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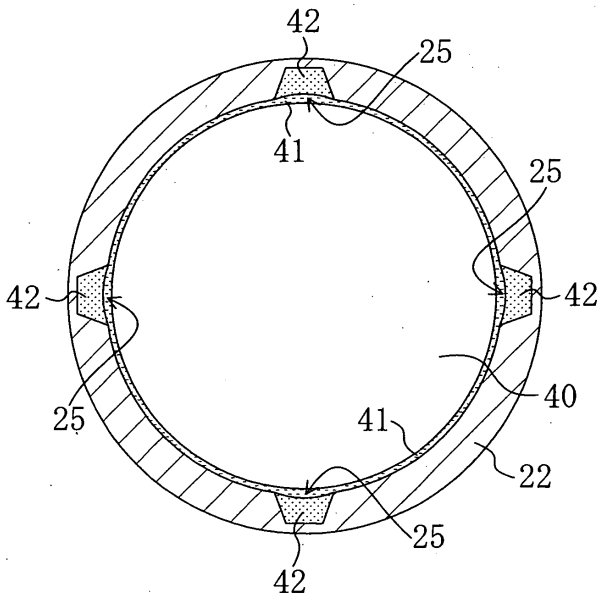
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(54) HEAT EXCHANGER AND REFRIGERATION DEVICE

(57) An oil groove (25) for trapping and transporting oil is formed in an inner wall surface of a heat transfer tube (22) of a heat exchanger (12, 13) to extend in an axial direction of the heat transfer tube (22).

FIG. 6



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Description

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger applied to a refrigeration system which performs a refrigeration cycle, and a refrigeration system including the heat exchanger. In particular, the invention relates to measures to enhance heat transfer in the heat exchanger.

BACKGROUND ART

[0002] So far, refrigeration systems which perform a vapor compression refrigeration cycle have been known and widely used for air conditioners, water heaters, and the like.

[0003] For example, an air conditioner disclosed by Patent Document 1 includes a refrigerant circuit connecting a compressor, an outdoor heat exchanger, an expander, and an indoor heat exchanger. The refrigerant circuit is filled with carbon dioxide as a refrigerant.

[0004] In cooling operation of the air conditioner, the refrigerant compressed to a critical pressure or higher flows through the outdoor heat exchanger. In the outdoor heat exchanger, the refrigerant exchanges heat with outdoor air by dissipating heat into the outdoor air. The refrigerant that dissipated heat in the outdoor heat exchanger is reduced in pressure in the expander, and then flows into the indoor heat exchanger. In the indoor heat exchanger, the refrigerant exchanges heat with indoor air by absorbing heat from the indoor air to evaporate. As a result, the indoor air is cooled. The refrigerant evaporated in the indoor heat exchanger is sucked into the compressor and recompressed.

Patent Document 1: Published Japanese Patent Application No. 2001-116371

DISCLOSURE OF THE INVENTION

PROBLEM THAT THE INVENTION IS TO SOLVE

[0005] In the above-described refrigeration system, lubricating oil (refrigeration oil) is used to smoothen the movement of sliding parts of the compressor. The oil is contained in the refrigerant flowing through the refrigerant circuit. Therefore, when the refrigerant flows through the heat exchanger such as an evaporator and a radiator, the oil remaining unsolved in the refrigerant adheres to an inner wall of a heat transfer tube, and an oil film may be formed over the whole inner circumferential wall of the heat transfer tube. This has been disadvantageous because the oil film may disturb heat transfer between the refrigerant and the air, and may deteriorate heat transfer performance of the heat exchanger.

[0006] Particularly in the refrigeration system disclosed by Patent Document 1 using carbon dioxide as the refrigerant to perform the refrigeration cycle, PAG (polyalkylene glycol) is generally used as the refrigeration oil. However, the oil of this kind is less compatible with carbon dioxide, and therefore it is likely to form the oil film in the heat transfer tube of the heat exchanger. Therefore, in the heat exchanger applied to the refrigeration system using the carbon dioxide refrigerant, decrease in heat transfer performance derived from the generation of the oil film has been significant.

[0007] In view of the foregoing, the present invention was developed. Regarding the heat exchanger applied to the refrigeration system for performing a vapor compression refrigeration cycle, an object of the present invention is to prevent the decrease in heat transfer performance of the heat exchanger derived from the generation of the oil film on the inner wall surface of the heat transfer tube of the heat exchanger.

MEANS OF SOLVING THE PROBLEM

[0008] In a first aspect, the present invention relates to a heat exchanger which is applied to a refrigeration system for performing a vapor compression refrigeration cycle and has a heat transfer tube (22). In the heat transfer tube (22) of the heat exchanger, an oil groove (25) for trapping and transporting oil in a refrigerant is formed in an inner wall surface of the heat transfer tube (22).

[0009] In the first aspect, regarding the heat exchanger connected to the refrigerant circuit of the refrigeration system, the oil groove (25) is formed in the inner wall surface of the heat transfer tube (22) in the heat exchanger. By forming the oil groove (25) in the heat transfer tube (22), oil contained in the refrigerant flowing through the heat transfer tube (22) is trapped in the oil groove (25) and transported through the oil groove (25).

[0010] Specifically, when the refrigerant flows through the heat transfer tube (22), the refrigerant passes a center part in the heat transfer tube (22), and the oil remaining unsolved in the refrigerant passes an outer part in the heat transfer tube (22). That is, the oil flows along the inner wall surface of the heat transfer tube (22), and forms an oil film on the whole inner wall surface of the heat transfer tube (22). In this respect, according to the present invention, the oil groove (25) is formed in the inner wall surface of the heat transfer tube (22). Therefore, the oil covering the inner wall surface of the heat transfer tube (22) is drawn into the oil groove (25) by surface tension, and flows in the oil groove (25). Thus, the present invention makes it possible to avoid the generation of the oil film on the inner wall surface of the heat transfer tube (22).

[0011] In a second aspect of the invention, regarding the heat exchanger of the first aspect of the invention, the oil groove (25) extends in an axial direction of the heat transfer tube (22).

[0012] In the second aspect, the oil groove (25) is formed in the inner wall surface of the heat transfer tube (22) to extend in the axial direction of the heat transfer tube (22). That is, according to the present invention, the

oil groove (25) extends in the same direction as the flow direction of the refrigerant. Therefore, when the oil is trapped in the oil groove (25) as described above, the oil smoothly flows in the oil groove (25) in the same direction as the refrigerant flowing outside the oil groove (25). Thus, the present invention allows suppression of the oil trapped in the oil groove (25) from flowing out of the oil groove (25).

[0013] In a third aspect of the invention, regarding the heat exchanger of the second aspect of the invention, a plurality of oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to be aligned at regular intervals in a circumferential direction of the heat transfer tube (22).

[0014] In the third aspect, the plurality of oil grooves (25) extending in the axial direction of the heat transfer tube (22) are aligned at regular intervals in the circumferential direction of the inner wall surface of the heat transfer tube (22). Therefore, the oil film formed on the whole inner wall surface of the heat transfer tube (22) is easily trapped in the oil grooves (25). Further, the amounts of oil trapped in the oil grooves (25) are equalized, and the oil trapping effect of the oil grooves (25) is improved.

[0015] In a fourth aspect of the invention, regarding the heat exchanger of the first aspect of the invention, a plurality of V-shaped oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to be aligned in the axial direction of the heat transfer tube (22).

[0016] In the fourth aspect, the plurality of V-shaped oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22). The oil grooves (25) are aligned in the axial direction of the heat transfer tube (22) so that every oil groove (25) is oriented to one side in the axial direction. In the heat exchanger with the oil grooves (25) thus formed, when the refrigerant is allowed to flow in the same direction as the orientation of the pointed ends of the V-shaped oil grooves (25), the refrigerant trapped in the oil grooves (25) is collected toward the pointed ends of the V-shaped grooves, and then comes out of the oil grooves (25) and flows in the same direction as the refrigerant. When the oil flows in this way in all the oil grooves (25), the oil flows on the inner wall surface of the heat transfer tube (22) along a line connecting the pointed ends of the V-shaped oil grooves (25). That is, in the heat transfer tube (22) of the present invention, an oil path connecting the pointed ends of the V-shaped oil grooves (25) is formed, so that the oil smoothly flows in the heat transfer tube (22).

[0017] In a fifth aspect of the invention, regarding the heat exchanger of any one of the first to fourth aspects of the invention, a lipophilic layer (27) made of a lipophilic material is formed on an inner wall surface of the oil groove (25).

[0018] In the fifth aspect, the lipophilic layer (27) having lipophilicity is formed on the inner wall surface of the oil groove (25). Therefore, the oil in the heat transfer tube (22) is easily drawn into the oil groove (25), and the oil is effectively trapped in the oil groove (25).

[0019] In a sixth aspect of the invention, regarding the heat exchanger of any one of the first to fifth aspects of the invention, an oil repellent layer (28) made of an oil repellent material is formed on part of the inner wall surface of the heat transfer tube (22) other than the oil groove (25).

[0020] In the sixth aspect, the oil repellent layer (28) is formed on the inner wall surface of the heat transfer tube (22) outside the oil groove (25). Therefore, according to the present invention, the oil present at the outside of the oil groove (25) is repelled by the oil repellent layer (28) and easily drawn into the oil groove (25). As a result, the oil is efficiently trapped in the oil groove (25).

[0021] In a seventh aspect of the invention, regarding the heat exchanger of the first aspect of the invention, a plurality of heat transfer enhancement grooves (50) helically running in a circumferential direction of the heat transfer tube (22) for enhancing heat transfer are formed in the inner wall surface of the heat transfer tube (22).

[0022] In the seventh aspect, the helical heat transfer enhancement grooves (50) are formed in the inner wall surface of the heat transfer tube (22). With the heat transfer enhancement grooves (50) thus formed, the surface area of the inner wall surface of the heat transfer tube (22) is increased, and the heat transfer performance of the heat exchanger is improved.

[0023] In an eighth aspect of the invention, regarding the heat exchanger of the seventh aspect, the oil groove (25) extends in the axial direction of the heat transfer tube (22) to intersect with the heat transfer enhancement grooves (50).

[0024] In the eights aspect, the oil groove (25) is formed in the inner wall surface of the heat transfer tube (22) to extend in the axial direction of the heat transfer tube (22) to intersect with the heat transfer enhancement grooves (50). That is, the oil groove (25) is formed to be connected with the plurality of heat transfer enhancement grooves (50). Therefore, even when the oil is accumulated in the heat transfer enhancement grooves (50), the oil can flow into the oil groove (25) through the heat transfer enhancement grooves (50). This avoids the generation of the oil film in the heat transfer enhancement grooves (50).

[0025] In a ninth aspect of the invention, regarding the heat exchanger of the eighth aspect of the invention, a plurality of oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to be aligned at regular intervals in the circumferential direction of the heat transfer tube (22).

[0026] In the ninth aspect, the plurality of oil grooves (25) extending in the axial direction of the heat transfer tube (22) are aligned at regular intervals in the circumferential direction of the heat transfer tube (22). Therefore, the oil film formed on the whole inner wall surface of the heat transfer tube (22) is easily trapped in the oil grooves (25). The amounts of oil trapped in the oil grooves (25) are equalized, and the oil trapping effect of

the oil grooves (25) is improved. Moreover, the oil accumulated in the heat transfer enhancement grooves (50) can quickly be discharged into the oil grooves (25), so that the generation of the oil film in the heat transfer enhancement grooves (50) can be avoided with more reliability.

[0027] In a tenth aspect of the invention, regarding the heat exchanger of any one of the seventh to ninth aspects of the invention, a width of an opening of the oil groove (25) is larger than a width of an opening of the heat transfer enhancement groove (50).

[0028] In the tenth aspect, the width of the opening of the oil groove (25) is larger than the width of the opening of the heat transfer enhancement groove (50). Therefore, the oil is less likely to enter the heat transfer enhancement grooves (50), and the oil is more likely enter the oil groove (25). Thus, the oil trapping effect of the oil groove (25) is improved.

[0029] In an eleventh aspect of the invention, regarding the heat exchanger of any one of the seventh to tenth aspects of the invention, a depth of the oil groove (25) is equal to or larger than a depth of the heat transfer enhancement groove (50).

[0030] In the eleventh aspect, the depth of the oil groove (25) is equal to or larger than the depth of the heat transfer enhancement groove (50). Therefore, the oil accumulated in the heat transfer enhancement grooves (50) can easily flow into the oil groove (25).

[0031] In a twelfth aspect, the present invention relates to a refrigeration system including a refrigerant circuit (10) which performs a vapor compression refrigeration cycle, wherein carbon dioxide as a refrigerant and polyalkylene glycol as refrigeration oil circulate in the refrigerant circuit (10), and the refrigerant circuit (10) includes the heat exchanger (12, 13) of any one of the first to eleventh aspects of the invention.

[0032] In the refrigeration system of the twelfth aspect, carbon dioxide is used as the refrigerant, and polyalkylene glycol (APG) is used as the refrigeration oil for smoothening the compressor mechanism, and the like. Due to low compatibility of PAG to carbon dioxide, the refrigerant and the oil are likely to separate in the heat exchanger (12, 13), and the oil film is easily formed on the whole inner wall surface of the heat transfer tube (22). However, according to the present invention, the oil groove (25) for trapping and transporting the oil is formed in the inner wall surface of the heat transfer tube (22). Therefore, in this refrigeration system, the generation of the oil film can be avoided in advance, and the decrease in heat transfer performance of the heat exchanger (12, 13) can be prevented.

EFFECT OF THE INVENTION

[0033] According to the present invention, the oil groove (25) for trapping the oil is formed in the inner wall surface of the heat transfer tube (22). Therefore, in contrast to the conventional heat exchanger in which the oil film is formed on the whole inner wall surface of the heat transfer tube, and the heat transfer performance of the heat exchanger is decreased, the present invention makes it possible to suppress the generation of the oil film by trapping the oil flowing on the inner wall surface of the heat transfer tube (22) in the oil groove (25). As a result, a contact area between the inner wall surface and the refrigerant is increased in the heat transfer tube (22), and the heat transfer between the refrigerant and a heating medium can be enhanced. By preventing the generation of the oil film in this manner, increase in pressure loss in the heat transfer tube (22) derived from the generation of the oil film can also be prevented.

[0034] Further, according to the present invention, the oil trapped in the oil groove (25) flows through the oil groove (25) and is quickly discharged out of the heat exchanger. This makes it possible to prevent the accumulation of the oil in the heat exchanger, and return a sufficient amount of oil to the compressor mechanism, and the like, with reliability.

[0035] Particularly in the second aspect of the invention, the oil groove (25) extends in the axial direction of the heat transfer tube (22). Therefore, the oil trapped in the oil groove (25) smoothly flows in the oil groove (25). This makes it possible to avoid the oil once trapped in the oil groove (25) from flowing out of the oil groove (25) and covering the inner wall surface of the heat transfer tube (22). Further, the oil accumulated in the oil groove (25) can quickly be discharged out of the heat exchanger through the oil groove (25).

[0036] According to the third aspect of the invention, a plurality of oil grooves (25) are aligned at regular intervals in the circumferential direction of the heat transfer tube (22). Therefore, according to the present invention, the oil present on the inner wall surface of the heat transfer tube (22) is easily drawn into the oil grooves (25), and the amounts of oil trapped in the oil grooves (25) can be equalized. Thus, the generation of the oil film described above can be prevented with more reliability.

[0037] According to the fourth aspect of the invention, a plurality of V-shaped oil grooves (25) are formed to provide an oil path in the heat transfer tube (22) with reliability, so that the oil can quickly be discharged out of the heat exchanger. Thus, the present invention makes it possible to return a sufficient amount of oil to the compressor mechanism, and the like, with reliability.

[0038] According to the fifth aspect of the invention, the lipophilic layer (27) is formed on the inner wall surface of the oil groove (25). Therefore, the oil trapping effect of the oil groove (25) can be improved, and the generation of the oil film can be prevented with more reliability. Further, the trapped oil is reliably transported through the oil groove (25) so that it is discharged out of the heat exchanger.

[0039] According to the sixth aspect of the invention, the oil repellent layer (28) is formed on the inner wall surface of the heat transfer tube (22). Therefore, the oil which is about to cover the inner wall surface of the heat

transfer tube (22) can be repelled and guided into the oil groove (25). Thus, the oil trapping effect of the oil groove (25) can further be improved.

[0040] According to the seventh aspect of the invention, the helical heat transfer enhancement grooves (50) are formed in the inner wall surface of the heat transfer tube (22). Therefore, the surface area of the inner wall surface of the heat transfer tube (22) is increased, and the heat transfer performance of the heat transfer tube (22) can further be improved.

[0041] According to the eighth aspect of the invention, the oil groove (25) extends in the axial direction of the heat transfer tube (22) to intersect with the helical heat transfer enhancement grooves (50). Therefore, the oil accumulated in the heat transfer enhancement grooves (50) can be discharged into the oil groove (25). Thus, the generation of the oil film in the heat transfer enhancement grooves (50) can be avoided, and the decrease in heat transfer performance of the heat transfer tube (22) can be prevented.

[0042] According to the ninth aspect of the invention, a plurality of oil grooves (25) are aligned at regular intervals in the circumferential direction of the heat transfer tube (22). Therefore, according to the present invention, the oil present on the inner wall surface of the heat transfer tube (22) is easily drawn into the oil groove (25), and the amounts of oil trapped in the oil grooves (25) can be equalized. Thus, the generation of the oil film on the inner wall surface of the heat transfer tube (22) can be prevented with more reliability. Further, since the oil accumulated in the heat transfer enhancement grooves (50) can quickly be discharged into the oil grooves (25), the generation of the oil film in the heat transfer enhancement grooves (50) can also be prevented with reliability.

[0043] According to the tenth aspect of the invention, the width of the opening of the oil groove (25) is larger than the width of the opening of the heat transfer enhancement groove (50). Therefore, the oil in the heat transfer tube (22) can actively be drawn into the oil grooves (25). Further, according to the eleventh aspect of the invention, the depth of the oil grooves (25) is equal to or larger than the depth of the heat transfer enhancement grooves (50). Therefore, the oil trapped in the heat transfer enhancement grooves (50) can reliably be discharged into the oil grooves (25). Thus, according to the present invention, the heat transfer can sufficiently be enhanced by the heat transfer enhancement grooves (50), and the heat transfer performance of the heat transfer tube (22) can further be improved.

[0044] According to the twelfth aspect of the invention, in a refrigeration system using carbon dioxide as the refrigerant, PAG which is less compatible with carbon dioxide can be trapped in the oil groove (25). That is, according to the present invention, in contrast to the conventional refrigeration system in which the oil film is easily formed on the inner wall surface of the heat transfer tube, the generation of the oil film can be prevented with reliability, and sufficient heat transfer performance of the heat exchanger (12, 13) can be obtained with reliability.

BRIEF DESCRIPTION OF DRAWINGS

[0045]

FIG. 1 is a piping diagram illustrating the schematic structure of a refrigerant circuit in a refrigeration system of Embodiment 1.

FIG. 2 is a perspective view illustrating the schematic structure of a heat exchanger of Embodiment 1.

FIG. 3 is an elevation view illustrating the schematic structure of the heat exchanger of Embodiment 1.

FIG. 4 is a perspective view illustrating the inside of a heat transfer tube in the heat exchanger of Embodiment 1.

FIG. 5 is a longitudinal sectional view of the heat transfer tube in the heat exchanger of Embodiment 1.

FIG. 6 is a view illustrating the oil trapping effect of the heat transfer tube in the heat exchanger of Embodiment 1.

FIG. 7 is a longitudinal sectional view illustrating part of a heat transfer tube in a heat exchanger of Embodiment 2.

FIG. 8 is a view illustrating the oil trapping effect of the heat transfer tube in the heat exchanger of Embodiment 2.

FIG. 9 is a perspective view illustrating the inside of a heat transfer tube in a heat exchanger of Embodiment 3.

FIG. 10 is a view illustrating the oil trapping effect of the heat transfer tube in the heat exchanger of Embodiment 3.

FIG. 11 is a perspective view, partially broken, illustrating the inside of a heat transfer tube in a heat exchanger of Embodiment 4.

FIG. 12 is a longitudinal sectional view of the heat transfer tube in the heat exchanger of Embodiment 4.

FIG. 13 is a perspective view illustrating an enlargement of an inner wall surface of the heat transfer tube in the heat exchanger of Embodiment 4.

FIG. 14 is an enlargement of the inner wall surface of the heat transfer tube in the heat exchanger of Embodiment 4, illustrating the relationship between dimension of an oil groove and dimension of a heat transfer enhancement groove.

EXPLANATION OF REFERENCE NUMRALS

[0046]

1	Air conditioner (refrigeration system)
10	Refrigerant circuit
12	Indoor heat exchanger (heat exchanger)
13	Outdoor heat exchanger (heat exchanger)
22	Heat transfer tube
25	Oil groove
27	Lipophilic layer (lipophilic material)

28 Oil repellent layer (oil repellent material)
50 Heat transfer enhancement groove

BEST MODE FOR CARRYING OUT THE INVENTION

[0047] Hereinafter, embodiments of the present invention will be described with reference to the accompanying drawings.

[Embodiment 1]

[0048] A heat exchanger according to Embodiment 1 of the present invention is applicable to a refrigeration system (1) which performs a vapor compression refrigeration cycle. The refrigeration system (1) of Embodiment 1 constitutes an air conditioner (1) capable of performing switchable cooling and heating of indoor air.

[General structure of refrigerant circuit]

[0049] As shown in FIG. 1, the air conditioner (1) includes a refrigerant circuit (10) filled with a refrigerant. The refrigerant circuit (10) is filled with carbon dioxide as the refrigerant. In the air conditioner (1), polyalkylene glycol (PAG), which is oil having polarity, is used as lubricating oil (refrigeration oil) for smoothening sliding parts of a compressor (11). PAG flows through the refrigerant circuit (10) together with the refrigerant discharged from the compressor (11). Therefore, carbon dioxide as the refrigerant and PAG as the refrigeration oil circulate in the refrigerant circuit (10). The refrigerant circuit performs a refrigeration cycle by compressing carbon dioxide to a critical pressure or higher (a so-called supercritical cycle).

[0050] The refrigerant circuit (10) includes a compressor (11), an outdoor heat exchanger (12), an indoor heat exchanger (13) and an expansion valve (14).

[0051] The compressor (11) may be, for example, a scroll compressor. The compressor (11) is connected to a discharge pipe (11a) into which the refrigerant discharged from the compressor mechanism flows, and a suction pipe (11b) into which the refrigerant to be sucked into the compressor mechanism flows. The outdoor heat exchanger (12) is placed in outdoor space. In the outdoor heat exchanger (12), the refrigerant flowing therein exchanges heat with outdoor air. The indoor heat exchanger (13) is placed in indoor space. In the indoor heat exchanger (13), the refrigerant flowing therein exchanges heat with indoor air. The outdoor heat exchanger (12) and the indoor heat exchanger (13) are heat exchangers of the present invention and constitute cross-fin heat exchangers, respectively.

[0052] The expansion valve (14) is connected between the outdoor heat exchanger (12) and the indoor heat exchanger (13). The expansion valve (14) may be, for example, an electronic expansion valve. A four-way switching valve (15) is also arranged in the refrigerant circuit (10). The four-way switching valve (15) has first to fourth ports. In the four-way switching valve (15), the first port is connected to the outdoor heat exchanger (12), the second port is connected to a suction side of the compressor (11), the third port is connected to a discharge side of the compressor (11), and the fourth port is connected to the indoor heat exchanger (13). The four-way switching valve (15) is switchable between a first state in which the first and third ports communicate with each other, and the second and fourth ports communicate with each other (a state depicted by a solid line in FIG. 1), and a second state in which the first and second ports communicate with each other, and the third and fourth ports communicate with each other (a state depicted by a broken line in FIG. 1).

[Structure of heat exchanger]

[0053] As shown in FIGS. 2 and 3, each of the heat exchangers (12, 13) includes a plurality of fins (21) and a heat transfer tube (22). Each of the fins (21) is made of aluminum and in the shape of a rectangular plate. The fins (21) are arranged parallel to each other at predetermined intervals.

[0054] The heat transfer tube (22) is made of a copper tube. The heat transfer tube (22) includes a plurality of straight portions (22a) and curved portions (22b) connecting the straight portions (22a). Each of the straight portions (22a) extends in the arrangement direction of the fins (21) and penetrates the fins (21). The curved portions (22b) are attached to the fin (21) at the front end and the fin (21) at the back end among the plurality of fins (21, 21, ...). Each of the curved portions (22b) is curved to connect the ends of two linear portions (22a).

[0055] As shown in FIGS. 4 and 5, a plurality of oil grooves (25) for trapping and transporting the oil in the refrigerant are formed in an inner wall surface of the heat transfer tube (22) in each of the heat exchangers (12, 13). In Embodiment 1, four oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22). In this embodiment, the oil grooves (25) are formed in both of the straight portions (22a) and the curved portions (22b). However, the oil grooves (25) may be formed only in the straight portions (22a). Each of the oil grooves (25) is defined by a pair of inclined surfaces (25a, 25a) inclined to separate from each other in a radially inward direction of the heat transfer tube (22), and a bottom surface (25b) formed between the inclined surfaces (25a, 25a). That is, when viewed in longitudinal section, each of the oil grooves (25) is in the shape of a trapezoid so that an opening area thereof is increasing in the radially inward direction of heat transfer tube (22).

[0056] Further, each of the oil grooves (25) extends in the axial direction of the heat transfer tube (22). That is, the oil grooves (25) are formed along the flow direction of the refrigerant in the heat transfer tube (22). The oil grooves (25) are arranged at regular intervals in the circumferential direction of the heat transfer tube (22). Specifically, the oil grooves (25) are arranged at angular in-

tervals of 90° in the circumferential direction of the heat transfer tube (22). The ratio (S2/S1) of the total longitudinal sectional area S2 of the oil grooves (25) to the longitudinal sectional area S1 of the heat transfer tube (22) is preferably 0.01 to 0.2, both inclusive.

-Working operation-

[0057] Working operation of the air conditioner (1) of Embodiment 1 will be described below. In the refrigerant circuit (10) of the air conditioner (1), the circulating direction of the refrigerant is changed by the setting of the four-way switching valve (15). Specifically, in the cooling operation, the four-way switching valve (15) is set to the state indicated by the solid line in FIG. 1. As a result, in the cooling operation, a refrigeration cycle is performed in which the outdoor heat exchanger (12) functions as a radiator, and the indoor heat exchanger (13) functions as an evaporator. On the other hand, in the heating operation, the four-way switching valve (15) is set to the state indicated by the broken line in FIG. 1. As a result, in the heating operation, a refrigeration cycle is performed in which the outdoor heat exchanger (12) functions as an evaporator, and the indoor heat exchanger (13) functions as a radiator. Hereinafter, the cooling operation of the air conditioner (1) will be described in detail.

[0058] In the refrigerant circuit (10) shown in FIG. 1, the refrigerant compressed to a critical pressure or higher in the compressor (11) is discharged from the discharge pipe (11a). At this time, oil used to smoothen the sliding parts of the compressor is discharged together with the high pressure refrigerant from the compressor (11). Then, the refrigerant flows into the outdoor heat exchanger (12). In the outdoor heat exchanger (12), the high pressure refrigerant dissipates heat into outdoor air. The high pressure refrigerant that dissipated heat into the outdoor heat exchanger (12) is reduced in pressure as it passes through the expansion valve (14), and converted to a low pressure refrigerant. Then, the refrigerant flows into the indoor heat exchanger (13). In the indoor heat exchanger (13), the refrigerant absorbs heat from indoor air and evaporates. As a result, the indoor air is cooled. The refrigerant evaporated in the indoor heat exchanger (13) flows through the suction pipe (11b) to be sucked into the compressor (11), and is recompressed.

[Function of oil groove]

[0059] In the above-described cooling and heating operations, when the refrigerant passes through the outdoor heat exchanger (12) and the indoor heat exchanger (13), oil remaining unsolved in the refrigerant may be separated from the refrigerant and cover the inner wall surface of the heat transfer tube (22). Therefore, in the conventional heat exchangers, an oil film is formed on the whole inner wall surface of the heat transfer tube, and heat transfer performance between the refrigerant and the air is decreased. In particular, when carbon dioxide is used as the refrigerant, and PAG is used as the refrigeration oil as described in the present embodiment, the refrigerant and the oil are likely to separate due to low compatibility of PAG to carbon dioxide. Therefore, the above-described oil film is easily generated. As a result, the heat transfer performance of the heat exchangers is significantly decreased, and the cooling and heating capacities of the air conditioner are also decreased. In the heat exchangers (12, 13) of the present embodiment, the oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to trap the oil in the oil grooves (25) for the purpose of preventing the decrease in heat transfer performance derived from the generation of the oil film.

[0060] Specifically, when the oil-containing refrigerant flows through the indoor heat exchanger (13) in the above-described cooling operation, for example, an evaporated gaseous refrigerant (40) flows in a center part of the heat transfer tube (22), while a liquid refrigerant (41) flows outside the gaseous refrigerant (40), as shown in FIG. 6. Oil (42) which is relatively high in viscosity and density flows outside the liquid refrigerant (41) on the inner wall surface of the heat transfer tube (22). Since the above-described oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22), the oil (42) is drawn into the oil grooves (25) by surface tension, and trapped in the oil grooves (25). As a result, the above-described oil film is hardly generated on the inner wall surface of the heat transfer tube (22), and the liquid refrigerant (41) and the inner wall surface of the heat transfer tube (22) are brought into direct contact. Thus, in the indoor heat exchanger (13), heat transfer between the indoor air and the liquid refrigerant is enhanced, and the liquid refrigerant evaporates with efficiency. On the other hand, the oil trapped in the oil grooves (25) flows in the oil grooves (25) in the same direction as the gaseous refrigerant (40) and the liquid refrigerant. Then, the oil is quickly discharged out of the indoor heat exchanger (13) together with the refrigerant.

-Effect of Embodiment 1-

[0061] According to Embodiment 1, the oil grooves (25) for trapping the oil are formed in the inner wall surface of the heat transfer tube (22). Therefore, in contrast to the conventional heat exchanger in which the oil film is formed on the whole inner wall surface of the heat transfer tube, and the heat transfer performance of the heat exchanger is decreased, the generation of the oil film can be suppressed by trapping the oil flowing on the inner wall surface of the heat transfer tube (22) in the oil grooves (25) of Embodiment 1. As a result, the decrease in heat transfer performance derived from the generation of the oil film can be prevented. Further, by preventing the generation of the oil film in this manner, increase in pressure loss in the heat transfer tube (22) derived from the generation of the oil film can also be prevented.

[0062] According to Embodiment 1, the oil grooves

(25) extend in the axial direction of the heat transfer tube (22). Therefore, the oil trapped in the oil grooves (25) smoothly flows in the oil grooves (25). This makes it possible to avoid the oil once trapped in the oil grooves (25) from flowing out of the oil grooves (25) and covering the inner wall surface of the heat transfer tube (22). Further, the oil accumulated in the oil grooves (25) can quickly be discharged out of the heat exchanger through the oil grooves (25). Thus, the oil can be avoided from remaining in the heat exchanger (12, 13), and lack of oil returning to the compressor (11) can be avoided.

[0063] According to Embodiment 1, a plurality of oil grooves (25) are arranged at angular intervals of 90° in the circumferential direction of the heat transfer tube (22). Therefore, according to Embodiment 1, the oil present on the inner wall surface of the heat transfer tube (22) is easily drawn into the oil grooves (25), and the amounts of oil trapped in the oil grooves (25) can be equalized. Thus, the generation of the oil film described above can be prevented with more reliability.

[Embodiment 2]

[0064] Heat exchangers (12, 13) according to Embodiment 2 of the present invention are different from those of Embodiment 1 in the structure of the heat transfer tube (22). Specifically, as shown in FIG. 7, the heat transfer tube (22) of Embodiment 2 is provided with more oil grooves (25) than those formed in Embodiment 1. In the same manner as Embodiment 1, the oil grooves (25) extend in the axial direction of the heat transfer tube (22).

[0065] According to Embodiment 2, a lipophilic layer (27) made of a lipophilic material is applied to the bottom surface (25b) of each of the oil grooves (25). Examples of the lipophilic material constituting the lipophilic layer (27) may be water glass, acrylic, an epoxy resin, polyvinyl alcohol, and other materials. Further, an oil repellent layer (28) made of an oil repellent material is applied on the inner wall surface of the heat transfer tube (22) outside the oil grooves (25). Examples of the oil repellent material constituting the oil repellent layer (28) may be materials based on polytetrafluoroethylene (so-called Teflon®), fluorine, paraffin, and silicon.

[0066] As shown in FIG. 8, when the refrigerant flows through the heat transfer tube (22) in the heat exchanger (12, 13) of Embodiment 2, oil (42) flowing close to the inner wall surface of the heat transfer tube (22) is repelled by the oil repellent layer (28) and drawn into the oil grooves (25). Since the lipophilic layer (27) is formed inside each of the oil grooves (25), the oil is efficiently trapped in the oil grooves (25). As a result, the oil film is hardly generated on the inner wall surface of the heat transfer tube (22) of Embodiment 2. The oil trapped in the oil grooves (25) is quickly discharged out of the heat exchanger (12, 13) through the oil grooves (25).

-Effect of Embodiment 2-

[0067] According to Embodiment 2, the generation of the oil film on the inner wall surface of the heat transfer tube (22) can also be prevented by forming the oil grooves (25) in the heat transfer tube (22). Further, the lipophilic layer (27) is formed on the inner wall surface of each of the oil grooves (25), and the oil repellent layer (28) is formed on part of the inner wall surface of the heat transfer tube (22) outside the oil grooves (25). Therefore, according to Embodiment 2, the oil trapping effect of the oil grooves (25) can be improved, and the generation of the oil film can be prevented with more reliability. Further, according to Embodiment 2, the trapped oil can reliably be transported through the oil grooves (25) and discharged out of the heat exchanger.

-Modification of Embodiment 2-

[0068] Only one of the lipophilic layer (27) and the oil repellent layer (28) of Embodiment 2 may be formed in the heat transfer tube (22). The lipophilic layer (27) may be formed on the inclined surfaces (25a) of the oil grooves (25). Further, the lipophilic layer (27) and the oil repellent layer (28) of Embodiment 2 may be applied to the heat exchangers (12, 13) of Embodiment 1.

[Embodiment 3]

[0069] Heat exchangers (12, 13) according to Embodiment 3 of the present invention are different from those of Embodiments 1 and 2 in the structure of the heat transfer tube (22). Specifically, as shown in FIG. 9, a plurality of V-shaped oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) of Embodiment 3. Each of the V-shaped oil grooves (25) is formed by connecting the ends of a pair of grooves (25c, 25c) running at an angle to the axial direction of the heat transfer tube (22). The oil grooves (25) are aligned at predetermined intervals in the axial direction of the heat transfer tube (22). The oil grooves (25) are formed so that a pointed end (25d) of each of the V-shaped grooves (25), at which the pair of grooves (25c, 25c) are connected, is directed to a discharge side in the flow direction of the refrigerant in the heat transfer tube (22). That is, the pointed ends (25d) of the oil grooves (25) are oriented to one side in the axial direction of the heat transfer tube (22). A group of the aligned oil grooves (25) is connected to another group of the aligned oil grooves (25) adjacent thereto in the circumferential direction, so that a so-called plurality of W-shaped grooves are formed in the heat transfer tube (22).

[0070] When the refrigerant flows through the heat transfer tube (22) in the heat exchanger (12, 13) of Embodiment 3 as shown in FIG. 10, oil (42) flowing close to the inner wall surface of the heat transfer tube (22) enters the grooves (25c, 25c) and flows toward the pointed end (25d) of the V-shaped groove. In this way, the oil trapped

in the oil grooves (25) flows to the pointed ends of the V-shaped grooves. Therefore, an oil path connecting the pointed ends (25d) of the V-shaped oil grooves (25) is formed in the heat transfer tube (22). The oil trapped in this way flows through the oil grooves (25) and the oil path connecting the oil grooves (25), and flows out of the heat exchanger (12, 13).

-Effect of Embodiment 3-

[0071] Also in Embodiment 3, the generation of the oil film on the inner wall surface of the heat transfer tube (22) can be prevented by forming the oil grooves (25) in the heat transfer tube (22). According to Embodiment 3, a plurality of V-shaped oil grooves (25) are formed to reliably form a flow path of the trapped oil, so that the oil can quickly be discharged out of the heat exchanger (12, 13). Thus, Embodiment 3 makes it possible to reliably avoid the lack of oil returning to the compressor (11).

[Embodiment 4]

[0072] Heat exchangers (12, 13) according to Embodiment 4 of the present invention are different from those of Embodiments described above in the structure of the heat transfer tube (22). Specifically, as shown in FIGS. 11 to 14, a plurality of heat transfer enhancement grooves (50) are formed in the inner wall surface of the heat transfer tube (22) of Embodiment 4. The heat transfer enhancement grooves (50) are helically running in the circumferential direction of the heat transfer tube (22) and parallel to each other. The longitudinal section of the heat transfer enhancement groove (50) is substantially in the shape of a trapezoid or a triangle, in which the opening area of the groove is increasing toward the opening end.

[0073] In the inner wall surface of the heat transfer tube (22) of Embodiment 4, four oil grooves (25) are formed in the same manner as described in the above-described embodiments. The oil grooves (25) extend in the axial direction of the heat transfer tube (22) and arranged at angular intervals of 90° in the circumferential direction of the heat transfer tube (22). The oil grooves (25) may not always extend linearly, and they may extend at a helix angle of 0 to 5 degrees. The longitudinal section of the oil groove (25) is substantially in the shape of a trapezoid, in which the opening area of the groove is increasing toward the opening end.

[0074] Each of the oil grooves (25) intersects with the plurality of heat transfer enhancement grooves (50) by crossing them. That is, as shown in FIG. 13 (a perspective view illustrating an enlargement of the inner wall surface of the heat transfer tube), the helical heat transfer enhancement grooves (50) are connected to the oil grooves (25) at both lengthwise ends.

[0075] Further, as shown in FIG. 14, a width W1 of the opening of the oil groove (25) is larger than a width W2 of the opening of the heat transfer enhancement groove (50). A depth D1 of the oil groove (25) is the same as a depth D2 of the heat transfer enhancement groove (50). However, the depth D1 may be larger than the depth D2, or the depth D1 may be equal to or larger than the depth D2. The width W1 of the opening of the oil groove (25) is suitably in the range of 0.2 mm to 1.0 mm.

[0076] When the refrigerant flows through the heat transfer tube (22) in the heat exchanger (12, 13) of Embodiment 4, oil (42) in the heat transfer tube (22) enters the oil grooves (25). According to Embodiment 4, the oil (42) may enter the heat transfer enhancement grooves (50), but it flows through the heat transfer enhancement grooves (50) and is discharged into the oil grooves (25) (see FIG. 13). Therefore, the generation of the oil film in the heat transfer enhancement grooves (50) is prevented. In this way, the oil (42) trapped in the oil grooves (25) is discharged out of the heat exchanger (12, 13) through the oil grooves (25).

-Effect of Embodiment 4-

[0077] According to Embodiment 4, the helical heat transfer enhancement grooves (50) are formed in the inner wall surface of the heat transfer tube (22). Therefore, the surface area of the inner wall surface of the heat transfer tube (22) is increased, and the heat transfer performance of the heat transfer tube (22) can further be improved. Further, since the oil grooves (25) extending in the axial direction of the heat transfer tube (22) intersect with the helical heat transfer enhancement grooves (50), the oil accumulated in the heat transfer enhancement grooves (50) can be discharged to the oil grooves (25). Therefore, the generation of the oil film in the heat transfer enhancement grooves (50) can be avoided, and the decrease in heat transfer performance of the heat transfer tube (22) can be prevented.

[0078] According to Embodiment 4, the four oil grooves (25) are aligned at equal intervals in the circumferential direction of the heat transfer tube (22). Therefore, the oil present on the inner wall surface of the heat transfer tube (22) is easily drawn into the oil grooves (25), and the amounts of oil trapped in the oil grooves (25) can be equalized. Thus, the generation of the oil film on the inner wall surface of the heat transfer tube (22) can be prevented with more reliability. Moreover, since the oil accumulated in the heat transfer enhancement grooves (50) can quickly be discharged to the oil grooves (25), the generation of the oil film in the heat transfer enhancement grooves (50) can also be prevented with reliability.

[0079] Still according to Embodiment 4, the width W1 of the opening of the oil groove (25) is larger than the width W2 of the opening of the heat transfer enhancement groove (50). Therefore, the oil in the heat transfer tube (22) can actively be drawn into the oil grooves (25). Further, since the depth D1 of the oil grooves (25) is equal to or larger than the depth D2 of the heat transfer enhancement grooves (50), the oil trapped in the heat transfer enhancement grooves (50) can reliably be discharged into the oil grooves (25). Thus, the heat transfer can suf-

ficiently be enhanced by the heat transfer enhancement grooves (50), and the heat transfer performance of the heat transfer tube (22) can further be improved.

[Other Embodiments]

[0080] The above-described embodiments may be varied as follows.

[0081] The shape of the oil groove (25) formed in the inner wall surface of the heat transfer tube (22) may be different from those described in the above-described embodiments. Specifically, the oil groove (25) may be a helical or serpentine groove, or the longitudinal section of the oil groove (25) may be in the shape of a triangle, an oval, or a semicircle.

[0082] The number of the oil grooves (25) is not limited to four. For example, the number of the oil grooves may be one, or more than four.

[0083] In the above-described embodiments, the heat exchangers (12, 13) of the present invention are applied to the refrigeration system in which carbon dioxide is used as the refrigerant, and PAG is used as the refrigeration oil. However, the heat exchangers (12, 13) may be applied to a refrigeration system using a refrigerant and refrigeration oil other than those described above. Specifically, the refrigerant may be R134a, R410a, R407c, R32, or other refrigerants, and the refrigeration oil may be poly-α-olefine, P06, fluorine-based oils, or other oils.

[0084] It should be noted that the embodiments are described as essentially preferred embodiments and do not limit the present invention, an object to which the present invention is applied and use of the invention.

INDUSTRIAL APPLICABILITY

[0085] As described above, the present invention is useful for heat exchangers applied to refrigeration systems that perform a refrigeration cycle.

Claims

1. A heat exchanger which is applied to a refrigeration system for performing a vapor compression refrigeration cycle and has a heat transfer tube (22) through which a refrigerant flows, wherein
an oil groove (25) for trapping and transporting oil contained in the refrigerant is formed in an inner wall surface of the heat transfer tube (22).

2. The heat exchanger of claim 1, wherein
the oil groove (25) extends in an axial direction of the heat transfer tube (22).

3. The heat exchanger of claim 2, wherein
a plurality of oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to be aligned at regular intervals in a circumferential direction of the heat transfer tube (22).

4. The heat exchanger of claim 1, wherein
a plurality of V-shaped oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to be aligned in the axial direction of the heat transfer tube (22).

5. The heat exchanger of claim 1, wherein
a lipophilic layer (27) made of a lipophilic material is formed on an inner wall surface of the oil groove (25).

6. The heat exchanger of claim 1, wherein
an oil repellent layer (28) made of an oil repellent material is formed on part of the inner wall surface of the heat transfer tube (22) other than the oil groove (25).

7. The heat exchanger of claim 1, wherein
a plurality of heat transfer enhancement grooves (50) helically running in a circumferential direction of the heat transfer tube (22) for enhancing heat transfer are formed in the inner wall surface of the heat transfer tube (22).

8. The heat exchanger of claim 7, wherein
the oil groove (25) extends in the axial direction of the heat transfer tube (22) to intersect with the heat transfer enhancement grooves (50).

9. The heat exchanger of claim 8, wherein
a plurality of oil grooves (25) are formed in the inner wall surface of the heat transfer tube (22) to be aligned at regular intervals in the circumferential direction of the heat transfer tube (22).

10. The heat exchanger of claim 7, wherein
a width of an opening of the oil groove (25) is larger than a width of an opening of the heat transfer enhancement groove (50).

11. The heat exchanger of claim 7, wherein
a depth of the oil groove (25) is equal to or larger than a depth of the heat transfer enhancement groove (50).

12. A refrigeration system comprising a refrigerant circuit (10) which performs a vapor compression refrigeration cycle, wherein
carbon dioxide as a refrigerant and polyalkylene glycol as refrigeration oil circulate in the refrigerant circuit (10), and the refrigerant circuit (10) includes the heat exchanger (12, 13) of any one of claims 1 to 11.

FIG. 1

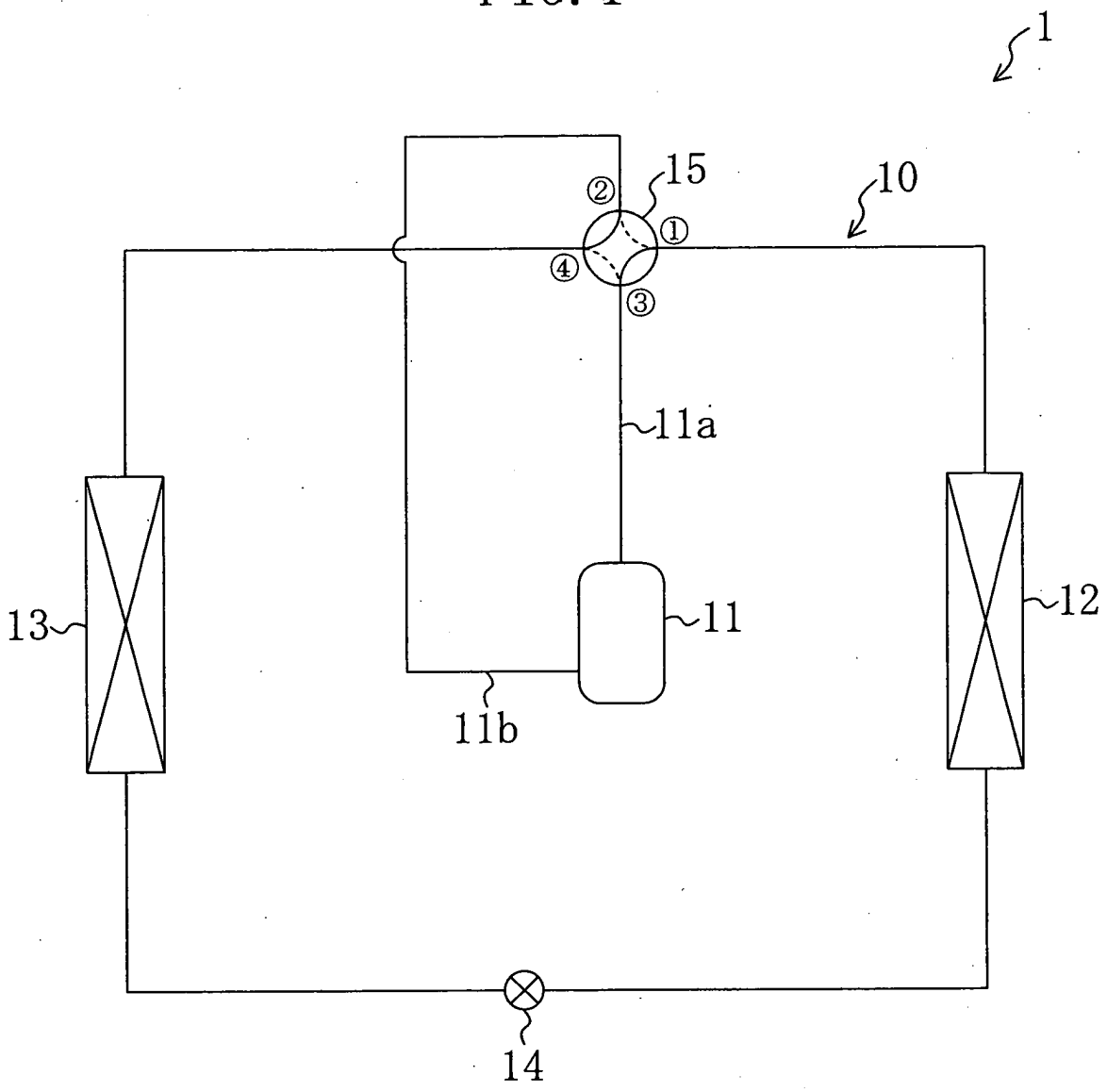


FIG. 2

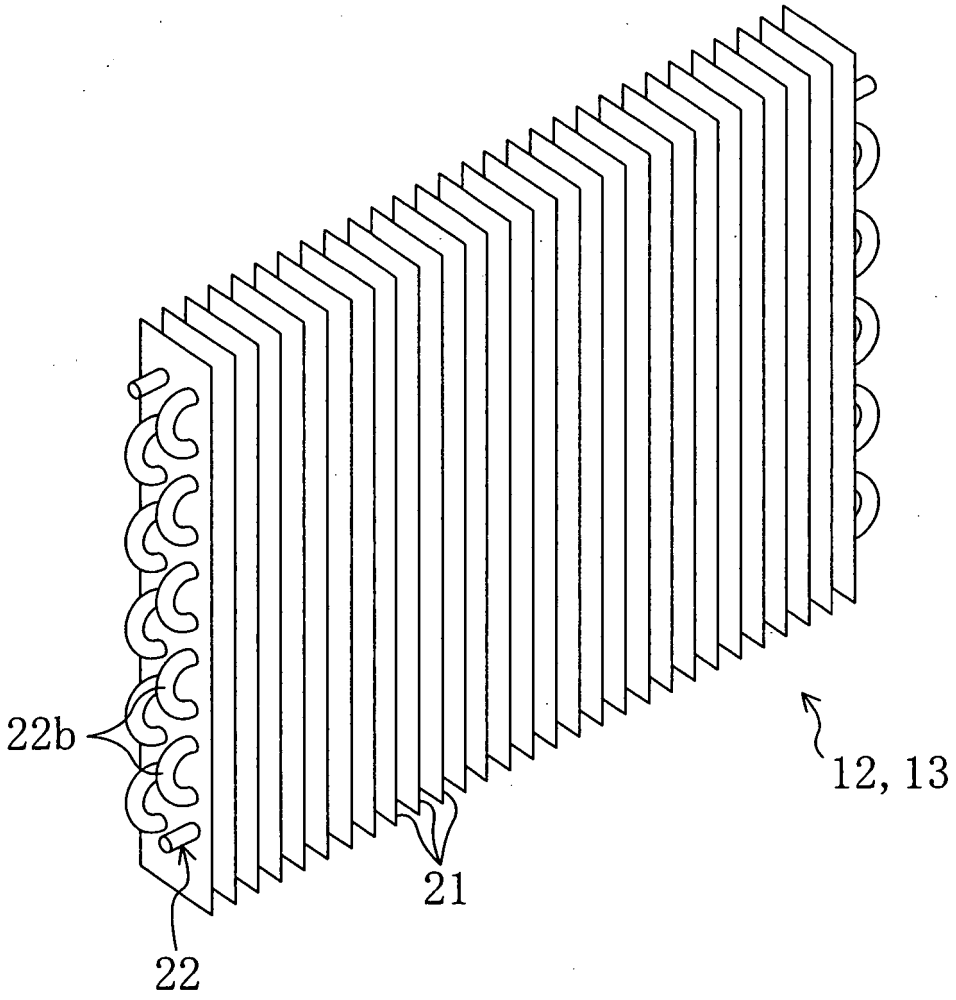


FIG. 3

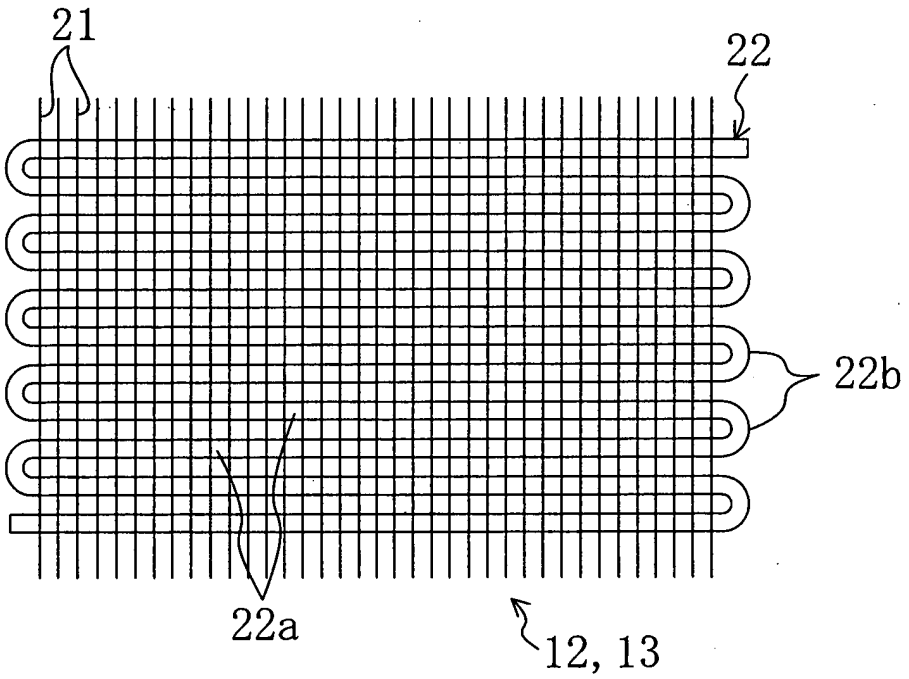


FIG. 4

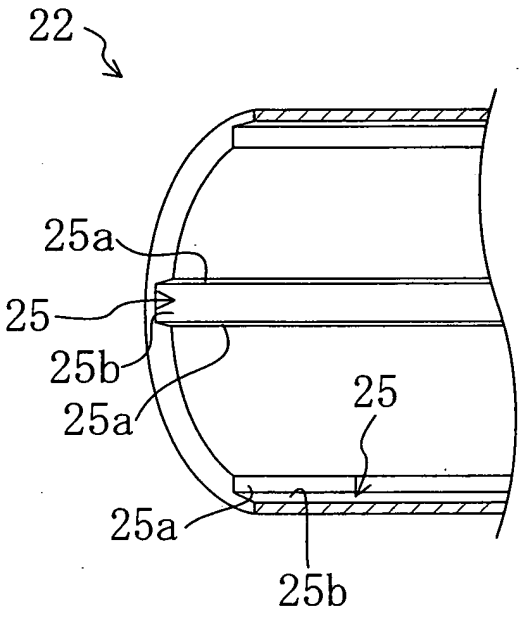


FIG. 5

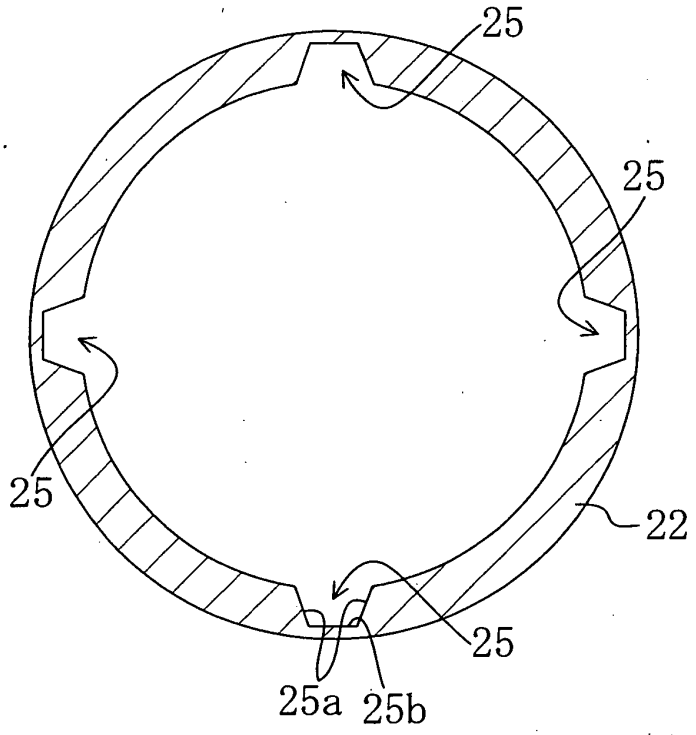


FIG. 6

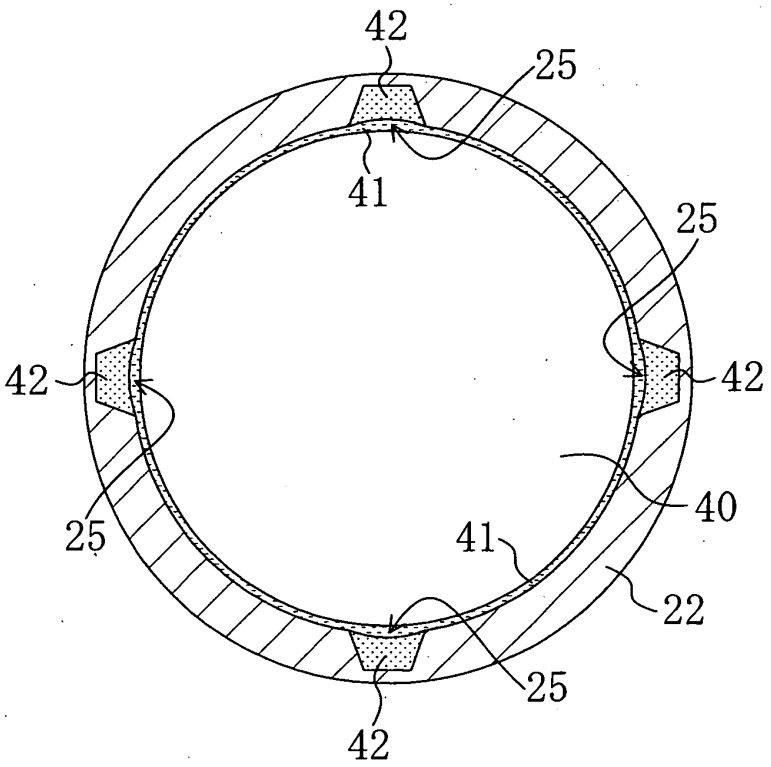


FIG. 7

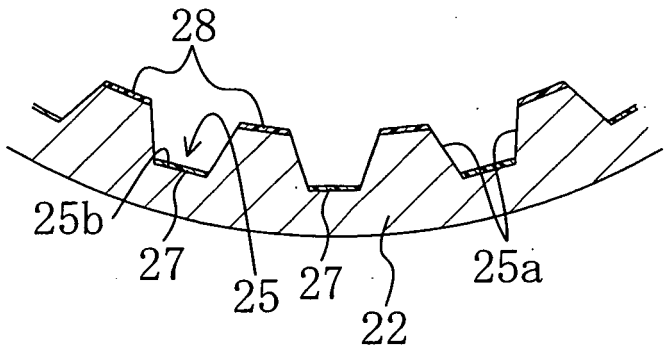


FIG. 8

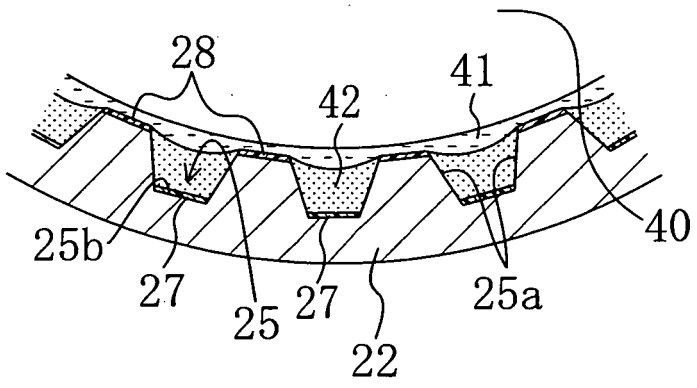


FIG. 9

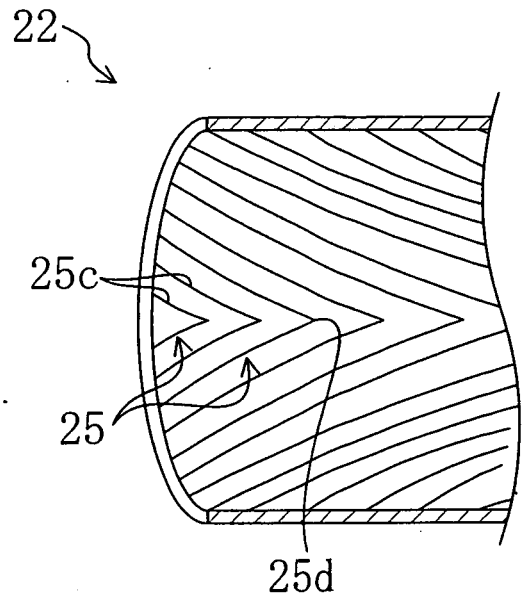


FIG. 10

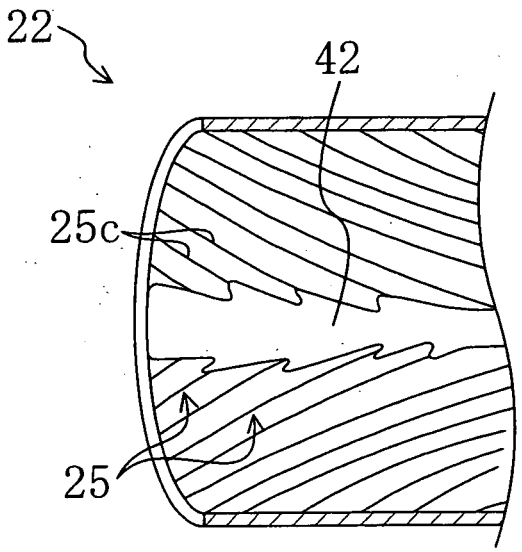


FIG. 11

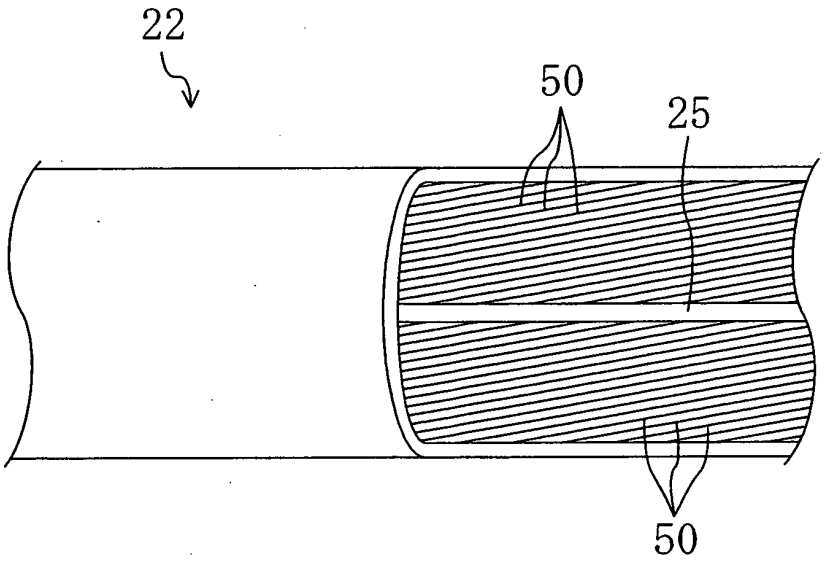


FIG. 12

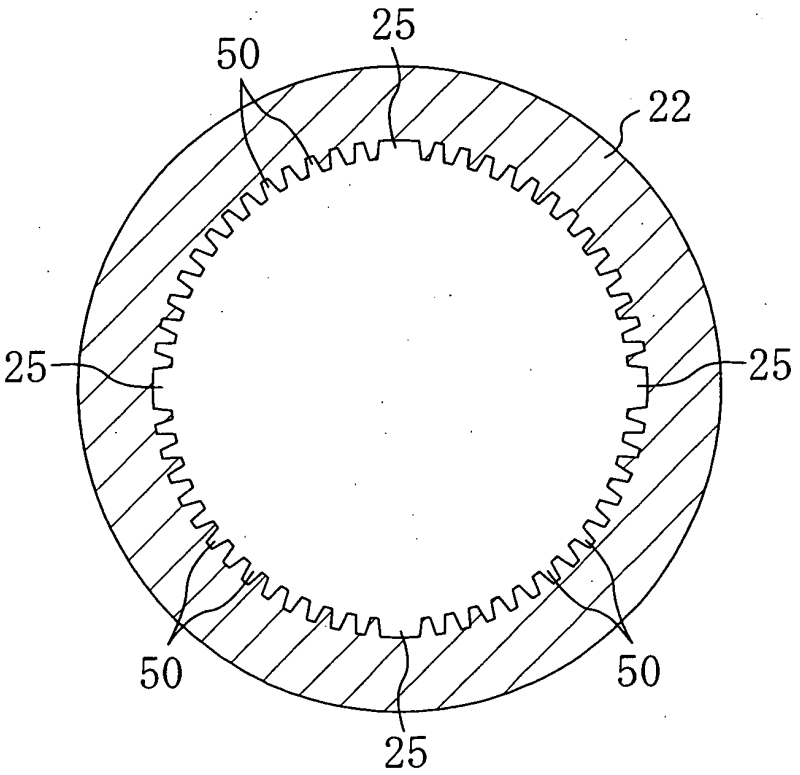


FIG. 13

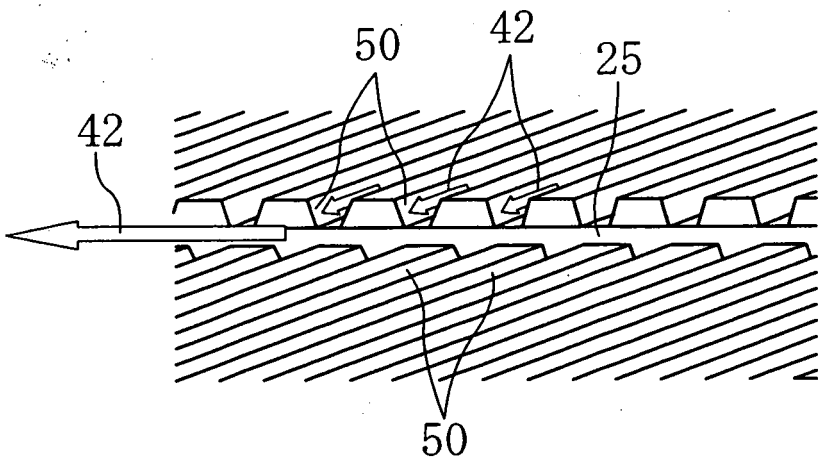
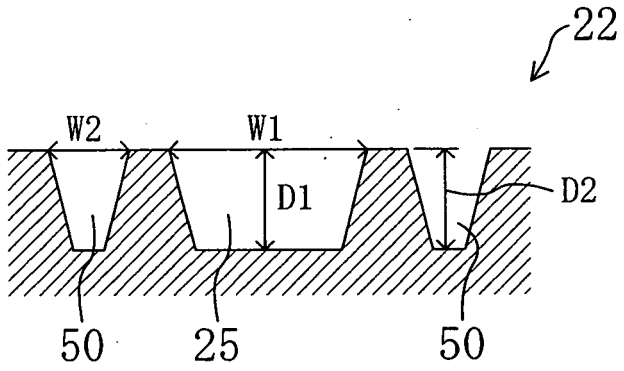


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/069260

A. CLASSIFICATION OF SUBJECT MATTER
F28F1/40(2006.01)i, *F25B1/00*(2006.01)i, *F25B39/00*(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)
F28F1/40, F25B1/00, F25B39/00

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 1996-2007
Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007

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 02/095302 A1 (Matsushita Electric Industrial Co., Ltd.), 28 November, 2002 (28.11.02), Full text; Figs. 1 to 8 & US 2004/0206109 A1 & EP 1389721 A1 & CN 1526061 A	1-3,12 4,7-11
Y	JP 2004-190968 A (Sumitomo Light Metal Industries, Ltd.), 08 July, 2004 (08.07.04), Par. Nos. [0013], [0021] to [0023]; Figs. 1 to 3 & US 2005/0188538 A1 & EP 1571408 A1 & WO 2004/053415 A1	4,7-11

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"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
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 October, 2007 (25.10.07)	13 November, 2007 (13.11.07)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/069260

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 10-206060 A (Kobe Steel, Ltd.), 07 August, 1998 (07.08.98), Par. No. [0021]; Figs. 1 to 3 & US 5915467 A1 & CN 1188229 A	8-10
A	JP 2003-262432 A (Denso Corp.), 19 September, 2003 (19.09.03), Par. Nos. [0023] to [0025], [0033], [0034]; Fig. 2 & US 2003/167793 A1 & DE 10309840 A & CN 1443999 A	5,6
A	JP 6-300372 A (Matsushita Refrigeration Co.), 28 October, 1994 (28.10.94), Par. Nos. [0017] to [0028]; Figs. 1 to 5 (Family: none)	5,6

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001116371 A **[0004]**