headers each connecting ends of a corresponding one of two sides of the plurality of thin-plate members. The plurality of thin-plate members satisfy a relationship of $3 \leq F_p/F_t \leq 21$, where F_p denotes a pitch of the plurality of thin-plate members adjacent to one another, and F_t denotes a thickness of each of the plurality of thin-plate members.

[0010] A heat pump apparatus according to the present invention includes a heat exchanger including a plurality of thin-plate members spaced apart from one another, fluid flowing through the space, a flow channel formed in each of the plurality of thin-plate members, a medium flowing through the flow channel, the medium exchanging heat with the fluid, and a pair of headers each connecting ends of a corresponding one of two sides of the plurality of thin-plate members, and a refrigerant circuit connecting a compressor, a condenser, an expansion unit, and an evaporator by pipes and circulating refrigerant. The evaporator is the heat exchanger. The heat exchanger is arranged and connected so that the refrigerant flows into one of the pair of headers provided on a lower side in a direction of gravity, flows through the flow channel formed in each of the plurality of thin-plate members in a direction from the lower side toward an upper side in the direction of gravity, flows into an other one of the pair of headers provided on the upper side in the direction of gravity, and is discharged from the other one of the pair of headers on the upper side in the direction of gravity. The heat exchanger is one of heat exchangers arranged in parallel on the upper side and on the lower side in the direction of gravity. The heat exchangers arranged in parallel are connected in parallel.

Advantageous Effects of Invention

[0011] According to the present invention, in the heat exchanger that includes the plurality of thin-plate members spaced apart from one another, the fluid flowing through the space, the flow channel formed in each of the plurality of thin-plate members, the medium flowing through the flow channel, the medium exchanging heat with the fluid, and the pair of headers each connecting the ends of a corresponding one of the two sides of the plurality of thin-plate members, heat exchangeability can be improved.

[0012] According to the present invention, in the heat pump apparatus that includes the heat exchanger including the plurality of thin-plate members spaced apart from one another, fluid flowing through the space, the flow channel formed in each of the plurality of thin-plate members, the medium flowing through the flow channel, the medium exchanging heat with the fluid, and the pair of headers each connecting the ends of a corresponding one of the two sides of the plurality of thin-plate members, and the refrigerant circuit connecting the compressor, the condenser, the expansion unit, and the evaporator by the pipes and circulating refrigerant, heat exchangeability can be improved.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a perspective view of a heat exchanger according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a side view of the heat exchanger according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a sectional diagram taken along line A-A illustrated in Fig. 2.

[Fig. 4] Fig. 4 is an enlarged view of part B illustrated in Fig. 3.

[Fig. 5] Fig. 5 is a graph illustrating a performance characteristic of the heat exchanger according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a refrigerant circuit diagram of an air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 7] Fig. 7 is a perspective view of heat exchangers according to Embodiment 2 of the present invention.

[Fig. 8] Fig. 8 is a sectional diagram illustrating an arrangement of thin-plate members included in the heat exchangers according to Embodiment 2 of the present invention.

[Fig. 9] Fig. 9 is a perspective view of a heat exchanger according to Embodiment 3 of the present invention.

[Fig. 10] Fig. 10 is a sectional diagram of an inlet-side header included in the heat exchanger according to Embodiment 3 of the present invention.

[Fig. 11] Fig. 11 is a diagram of an inner pipe included in the heat exchanger according to Embodiment 3 of the present invention.

[Fig. 12] Fig. 12 is a side view of heat exchangers according to Embodiment 4 of the present invention.

Description of Embodiments

Embodiment 1

[0014] Fig. 1 is a perspective view of a heat exchanger according to Embodiment 1 of the present invention.

[0015] Fig. 2 is a side view of the heat exchanger according to Embodiment 1 of the present invention.

[0016] Fig. 3 is a sectional diagram taken along line A-A illustrated in Fig. 2.

[0017] Fig. 4 is an enlarged view of part B illustrated in Fig. 3.

[0018] As illustrated in Figs. 1 to 4, the heat exchanger includes a plurality of fins, that is, thin-plate members 1, and a pair of headers (an inlet-side header 2 and an outlet-side header 3).

[0019] The plurality of thin-plate members 1 each have, for example, a thickness of about 2 mm or less and are made of aluminum.

[0020] The plurality of thin-plate members 1 are spaced apart from one another. Fluid (for example, air) flows through the spaces between the thin-plate members 1. The plurality of thin-plate members 1 each internally have one or a plurality of flow channels 11 in which a medium (for example, refrigerant) flows. A portion between two ends of one thin-plate member 1 and a portion between two ends of another thin-plate member 1 adjacent thereto are not connected to each other with any thin-plate member internally having no flow channels. That is, a member that promotes heat exchange between the fluid and the thin-plate members 1 is not provided between adjacent ones of the thin-plate members 1.

[0021] The pair of headers (the inlet-side header 2 and the outlet-side header 3) each connects ends of a corresponding one of the two sides of the plurality of thin-plate members 1. For example, the refrigerant flows into the inlet-side header 2 from a refrigerant inlet 4 of the inlet-side header 2. The refrigerant having flowed into the inlet-side header 2 passes through the flow channels 11 of the plurality of thin-plate members 1 and flows into the outlet-side header 3. Then, the

refrigerant is discharged from a refrigerant outlet 5 of the outlet-side header 3. Note that the direction of the flow of the refrigerant is not limited to the above and may be opposite to the above direction.

[0022] With such a configuration, the heat exchanger causes the air passing through the spaces between the plurality of thin-plate members 1 and the refrigerant flowing in the flow channels 11 provided in the plurality of thin-plate members 1 to exchange heat with each other.

[0023] Furthermore, the plurality of thin-plate members 1 satisfy a relationship of $3 \leq Fp/Ft \leq 21$, where Fp denotes the intervals of the thin-plate members 1 that are adjacent to one another (i.e., the fin pitch), and Ft denotes the thickness of each of the thin-plate members 1.

[0024] Fig. 5 is a graph illustrating a performance characteristic of the heat exchanger according to Embodiment 1 of the present invention.

[0025] When a case of a conventional heat exchanger is used as the reference (100%), Fig. 5 illustrates a relationship between a ratio ($AK/\Delta P$) of heat-transfer performance AK [W/K] to air-side draft resistance ΔP of the heat exchanger and a ratio (Fp/Ft) of the pitch Fp of the thin-plate members 1 to the thickness Ft of each thin-plate member 1.

[0026] Here, the AK value is the result of multiplying an overall heat-transfer coefficient K and a heat-transfer area A of the heat exchanger and represents the heat-transfer characteristic of the heat exchanger.

[0027] Note that the conventional heat exchanger used as the reference is a plate-fin heat exchanger that causes air passing through spaces between a plurality of thin-plate members (thin-plate members each internally having no flow channels) and refrigerant flowing in a plurality of heat-exchanger tubes to exchange heat with each other. Furthermore, the heat-exchanger tubes of the conventional heat exchanger are provided in two rows that are arranged side by side in the direction of the airflow and in a plurality of steps that are stacked in a direction orthogonal to the airflow. Furthermore, the heat-exchanger tubes are each a circular tube of ϕ 7.94 mm, the pitch of the thin-plate members (thin-plate members each internally having no flow channels) is 1.6 mm, the step pitch Dp of the heat-exchanger tubes is 20.4 mm, and the row pitch Lp of the heat-exchanger tubes is 17.7 mm.

[0028] As graphed in Fig. 5, if Fp/Ft becomes too small, $AK/\Delta P$ becomes small. Furthermore, if Fp/Ft becomes too large, $AK/\Delta P$ becomes small. That is, there is an appropriate range of Fp/Ft that can improve $AK/\Delta P$.

[0029] For example, at a specific pitch Fp of the thin-plate members 1, if the thickness Ft of the thin-plate member 1 increases, the channel area of the flow channels 11 increases. Accordingly, the flow speed of the refrigerant increases, the overall heat-transfer coefficient K increases, the heat-transfer performance AK becomes high, and $AK/\Delta P$ increases. However, if the thickness Ft of the thin-plate member 1 becomes too large, the air-side draft resistance ΔP becomes high. Accordingly, $AK/\Delta P$ is reduced.

[0030] Furthermore, for example, if the thickness Ft of the thin-plate member 1 becomes small, the air-side draft resistance ΔP becomes low. Accordingly, $AK/\Delta P$ increases. However, if the thickness Ft of the thin-plate member 1 becomes too small, the channel area of the flow channels 11 is reduced. Furthermore, with a reduction in the flow speed of the refrigerant, the overall heat-transfer coefficient K is reduced, and the heat-transfer performance AK becomes low. Consequently, $AK/\Delta P$ is lowered.

[0031] In view of the above, the heat exchanger according to Embodiment 1 satisfies the relationship of $3 \leq Fp/Ft \leq 21$ so that $AK/\Delta P$ becomes higher than or equal to that (100%) of the conventional heat exchanger.

[0032] Thus, the heat exchanger can exhibit improved heat exchangeability.

[0033] Furthermore, in the case of a plate-fin heat exchanger that causes air passing through spaces between a plurality of thin-plate members (thin-plate members each internally having no flow channels) and refrigerant flowing in a plurality of heat-exchanger tubes to exchange heat with each other as in the conventional heat exchanger, a thermal contact resistance is generated between each of the heat-exchanger tubes and a corresponding one of the thin-plate members (thin-plate members internally having no flow channels). Furthermore, a thermal conductivity resistance is generated in each of the thin-plate members (thin-plate members each internally having no flow channels).

[0034] In contrast, the heat exchanger according to Embodiment 1 has the flow channels 11 in which the refrigerant flows provided inside each of the thin-plate members 1. Therefore, the thermal conductivity resistance is low. Moreover, the thermal contact resistance generated between each of the thin-plate members (thin-plate members each internally having no flow channels) and a corresponding one of the heat-exchanger tubes in the conventional heat exchanger is not generated. Hence, the heat exchangeability of the heat exchanger can be made higher than that of the conventional heat exchanger.

[0035] A case where the above heat exchanger is applied to a refrigerant circuit included in an air-conditioning apparatus will be described below.

[0036] Fig. 6 is a refrigerant circuit diagram of an air-conditioning apparatus according to Embodiment 1 of the present invention.

[0037] The refrigerant circuit illustrated in Fig. 6 includes a compressor 33, a condenser 34, an expansion device 35 as an expansion unit, and an evaporator 36. Furthermore, the air-conditioning apparatus includes fans 37 that each send air to a corresponding one of the condenser 34 and the evaporator 36, and fan motors 38 that each drive a corresponding one of fans 37.

[0038] Applying the above heat exchanger to one of or both of the condenser 34 and the evaporator 36 provides an air-conditioning apparatus having high energy efficiency.

[0039] Here, the energy efficiency is expressed as follows:

5 Heating-energy efficiency = capacity of indoor heat exchanger
(condenser) /total input

10 Cooling-energy efficiency = capacity of indoor heat exchanger
(evaporator) /total input

15 **[0040]** If the above heat exchanger is used as the evaporator 36, the heat exchanger is oriented so that the longitudinal direction of the plurality of thin-plate members 1 corresponds to the direction of gravity. That is, in each of the thin-plate members 1, the refrigerant makes an ascending flow that goes from the lower side toward the upper side in the direction of gravity.

20 **[0041]** Furthermore, if the above heat exchanger is used as the evaporator 36, the refrigerant flows into the inlet-side header 2, which is one of the pair of headers (the inlet-side header 2 and the outlet-side header 3), provided on the lower side in the direction of gravity. The refrigerant having flowed into the inlet-side header 2 passes through all of the flow channels 11 provided in the plurality of thin-plate members 1, and flows into the outlet-side header 3 provided on the upper side in the direction of gravity.

25 **[0042]** That is, the refrigerant having flowed into the inlet-side header 2 is distributed to the plurality of flow channels 11 provided in each of the plurality of thin-plate members 1, and flows from the bottom toward the top of each of the plurality of thin-plate members 1. Subsequently, the refrigerant is discharged from the outlet-side header 3.

[0043] Note that the inlet-side header 2 corresponds to "the header provided on the lower side in the direction of gravity" according to the present invention, and the outlet-side header 3 corresponds to "the header provided on the upper side in the direction of gravity" according to the present invention.

30 **[0044]** Here, the refrigerant flowing in the evaporator 36 is in a two-phase gas-liquid state. The two-phase gas-liquid refrigerant occasionally flows in a plug-flow or slug-flow pattern. If the above heat exchanger is used as the evaporator 36, the refrigerant flows through the flow channels 11 of the plurality of thin-plate members 1 from the bottom to the top. Thus, if the refrigerant flows in a plug-flow or slug-flow pattern, the refrigerant can smoothly flow upward with the buoyancy of bubbles.

35 **[0045]** Thus, the heat exchanger can exhibit improved heat exchangeability.

[0046] Furthermore, if the evaporating temperature of the refrigerant flowing in the evaporator 36 is lowered, the vapor in the air may be condensed into dew drops (condensed water) on the surfaces of the plurality of thin-plate members 1. If the above heat exchanger is used as the evaporator 36, the heat exchanger is oriented so that the longitudinal direction of the plurality of thin-plate members 1 corresponds to the direction of gravity from the lower side toward the upper side. Thus, dew drops smoothly run down between adjacent ones of the plurality of thin-plate members 1. Thus, improved dew drainability can be provided. Furthermore, in a defrosting operation in which frost generated on the evaporator 36 is melted, the generation of solid ice that may build up in a lower part of the heat exchanger can be prevented.

40 **[0047]** Note that the above advantageous effects are produced even if the plurality of thin-plate members 1 do not satisfy the relationship of $3 \leq Fp/Ft \leq 21$. If the plurality of thin-plate members 1 satisfy the relationship of $3 \leq Fp/Ft \leq 21$, the heat exchanger can exhibit further improved heat exchangeability.

Embodiment 2

50 **[0048]** Heat exchangers according to Embodiment 2 will be described below, focusing on differences from Embodiment 1. Components that are the same as those of Embodiment 1 are denoted by corresponding ones of the reference signs.

[0049] Fig. 7 is a perspective view of the heat exchangers according to Embodiment 2 of the present invention.

[0050] Fig. 8 is a sectional diagram illustrating an arrangement of thin-plate members included in the heat exchangers according to Embodiment 2 of the present invention.

55 **[0051]** As illustrated in Figs. 7 and 8, in Embodiment 2, two heat exchangers are provided side by side in the direction of the flow of the fluid (air). Furthermore, in the direction of the flow of the fluid (air), the plurality of thin-plate members 1 on the upstream side do not overlap the plurality of thin-plate members 1 on the downstream side. That is, the plurality of thin-plate members 1 are arranged in a staggered manner.

[0052] Thus, the flow of the air developed between adjacent ones of the plurality of thin-plate members 1 included in

the first heat exchanger can further be developed at a new boundary layer formed at the front edges of the plurality of thin-plate members 1 included in the second heat exchanger. Consequently, heat transfer can be promoted.

[0053] While Embodiment 2 concerns a case where two heat exchangers are provided, the present invention is not limited to such a case. Three or more heat exchangers may be provided.

[0054] Furthermore, the above advantageous effects are produced even if the plurality of thin-plate members 1 do not satisfy the relationship of $3 \leq F_p/F_t \leq 21$. If the plurality of thin-plate members 1 satisfy the relationship of $3 \leq F_p/F_t \leq 21$, the heat exchanger can exhibit further improved heat exchangeability.

Embodiment 3

[0055] A heat exchanger according to Embodiment 3 will be described below, focusing on differences from Embodiment 1. Components that are the same as those of Embodiment 1 are denoted by corresponding ones of the reference signs.

[0056] Fig. 9 is a perspective view of the heat exchanger according to Embodiment 3 of the present invention.

[0057] Fig. 10 is a sectional diagram of an inlet-side header included in the heat exchanger according to Embodiment 3 of the present invention.

[0058] Fig. 11 is a diagram of an inner pipe included in the heat exchanger according to Embodiment 3 of the present invention.

[0059] As illustrated in Figs. 9 to 11, the inlet-side header 2 of the heat exchanger according to Embodiment 3 includes an outer pipe 6 and an inner pipe 7 provided inside the outer pipe 6.

[0060] An end of each of the plurality of thin-plate members 1 is connected to the outer pipe 6. The outer pipe 6 is, for example, a pipe having a rectangular cross-sectional shape, with the two ends thereof closed. A tube that forms the refrigerant inlet 4 extends through a sidewall of the outer pipe 6. The refrigerant is taken into the inner pipe 7 from the refrigerant inlet 4.

[0061] The inner pipe 7 is, for example, a circular pipe. The inner pipe 7 is provided with the refrigerant inlet 4 from which the refrigerant flows in, and a plurality of outlets 71 from which the refrigerant flowing in from the refrigerant inlet 4 is discharged into the outer pipe 6. The length of the inner pipe 7 is substantially equal to the length of the area in which the plurality of thin-plate members 1 are arranged. The plurality of outlets 71 are provided only on the lower side (a lower part in the direction of gravity) of the inner pipe 7. The plurality of outlets 71 are arranged at substantially constant intervals in the longitudinal direction of the inner pipe 7.

[0062] If the heat exchanger having such a configuration is used as the evaporator 36, refrigerant in a liquid phase flows into the inner pipe 7 from the refrigerant inlet 4. The liquid-phase refrigerant having flowed into the inner pipe 7 is discharged into the outer pipe 6 from each of the plurality of outlets 71. Thus, in the inlet-side header 2, the liquid-phase refrigerant is stirred and is evenly distributed to the plurality of thin-plate members 1. Hence, local drying of the refrigerant in some of the plurality of thin-plate members 1 is less likely to occur. Consequently, the heat exchanger can exhibit improved heat exchangeability.

[0063] Furthermore, the above advantageous effects are produced even if the plurality of thin-plate members 1 do not satisfy the relationship of $3 \leq F_p/F_t \leq 21$. If the plurality of thin-plate members 1 satisfy the relationship of $3 \leq F_p/F_t \leq 21$, the heat exchanger can exhibit further improved heat exchangeability.

Embodiment 4

[0064] Heat exchangers according to Embodiment 4 will be described below, focusing on differences from Embodiment 1. Components that are the same as those of Embodiment 1 are denoted by corresponding ones of the reference signs.

[0065] Fig. 12 is a side view of the heat exchangers according to Embodiment 4 of the present invention.

[0066] As illustrated in Fig. 12, in Embodiment 4, two heat exchangers are mounted one on top of the other in the direction of gravity. Each of the two heat exchangers is oriented so that the longitudinal direction of the plurality of thin-plate members 1 corresponds to the direction of gravity. Furthermore, the inlet-side header 2 of the heat exchanger on the upper side and the inlet-side header 2 of the heat exchanger on the lower side are connected in parallel, and the outlet-side header 3 of the heat exchanger on the upper side and the outlet-side header 3 of the heat exchanger on the lower side are connected in parallel. That is, in Embodiment 4, the heat exchangers are arranged in parallel on the upper side and the lower side in the direction of gravity. Furthermore, if the set of the heat exchangers is used as the evaporator 36, the refrigerant flows, in each of the heat exchangers, into the inlet-side header 2 provided on the lower side in the direction of gravity and is discharged from the outlet-side header 3 provided on the upper side in the direction of gravity. Note that the flow channels 11 provided in each of the plurality of thin-plate members 1 each have a size corresponding to the diameter of the fluid (an equivalent diameter) of 0.05 to 0.2 mm.

[0067] In general, when the flow rate of refrigerant flowing into a flow channel is reduced, the heat-transfer coefficient of that flow channel is reduced. However, if the heat exchanger is used as the evaporator 36, that is, if a two-phase gas-liquid refrigerant flows through the thin-plate member 1 upward from the lower side toward the upper side in the direction

of gravity, the heat-transfer coefficient of each of the flow channels 11 is less likely to be reduced or is increased even if the flow rate of the refrigerant flowing into the flow channels 11 is reduced, because the refrigerant is distributed among the plurality of flow channels 11. The reason is as follows. When the flow rate of the refrigerant is reduced, the refrigerant in the liquid phase stagnates because the diameter of each of the flow channels 11 is 1 mm or less. Consequently, the refrigerant tends to boil. If the flow channels 11 each have a rectangular cross-sectional shape as illustrated in Fig. 4, the above phenomenon is particularly remarkable.

[0068] That is, in each of the heat exchangers according to Embodiment 4, compared with a case where each thin-plate member 1 is a circular pipe internally having a circular flow channel whose cross-sectional area is equal to the sum of the cross-sectional areas of the flow channels 11, the flow rate of the refrigerant per flow channel 11 is small because the thin-plate members 1 each have a plurality of flow channels 11. The reduction in the flow rate of the refrigerant causes a phenomenon that the heat-transfer coefficient of each of the flow channels 11 becomes equal to the heat-transfer coefficient of the circular pipe. Consequently, the change in the phase of the refrigerant in each of the flow channels 11 is promoted.

[0069] Furthermore, even if each of the thin-plate members 1 has only one flow channel 11, the number of thin-plate members 1 can be made larger than the number of circular pipes, that is, the total number of flow channels 11 can be made larger than the number of circular pipes, because each of the thin-plate members 1 is thin. Thus, the flow rate of the refrigerant per flow channel 11 is reduced, and the reduction in the flow rate of the refrigerant causes the phenomenon that the heat-transfer coefficient of each of the flow channels 11 becomes equal to the heat-transfer coefficient of the circular pipe. Consequently, the change in the phase of the refrigerant in each of the flow channels 11 is promoted.

[0070] Thus, to maintain the performance of the refrigeration cycle while setting the quality of the refrigerant at the outlet of each of the flow channels 11 to about 1 or lower, the length of each of the plurality of thin-plate members 1 needs to be made shorter than that of the conventional heat exchanger.

[0071] For the above reasons, in Embodiment 4, two heat exchangers are mounted one on top of the other in the direction of gravity, and the length of each of the plurality of thin-plate members 1 is reduced. Thus a satisfactory heat-exchange capacity is provided while the performance of the refrigeration cycle is maintained. For example, if the heat exchanger is incorporated into an outdoor unit of an air-conditioning apparatus, a satisfactory heat-exchange capacity can be provided even if the outdoor unit has substantially the same unit height as the conventional outdoor unit.

[0072] Furthermore, the above advantageous effects are produced even if the plurality of thin-plate members 1 do not satisfy the relationship of $3 \leq F_p/F_t \leq 21$. If the plurality of thin-plate members 1 satisfy the relationship of $3 \leq F_p/F_t \leq 21$, the heat exchanger can exhibit further improved heat exchangeability.

[0073] While the heat exchangers according to Embodiments 1 to 4 and air-conditioning apparatuses including the same have been described, the configurations of the heat exchangers according to Embodiments 1 to 4 and the air-conditioning apparatuses including the same may be combined arbitrarily. In such a case, the heat exchanger can also exhibit improved effectiveness.

[0074] Furthermore, the heat exchanger according to any of Embodiments 1 to 4 and the air-conditioning apparatus including the same can produce the above advantageous effects with any refrigerant such as R410A, R32, and HFO1234yf.

[0075] Furthermore, while the above description concerns an exemplary case where the working fluids are air and refrigerant, the above advantageous effects can be produced with any of other fluids such as gas, liquid, and gas-liquid mixed fluid.

[0076] Furthermore, the above advantageous effects can be produced even if the heat exchanger according to any of Embodiments 1 to 4 is incorporated into either an indoor unit or an outdoor unit of an air-conditioning apparatus.

[0077] Furthermore, the heat exchanger according to any of Embodiments 1 to 4 and the air-conditioning apparatus including the same can produce the above advantageous effects with any refrigerating machine oil based any oil such as mineral oil, alkylbenzene oil, ester oil, ethereal oil, and fluorine oil, regardless of whether or not the refrigerant and the oil are soluble in each other.

Industrial Applicability

[0078] The present invention is applicable not only to the above air-conditioning apparatus but also to a heat pump apparatus in which energy-saving performance needs to be improved with improved heat exchangeability.

Reference Signs List

[0079]

1 thin-plate member 2 inlet-side header 3 outlet-side header 4 refrigerant inlet 5 refrigerant outlet 6 outer pipe 7 inner pipe 11 flow channel 33 compressor 34 condenser 35 expansion device 36 evaporator 37 fan 38 fan motor

71 outlet

Claims

1. A heat exchanger comprising:

a plurality of thin-plate members spaced apart from one another, fluid flowing through the space, a flow channel formed in each of the plurality of thin-plate members, a medium flowing through the flow channel, the medium exchanging heat with the fluid; and
a pair of headers each connecting ends of a corresponding one of two sides of the plurality of thin-plate members, the plurality of thin-plate members satisfying a relationship of

$$3 \leq F_p/F_t \leq 21,$$

where F_p denotes a pitch of the plurality of thin-plate members adjacent to one another, and F_t denotes a thickness of each of the plurality of thin-plate members.

2. The heat exchanger of claim 1, wherein a member promoting heat exchange between the fluid and the plurality of thin-plate members is not provided between adjacent ones of the plurality of thin-plate members.

3. A heat pump apparatus comprising a refrigerant circuit connecting a compressor, a condenser, an expansion unit, and an evaporator by pipes and circulating refrigerant, wherein at least one of the condenser and the evaporator is the heat exchanger of claim 1 or 2.

4. A heat pump apparatus comprising a refrigerant circuit connecting a compressor, a condenser, an expansion unit, and an evaporator by pipes and circulating refrigerant, wherein the evaporator is the heat exchanger of claim 1 or 2, and wherein the heat exchanger is arranged and connected so that the refrigerant flows into one of the pair of headers provided on a lower side in a direction of gravity, flows through the flow channel formed in each of the plurality of thin-plate members in a direction from the lower side toward an upper side in the direction of gravity, flows into an other one of the pair of headers on the upper side in the direction of gravity, and is discharged from the other one of the pair of headers on the upper side in the direction of gravity.

5. The heat pump apparatus of claim 4, wherein the heat exchanger is one of heat exchangers arranged in parallel on the upper side and on the lower side in the direction of gravity, and wherein the heat exchangers arranged in parallel are connected in parallel.

6. A heat pump apparatus comprising:

a heat exchanger including

a plurality of thin-plate members spaced apart from one another, fluid flowing through the space, a flow channel formed in each of the plurality of thin-plate members, a medium flowing through the flow channel, the medium exchanging heat with the fluid, and
a pair of headers each connecting ends of a corresponding one of two sides of the plurality of thin-plate members; and

a refrigerant circuit connecting a compressor, a condenser, an expansion unit, and an evaporator by pipes and circulating refrigerant,
wherein the evaporator is the heat exchanger,
wherein the heat exchanger is arranged and connected so that

the refrigerant flows into one of the pair of headers provided on a lower side in a direction of gravity, flows through the flow channel formed in each of the plurality of thin-plate members in a direction from the lower side toward an upper side in the direction of gravity, flows into an other one of the pair of headers provided on the upper side in the direction of gravity, and is discharged from the other one of the pair of headers on the upper side in the direction of gravity,

wherein the heat exchanger is one of heat exchangers arranged in parallel on the upper side and on the lower side in the direction of gravity, and
wherein the heat exchangers arranged in parallel are connected in parallel.

7. The heat pump apparatus of claim 6, wherein a member promoting heat exchange between the fluid and the plurality of thin-plate members is not provided between adjacent ones of the plurality of thin-plate members.

8. The heat pump apparatus of any one of claims 5 to 7, wherein the flow channel formed in each of the plurality of thin-plate members has a rectangular cross-sectional shape.

9. The heat pump apparatus of any one of claims 3 to 8, wherein one of the pair of headers provided on a lower side in a direction of gravity includes

an outer pipe connecting the ends of one side of the plurality of thin-plate members; and
an inner pipe provided inside the outer pipe,

wherein the inner pipe has an inlet and a plurality of outlets, the refrigerant flowing into the inlet and being discharged from the plurality of outlets to the outer pipe.

10. The heat pump apparatus of claim 9, wherein the plurality of outlets are provided only in a lower part of the inner pipe in the direction of gravity.

11. The heat pump apparatus of any one of claims 3 to 10, wherein the heat exchanger is one of a plurality of heat exchangers arranged side by side in a direction of flow of the fluid, and
wherein, in the direction of flow of the fluid, each of the plurality of thin-plate members provided on an upstream side is alternately staggered with respect to a corresponding one of the plurality of thin-plate members provided on a downstream side.

FIG. 1

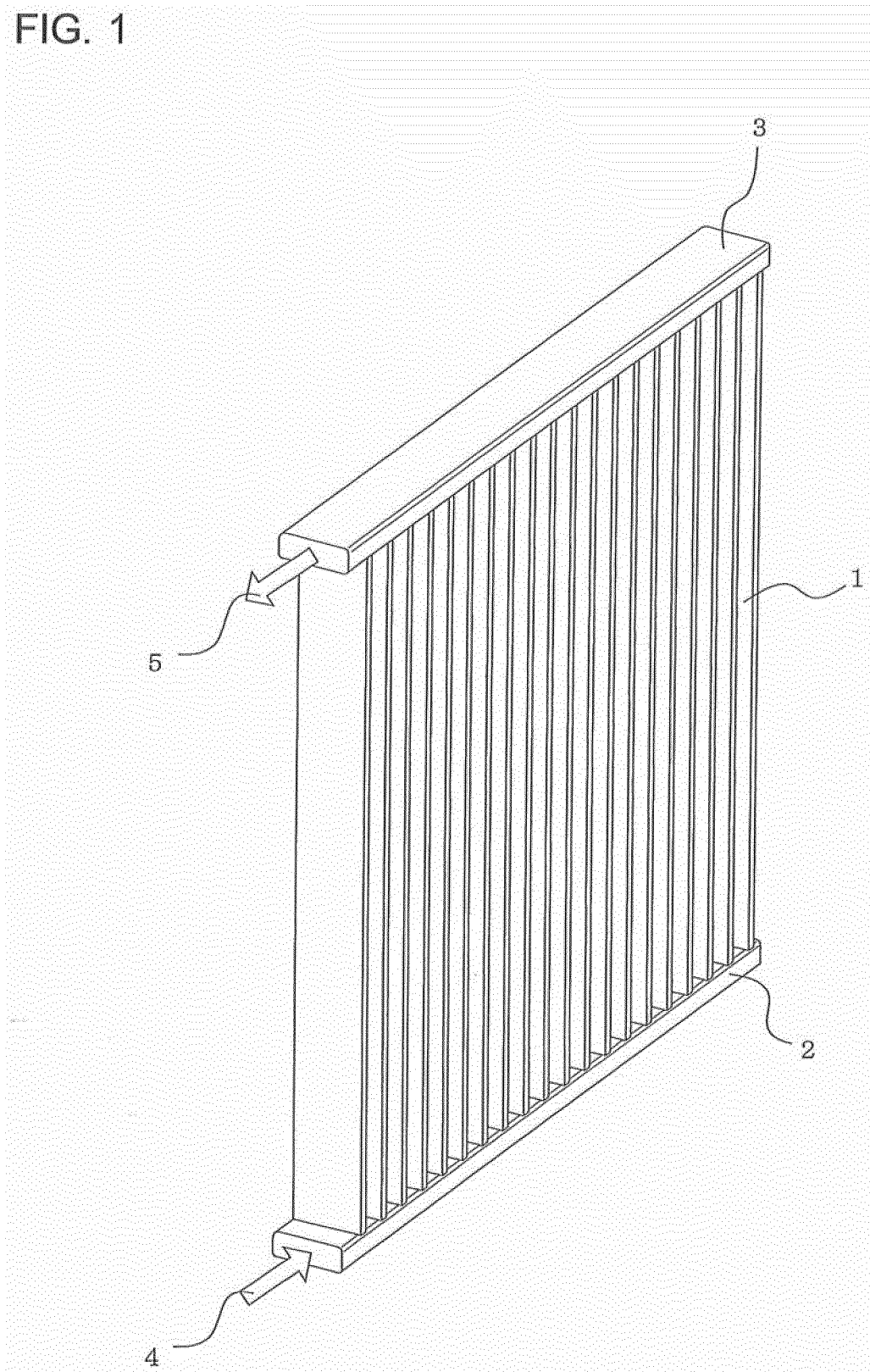


FIG. 2

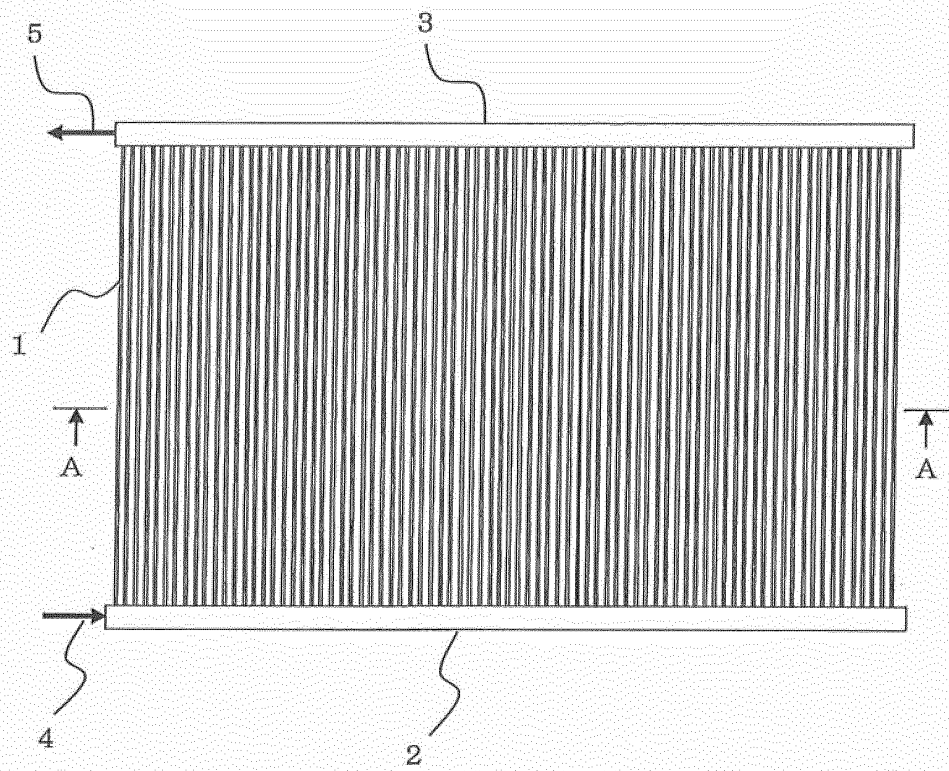


FIG. 3

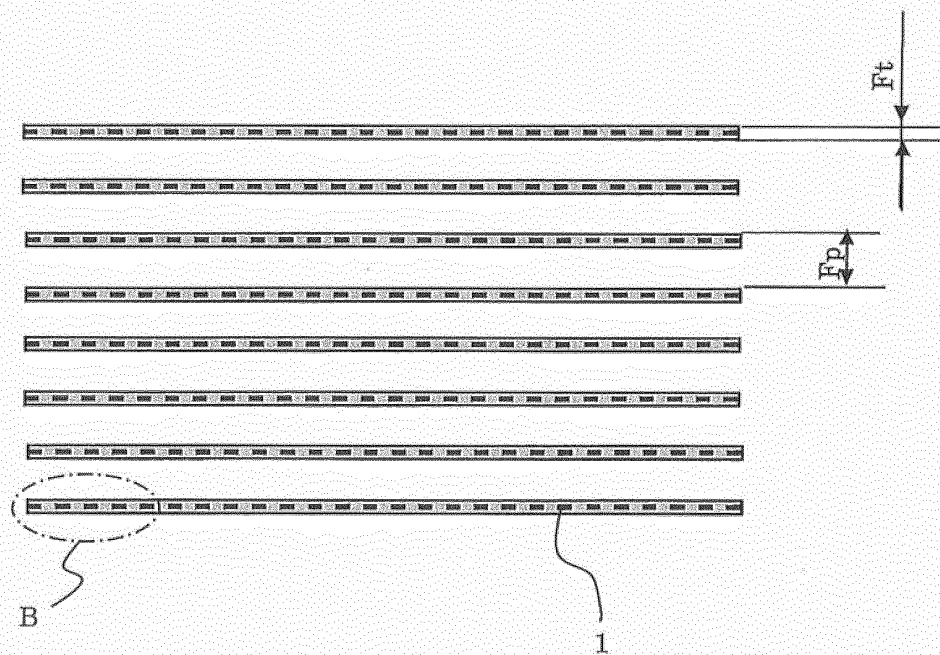


FIG. 4

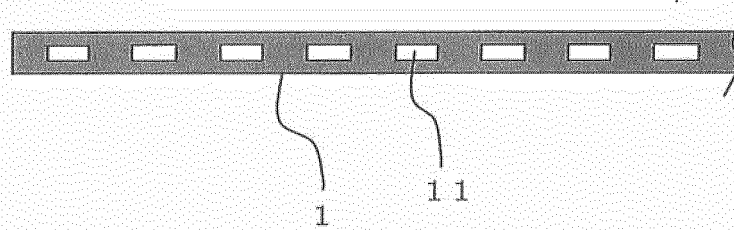


FIG. 5

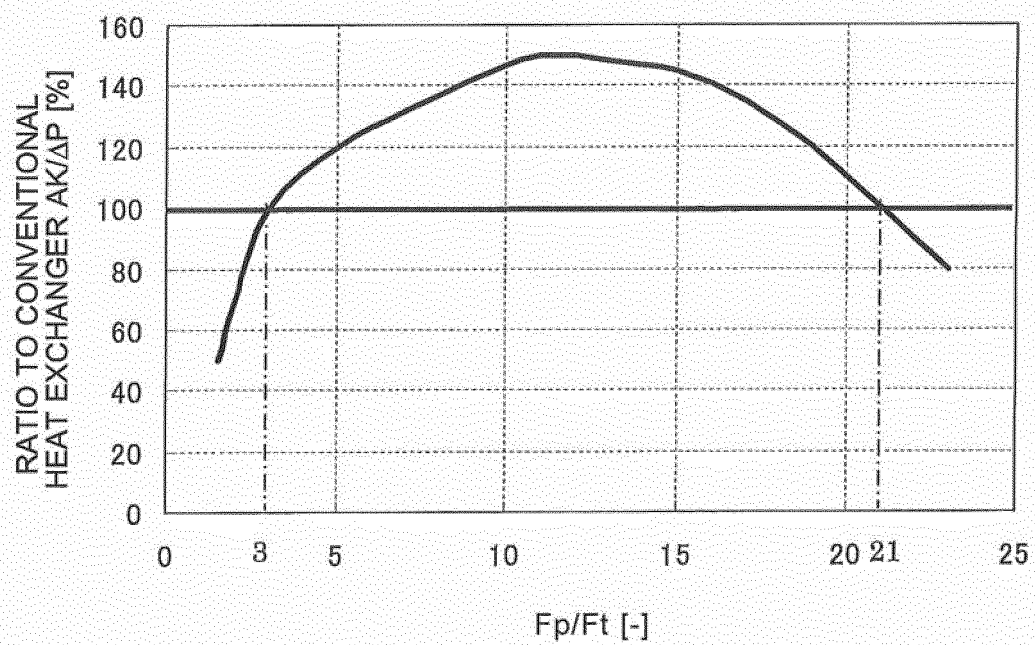


FIG. 6

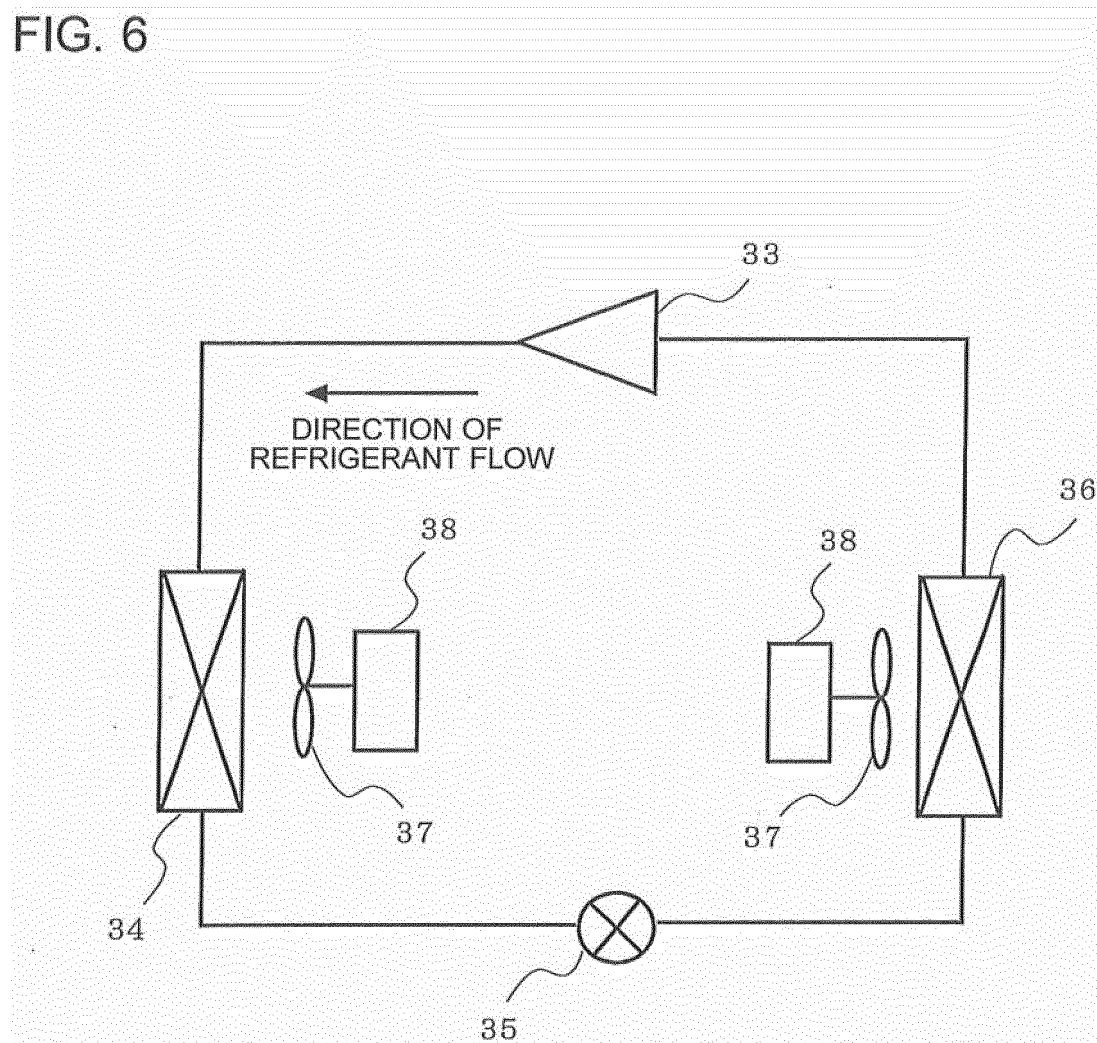


FIG. 7

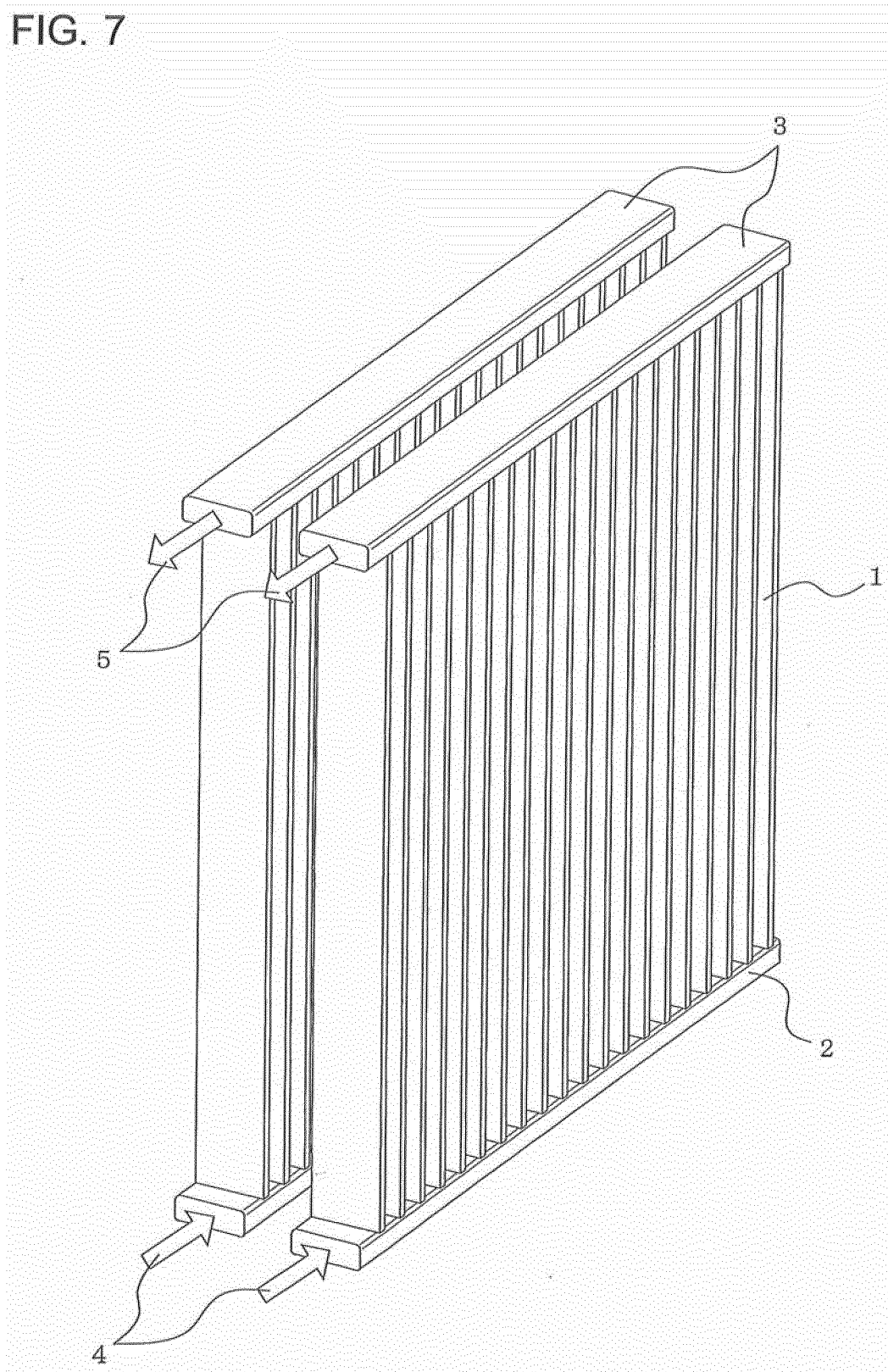


FIG. 8

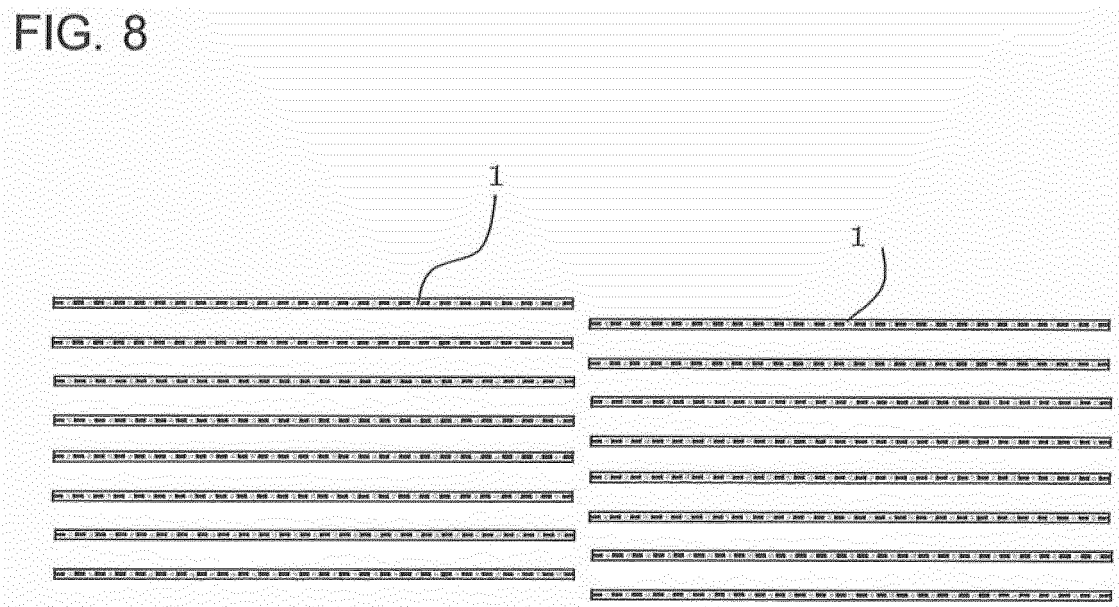


FIG. 9

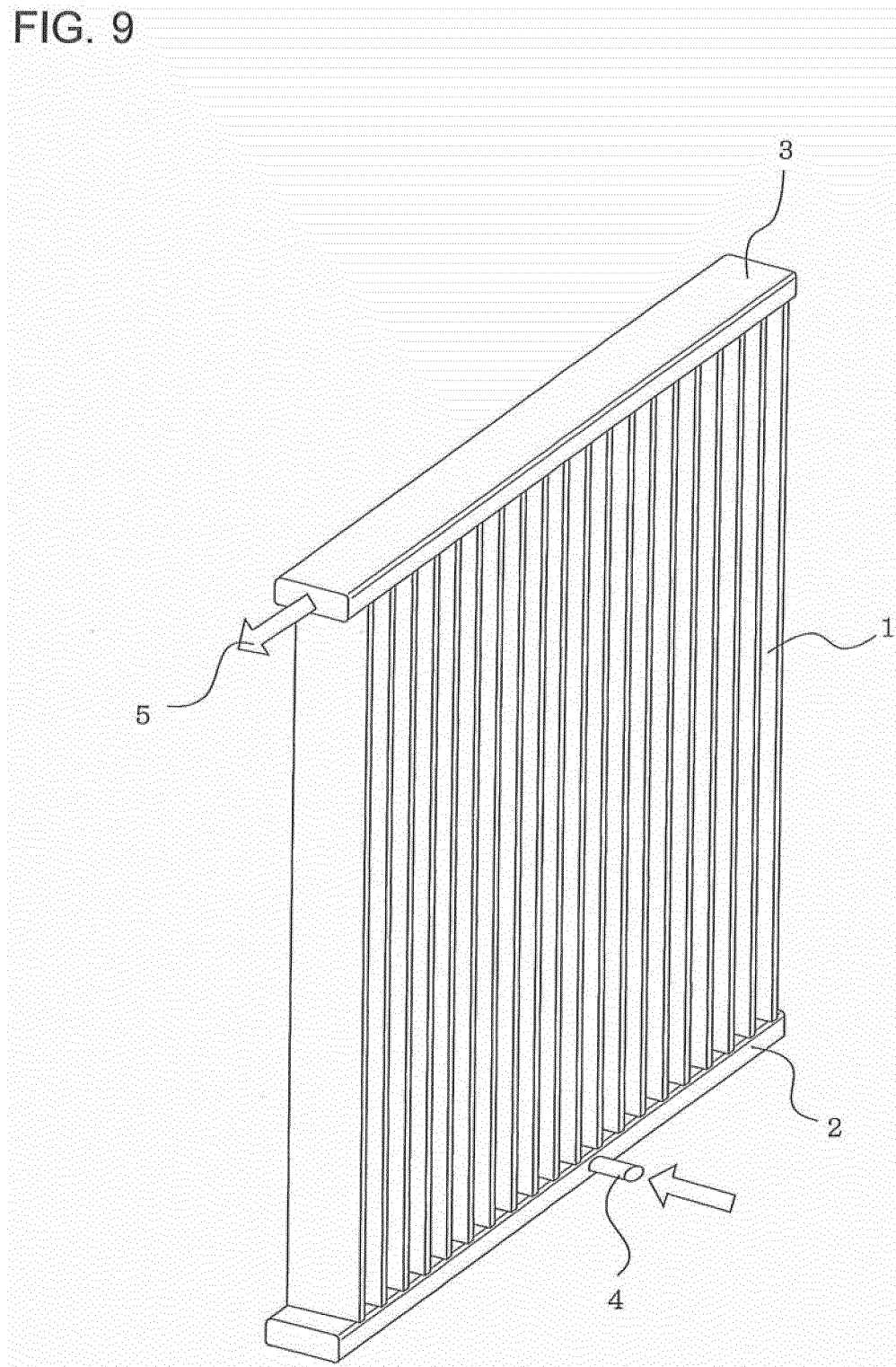


FIG. 10

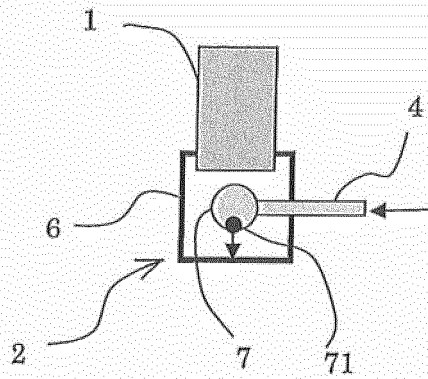


FIG. 11

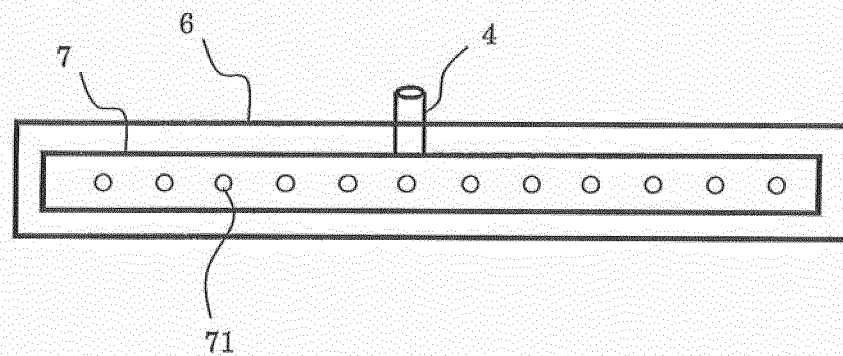
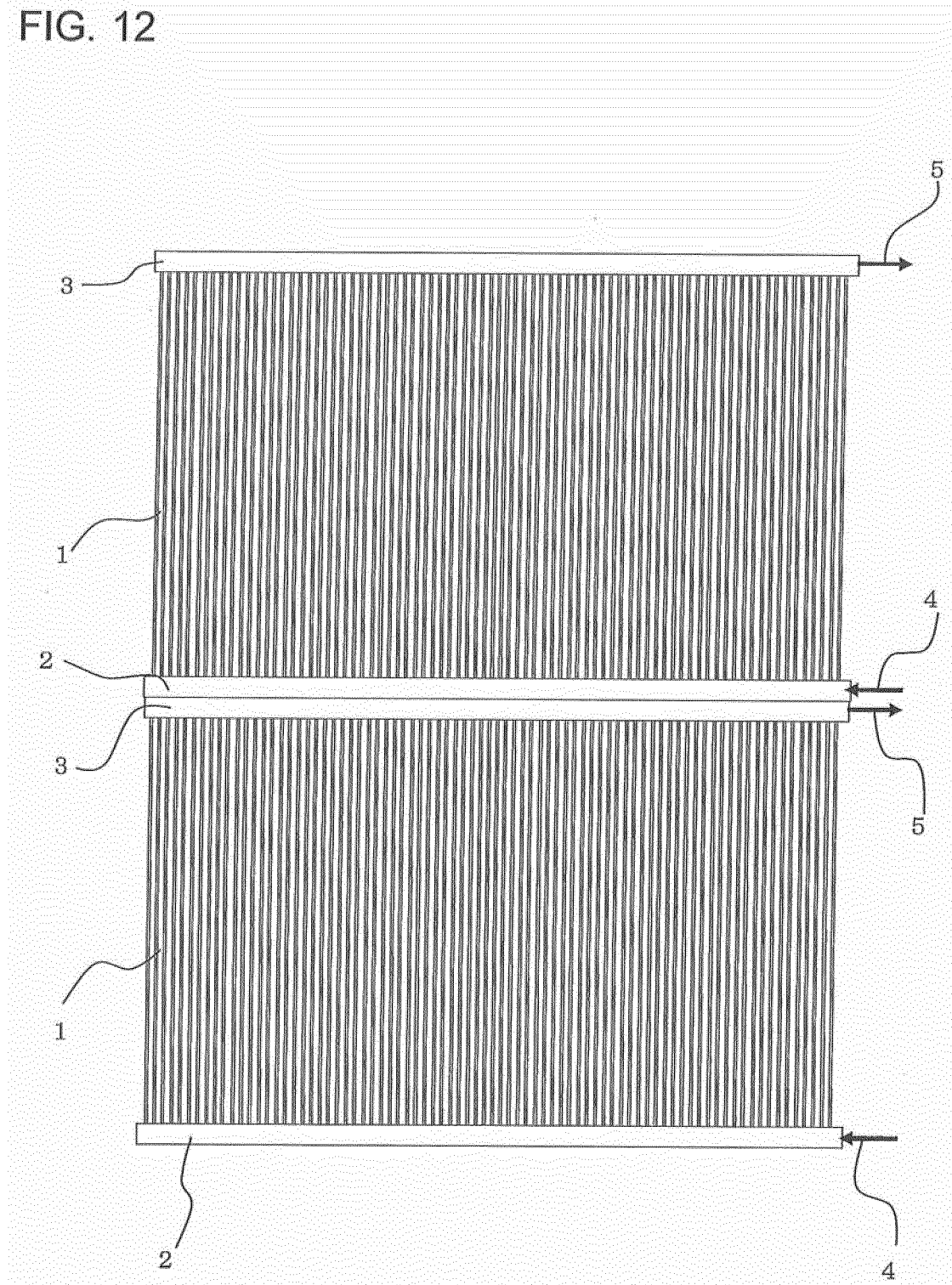


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/068203

A. CLASSIFICATION OF SUBJECT MATTER

F28D1/053(2006.01)i, F25B5/02(2006.01)i, F25B39/02(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)

F28D1/053, F25B5/02, F25B39/02

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 1996-2014
 Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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.
X Y	WO 2013/008464 A1 (Panasonic Corp.), 17 January 2013 (17.01.2013), paragraphs [0032] to [0036], [0068]; fig. 1 to 4, 17A & EP 2733452 A1 & US 2014/0137592 A1 & CN 103649667 A	1, 3 2, 4-11
X Y	JP 2005-195325 A (Denso Corp.), 21 July 2005 (21.07.2005), paragraphs [0001], [0026]; fig. 1, 8 to 11 (Family: none)	1, 3 2, 8-11
X Y	WO 2005/073655 A1 (Calsonic Kansei Corp.), 11 August 2005 (11.08.2005), paragraphs [0025] to [0033], [0043]; fig. 1 to 4 (Family: none)	1-3 4-11

☒ 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
22 September, 2014 (22.09.14)Date of mailing of the international search report
30 September, 2014 (30.09.14)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/068203

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 2002-139295 A (Toyo Radiator Co., Ltd.), 17 May 2002 (17.05.2002), paragraphs [0002] to [0003]; fig. 3 (Family: none)	4-11
Y	JP 2002-181487 A (Daikin Industries, Ltd.), 26 June 2002 (26.06.2002), paragraphs [0026], [0034]; fig. 1, 5 (Family: none)	5-11
Y	JP 2005-180910 A (Husmann Corp.), 07 July 2005 (07.07.2005), paragraph [0027]; fig. 6 (Family: none)	10-11
Y	JP 2007-17061 A (Calsonic Kansei Corp.), 25 January 2007 (25.01.2007), paragraphs [0009] to [0014]; fig. 5 (Family: none)	11
A	JP 2001-91099 A (Sanyo Electric Co., Ltd.), 06 April 2001 (06.04.2001), paragraphs [0015] to [0016]; fig. 1, 2 (Family: none)	1-11

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

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 2008528943 PCT [0004]