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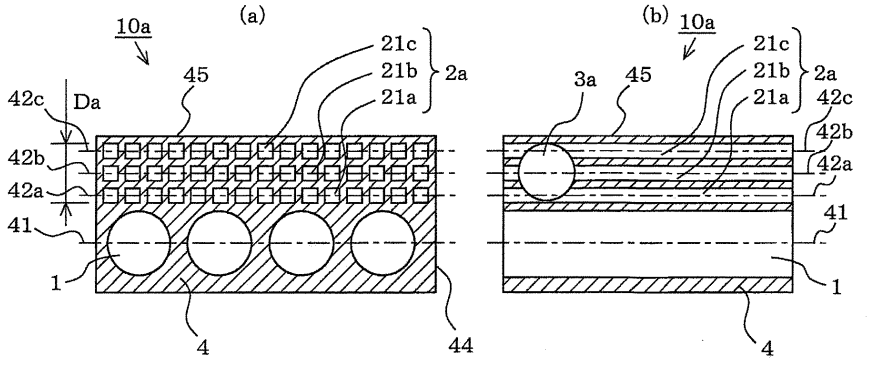
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(54) HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE

(57) A type-A heat exchanger (10a) includes a plurality of first fluid passages (1) provided parallel to one another in a first plane (41) that is a flat plane present in a heat transfer block (4), so as to extend through the heat transfer block (4); a plurality of second fluid passages (2a) (second fluid passages (21a, 21b, and 21c)) provided parallel to the first fluid passages (1) in second planes (42a, 42b, and 42c) that are present in the heat transfer block and are parallel to the first plane (41), so as to extend through the heat transfer block (4); and a lateral hole (3a) provided in the heat transfer block (4) and communicating with all of the second fluid passages (2a). The lateral hole (3a) extends perpendicularly to the second fluid passages (2a). A heat-pump heating system (60) which exemplifies a refrigeration cycle apparatus includes the type-A heat exchanger (10a). Hence, although the lateral hole (3a) communicates with a plurality of fluid passages, the pressure loss can be reduced.

F I G. 1



EP 2 840 342 A1

Description

Technical Field

[0001] The present invention relates to a heat exchanger and a refrigeration cycle apparatus and, in particular, to a heat exchanger including, in a heat transfer block, first fluid passages in which a high-temperature fluid flows and second fluid passages in which a low-temperature fluid flows, and a refrigeration cycle apparatus including the heat exchanger.

Background Art

[0002] Conventionally, heat-pump refrigeration/air-conditioning systems including vapor-compression refrigeration cycles have been used. A refrigeration cycle includes a heat exchanger that allows a first fluid and a second fluid to exchange heat with each other.

[0003] In the heat exchanger, first fluid passages in which the first fluid flows and second fluid passages in which the second fluid flows are provided substantially parallel to each other in one block (a solid body), and heat is exchanged between the first fluid and the second fluid by supplying the two fluids in the same direction (to be referred to as "parallel directions" or "parallel flows" hereinafter) or in directions opposite to each other (to be referred to as "opposite directions" or "opposed flows or counterflows" hereinafter) in the respective passages.

[0004] For example, when the first fluid is "water" and the second fluid is "R410a," heat is exchanged between the water having a low temperature and a low pressure and R410a having a high temperature and a high pressure, whereby the water is heated (while R410a is cooled).

[0005] As one of measures for an improvement in performance and size reduction of the heat exchanger, the diameter of the first fluid passages or the second fluid passages is reduced. By the diameter reduction, the heat transfer area per unit volume of the heat exchanger can be increased to, in turn, increase the heat transfer rate.

[0006] Unlike the case where the first fluid passages and the second fluid passages are provided in one block (a solid body), there is a known heat exchanger tube in which only one kind of passages are provided in a block, which is provided in another passage, whereby the diameter of the passages provided in the block is reduced. The heat exchanger tube has a flat cross-sectional shape and includes a plurality of passages in which a fluid flows. The plurality of passages are integrally formed by extrusion molding (see, for example, Patent Literature 1).

List of Citation

Patent Literature

[0007] Patent Literature 1: Japanese Unexamined Patent Application Publication JP-A-2000-234 881 (pages 3 & 4 and FIG. 2)

Summary of the Invention

Technical Problem

[0008] In the technology disclosed in Patent Literature 1, since the block is provided in the other passage, there is a temperature difference (a difference in amount of heat exchange) between those passages in the block that are on the upstream side of the other passage and those passages in the block that are on the downstream side of the other passage.

[0009] Therefore, lateral holes are provided to communicate with the passages in the block on the upstream side and the passages in the block on the downstream side, whereby the difference in fluid temperature between the passages in the block is reduced.

[0010] Thus, a lateral hole needs to be provided so that the fluid is distributed to all of the passages and is mixed. Since the diameter of the lateral hole is limited by the height of the passages, there has arisen a problem that the passage cross-sectional area is relatively small in a portion having the lateral hole and that the pressure loss increases with the repetition of expansion and contraction of the passages in the block. That is, since the passage cross-sectional area varies (the header cross-sectional area is small), the flow speed of the fluid increases in a header portion. Consequently, the pressure loss increases. With such repetition, the pressure loss in the heat exchanger increases.

[0011] There has arisen the same problem that when the technology disclosed in Patent Literature 1 is applied to a heat exchanger including first fluid passages and second fluid passages that are provided in one block (a solid body). Particularly, although the invention disclosed in Patent Literature 1 employs one row of a combination of first fluid passages and second fluid passages, if a heat exchanger includes multiple rows of combinations of first fluid passages and second fluid passages, the fluid flows from one row into another.

[0012] Therefore, the number of times the fluid flows through the header portion is relatively large. Consequently, the passage cross-sectional area repeatedly expands and contracts, and the pressure loss in the heat exchanger increases.

[0013] Furthermore, when the fluid is distributed among the passages under a certain condition of the fluid flowing into the heat exchanger and, in particular, under a condition that the fluid is in a two-phase gas-liquid state in which a mixture of gas and liquid exists, the proportions of the gas and the liquid vary in each individual passage. That is, uneven distribution occurs, so that the performance of the heat exchanger is deteriorated.

[0014] The present invention is to solve the above problems and provides a heat exchanger in which the pressure loss can be reduced even if a plurality of fluid passages are made to communicate with one another,

and a deterioration in performance of the heat exchanger can be suppressed by achieving even distribution among the passages, and a refrigeration cycle apparatus including the heat exchanger.

Solution to the Problem

[0015] A heat exchanger according to the present invention includes a plurality of first fluid passages provided parallel to one another in a first plane that is a flat plane present in a heat transfer block, so as to extend through the heat transfer block; a plurality of second fluid passages provided parallel to the first fluid passages in a second plane that is present in the heat transfer block and is parallel to the first plane, so as to extend through the heat transfer block; and at least one lateral hole provided in the heat transfer block and communicating with the second fluid passages. The at least one lateral hole extends perpendicularly to the second fluid passages.

[0016] A diameter of the at least one lateral hole and a number of at least one lateral hole are determined in such a manner as to satisfy $L/A^2d > L_y/A_y^2d_y$, where A, d, and L are a passage cross-sectional area, an equivalent diameter, and a length, respectively, of the second fluid passages, and A_y, d_y, and L_y are a passage cross-sectional area, an equivalent diameter, and an equivalent length, respectively, of the at least one lateral hole.

[0017] The at least one lateral hole communicates with all of the second fluid passages so as not to protrude into a portion of the heat transfer block that is between the first fluid passages and some of the second fluid passages that are adjacent to the first fluid passages.

Advantageous Effects of the Invention

[0018] Since the heat exchanger according to the present invention is configured as described above, the cross-sectional area of the lateral hole can be designed optimally. Therefore, the pressure loss can be reduced, and a deterioration in performance of the heat exchanger can be suppressed by achieving even distribution.

Brief Description of Drawings

[0019]

FIG. 1 shows sectional views for explaining a type-A heat exchanger according to Embodiment 1 of the present invention.

FIG. 2 shows sectional views for explaining type-B and type -C heat exchangers according to Embodiment 1 of the present invention.

FIG. 3 shows sectional views for explaining a type-D heat exchanger according to Embodiment 2 of the present invention.

FIG. 4 shows sectional views for explaining a type-E heat exchanger according to Embodiment 2 of the present invention.

FIG. 5 shows sectional views for explaining a type-F heat exchanger according to Embodiment 2 of the present invention.

FIG. 6 shows sectional views for explaining type-H and -I heat exchangers according to Embodiment 3 of the present invention.

FIG. 7 shows sectional views for explaining a type-J heat exchanger according to Embodiment 4 of the present invention.

FIG. 8 shows sectional views for explaining type-K, type-L, and type-M heat exchangers according to Embodiment 5 of the present invention.

FIG. 9 is a diagram illustrating devices included in a heat-pump heating system, to explain a refrigeration cycle apparatus according to Embodiment 7 of the present invention.

FIG. 10 is a diagram illustrating devices included in a heat-pump hot-water supply system, to explain a refrigeration cycle apparatus according to Embodiment 8 of the present invention.

FIG. 11 is a Baker's chart referred to for describing the refrigeration cycle apparatus according to Embodiment 6 of the present invention.

Description of Embodiments

Embodiment 1

[0020] FIGS. 1 and 2 schematically illustrate heat exchangers according to Embodiment 1 of the present invention. FIG. 1(a) shows a sectional view of a type-A heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 1(b) shows a sectional view of the type-A heat exchanger that is taken along a plane parallel to the longitudinal direction.

[0021] FIG. 2(a) shows a sectional view of a type-B heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 2(b) shows a sectional view of the type-B heat exchanger that is taken along a plane parallel to the longitudinal direction. FIG. 2(c) shows a sectional view of a type-C heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 2(d) shows a sectional view of the type-C heat exchanger that is taken along a plane parallel to the longitudinal direction.

[0022] In each of the drawings, elements that are the same as or equivalent to one another are denoted by common reference numerals (numbers), and a description of some of them will be omitted. In describing common features, suffixes (a, b, ...) to the reference numerals will often be omitted (the same applies to Embodiments 2 to 5).

Type-A Heat Exchanger

[0023] Referring to FIG. 1(a) and FIG. 1(b), a type-A heat exchanger 10a includes, in a heat transfer block 4, a plurality of (for example, four) first fluid passages 1, a

plurality of (for example, forty-five) second fluid passages 2a arranged such that the direction of flow is parallel to that of the first fluid passages 1, and one lateral hole 3a extending perpendicularly to the second fluid passages 2a and communicating with all of the second fluid passages 2a.

First Fluid Passages and Second Fluid Passages

[0024] The plurality of first fluid passages 1 are arranged in a first plane 41, which is a flat plane, in such a manner as to be parallel to one another. The first fluid passages 1 each have a circular cross-sectional shape.

[0025] The second fluid passages 2a are parallel to the first fluid passages 1 and generally refer to the following: a plurality of (for example, fifteen) second fluid passages 21a provided in a second plane 42a that is a flat plane substantially parallel to the first plane 41, a plurality of (for example, fifteen) second fluid passages 21b provided in a second plane 42b that is substantially parallel to the first plane 41, and a plurality of (for example, fifteen) second fluid passages 21c provided in a second plane 42c that is substantially parallel to the first plane 41.

[0026] That is, the second fluid passages 2a are provided in three layers so that each layer includes fifteen passages. The second fluid passages 2a each have a quadrate cross-sectional shape.

[0027] The "longitudinal direction" refers to the axial direction of the first fluid passages 1 and the second fluid passages 2a.

[0028] While the above description concerns a case where the first fluid passages 1 each have a circular cross-sectional shape and the second fluid passages 2a each have a quadrate cross-sectional shape, the present invention is not limited to such a case. The passages 1 and 2a can each have an arbitrary cross-sectional shape.

Lateral Hole

[0029] The lateral hole 3a extends perpendicularly to the second fluid passages and communicates with the plurality of (for example, forty-five) second fluid passages. The lateral hole 3a does not protrude into a portion of the heat transfer block 4 that is between the first fluid passages 1 and the second fluid passages 21a adjacent to the former passages.

[0030] The diameter of the lateral hole 3a and the number of lateral holes 3a are determined in accordance with the mass velocity of the fluid flowing into the lateral hole 3a, the length of the lateral hole, and the dimensions and the number of second fluid passages, whereby the pressure loss can be reduced.

[0031] When the second fluid flows in the longitudinal direction of the heat transfer block, a pressure loss ΔP is "$\Delta P = \lambda \times L/d \times v^2/2 \times \rho$," where ρ is the density of the second fluid, v is the flow speed ("$v = G/\rho \times 1/A$," where G is the mass velocity, and A is the passage cross-sectional area), λ is the coefficient of pressure loss, d is the equivalent diameter of each second fluid passage ("$d = 4S/L'$," where S is the total cross-sectional area, and L' is the length of the wetted perimeter), and L is the length of the second fluid passage.

[0032] Likewise, when the second fluid flows through the lateral hole 3a, a pressure loss ΔP_y is "$\Delta P_y = \lambda_y \times L_y/d_y \times v_y^2/2 \times \rho$," where v_y is the flow speed in a portion having the lateral hole 3a. It is preferable to determine the diameter of the lateral hole and the number of lateral holes that make the pressure loss in the portion having the lateral hole 3a smaller than the pressure loss occurring when the second fluid flows in the longitudinal direction of the heat transfer block. In other words, it is preferable to determine the diameter of the lateral hole 3a and the number of lateral holes 3a so as to satisfy"$\Delta P > \Delta P_y$", that is, "$L/A^2d > L_y/A_y^2d_y$."

[0033] For instance, when, as illustrated in FIG. 1, a line of fifteen 1-mm^2 second fluid passages are provided in three layers, the heat transfer block has a length of 300 mm, and the lateral hole has a length of 25 mm, it is preferable that the diameter of the lateral hole 3a and the number of lateral holes 3a satisfy "$L/A^2d = 0.3/(4.5\times10^{-5})^2\times0.001 = 1.48\times10^{11} > Ly/A_y^2d_y$." Specifically, it is preferable that the lateral hole 3a have a diameter of "$d_y > 0.003$," that is, 3 mm or larger. If the passage cross-sectional area falls outside the foregoing range, the pressure loss in the portion having the lateral hole is relatively high, unpreferably leading to a deterioration in performance of the heat exchanger.

[0034] While a lateral hole 3a is formed by machining (drilling), plasticization (punching), or the like performed from one side face 44 of the heat transfer block 4, the present invention does not limit the method of forming a lateral hole 3a.

Advantageous Effects

[0035] The type-A heat exchanger 10a configured as described above produces the following advantageous effects.

[0036] The lateral hole 3a having the passage cross-sectional area that falls within the above range is larger than the lateral hole of the known heat exchanger having a diameter corresponding to the size of one layer (see Patent Literature 1).

[0037] Therefore, when the fluid flows through the type-A heat exchanger 10a, the influence of expansion and contraction of the passage in the portions having the lateral hole 3a is relatively little. Since the lateral hole 3a functions as a header portion, the pressure loss in the lateral hole 3a, that is, the pressure loss in the type-A heat exchanger 10a, is relatively low.

[0038] With the aforementioned arrangement, the second fluid passages 2a are provided in a plurality of layers so that a diameter Da of the lateral hole 3a is increased, so that the heat transfer area of the second fluid passages 2a, in turn, is increased. Thus, the heat exchange per-

formance can be improved.

[0039] Particularly, the heat exchanger includes multiple rows of combinations of first and second fluid passages, the second fluid flows from one row into another. Therefore, the number of times the second fluid passes through the lateral hole 3a (equivalent to a header portion) is relatively large.

[0040] Consequently, the passage cross-sectional area repeatedly expands and contracts. However, since the passage cross-sectional area in the lateral hole 3a is large in the type-A heat exchanger 10a, the effect of reducing the pressure loss is pronounced.

[0041] With the lateral hole 3a having the diameter Da corresponding to the passage cross-sectional area that falls within the above range, the distance between the lateral hole 3a and the first fluid passages 1 can be made smaller than when the thickness of the heat transfer block is increased as in the known heat exchanger in which the passages are provided in one layer and the lateral hole having a diameter equivalent to it. Hence, the heat exchange performance can be improved.

[0042] The lateral hole 3a having the diameter Da corresponding to the passage cross-sectional area that falls within the above range does not protrude into the portion of the heat transfer block 4 that is between the first fluid passages 1 and the second fluid passages 21a adjacent to the former passages. With this arrangement, the distance between the first fluid passages 1 and the second fluid passages 21a can be reduced. Thus, the heat exchange performance can be improved.

[0043] Furthermore, the lateral hole 3a does not protrude into a portion of the heat transfer block 4 that is on the outer side of the second fluid passages 21c that are farthest from the first fluid passages 1. That is, for each set of second fluid passages 2a that are arranged in a plurality of layers, the height of the lateral hole 3a is set to fall within the length from the lowest layer of second fluid passages 2a to the highest layer of second fluid passages 2a.

[0044] With this arrangement, the thickness of the heat transfer block 4 can be reduced. When a set of first fluid passages 1, a set of second fluid passages 2a, and another set of first fluid passages 1 are stacked in layers in sequence, the second fluid passages 2a in the middle layer can be positioned near the upper and lower layers of first fluid passages 1. Thus, the heat exchange performance can be improved.

[0045] The method of forming a heat transfer block 4 is not limited. However, for example, when a heat transfer block 4 is formed by integral extrusion, it is easy to increase/decrease the number of first fluid passages 1 and the number of first planes 41 or to increase/decrease the number of second fluid passages and the number of second planes 42. Therefore, the passage cross-sectional area in the lateral hole 3a can be designed optimally.

[0046] In the type-A heat exchanger 10a, a pipe joint (for example, a tube or the like; not illustrated) for pipe connection is soldered to the lateral hole 3a on one side face 44 of the heat transfer block 4. Hence, by connecting a pipe of a system (for example, a hot-water supply system or the like) to the pipe joint, the type-A heat exchanger 10a becomes available. In this state, the two longitudinal ends of each of the second fluid passages 2a are closed.

[0047] Alternatively, the opening of the lateral hole 3a in one side face 44 of the heat transfer block 4 may be closed with a lid. In this state, the two longitudinal ends of each of the second fluid passages 2a are connected to pipes (directly to pipe joints or indirectly with external header portions) of a system (for example, a hot-water supply system or the like).

[0048] The fluid (first fluid) flowing in the first fluid passages 1 and the fluid (second fluid) flowing in the second fluid passages 2a are not limited. The first fluid may be any water such as tap water, distilled water, or brine while the second fluid may not only be R410a but also be a natural refrigerant such as a fluorocarbon refrigerant or hydrogen carbide or any mixture of the foregoing materials.

[0049] The direction in which the fluid flows in the first fluid passages 1 and the direction in which the fluid flows in the second fluid passages 2a may be parallel to each other or opposite to each other.

Type-B Heat Exchanger

[0050] Referring to FIG. 2(a) and FIG. 2(b), a type-B heat exchanger 10b includes, in a heat transfer block 4, four first fluid passages 1, second fluid passages 2b provided in five layers so that each layer includes fifteen second fluid passages 2b (seventy-five in total), and one lateral hole 3b extending perpendicularly to the second fluid passages 2b and communicating with the second fluid passages 2b.

[0051] In this case, the type-B heat exchanger 10b is equivalent to the type-A heat exchanger 10a additionally provided with a plurality of (for example, fifteen) second fluid passages 21d and a plurality of (for example, fifteen) second fluid passages 21e that are arranged in second planes 42d and 42e, respectively, extending substantially parallel to the first plane 41. An inside diameter Db of the lateral hole 3b is large because the lateral hole 3b extends across the five layers of second fluid passages 2b.

Type-C Heat Exchanger

[0052] Referring to FIG. 2(c) and FIG. 2(d), a type-C heat exchanger 10c includes, in a heat transfer block 4, four first fluid passages 1, second fluid passages 2c provided in two layers so that each layer includes fifteen second fluid passages 2c (thirty in total), and one lateral hole 3c extending perpendicularly to the second fluid passages 2c and communicating with the second fluid passages 2c. In this case, an inside diameter Dc of the lateral hole 3c is small because the lateral hole 3c only needs to extend over the two layers of second fluid passages 2c.

[0053] If the fluid flowing in the heat exchanger undergoes phase transition, the flow speed of the fluid for the same mass velocity is lowest in a liquid state, is second lowest in a two-phase gas-liquid state, and is highest in a gas state. To reduce the pressure loss, the diameter of the lateral hole needs to be set in accordance with the state of the refrigerant, that is, the flow speed of the refrigerant. Specifically, the diameter of the lateral hole 3 is increased (the type-A to type-C heat exchangers are selectively used) in accordance with the flow speed of the fluid that changes with the state of the fluid.

[0054] By selectively using the different types of heat exchangers, the pressure loss in the second fluid passages 2 can be reduced.

[0055] The above classification into type-A to -C heat exchangers is done for the sake of convenience of description and does not limit the number of first fluid passages 1, the number of layers of second fluid passages 2, and the number of second fluid passages 2 included in each of the layers.

[0056] While the diameter of the lateral hole 3 in the above description is defined as the diameter Da that covers the range from the second fluid passages 21a to the second fluid passages 21c for the sake of convenience of description, the diameter of the lateral hole 3 may be smaller than the diameter Da as long as the diameter can cover the range from the second fluid passages 21a to the second fluid passages 21c.

Embodiment 2

[0057] FIGS. 3 to 5 schematically illustrate heat exchangers according to Embodiment 2 of the present invention. FIG. 3(a) shows a sectional view of a type-D heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 3(b) shows a sectional view of the type-D heat exchanger that is taken along a plane parallel to the longitudinal direction.

[0058] FIG. 4(a) shows a sectional view of a type-E heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 4(b) shows a sectional view of the type-E heat exchanger that is taken along a plane parallel to the longitudinal direction.

[0059] FIG. 5(a) shows a sectional view of a type-F heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 5(b) shows a sectional view of the type-F heat exchanger that is taken along a plane parallel to the longitudinal direction. Elements that are the same as or equivalent to those of Embodiment 1 are denoted by common reference numerals, and a description of some of them will be omitted.

Type-D Heat Exchanger

[0060] Referring to FIG. 3(a) and FIG. 3(b), a type-D heat exchanger 10d includes, in a heat transfer block 4, four first fluid passages 1, second fluid passages 2d provided in two layers so that each layer includes fifteen second fluid passages 2d, and a rectangular lateral hole 3d communicating with the second fluid passages 2d.

[0061] In this case, the lateral hole 3d has a height corresponding to the height of the second fluid passages 2d, with its long sides extending in the longitudinal direction. The lateral hole 3d extends perpendicularly to the second fluid passages 2d. Other configurations and operations are the same as in Embodiment 1.

[0062] The type-D heat exchanger 10d configured as described above produces the following advantageous effects.

[0063] Specifically, in the type-D heat exchanger 10d having the rectangular lateral hole 3d, since the passage cross-sectional area in the lateral hole 3d is larger than that in the case of a circular lateral hole, the influence of the expansion and contraction of the passage is relatively little in the former. Therefore, the pressure loss in the lateral hole 3d, that is, the pressure loss in the type-D heat exchanger 10d, is relatively low in the former.

[0064] The length of the long sides is designed such that good performance is obtained in the distribution of the refrigerant. Therefore, a deterioration in performance of the heat exchanger that is attributed to a deterioration in distribution performance can be suppressed.

[0065] Furthermore, the lateral hole 3d has a rectangular shape, whereby the thickness of the heat transfer block 4 is kept small (not increased). With a reduction in thickness of the heat exchanger, the size and the material cost of the heat exchanger can be reduced.

[0066] Since the cross-sectional area of the rectangular lateral hole 3d is larger than that when the lateral hole 3d has a circular shape, the material cost can be made lower than that in the case where the lateral hole 3d has a circular shape, by an amount of material corresponding to the increment of the cross-sectional area.

[0067] While the above description concerns a case where the long sides of the lateral hole 3d extend in the longitudinal direction, the short sides of the lateral hole 3d may extend in the longitudinal direction.

Type-E Heat Exchanger

[0068] Referring to FIG. 4(a) and FIG. 4(b), a type-E heat exchanger 10e includes, in a heat transfer block 4, four first fluid passages 1, second fluid passages 2e provided in two layers so that each layer includes fifteen second fluid passages 2e, and an elliptical lateral hole 3e communicating with the second fluid passages 2e.

[0069] In this case, the lateral hole 3e has a height corresponding to the height of the second fluid passages 2e, with its long sides extending in the longitudinal direction. The lateral hole 3e extends perpendicularly to the second fluid passages 2e. Other configurations and operations are the same as in Embodiment 1.

[0070] The type-E heat exchanger 10e configured as described above produces the following advantageous effects.

[0071] Specifically, in the type-E heat exchanger 10e

having the elliptical lateral hole 3e, since the passage cross-sectional area in the lateral hole 3e is larger than that in the case of a circular lateral hole, the influence of the expansion and contraction of the passage is relatively little in the former. Therefore, the pressure loss in the lateral hole 3e, that is, the pressure loss in the type-E heat exchanger 10e, is relatively low in the former.

[0072] The length of the long sides is designed such that good performance is obtained in the distribution of the refrigerant. Therefore, a deterioration in performance of the heat exchanger that is attributed to a deterioration in distribution performance can be suppressed.

[0073] Furthermore, the lateral hole 3e has an elliptical shape, whereby the thickness of the heat transfer block 4 is kept small (not increased). With a reduction in thickness of the heat exchanger, the size and the material cost of the heat exchanger can be reduced.

[0074] Since the cross-sectional area of the elliptical lateral hole 3e is larger than that when the lateral hole 3e has a circular shape, the material cost can be made lower than that in the case where the lateral hole 3e has a circular shape, by an amount of material corresponding to the increment of the cross-sectional area.

[0075] The type-E heat exchanger 10e is obtained by changing the rectangular shape of one lateral hole 3d of the type-D heat exchanger 10d into an elliptical shape. This makes it easy to form a lateral hole 3e by machining such as end milling.

[0076] While the above description concerns a case where the long sides of the lateral hole 3e extend in the longitudinal direction, the short sides of the lateral hole 3e may extend in the longitudinal direction.

Type-F Heat Exchanger

[0077] Referring to FIG. 5(a) and FIG. 5(b), a type-F heat exchanger 10f includes, in a heat transfer block 4, four first fluid passages 1, second fluid passages 2f provided in two layers so that each layer includes fifteen second fluid passages 2f, and a plurality of lateral holes 3f communicating with the second fluid passages 2f.

[0078] In this case, the lateral holes 3f each have a diameter corresponding to the height of the second fluid passages 2f. The plurality of (for example, two) lateral holes 3f each extend perpendicularly to the second fluid passages 2f and are arranged in the direction of the passages. Other configurations and operations are the same as in Embodiment 1.

[0079] The type-F heat exchanger 10f configured as described above produces the following advantageous effects.

[0080] Specifically, in the type-F heat exchanger 10f having the plurality of lateral holes 3f, since the passage cross-sectional area in the lateral holes 3f is larger than that when one lateral hole is provided, the influence of the expansion and contraction of the passage is relatively little in the former. Therefore, the pressure loss in the lateral holes 3f, that is, the pressure loss in the type-F heat exchanger 10f, is relatively low in the former.

[0081] Furthermore, the plurality of lateral holes 3f are provided, whereby the thickness of the heat transfer block 4 is kept small (not increased). With a reduction in thickness of the heat exchanger, the size and the material cost of the heat exchanger can be reduced.

[0082] The length of the long sides is designed such that good performance is obtained in the distribution of the refrigerant. Therefore, a deterioration in performance of the heat exchanger that is attributed to a deterioration in distribution performance can be suppressed.

[0083] Furthermore, the plurality of lateral holes 3f are provided, whereby the thickness of the heat transfer block 4 is kept small (not increased). With a reduction in thickness of the heat exchanger, the size and the material cost of the heat exchanger can be reduced.

[0084] Since the cross-sectional area in the plurality of lateral holes 3f is larger than that when a single circular lateral hole 3f is provided, the material cost can be made lower than that in the case where a single circular lateral hole 3f is provided, by an amount of material corresponding to the increment of the cross-sectional area.

[0085] The type-F heat exchanger 10f is obtained by changing one rectangular lateral hole 3d of the type-D heat exchanger 10d into a plurality of circular lateral holes. This makes it easy to form lateral holes 3f by machining such as end milling.

[0086] Furthermore, with the plurality of lateral holes 3f, the pressure resistance can be improved compared with the cases of rectangular and elliptical lateral holes.

[0087] While the above description concerns a case where two lateral holes 3f are provided, the number of lateral holes 3f is not limited.

Embodiment 3

[0088] FIG. 6 schematically illustrates heat exchangers according to Embodiment 3 of the present invention. FIG. 6(a) shows a sectional view of a type-H heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 6(b) shows a sectional view of the type-H heat exchanger that is taken along a plane parallel to the longitudinal direction.

[0089] FIG. 6(c) shows a sectional view of a type-I heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 6(d) shows a sectional view of the type-I heat exchanger that is taken along a plane parallel to the longitudinal direction. Elements that are the same as or equivalent to those of Embodiment 1 are denoted by common reference numerals, and a description of some of them will be omitted.

Type-H Heat Exchanger

[0090] Referring to FIG. 6(a) and FIG. 6(b), a type-H heat exchanger 10h includes, in a heat transfer block 4, four first fluid passages 1 provided in one layer, fifteen second fluid passages 21a provided in one layer, a lateral

hole 3h, and a slit-like space 5h extending parallel to the second fluid passages 21a and provided on a side that is opposite to the first fluid passages 1. That is, the second fluid passages 21a are provided between the first fluid passages 1 and the slit-like space 5h.

[0091] In this case, the slit-like space 5h is provided in a third plane 43 that is parallel to the second plane 42a, the lateral hole 3h extends across the second fluid passages 21a and the slit-like space 5h, and a portion of the slit-like space 5h where the lateral hole 3h is provided is sealed so that the second fluid does not flow into the slit-like space 5h from the second fluid passages 21a via the lateral hole 3h.

[0092] Specifically, a sealing block 81 is provided in a predetermined area of the slit-like space 5h in a fluid-tight manner, and the lateral hole 3h extends through a portion of the sealing block 81. The method of sealing is not limited to the use of the sealing block 81.

[0093] Hence, the lateral hole 3h functions as a passage in which, in side view, a portion that is substantially half (a semicircle) of a circle having a diameter Dh covering the second fluid passages 21a and the slit-like space 5h communicates with the first fluid passages 1 and the second fluid passages 21a. Other configurations and operations are the same as in Embodiment 1.

[0094] The type-H heat exchanger 10h configured as described above produces the following advantageous effects.

[0095] In the type-H heat exchanger 10h in which the diameter of the lateral hole 3h is relatively large because of the presence of the slit-like space 5h, the passage cross-sectional area in the portion having the lateral hole 3h (the area of the semicircular communicating portion) is relatively large. Therefore, the influence of the expansion and contraction of the passage is relatively little.

[0096] Accordingly, the pressure loss in the lateral hole 3h, that is, in the type-H heat exchanger 10h, is kept low. Furthermore, because of the presence of the slit-like space 5h, a portion having the slit-like space 5h functions as a heat insulating layer and prevents heat from being transferred from the second fluid passages 21a to the outside of the heat transfer block 4. Thus, the heat exchange performance can be improved.

[0097] While the above description concerns a case where the lateral hole 3h has a circular cross-sectional shape, the shape of the lateral hole 3h is not limited.

Type-I Heat Exchanger

[0098] Referring to FIG. 6(c) and FIG. 6(d), a type-I heat exchanger 10i is obtained by dividing the slit-like space 5h of the type-H heat exchanger 10h into a plurality of slit-like spaces 5i. While the slit-like spaces 5i each having a rectangular cross-sectional shape are illustrated, the present invention is not limited to such a case. The cross-section of each of the slit-like spaces 5i may have a circular shape, an elliptical shape, or any other quadrate shape such as a square shape.

[0099] In this case, a sealing block 82 is provided in a predetermined area of each of the slit-like spaces 5i, each having a rectangular cross-sectional shape, in a fluid-tight manner.

[0100] Hence, the type-I heat exchanger 10i produces the same advantageous effects as the type-H heat exchanger 10h and has high rigidity on a side face 45 of the heat transfer block 4 that is near the slit-like spaces 5i. Therefore, the heat transfer block 4 is more difficult to deform than that of the type-H heat exchanger 10h.

[0101] The method of forming a heat transfer block 4 is not limited. However, if a heat transfer block 4 is formed by, for example, integral extrusion, the form of the slit-like spaces 5i can more flexibly be selected with an increase or decrease in the number of first fluid passages 1 and in the number of first planes 41, or an increase or decrease in the number of second fluid passages and in the number of second planes 42.

Embodiment 4

[0102] FIG. 7 schematically illustrates a heat exchanger according to Embodiment 4 of the present invention. FIG. 7(a) shows a sectional view of a type-J heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 7(b) shows a sectional view of the type-J heat exchanger that is taken along a plane parallel to the longitudinal direction. Elements that are the same as or equivalent to those of Embodiment 1 are denoted by common reference numerals, and a description of some of them will be omitted.

Type-J Heat Exchanger

[0103] Referring to FIG. 7(a) and FIG. 7(b), a type-J heat exchanger 10j is obtained by dividing the slit-like spaces 5i of the type-I heat exchanger 10i into two layers.

[0104] That is, slit-like spaces 5j include a plurality of lower-layer slit-like spaces 51a provided at intervals in a third plane 43a that is parallel to the second plane 42a, and a plurality of upper-layer slit-like spaces 51b provided at intervals in a third plane 43b that is parallel to the third plane 43a. The lower-layer slit-like spaces 51a and the upper-layer slit-like spaces 51b each have a substantially square cross-sectional shape.

[0105] Each of the upper-layer slit-like spaces 51b is provided above an area between a corresponding pair of lower-layer slit-like spaces 51a (that is, each of the lower-layer slit-like spaces 51a is provided below an area between a corresponding pair of upper-layer slit-like spaces 51b), whereby the slit-like spaces 51a and 51b are formed in a checkered pattern.

[0106] A sealing block 83a and a sealing block 83b are provided in predetermined areas of each of the lower-layer slit-like spaces 51a and each of the upper-layer slit-like spaces 51b, respectively, in a fluid-tight manner.

[0107] Hence, except that the slit-like spaces 5j include the lower-layer slit-like spaces 51b and the upper-layer

slit-like spaces 51a that serve as fine passages, the type-J heat exchanger 10j is identical to the type-H heat exchanger 10h. Therefore, the heat exchange 10j produces the same advantageous effects as the type-H heat exchanger 10h.

[0108] The method of forming a heat transfer block 4 is not limited. However, if the heat transfer block 4 is formed by, for example, integral extrusion, the form of the slit-like spaces 5j can more flexibly be selected with an increase or decrease in the number of first fluid passages 1 and in the number of first planes 41, or an increase or decrease in the number of second fluid passages and in the number of second planes 42.

Embodiment 5

[0109] FIG. 8 schematically illustrates heat exchangers according to Embodiment 5 of the present invention. FIG. 8(a) shows a sectional view of a type-K heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 8(b) shows a sectional view of the type-K heat exchanger that is taken along a plane parallel to the longitudinal direction.

[0110] FIG. 8(c) shows a sectional view of a type-L heat exchanger that is taken along a plane perpendicular to the longitudinal direction. FIG. 8(d) shows a sectional view of the type-L heat exchanger that is taken along a plane parallel to the longitudinal direction. FIG. 8(e) shows a sectional view of a type-M heat exchanger that is taken along a plane perpendicular to the longitudinal direction.

[0111] FIG. 8(f) shows a sectional view of the type-M heat exchanger that is taken along a plane parallel to the longitudinal direction. Elements that are the same as or equivalent to those of Embodiment 1 are denoted by common reference numerals, and a description of some of them will be omitted.

Type-K Heat Exchanger

[0112] Referring to FIG. 8(a) and FIG. 8(b), a type-K heat exchanger 10k includes, in the heat transfer block 4, four first fluid passages 1, second fluid passages 2k provided in six layers so that each layer includes fifteen second fluid passages 2k (ninety in total), and one lateral hole 3k extending perpendicularly to the second fluid passages 2k and communicating with the second fluid passages 2k.

[0113] That is, the type-K heat exchanger 10k is obtained by adding, to the type-B heat exchanger 10b, a plurality of (for example, fifteen) second fluid passages 21f provided in a second plane 42f that is substantially parallel to the first plane 41. In this case, an inside diameter Dk of the lateral hole 3k is large because the lateral hole 3k extends across the six layers of second fluid passages 2k.

Type-L Heat Exchanger

[0114] Referring to FIG. 8(c) and FIG. 8(d), a type-L heat exchanger 101 (10-ell) is obtained by dividing the lateral hole 3k of the type-K heat exchanger 10k into two lateral holes. Specifically, lateral holes 31 (3-ell) include a small-diameter lateral hole 33a that communicates with all of three layers of second fluid passages 21a to 21c defined as a lower-layer group, and a small-diameter lateral hole 33b that communicates with all of three layers of second fluid passages 21d to 21f defined as an upper-layer group.

[0115] Hence, the inside diameter of each of the lateral holes 31 (3-ell) is approximately 1/2 of the inside diameter of the lateral hole 3k.

[0116] If the fluid flowing in the heat exchanger undergoes phase transition, the flow speed of the fluid for the same mass velocity is lowest in a liquid state, is second lowest in a two-phase gas-liquid state, and is highest in a gas state. To reduce the pressure loss, the inside diameter of the lateral holes needs to be set in accordance with the state of the refrigerant, that is, the flow speed of the refrigerant.

[0117] With the aforementioned arrangement, if the change in flow speed that depends on the state of the fluid cannot be dealt with by the type-K heat exchanger 10k (the inside diameter Dk), the type-L heat exchanger 101 (10-ell, or the inside diameter D1 (D-ell)) can be used.

Type-M Heat Exchanger

[0118] Referring to FIG. 8(e) and FIG. 8(f), a type-M heat exchanger 10m is obtained by dividing the lateral hole 3k of the type-K heat exchanger 10k into three lateral holes. Specifically, lateral holes 3m include a small-diameter lateral hole 32a that communicates with both of two layers of second fluid passages 21a and 21b defined as a lower-layer group, a small-diameter lateral hole 32b that communicates with both of two layers of second fluid passages 21c and 21d defined as a middle-layer group, and a small-diameter lateral hole 32c that communicates with both of two layers of second fluid passages 21e and 21f defined as an upper-layer group.

[0119] Hence, the inside diameter of each of the lateral holes 3m is approximately 1/3 of the inside diameter of the lateral hole 3k.

[0120] With the aforementioned arrangement, if the change in flow speed that depends on the state of the fluid cannot be dealt with by the type-K heat exchanger 10k or the type-L heat exchanger 101 (10-ell), the type-M heat exchanger 10m can be used.

[0121] While the above description concerns an exemplary case of the second fluid passages that are provided in six layers, the present invention is not limited to such a case. The second fluid passages may be provided in any number of layers.

[0122] Moreover, any of the slit-like spaces 5h to 5j described in Embodiments 3 and 4 may be employed. In

that case, the sealing block 81 or the like is provided to the employed one of the slit-like spaces 5h to 5j, and the second fluid passages 21d to 21f (or 21e and 21f) included in one of the groups that is the nearest to the employed one of the slit-like spaces 5h to 5j extend through a portion of the sealing block 81 or the like.

Embodiment 6

[0123] The lateral holes described in Embodiments 1 to 5 may have an elliptical shape or a quadrate shape. In particular, in the cases of an elliptical shape and a quadrate shape, the width of the lateral hole can be increased in the direction of flow in the second flow passages. That is, by determining the passage cross-sectional area in the lateral hole in accordance with the mass velocity of the refrigerant flowing into it and the mass velocity ratio of vapor to liquid (to be referred to as the quality hereinafter), the pressure loss can be reduced.

[0124] Furthermore, by designing the passage cross-sectional area optimally, a two-phase refrigerant is allowed to flow into the plurality of second fluid passages in a mode (to be referred to as a flow regime hereinafter) that is easily distributed evenly among the second fluid passages.

[0125] Thus, an effect of suppressing a deterioration in performance of the heat exchanger due to poor distribution is produced. The flow that is easily distributed evenly is any of an annular flow, an annular mist flow or an annular dispersed flow, a bubble flow, a slug flow and a plug flow.

[0126] It is desirable to let the refrigerant flow into the lateral hole in any of the foregoing flow regimes. The mode of the flow of a two-phase fluid can be checked on a flow regime map or a flow pattern map (for example, a Baker's chart (see FIG. 11)).

[0127] The following refrigeration cycle apparatus according to Embodiment 6 of the present invention uses the flow regimes.

Letting "G" be the mass velocity of the refrigerant flowing into the lateral hole;
"Gg and Gl" be the mass velocities in the gas and liquid phases, respectively;
"pg and ρ1" be the densities in the gas and liquid phases, respectively;
"μg and μl" be the viscosity coefficients in the gas and liquid phases, respectively;
"σ" be the surface tension;
"ρa and pw" be the densities of air and water, respectively, at an atmospheric temperature of 20°C;
"μw" be the viscosity coefficient of water at an atmospheric temperature of 20°C;
"σw" be the surface tension of water with respect to air at an atmospheric temperature of 20°C; and
"λ (= $((\rho g/\rho a)\times(\rho l/\rho w))^{1/2}$)" and "$\phi$ (= $(\sigma w/\sigma)\times((\mu l/\mu w)\times(\rho w/\rho l)^2)^{1/3}$)" be correction factors,

"Gl/Gg$\times\lambda\times\phi$" and "Gg/λ" have a relation expressed on the flow regime map in any of the respective zones of annular flow, annular mist flow, slug flow, bubble flow, and plug flow.

[0128] That is, it is preferable to determine the passage cross-sectional area in the lateral hole such that "Gg/λ > 84544$\times$(G1/Gg$\times\lambda\times\phi^{-0.76}$" is satisfied.

[0129] For instance, if the mass velocity is 200 kg/m^{2}s; the quality at the inlet is 0.2; and the pressure is 2 MPa, "Gl/Gg$\times\lambda\times\phi$ = 266" holds. Accordingly, "84544$\times$(Gl/Gg$\times\lambda\times\phi)^{-0.676}$ = 1952" holds.

[0130] In other words, it is preferable that the lateral hole have a passage cross-sectional area satisfying "Gg/λ > 1952." Letting "Ah" be the passage cross-sectional area in the lateral hole, the foregoing range is expressed as "Ah < 2.78$\times10^{-3}$ m^2." If the passage cross-sectional area falls outside the foregoing range, the flow regime is deteriorated, unpreferably leading to a deterioration in performance of the heat exchanger.

Embodiment 7: Heat-Pump Heating System

[0131] FIG. 9 is a diagram illustrating devices included in a heat-pump heating system that utilizes heating energy, to explain a refrigeration cycle apparatus according to Embodiment 7 of the present invention. Elements that are the same as those of Embodiment 1 are denoted by common reference numerals, and a description of some of them will be omitted.

[0132] Referring to FIG. 9, a heat-pump heating system 60 includes a use-side fluid pipe 61 in which a first fluid flows, a heat-source-side fluid pipe 62 in which a second fluid flows, and the type-A heat exchanger 10a that allows the first fluid and the second fluid to exchange heat with each other. That is, the first fluid passages 1 form a part of the use-side fluid pipe 61, and the second fluid passages 2 form a part of the heat-source-side fluid pipe 62.

[0133] In the heat-pump heating system 60, "water" is used as the first fluid, and "R410a" is used as the second fluid.

[0134] The use-side fluid pipe 61 connects the type-A heat exchanger 10a (the first fluid passages 1), a pump 61a, and a use-side heat exchanger 61b to one another in sequence, thereby circulating the first fluid through them.

[0135] The heat-source-side fluid pipe 62 connects a compressor 62a, the type-A heat exchanger 10a (the second fluid passages 2), an expansion valve 62b, and a heat-source-side heat exchanger 62c and a fan 62d to one another in sequence, thereby circulating the second fluid through them.

[0136] The first fluid in the use-side fluid pipe 61 is heated (receives heating energy from the second fluid) in the type-A heat exchanger 10a, is discharged from the pump 61a, and rejects heat (transfers the heating energy to the fluid or the like on the use side) in the use-side heat ex-

changer 61b. For example, a radiator, a floor heater, or the like is applied to the use-side heat exchanger 61b, whereby a heating system is provided.

[0137] In the heat-source-side fluid pipe 62, the second fluid having a high temperature and a high pressure by flowing through the compressor 62a exchanges heat with (transfers the heating energy to) the first fluid in the type-A heat exchanger 10a. Subsequently, the pressure of the second fluid is reduced by the expansion valve 62b.

[0138] The second fluid now having a low temperature and a low pressure exchanges heat with (releases cooling energy to) air that is blown to it by the fan 62d in the heat-source-side heat exchanger 62c. Then, after the second fluid has evaporated, the second fluid returns to the compressor 62a.

[0139] As illustrated in FIG. 9, performing heating through the use-side heat exchanger 61b by using the heat-pump heating system 60 including the type-A heat exchanger 10a according to the present invention as a heat source produces an effect of saving more energy than in known heating systems in which boilers are used as heat sources.

[0140] While the above description concerns a case where the type-A heat exchanger 10a is employed, the present invention is not limited to such a case. Any of the type-B to -M heat exchangers may be employed. Moreover, as described above, the number of first fluid passages 1, the number of layers of second fluid passages 2, and the number of second fluid passages 2 included in each of the layers are not limited.

Embodiment 8: Heat-Pump Hot-Water Supply System

[0141] FIG. 10 is a diagram illustrating devices included in a heat-pump hot-water supply system that utilizes heating energy, to explain a refrigeration cycle apparatus according to Embodiment 8 of the present invention. Elements that are the same as those of Embodiment 1 or 2 are denoted by common reference numerals, and a description of some of them will be omitted.

[0142] Referring to FIG. 10, a heat-pump hot-water supply system 70 is obtained by placing the use-side heat exchanger 61b of the heat-pump system 60 in a tank 63 so that water supplied into the tank 63 is heated and taken.

[0143] As illustrated in FIG. 10, supplying hot water through the use-side heat exchanger 61b by using the heat-pump hot-water supply system 70 (equivalent to a heat-pump hot-water-supply/heating system) including the type-A heat exchanger 10a according to the present invention as a heat source produces an effect of saving more energy than in known hot-water supply systems in which boilers are used as heat sources.

List of Reference Signs

[0144]

1	first fluid passage
2	second fluid passage
3	lateral hole
4	heat transfer block
5	slit-like space
10a	type-A heat exchanger
10b	type-B heat exchanger
10c	type-C heat exchanger
10d	type-D heat exchanger
10e	type-E heat exchanger
10f	type-F heat exchanger
10h	type-H heat exchanger
10i	type-I heat exchanger
10j	type-J heat exchanger
10k	type-K heat exchanger
101	type-L heat exchanger
10m	type-M heat exchanger
21a to 21f	second fluid passage
32a	small-diameter lateral hole
32b	small-diameter lateral hole
32c	small-diameter lateral hole
33a	small-diameter lateral hole
33b	small-diameter lateral hole
41	first plane
42a to 42c	second plane
43	third plane
44	side face
45	side face
51a	lower-layer slit-like space
51b	upper-layer slit-like space
60	heat-pump heating system (Embodiment 6)
61	use-side fluid pipe
61a	pump
61b	use-side heat exchanger
62	heat-source-side fluid pipe
62a	compressor
62b	expansion valve
62c	heat-source-side heat exchanger
62d	fan
63	tank
70	heat-pump hot-water supply system (Embodiment 7)
81	sealing block
82	sealing block
83a	sealing block
83b	sealing block

Claims

1. A heat exchanger comprising:

- a plurality of first fluid passages provided parallel to one another in a first plane that is a flat plane present in a heat transfer block, so as to extend through the heat transfer block;
- a plurality of second fluid passages provided

parallel to the first fluid passages in a second plane that is present in the heat transfer block and is parallel to the first plane, so as to extend through the heat transfer block; and

- at least one lateral hole provided in the heat transfer block and communicating with all of the second fluid passages,

wherein the at least one lateral hole extends perpendicularly to the second fluid passages,

wherein a diameter of the at least one lateral hole and a number of at least one lateral hole are determined in such a manner as to satisfy $L/A^2d > L_y/A_y^2d_y$, where A, d, and L are a passage cross-sectional area, an equivalent diameter, and a length, respectively, of second fluid passages, and A_y, d_y, and L_y are a passage cross-sectional area, an equivalent diameter, and an equivalent length, respectively, of the at least one lateral hole, and

wherein the at least one lateral hole communicates with all of the second fluid passages so as not to protrude into a portion of the heat transfer block that is between the first fluid passages and some of the second fluid passages that are adjacent to the first fluid passages.

2. The heat exchanger of claim 1,
wherein the second plane includes second planes corresponding to a plurality of layers that are parallel to one another, and
wherein the at least one lateral hole communicates with the second fluid passages provided in all of the plurality of layers.

3. The heat exchanger of claim 1,
wherein the second plane includes second planes corresponding to a plurality of layers that are parallel to one another, and
wherein the at least one lateral hole has a rectangular shape and communicates with the second fluid passages provided in all of the plurality of layers.

4. The heat exchanger of claim 1,
wherein the second plane includes second planes corresponding to a plurality of layers that are parallel to one another, and
wherein the at least one lateral hole has an elliptical shape and communicates with the second fluid passages provided in all of the plurality of layers.

5. The heat exchanger of claim 1,
wherein the second plane includes second planes corresponding to a plurality of layers that are parallel to one another,
wherein the second fluid passages are divided into a plurality of groups, and
wherein the at least one lateral hole is provided for each of the plurality of groups of second fluid passages.

6. The heat exchanger of claim 1,
wherein the second plane includes second planes corresponding to a plurality of layers, and
wherein the at least one lateral hole includes a plurality of lateral holes provided at predetermined intervals.

7. The heat exchanger of claim 1,
further comprising a slit-like space that is provided opposite to the first fluid passages across the second fluid passages and has a predetermined thickness.

8. The heat exchanger of claim 7,
wherein the slit-like space includes a plurality of small-width slit-like spaces that extend parallel to one another.

9. The heat exchanger of claim 7,
wherein a sealing block is provided in a predetermined area of the slit-like space in a fluid-tight manner, and
wherein the at least one lateral hole is formed by machining or plasticization performed from one side face of the heat transfer block such that the at least one lateral hole extends through a portion of the sealing block, and an opening that is provided in the side face is closed.

10. The heat exchanger of any one of claims 1 to 9,
wherein, letting
G be a mass velocity of a refrigerant flowing into the at least one lateral hole;
Gg and Gl be mass velocities in a gas phase and in a liquid phase, respectively;
pg and pl be densities in the gas phase and in the liquid phase, respectively;
μg and μl be viscosity coefficients in the gas phase and in the liquid phase, respectively;
σ be a surface tension;
ρa and ρw be densities of air and water, respectively, at an atmospheric temperature of 20°C;
μw be a viscosity coefficient of water at an atmospheric temperature of 20°C;
σw be a surface tension of water with respect to air at an atmospheric temperature of 20°C; and
λ (= $((\rho g/\rho a)\times(\rho l/\rho w))^{1/2}$) and ϕ (= $(\sigma w/\sigma)\times((\mu l/\mu w)\times(\rho w/\rho l)^2)^{1/3}$ be correction factors,
the passage cross-sectional area in the at least one lateral hole is determined in such a manner as to satisfy a relation between Gg/λ and $Gl/Gg\times\lambda\times\phi$ expressed on a flow regime map as:

$Gg/\lambda > 84544\times(Gl/Gg\times\lambda\times\phi)^{-0.676}$, which holds in respective zones of annular flow, annular mist flow, slug flow, bubble flow, and plug flow.

11. A refrigeration cycle apparatus comprising
a use-side fluid pipe in which a first fluid is adapted to flow;
a heat-source-side fluid pipe in which a second fluid is adapted to flow; and
the heat exchanger of any one of claims 1 to 10 that is adapted to allow the first fluid and the second fluid to exchange heat with each other, wherein the use-side fluid pipe connects the first fluid passages of the heat exchanger, a pump that is adapted to feed the first fluid, and a use-side heat exchanger to one another in sequence so as to circulate the first fluid therethrough, and
wherein the heat-source-side fluid pipe connects a compressor configured to compress the second fluid in the heat exchanger, the second fluid passages, an expansion valve, and the heat-source-side heat exchanger to one another in sequence so as to circulate the second fluid therethrough.

FIG. 1

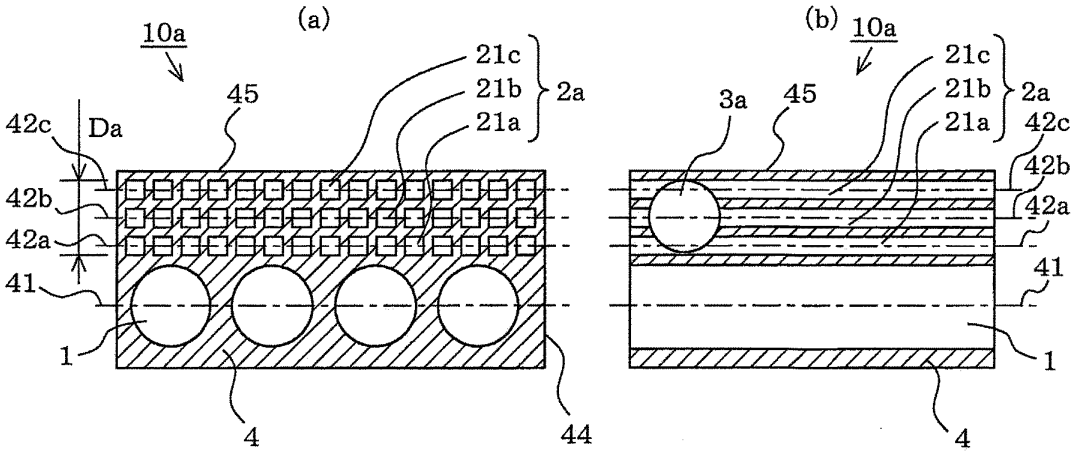

(a)
10a
45
21c
21b
21a
2a
42c
Da
42b
42a
41
1
4
44
(b)
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3a
45
21c
21b
21a
2a
42c
42b
42a
41
1
4

FIG. 2

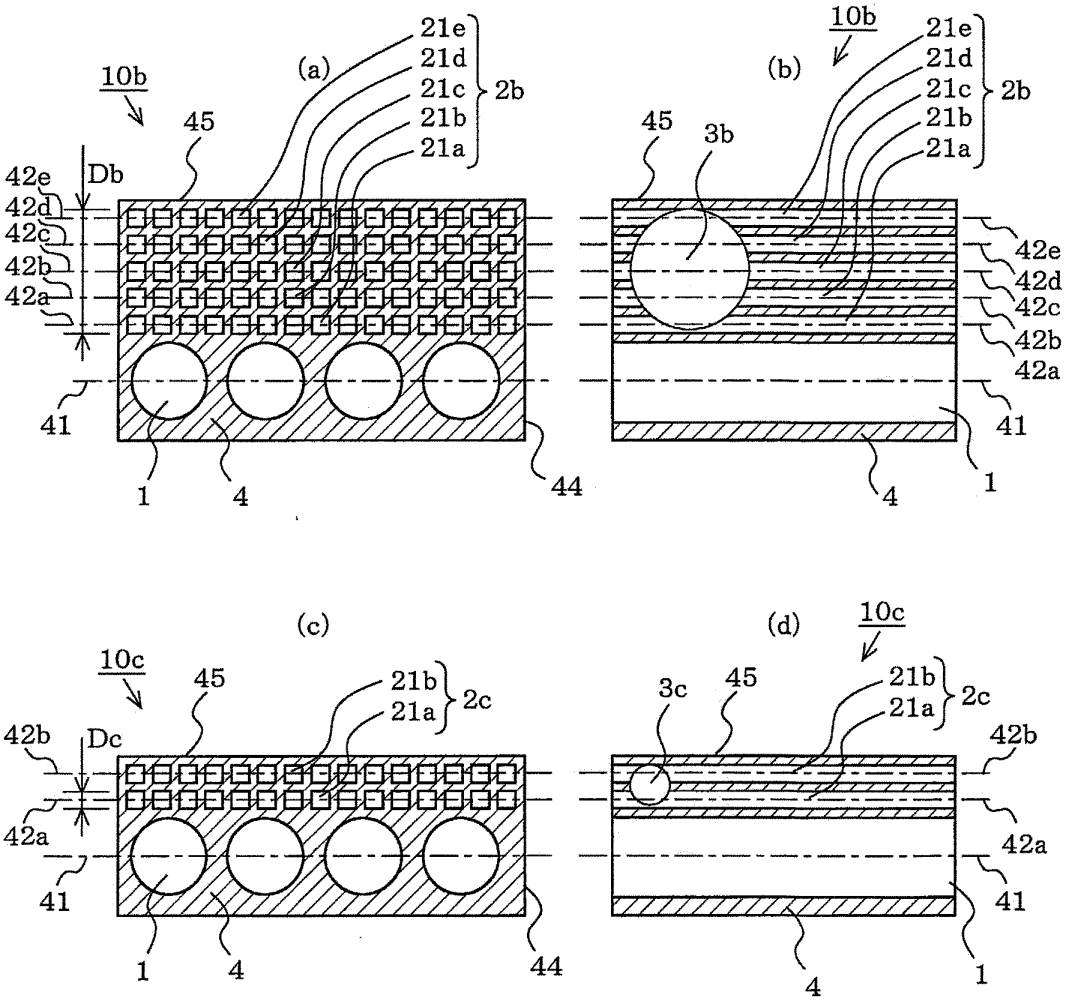

(a)
10b
45
21e
21d
21c
21b
21a
2b
42e
Db
42d
42c
42b
42a
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4
44
(b)
10b
45
3b
21e
21d
21c
21b
21a
2b
42e
42d
42c
42b
42a
41
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(c)
10c
45
21b
21a
2c
42b
Dc
42a
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42a
41
1
4

FIG. 3

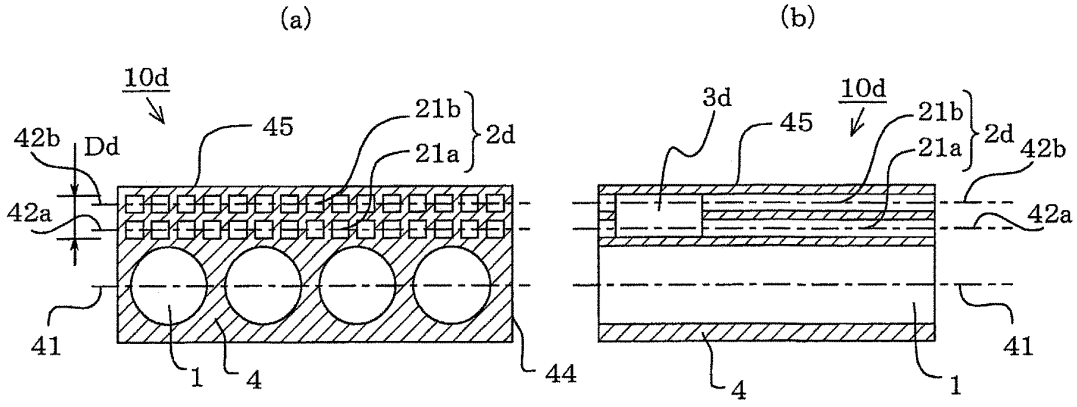


FIG. 4

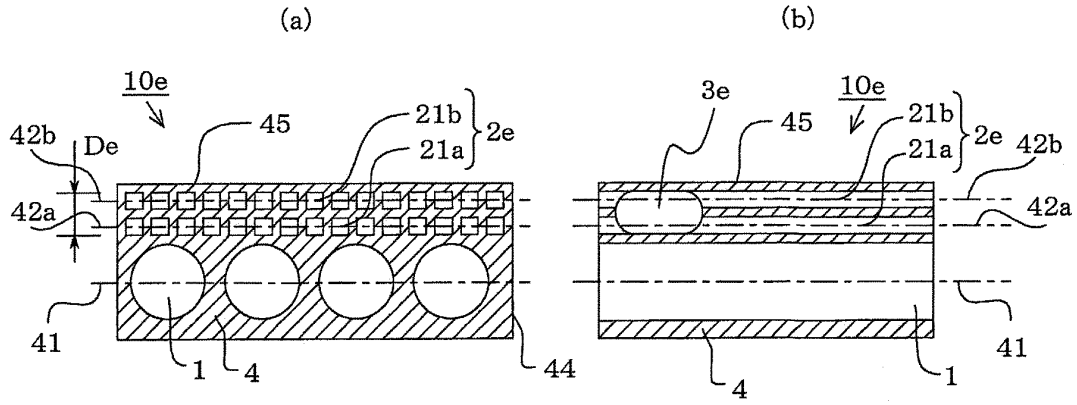


FIG. 5

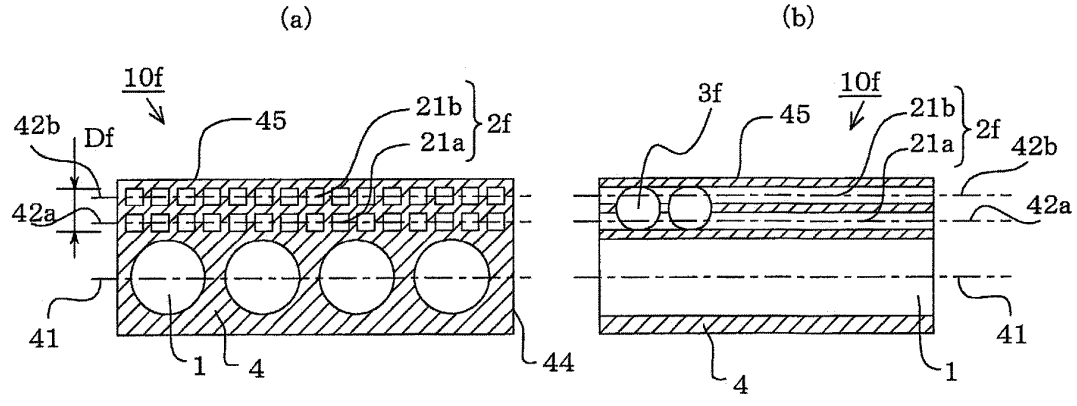


FIG. 6

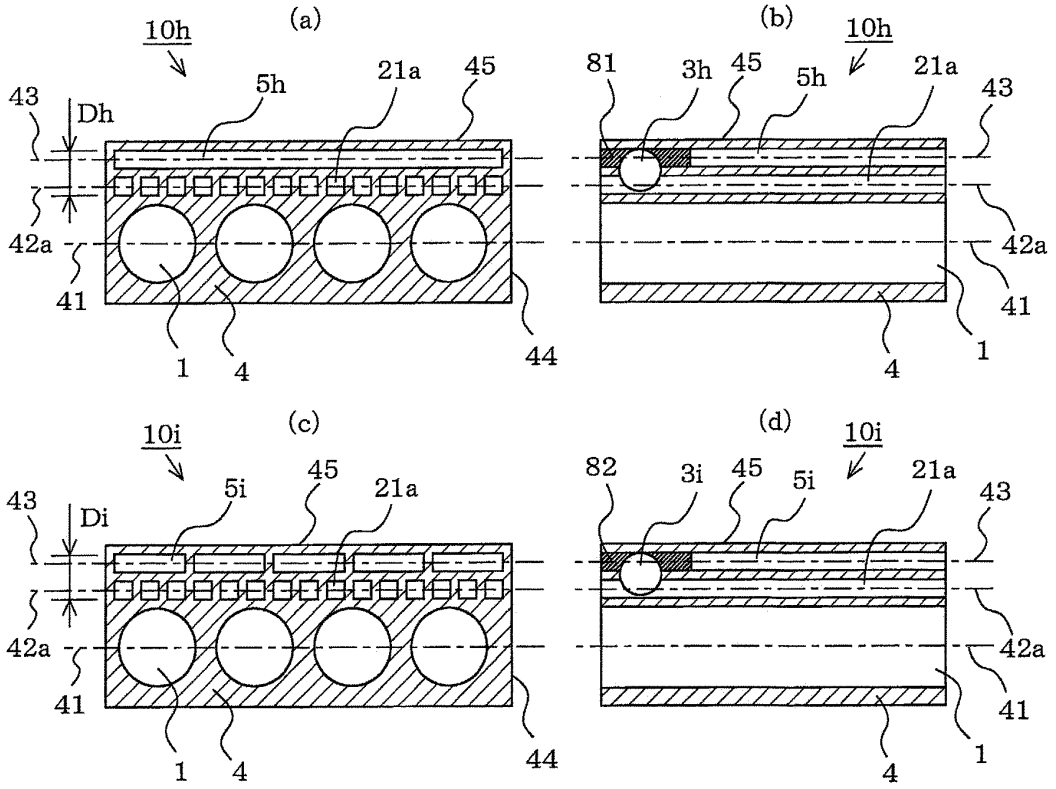

(a)
10h
5h
21a
45
43
Dh
42a
41
1
4
44
(b)
10h
81
3h
45
5h
21a
43
42a
41
1
4
(c)
10i
5i
45
21a
43
Di
42a
41
1
4
44
(d)
10i
82
3i
45
5i
21a
43
42a
41
1
4

FIG. 7

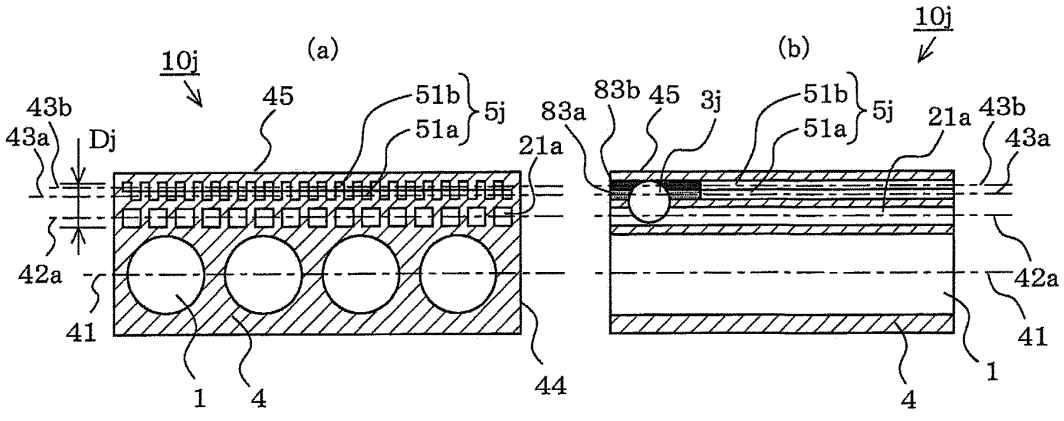

(a)
10j
45
51b
51a
5j
43b
43a
Dj
21a
42a
41
1
4
44
(b)
10j
83b
45
3j
83a
51b
51a
5j
21a
43b
43a
42a
41
1
4

FIG. 8

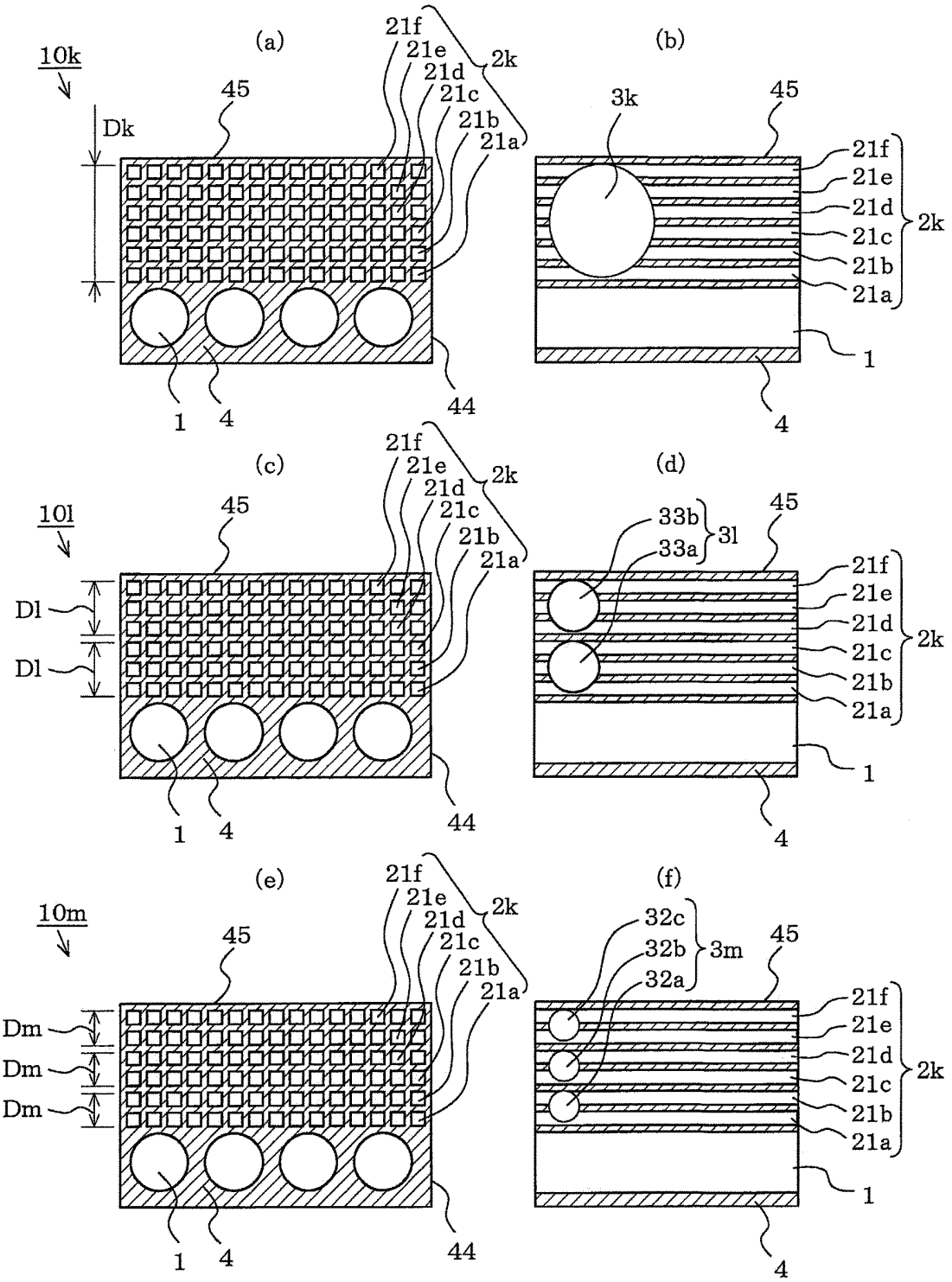

(a)
(b)
(c)
(d)
(e)
(f)
10k
10l
10m
Dk
Dl
Dm
45
3k
21f
21e
21d
21c
21b
21a
2k
1
4
44
33b
33a
3l
32c
32b
32a
3m

FIG. 9

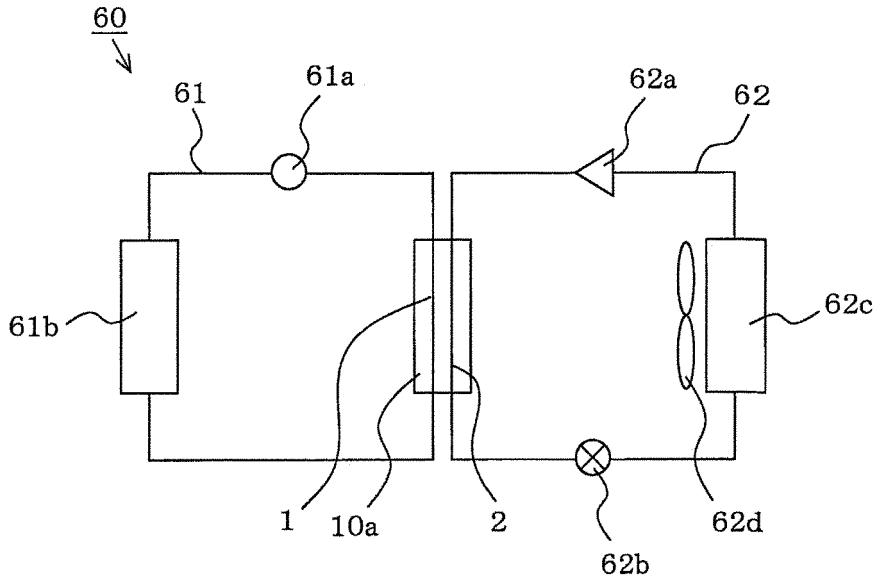

60
61
61a
62a
62
61b
62c
1
10a
2
62b
62d

FIG. 10

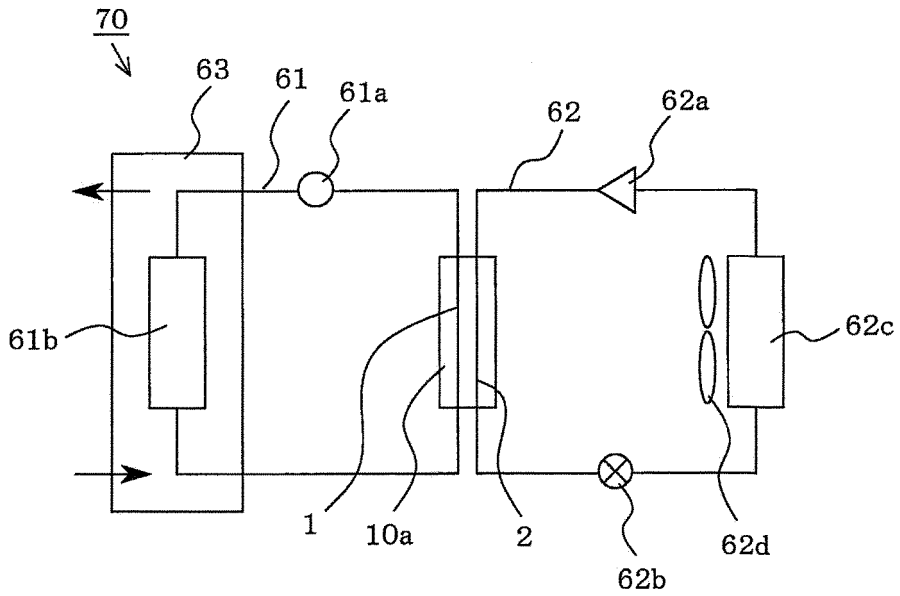
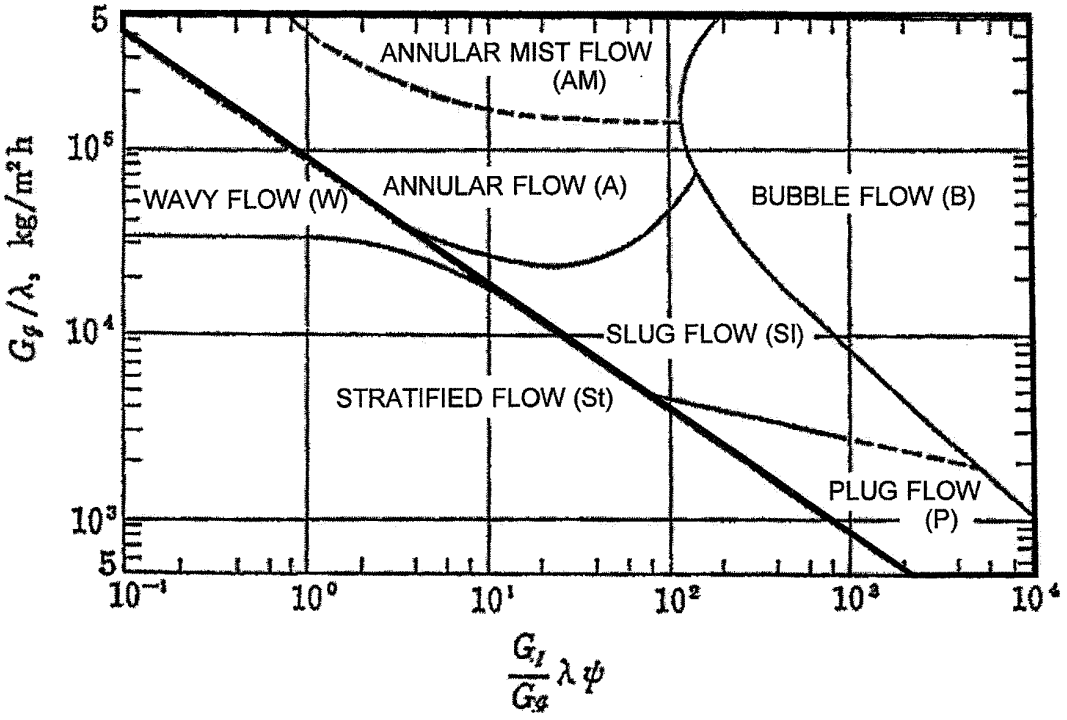

70
63
61
61a
62
62a
61b
62c
1
10a
2
62b
62d

FIG. 11


ANNULAR MIST FLOW
(AM)
WAVY FLOW (W)
ANNULAR FLOW (A)
BUBBLE FLOW (B)
SLUG FLOW (SI)
STRATIFIED FLOW (St)
PLUG FLOW
(P)
5
10⁵
10⁴
10³
5
10⁻¹
10⁰
10¹
10²
10³
10⁴
Gg/λ, kg/m²h
GI/Gg λψ

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/072132

A. CLASSIFICATION OF SUBJECT MATTER
F28D7/00(2006.01)i, *F25B1/00*(2006.01)i, *F28F1/02*(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)
F28D7/00, F25B1/00, F28F1/02

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 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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.
A	WO 2007/122685 A1 (Mitsubishi Electric Corp.), 10 November 2007 (10.11.2007), entire text; all drawings (particularly, paragraphs [0107] to [0110]; fig. 15) & US 2010/0162749 A1 & EP 2009380 A1 & EP 2144028 A1 & EP 2154459 A1 & CN 101432590 A	1-11
A	WO 2012/017681 A1 (Mitsubishi Electric Corp.), 09 February 2012 (09.02.2012), entire text; all drawings (particularly, paragraphs [0061] to [0087]; fig. 10, 11) (Family: none)	1-11

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

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Date of the actual completion of the international search	Date of mailing of the international search report
22 November, 2012 (22.11.12)	04 December, 2012 (04.12.12)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/072132

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2011-7486 A (Valeo System Thermiques), 13 January 2011 (13.01.2011), entire text; all drawings (particularly, paragraphs [0040] to [0057]; fig. 2a, 2b, 8) & US 2010/0300665 A1 & EP 2273224 A1 & FR 2946132 A & CN 101922884 A & AT 557250 T & ES 2387355 T	1-11
A	JP 2001-33182 A (Ford Motor Co.), 09 February 2001 (09.02.2001), entire text; all drawings & US 6247529 B1 & GB 2356039 A & GB 14744 D0 & DE 10014099 A	1-11
A	JP 2000-234881 A (Showa Aluminum Corp.), 29 August 2000 (29.08.2000), entire text; all drawings (Family: none)	1-11
A	JP 2002-18512 A (Yugen Kaisha Yano Engineering), 22 January 2002 (22.01.2002), entire text; all drawings (particularly, paragraphs [0002] to [0005], [0020] to [0035]; fig. 1, 6, 12) & US 2002/0017372 A1 & EP 1174198 A2 & AU 5419501 A & CA 2352028 A & TW 495397 B & KR 10-2002-0004871 A & CN 1330989 A & CA 2352028 A1	1-11
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 58896/1984(Laid-open No. 170582/1985) (Toyo Radiator Co., Ltd.), 12 November 1985 (12.11.1985), entire text; all drawings (Family: none)	1-11
A	JP 2007-17132 A (Denso Corp.), 25 January 2007 (25.01.2007), entire text; all drawings (particularly, paragraphs [0061] to [0065]; fig. 7 to 9) (Family: none)	1-11

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Patent documents cited in the description

- JP 2000234881 A **[0007]**