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

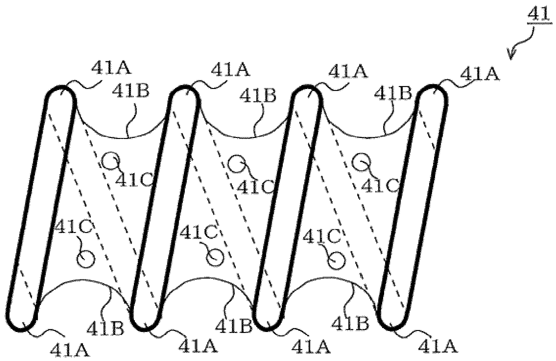
(72) Inventors:
- **HATANAKA, Kensaku**
  Tokyo 100-8310 (JP)
- **TONEGAWA, Toru**
  Tokyo 100-8310 (JP)

(74) Representative: **Mewburn Ellis LLP**
City Tower
40 Basinghall Street
London EC2V 5DE (GB)

(54) HEAT EXCHANGER AND REFRIGERATION CYCLE DEVICE PROVIDED WITH HEAT EXCHANGER

(57) The title of the invention is a heat exchanger and a refrigeration cycle apparatus including the heat exchanger. A first pipe has an inflow port for a heat medium and an outflow port for the heat medium, the inflow port and the outflow port communicate with a first flow path. The first pipe includes a crest portion, which protrudes in a diameter-increasing direction in which a diameter of the first pipe is increased, and a trough portion having an outer diameter smaller than that of a part in which the crest portion is formed, and a second pipe is wound around the trough portion. The crest portion is formed in a helical shape in the first flow path in a direction in which the heat medium flows. The trough portion is formed in a helical shape along the crest portion. The trough portion includes a plurality of concave portions, which are formed so as to be aligned with each other in a helical direction that is a direction in which the trough portion is formed, and are recessed in a diameter-decreasing direction in which the diameter of the first pipe is increased.

FIG. 2B



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Description

Technical Field

[0001] The present invention relates to a heat exchanger and a refrigeration cycle apparatus including the heat exchanger, and more particularly, to a heat exchanger having a structure in which a pipe through which refrigerant flows is wound around a pipe through which water or another heat medium flows.

Background Art

[0002] For example, as a gas cooler of a heat-pump water heating apparatus, proposed is a gas cooler including a first pipe (core pipe), in which a flow path through which a heat medium (water) flows is formed, and a second pipe (outer pipe) through which refrigerant flows, and is wound around an outer periphery of the first pipe (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2008-249163

Summary of Invention

Technical Problem

[0004] A distribution of a flow velocity of water in the first pipe varies depending on the shape of the first pipe. In general, a flow velocity of water passing through an inner peripheral surface side of the first pipe is lower than a flow velocity of water passing through a diameter center of the first pipe. In this case, the flow of the water passing through the inner peripheral surface side of the first pipe tends to stagnate, and hence the temperature of the water rises as compared with the water passing through the diameter center of the first pipe. That is, in the water passing through the inner peripheral surface side of the first pipe, the amount of heat received from the refrigerant flowing through the second pipe tends to increase.

[0005] In this case, in order to, for example, improve heat exchange performance between the water flowing through the first pipe and the refrigerant flowing through the second pipe, a structure including irregularities is often formed in the first pipe. That is, the flow of the water passing through the inner peripheral surface side of the first pipe tends to stagnate, while in a part having such a structure formed therein, the flow of the water further tends to stagnate and the water temperature tends to increase. For this reason, scale contained in water tends to be precipitated in the part having such a structure. This is because a solubility of the scale in water decreases as the water temperature increases, and the scale is precipitated without being dissolved in water in a part in which the water temperature tends to rise.

[0006] The present invention has been made in order to solve the above-mentioned problem, and an object thereof is to provide a heat exchanger capable of suppressing precipitation of scale in a pipe, as well as to provide a refrigeration cycle apparatus including the heat exchanger.

Solution to Problem

[0007] According to one embodiment of the present invention, there is provided a heat exchanger including: a first pipe having a first flow path formed therein, the first flow path being configured to flow a heat medium therethrough, and a second pipe having a second flow path formed therein and being wound around the first pipe, the second flow path being configured to flow refrigerant therethrough, wherein the first pipe has an inflow port for the heat medium and an outflow port for the heat medium formed therein so that the inflow port and the outflow port communicate with the first flow path, wherein the first pipe includes: a crest portion, which protrudes in a diameter-increasing direction in which a diameter of the first pipe is increased; and a trough portion having an outer diameter smaller than an outer diameter of a part in which the crest portion is formed and around which the second pipe is wound, wherein the crest portion is formed in a helical shape in the first flow path in a direction in which the heat medium flows, wherein the trough portion is formed in a helical shape along the crest portion, and wherein the trough portion includes a plurality of concave portions, which are formed so as to be aligned with each other in a helical direction that is a direction in which the trough portion is formed, and are recessed in a diameter-decreasing direction in which the diameter of the first pipe is decreased.

Advantageous Effects of Invention

[0008] The heat exchanger according to one embodiment of the present invention, which has the above-mentioned configuration, can inhibit scale from being precipitated in the first pipe.

Brief Description of Drawings

[0009]

Fig. 1 is a diagram illustrating an example of a schematic configuration of a refrigeration cycle apparatus including a heat exchanger according to one embodiment of the present invention.

Fig. 2A is a perspective view of the heat exchanger according to the embodiment of the present invention.

Fig. 2B is an explanatory diagram of a first pipe of the heat exchanger according to the embodiment of the present invention.

Fig. 2C is an explanatory diagram of the first pipe of the heat exchanger according to the embodiment of the present invention and a second pipe wound around the first pipe.

Fig. 2D is an enlarged view of a cross section of a part of the heat exchanger according to the embodiment of the present invention.

Fig. 2E is an explanatory diagram of a part on an outlet side for a heat medium of the first pipe of the heat exchanger according to the embodiment of the present invention.

Fig. 2F is an explanatory diagram of a part of an inlet side for the heat medium of the first pipe of the heat exchanger according to the embodiment of the present invention.

Fig. 2G is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe in which no concave portions are formed.

Fig. 2H is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe of the heat exchanger according to the embodiment of the present invention.

Fig. 3A is a graph showing a refrigerant temperature and a heat medium temperature of the heat exchanger, which are exhibited when a heat medium temperature at an outlet of a first flow path of the heat exchanger is about 65 degrees Celsius.

Fig. 3B is a graph showing a refrigerant temperature and a heat medium temperature of the heat exchanger, which are exhibited when the heat medium temperature at the outlet of the first flow path of the heat exchanger is about 90 degrees Celsius.

Fig. 3C is an explanatory diagram illustrating a relationship among a first region, a second region, and a boundary position.

Fig. 4A is an explanatory diagram of the first pipe in which three threads are formed by crest portions and trough portions.

Fig. 4B is an explanatory diagram of the first pipe in which four threads are formed by crest portions and through portions.

Fig. 4C is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe illustrated in Fig. 4A.

Fig. 4D is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe illustrated in Fig. 4B.

Fig. 5 is a block diagram of a controller.

Fig. 6 is an explanatory graph of a solubility in the heat medium.

Description of Embodiments

[0010] Now, referring to the drawings as appropriate, a description is given on an embodiment of the present invention. In the drawings including Fig. 1 referred to below, a relationship of sizes of components may be different from that of an actual product. Moreover, in the drawings including Fig. 1 referred to below, components which are denoted by the same reference symbols are the same or corresponding components, and this applies to the entire description. Further, modes of components in the entire description are mere examples, and the components are not limited to those given in the description.

Embodiment

[0011] Fig. 1 is a diagram illustrating an example of a schematic configuration of a refrigeration cycle apparatus 100 including a heat exchanger 2 according to this embodiment. With reference to Fig. 1, a description is given on a configuration of the refrigeration cycle apparatus 100.

[Description of Entire Configuration]

[0012] The refrigeration cycle apparatus 100 includes a refrigerant circuit C1, a heat medium circuit C2, a controller Cnt, and different kinds of detection units 10A to 10D. The refrigeration cycle apparatus 100 is also connected to a hot-water using unit U and a water supply circuit C3. The hot-water using unit U corresponds to each of different kinds of components, for example, a water faucet and a bath unit in a home, which require hot water. The water supply circuit C3 corresponds to a pipe for water supply or another component.

[0013] The refrigerant circuit C1 circulates refrigerant therethrough. As the refrigerant, for example, a carbon dioxide refrigerant can be employed. The refrigerant circuit C1 includes a compressor 1 configured to compress the refrigerant, a second flow path FP2 (see Fig. 2D) of the heat exchanger 2 functioning as a condenser, an expansion device 3, and a heat exchanger 4 functioning as an evaporator. The second flow path FP2 refers to one of flow paths of the heat exchanger 2 in which the refrigerant flows.

[0014] The heat exchanger 2 exchanges heat between the refrigerant flowing through the refrigerant circuit C1 and a heat medium passing therethrough to condense the refrigerant. The heat exchanger 2 is a heat medium-refrigerant heat exchanger configured to exchange heat between the heat medium and the refrigerant. In this embodiment, the heat exchanger 2 is formed of a double pipe heat exchanger in which a first pipe 41 having the heat medium flowing therethrough and a second pipe 42 having the refrigerant flowing therethrough are brought into contact with each other. The heat exchanger 4 can be formed of, for example, a fin-tube heat exchanger.

[0015] The heat medium circuit C2 circulates a heat medium therethrough. As the heat medium, for example, water or an antifreeze solution can be employed. The heat medium circuit C2 includes a first flow path FP1 (see Fig. 2D) of the heat exchanger 2 and a pump 5 configured to convey the heat medium. The first flow path FP1 refers to one of the flow paths of the heat exchanger 2 in which the heat medium flows.

[0016] The detection unit 10A is an outside air temperature detection sensor configured to detect an outside air temperature. The detection unit 10B is a discharge refrigerant temperature detection sensor configured to detect a refrigerant temperature on a discharge side of the compressor 1. The detection unit 10C is an inlet temperature detection sensor configured to detect a heat medium temperature at an inlet of the heat exchanger 2. The detection unit 10D is an outlet temperature detection sensor configured to detect a heat medium temperature at an outlet of the heat exchanger 2. A detection unit 10E is a flow rate detection sensor configured to detect a flow rate of the heat medium flowing through the heat medium circuit C2.

[0017] The controller Cnt controls the compressor 1, the expansion device 3, the pump 5, and other components based on detection results obtained by the detection units 10A to 10D. In this embodiment, as described later, due to a structure provided in the heat exchanger 2, scale contained in the heat medium is hard to be precipitated in the heat exchanger 2. Meanwhile, it is difficult to completely prevent the precipitation of the scale, and hence the refrigeration cycle apparatus 100 has a function of determining the precipitation of the scale in the heat exchanger 2. The scale refers to a precipitate containing calcium carbonate as its main component.

[0018] Each functional unit included in the controller Cnt is formed of dedicated hardware or a micro processing unit (MPU) configured to execute a program stored in a memory.

[0019] When the controller Cnt is formed of the dedicated hardware, the controller Cnt corresponds to, for example, a single circuit, a composite circuit, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a combination of those circuits. The functional units implemented by the controller Cnt may each be achieved by individual pieces of hardware, or a single piece of hardware may be used to achieve the functional units.

[0020] When the controller Cnt is formed of the MPU, each function executed by the controller Cnt is achieved by software, firmware, or a combination of software and firmware. The software or the firmware is described as a program and is stored in a memory. The MPU is configured to read out and execute the program stored in the memory, to thereby achieve each of the functions of the controller Cnt. The memory is, for example, a RAM, a ROM, a flash memory, an EPROM, an EEPROM, or other types of non-volatile or volatile semiconductor memory.

[Detailed Description of Heat Exchanger 2]

[0021] Fig. 2A is a perspective view of the heat exchanger 2 according to this embodiment.

[0022] Fig. 2B is an explanatory diagram of the first pipe 41 of the heat exchanger 2 according to this embodiment.

[0023] Fig. 2C is an explanatory diagram of the first pipe 41 of the heat exchanger 2 according to this embodiment and the second pipe 42 wound around the first pipe 41.

[0024] Fig. 2D is an enlarged view of a cross section of a part of the heat exchanger 2 according to this embodiment.

[0025] With reference to Fig. 2A to Fig. 2D, a description is given on a detailed configuration of the heat exchanger 2.

[0026] The heat exchanger 2 includes the first pipe 41, in which the first flow path FP1 through which the heat medium flows is formed, and the second pipe 42, in which the second flow path FP2 through which the refrigerant flows is formed, and the second pipe 42 is wound around the first pipe 41.

[0027] In the first pipe 41, an inflow port 41a for the heat medium and an outflow port 41b for the heat medium are formed so as to communicate with the first flow path FP1. In the second pipe 42, an inflow port 42a for the refrigerant and an outflow port 42b for the refrigerant are formed so as to communicate with the second flow path FP2. The heat exchanger 2 can be connected to the refrigerant circuit C1 and the heat medium circuit C2 so that, for example, a direction in which the heat medium flows through the first pipe 41 and a direction in which the refrigerant flows through the second pipe 42 face to each other. This improves heat exchange efficiency between the heat medium and the refrigerant.

[0028] The first pipe 41 includes a crest portion 41A, which protrudes in a diameter-increasing direction DR1 for increasing a diameter of the first pipe 41. The crest portion 41A is formed in a helical shape in a direction of the first flow path FP1 in which the heat medium flows. The crest portion 41A is formed in the first pipe 41 in a helical shape. In this case, as illustrated in Fig. 2D, the diameter-increasing direction DR1 refers to a direction extending from an inner peripheral surface S1 side of the first pipe 41 to an outer peripheral surface S2 of the first pipe 41.

[0029] In the first pipe 41, a trough portion 41B having an outer diameter smaller than that of a part in which the crest portion 41A is formed is formed. As illustrated in Fig. 2C and Fig. 2D, the second pipe 42 is wound around the trough portion 41B. The trough portion 41B is formed in a helical shape along the crest portion 41A. That is, the crest portion 41A and the trough portion 41B are formed in parallel with each other.

[0030] A case of forming one thread by crest portion 41A in the first pipe 41 is now described as an example. For example, in Fig. 2B, in order to clarify the location of the crest portion 41A, four threads formed by crest portions 41A are illustrated on each of the top and bottom of the first pipe 41 for the sake of convenience of description. However, in Fig. 2B, a plurality of threads formed by crest portions 41A are not formed in the first pipe 41, but one thread formed by crest portion 41A is formed in the first pipe 41 so as to extend in a helical shape.

[0031] The crest portion 41A is formed so as to extend around the first pipe 41 a plurality of times. The trough portion 41B is also formed so as to extend around the first pipe 41 a plurality of times. In addition, the trough portion 41B is formed between the crest portion 41A in the N-th round and the crest portion 41A in the (N+1)th round. Meanwhile, the crest portion 41A is formed between the trough portion 41B in the N-th round and the crest portion 41A in the (N+1)th round. N is a natural number.

[0032] As illustrated in Fig. 2D, the trough portion 41B includes a plurality of concave portions 41C, which are formed so as to be aligned with each other in a helical direction which is a direction in which the trough portion 41B is formed, and are recessed in a diameter-decreasing direction DR2 in which the diameter of the first pipe 41 is decreased. The heat exchanger 2 has a structure in which the crest portion 41A and the trough portion 41B are formed, and a flow of the heat medium tends to stagnate particularly in a part of the crest portion 41A. That is, as illustrated in Fig. 2D, a stagnation portion T is formed in the heat exchanger 2. In the stagnation portion T, the flow of the heat medium tends to stagnate and the flow velocity of the heat medium is slow. In this case, the heat medium in the stagnation portion T is liable to cause a local temperature rise due to the stagnant flow. In addition, a solubility of scale in the heat medium decreases as the temperature of the heat medium rises. Therefore, in the stagnation portion T, scale that can no longer be dissolved in the heat medium tends to be precipitated. If the scale precipitated in the pipe peels off, the pipe is caused to be clogged by the peeled-off scale.

[0033] The concave portions 41C are formed in the heat exchanger 2 according to this embodiment, and hence agitation of the heat medium in the stagnation portion T is promoted. That is, when the heat medium passes through the concave portion 41C, a vortex is formed at a position at which the concave portion 41C is formed. As a result, the heat medium flowing through a central side of the first pipe 41 and the heat medium flowing through the stagnation portion T side of the first pipe 41 are agitated. The agitation can suppress a local temperature rise in the stagnation portion T, and also can suppress precipitation of scale in the first pipe 41.

[0034] The first pipe 41 has a smaller inner diameter in a part having the concave portion 41C formed therein than in a part having the trough portion 41B formed therein. That is, in the part having the concave portion 41C formed therein, not only the outer peripheral surface S2 of the first pipe 41 is recessed, but also the inner peripheral surface S1 is recessed.

[0035] The first pipe 41 and the second pipe 42 can be joined together by, for example, soldering. This improves heat transfer efficiency between the refrigerant and the heat medium, and an effect of improving the strength of the heat exchanger 2 can be expected.

[0036] Fig. 2E is an explanatory diagram of a part on an outlet side for the heat medium of the first pipe 41 of the heat exchanger 2 according to this embodiment.

[0037] Fig. 2F is an explanatory diagram of a part on an inlet side for the heat medium of the first pipe 41 of the heat exchanger 2 according to this embodiment.

[0038] With reference to Fig. 2E and Fig. 2F, a description is given on a distribution of the concave portions 41C in the first pipe 41.

[0039] The first pipe 41 is configured such that more concave portions 41C are distributed on the outflow port 41b side than on the inflow port 41a side. This configuration is designed by taking into consideration the fact that the temperature of the heat medium flowing through the first flow path FP1 rises as the heat medium flows from the inflow port 41a toward the outflow port 41b side, which is liable to cause the local temperature rise of the heat medium in the stagnation portion T. The first pipe 41 has the following configuration.

[0040] A part of the first pipe 41 on the inflow port 41a side is set as a first region Rg1, and a part of the first pipe 41 on the outflow port 41b side is set as a second region Rg2 (see Fig. 3C).

[0041] The concave portions 41C have a larger total area per unit length in the second region Rg2 than a total area per unit length in the first region Rg1. This configuration, which has a mode of forming a plurality of concave portions 41C in spot-like shapes, can be paraphrased as follows. That is, the concave portions 41C are distributed so that the number of concave portions 41C formed per unit length in the second region Rg2 is larger than the number of concave portions 41C formed per unit length in the first region Rg1.

[0042] This promotes the agitation of the heat medium in the part of the first pipe 41 on the outflow port 41b side, which is liable to cause the temperature rise of the heat medium. The agitation can suppress a local temperature rise in the stagnation portion T, and can suppress precipitation of scale. Configurations of the first region Rg1 and the second region Rg2 are described in detail with reference to Fig. 3A, Fig. 3B, and Fig. 3C.

[Flow Velocity Distribution of Heat Medium in First Pipe 41]

[0043] Fig. 2G is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe in which no concave portions 41C are formed.

[0044] Fig. 2H is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe 41 of the heat exchanger 2 according to this embodiment.

[0045] In Fig. 2G and Fig. 2H, the flow velocity of the heat medium decreases in the order of flows FL1, flows FL2, flows FL3, and flows FL4. As illustrated in Fig. 2G, when no concave portions 41C are formed, the flows FL1 are formed in a central part of the pipe, and have a high flow velocity. In addition, the flows FL2 are formed in an outer part of the flows FL1, and have a flow velocity lower than that in the central part, but the flow velocity is relatively high. However, when no concave portions 41C are formed as illustrated in Fig. 2G, the flows FL3 are formed in the vicinity of the inner peripheral surface S1 of the pipe, and have a low flow velocity. In addition, the flows FL4 are formed in a part having the stagnation portion T formed therein, and have a lower flow velocity.

[0046] Meanwhile, when the concave portions 41C are formed as illustrated in Fig. 2H, flows FL are formed over a range wider than in the case illustrated in Fig. 2G. In addition, the flows FL2 are formed near the inner peripheral surface S1 of the first pipe 41, and the flows FL3 are formed in the stagnation portion T. Even on the inner peripheral surface S1 side, the flow velocity hardly falls as compared with the case of Fig. 2G. That is, Fig. 2H indicates that the agitation of the heat medium is promoted by the action of the concave portions 41C, with the result that the flow velocity hardly falls even in the stagnation portion T. In this manner, in the heat exchanger 2 according to this embodiment, the concave portions 41C are formed, the agitation of the heat medium is promoted, and hence it is possible to suppress a local temperature rise in the stagnation portion T, to thereby suppress precipitation of scale.

[Distribution of Refrigerant Temperature and Heat Medium Temperature of Heat Exchanger 2]

[0047] Fig. 3A is a graph showing a refrigerant temperature and a heat medium temperature of the heat exchanger 2 which are exhibited when the heat medium temperature at the outlet of the first flow path FP1 of the heat exchanger 2 is about 65 degrees Celsius.

[0048] Fig. 3B is a graph showing a refrigerant temperature and a heat medium temperature of the heat exchanger 2 which are exhibited when the heat medium temperature at the outlet of the first flow path FP1 of the heat exchanger 2 is about 90 degrees Celsius.

[0049] Fig. 3C is an explanatory diagram showing a relationship among the first region Rg1, the second region Rg2, and a boundary position "mp".

[0050] In Fig. 3A, a case in which a tapping temperature is 65 degrees Celsius (the heat medium temperature of the heat medium flowing out of the outflow port 41b is 65 degrees Celsius) is shown, while in Fig. 3B, a case in which the tapping temperature is 90 degrees Celsius (the heat medium temperature of the heat medium flowing out of the outflow port 41b is 65 degrees Celsius) is shown.

[0051] As shown in Fig. 3A, a temperature difference between the heat medium and the refrigerant on the outlet side (outlet side of the first flow path FP1) is large. Specifically, the refrigerant temperature is higher than the heat medium temperature by about 10 degrees Celsius to about 30 degrees Celsius in a range from the outflow port 41b as the outlet of the first flow path FP1 to a portion corresponding to a dimensionless distance of 0.1. Therefore, in the first pipe 41, a local temperature rise is liable to occur and scale tends to be precipitated in the range from the outflow port 41b as the outlet of the first flow path FP1 to the portion corresponding to the dimensionless distance of 0.1.

[0052] The dimensionless distance is a ratio of the length of a part of the first pipe 41 to the total length of the first pipe 41. When the dimensionless distance is 0.1, the dimensionless distance indicates the length of 1/10 of the first pipe 41.

[0053] As shown in Fig. 3B, this tendency applies to an increased tapping temperature, and the temperature difference between the heat medium and the refrigerant on the outlet side (outlet side of the first flow path FP1) is large.

[0054] Firstly, in the part of the first pipe 41 on the outflow port 41b side, the heat medium temperature itself is higher than that on the part on the inflow port 41a side. Secondly, as can be understood from Fig. 3A and Fig. 3B, in the part of the first pipe 41 on the outflow port 41b side, the temperature difference between the heat medium and the refrigerant tends to be larger than that in the part on the inflow port 41a side. Therefore, in the part of the first pipe 41 on the outflow port 41b side, the heat medium temperature exhibited in the first pipe 41 locally increases, and the scale tends to be precipitated. In view of this, the heat exchanger 2 has the following configuration.

[0055] As illustrated in Fig. 3C, a position dividing a total length of the first pipe 41 into a length from the inflow port 41a and a length from the outflow port 41b in a ratio of six to four is set as the boundary position "mp". The first region Rg1 is a part of the first pipe 41 ranging from the inflow port 41a to the boundary position "mp". The second region Rg2 is a part of the first pipe 41 ranging from the boundary position "mp" to the outflow port 41b. In this manner, in the part of the first pipe 41 on the outflow port 41b side, the number of portions formed per unit length is increased. That is, the first pipe 41 is set to have the second region Rg2 ranging from the outflow port 41b as the outlet of the first flow path FP1 to a portion corresponding to a dimensionless distance of 0.4. With this setting, it is possible to effectively suppress a local temperature rise in the range from the outflow port 41b as the outlet of the first flow path FP1 to the portion corresponding to the dimensionless distance of 0.1, to thereby suppress precipitation of scale.

[0056] In this embodiment, the first region Rg1 and the second region Rg2 are defined not based on the second pipe 42 but based on the first pipe 41. More specifically, the first region Rg1 and the second region Rg2 are defined based on the inflow port 41a of the first pipe 41. However, the present invention is not limited to this definition method. For example, the first region Rg1 and the second region Rg2 may be defined based on the outflow port 41b. Alternatively, the first region Rg1 and the second region Rg2 may be defined based on a second pipe.

[0057] This embodiment is described on the assumption that each of the crest portions 41A has the same protrusion amount, but the present invention is not limited thereto. For example, in the part on the outflow port 41b side for the heat medium, the protrusion amount of the crest portion 41A may be smaller than that in the part on the inflow port 41a side for the heat medium. With this setting, water becomes harder to stagnate in the stagnation portion T on the outflow port 41b side, and it is possible to suppress a local temperature rise in the first pipe 41, to thereby suppress precipitation of scale. For example, the protrusion amount of the crest portion 41A may be reduced from the same position as a position at which the number of formation of the concave portions 41C is to be increased.

[0058] The concave portions 41C can be formed by, for example, dimple processing. This means that the concave portions 41C are recessed in spot-like shapes. The present invention is not limited to the concave portions 41C recessed in spot-like shapes, and the concave portions 41C may be recessed in a linear shape. In other words, the concave portions 41C may be formed in a groove shape.

[0059] Further, the concave portion 41C is described as a concave portion having a circular shape, but the present invention is not limited thereto. For example, the concave portion 41C may be a quadrangle or another polygonal shape.

[0060] Further, the respective concave portions 41C are described as having the same shape, but the present invention is not limited thereto, and the respective concave portions 41C may have different shapes. For example, the shapes of the concave portions 41C may be different between the first region Rg1 and the second region Rg2.

[Modification Example]

[0061] Fig. 4A is an explanatory diagram of the first pipe 41 in which three threads are formed by crest portions 41A and three threads are formed by trough portions 41B.

[0062] Fig. 4B is an explanatory diagram of the first pipe 41 in which four threads are formed by crest portions 41A and four threads are formed by trough portions 41B.

[0063] Part (a) in Fig. 4A is a sectional view of the first pipe 41 taken along a direction in parallel with a direction in which the heat medium flows, and part (b) in Fig. 4A is a sectional view taken along the line A-A of the part (a) of Fig. 4A.

[0064] Part (a) in Fig. 4B is a sectional view of the first pipe 41 taken along a direction in parallel with a direction in which the heat medium flows, part (b) in Fig. 4B(b) is a sectional view taken along the line B-B of the part (a) of Fig. 4B.

[0065] A modification example of the heat exchanger 2 is described with reference to Fig. 3C.

[0066] This embodiment has a mode in which one thread formed by crest portion 41A and one thread formed by trough portion 41B are formed in the first pipe 41, but the present invention is not limited thereto. The modification example has a mode in which, as illustrated in Fig. 4A and Fig. 4B, a plurality of threads formed by crest portions 41A and a plurality of threads formed by trough portions 41B are formed in the first pipe 41.

[0067] In Fig. 4A, three threads are formed by crest portions 41A and three threads are formed by trough portions 41B. That is, a first crest portion 41A1, a second crest portion 41A2, and a third crest portion 41A3 are formed in the first pipe 41. In addition, a first trough portion 41B1, a second trough portion 41B2, and a third trough portion 41B3 are formed in the first pipe 41.

[0068] The first trough portion 41B1 is formed between the first crest portion 41A1 and the second crest portion 41A2. The second trough portion 41B2 is formed between the second crest portion 41A2 and the third crest portion 41A3. The third trough portion 41B3 is formed between the third crest portion 41A3 and the first crest portion 41A1.

[0069] In Fig. 4B, four threads are formed by crest portions 41A and four threads are formed by trough portions 41B. That is, a first crest portion 41A1, a second crest portion 41A2, a third crest portion 41A3, and a fourth crest portion 41A4 are formed in the first pipe 41. In addition, a first trough portion 41B1, a second trough portion 41B2, a third trough portion 41B3, and a fourth crest portion 41A4 are formed in the first pipe 41.

[0070] The first trough portion 41B1 is formed between the first crest portion 41A1 and the second crest portion 41A2. The second trough portion 41B2 is formed between the second crest portion 41A2 and the third crest portion 41A3. The third trough portion 41B3 is formed between the third crest portion 41A3 and the fourth crest portion 41A4. The fourth trough portion 41B4 is formed between the fourth crest portion 41A4 and the first crest portion 41A1.

[0071] As the number of threads formed by crest portions 41A increases, the protrusion amount in the diameter-increasing direction DR1 for increasing the diameter of the first pipe 41 decreases. That is, as the number of threads formed by crest portions 41A increases, a shape that causes the heat medium to be harder to stagnate in the stagnation portion T is provided. Thus, it becomes easier to suppress a local temperature rise in the first pipe 41, and it also becomes easier to suppress precipitation of scale.

[0072] In addition, the first pipe 41 may be configured such that the number of threads formed by crest portions 41A in the first region Rg1 and the number of threads formed by crest portions 41A in the second region Rg2 are different from each other.

[0073] Specifically, the first pipe 41 may be configured such that the number of threads formed by crest portions 41A in the second region Rg2 is larger than the number of threads formed by crest portions 41A in the first region Rg1.

[0074] This can suppress precipitation of scale particularly in a part of the first pipe 41 which is liable to cause a local temperature rise.

[0075] For example, it is preferred that three threads formed by crest portions 41A and three threads formed by trough portions 41B be formed in the first region Rg1, and four threads formed by crest portions 41A and four threads formed by trough portions 41B be formed in the second region Rg2.

[0076] Fig. 4C is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe 41 in Fig. 4A.

[0077] Fig. 4D is an explanatory diagram of a flow velocity distribution of the heat medium in the first pipe 41 in Fig. 4B.

[0078] As illustrated in Fig. 4C and Fig. 4D, it is understood that the flow of the heat medium is harder to stagnate in a mode in which the number of threads formed by crest portions 41A and the number of threads formed by trough portions 41B are each four, which is illustrated in Fig. 4D, than in a mode in which the number of threads formed by crest portions 41A and the number of threads formed by trough portions 41B are each three, which is illustrated in Fig. 4C. Particularly on the inner peripheral surface S1 side of the first pipe 41, an influence of being hard to stagnate in flow of the heat medium in the first pipe 41 increases, and the flow is harder to stagnate in the mode in which the number of threads formed by each of the crest portions and the trough portions is four.

[Control of Refrigeration Cycle Apparatus 100]

[0079] Fig. 5 is a block diagram of the controller Cnt.

[0080] The controller Cnt includes a determination unit 90A configured to determine whether or not scale has adhered and a calculation unit 90B configured to calculate the flow rate of the heat medium conveyed from the pump 5. The controller Cnt also includes an actuator control unit 90C configured to control, for example, the expansion device 3, the compressor 1, and a fan 4A provided to the evaporator based on a determination result obtained by the determination unit 90A. The controller Cnt further includes a target discharge refrigerant temperature setting unit 90D configured to set a target discharge refrigerant temperature of the compressor 1 and a maximum value setting unit 90E configured to set the maximum value of the target discharge refrigerant temperature set by the target discharge refrigerant temperature setting unit 90D.

[0081] The controller Cnt can determine whether precipitation (adhesion) of scale occurs in the first flow path FP1 by the following method. When the flow rate detected by the flow rate detection sensor is smaller than the calculated flow rate of the heating medium conveyed from the pump 5, the determination unit 90A of the controller Cnt determines that scale has adhered to the first flow path FP1. The calculation unit 90B of the controller Cnt can acquire the calculated flow rate based on, for example, the heat medium temperature at the inlet of the first flow path FP1 and a target heat medium temperature (target outlet temperature) at the outlet of the first flow path FP1. The controller Cnt can acquire the heat medium temperature at the inlet of the first flow path FP1 from a temperature detected by the detection unit 10C.

[0082] When it is determined that scale has adhered to the first flow path FP1, the actuator control unit 90C of the controller Cnt executes first control for increasing an opening degree of the expansion device 3. In addition to the first control, the actuator control unit 90C of the controller Cnt may execute second control for reducing a rotation speed of the compressor 1 and third control for increasing a rotation speed of the fan 4A provided to the evaporator. That is, the controller Cnt executes at least one of the first control, the second control, or the third control. This can prevent the temperature of the heat medium flowing through the first pipe 41 from rising excessively, and prevents more scale from being precipitated in the first pipe 41.

[0083] When the determination unit 90A does not determine that scale has adhered to the first flow path FP1, the actuator control unit 90C of the controller Cnt controls the opening degree of the expansion device 3 so that the target discharge refrigerant temperature of the compressor 1 is approached. In this case, the target discharge refrigerant temperature setting unit 90D of the controller Cnt can calculate the target discharge refrigerant temperature based on the outside air temperature and a predetermined target outlet temperature of the first flow path FP1. The controller Cnt can acquire the outside air temperature from a temperature detected by the detection unit 10A.

[0084] The target discharge refrigerant temperature setting unit 90D of the controller Cnt is configured to reduce the target discharge refrigerant temperature when it is determined that scale has adhered to the first flow path FP1. With this configuration, the actuator control unit 90C of the controller Cnt performs control so as to increase the opening degree of the expansion device 3. Therefore, it is possible to prevent the temperature of the heat medium flowing through the first pipe 41 from rising excessively, to thereby prevent a large amount of scale from being precipitated in the first pipe 41.

[0085] When it is determined that scale has adhered to the first flow path FP1, the maximum value setting unit 90E of the controller Cnt sets the maximum value of the target discharge refrigerant temperature of the compressor 1 to 70 degrees Celsius. This configuration is described next.

[0086] Fig. 6 is an explanatory graph of the solubility in the heat medium.

[0087] A curved line shown in Fig. 6 indicates the solubility in the heat medium in accordance with the temperature. As shown in Fig. 6, the solubility of the scale in the heat medium decreases. Characteristics of the solubility exhibited when the heat medium temperature is equal to or lower than 40 degrees Celsius are indicated by a straight line L1. Meanwhile, characteristics of the solubility exhibited when the heat medium temperature is equal to or higher than 40 degrees Celsius are indicated by a straight line L2. As can be understood from the inclinations of the straight line L1 and the straight line L2, the solubility greatly changes with a heat medium temperature of about 40 degrees Celsius being assumed as a boundary.

[0088] By reducing the temperature of the refrigerant flowing into the heat exchanger 2, it is possible to inhibit the heat medium temperature from rising excessively, to thereby inhibit scale from being precipitated in the heat exchanger 2. For example, by setting the maximum value of the target discharge refrigerant temperature of the compressor 1 to about 70 degrees Celsius, it is possible to effectively suppress precipitation of scale in the heat exchanger 2.

[0089] The actuator control unit 90C of the controller Cnt controls a frequency of the compressor 1 based on, for example, the outside air temperature and the heat medium temperature at the inlet of the first flow path FP1. The controller Cnt can acquire the outside air temperature from the temperature detected by the detection unit 10A. The controller Cnt can further acquire the heat medium temperature at the inlet of the first flow path FP1 from the temperature detected by the detection unit 10C.

Reference Signs List

[0090] 1 compressor 2 heat exchanger 3 expansion device 4 heat exchanger 4A fan 5 pump 7 hot-water supply tank 10A detection unit 10B detection unit 10C detection unit 10D detection unit 10E detection unit 41 first pipe 41A crest portion 41A1 first crest portion 41A2 second crest portion 41A3 third crest portion 41A4 fourth crest portion 41B trough portions 41B1 first trough portion 41B2 second trough portion 41B3 third trough portion 41B4 fourth trough portion 41C concave portion 41a inflow port 41b outflow port 42 second pipe 42a inflow port 42b outflow port 90A determination unit 90B calculation unit 90C actuator control unit 90Cnt actuator control unit 90D target discharge refrigerant temperature setting unit 90E maximum value setting unit 100 refrigeration cycle apparatus C1 refrigerant circuit C2 heat medium circuit C3 water supply circuit Cnt controller DR1 diameter-increasing direction DR2 diameter-decreasing direction FP1 first flow path FP2 second flow path Rg1 first region Rg2 second region S1 inner peripheral surface S2 outer peripheral surface T stagnation portion U hot-water using unit mp boundary position

Claims

1. A heat exchanger, comprising:

    a first pipe having a first flow path formed therein, the first flow path being configured to flow a heat medium therethrough; and
    a second pipe having a second flow path formed therein and being wound around the first pipe, the second flow path being configured to flow refrigerant therethrough,
    wherein the first pipe has an inflow port for the heat medium and an outflow port for the heat medium so that the inflow port and the outflow port communicate with the first flow path,
    wherein the first pipe includes:

        a crest portion, which protrudes in a diameter-increasing direction in which a diameter of the first pipe is increased; and
        a trough portion having an outer diameter smaller than an outer diameter of a part in which the crest portion is formed and around which the second pipe is wound,

    wherein the crest portion is formed in a helical shape in the first flow path in a direction in which the heat medium flows,
    wherein the trough portion is formed in a helical shape along the crest portion, and
    wherein the trough portion includes a plurality of concave portions, which are formed so as to be aligned with each other in a helical direction that is a direction in which the trough portion is formed, and are recessed in a diameter-decreasing direction in which the diameter of the first pipe is decreased.

2. The heat exchanger of claim 1, wherein the plurality of concave portions are formed so that, when a part of the first pipe on the inflow port side is taken as a first region and a part of the first pipe on the outflow port side is taken as a second region, a total area per unit length of the formed concave portions in the second region is larger than a total area per unit length of the formed concave portions in the first region.

3. The heat exchanger of claim 2, wherein the plurality of concave portions are formed so that, when a position dividing a total length of the first pipe into a length from the inflow port and a length from the outflow port in a ratio of six to four is taken as a boundary position:

    the first region is a part of the first pipe ranging from the inflow port to the boundary position; and
    the second region is a part of the first pipe ranging from the boundary position to the outflow port.

4. The heat exchanger of any one of claims 1 to 3, wherein the first pipe is formed so that a number of threads formed by the crest portions in the first region and a number of threads formed by crest portions in the second region are different from each other.

5. The heat exchanger of claim 4, wherein the first pipe is formed so that the number of threads formed by crest portions in the second region is larger than the number of threads formed by crest portions in the first region.

6. The heat exchanger of claim 5,
wherein the number of threads formed by crest portions in the first region is three, and
the number of threads formed by crest portions in the second region is four.

7. A refrigeration cycle apparatus, comprising:

a refrigerant circuit including a compressor, the second flow path of the heat exchanger of any one of claims 1 to 6, an expansion device, and an evaporator;
a heat medium circuit including the first flow path of the heat exchanger and a pump;
a flow rate detection sensor configured to detect a flow rate of a heat medium flowing through the heat medium circuit; and
a controller configured to control the compressor, the expansion device, and the pump,
wherein the controller is configured to determine that scale has adhered in the first flow path when the flow rate detected by the flow rate detection sensor is lower than a calculated flow rate of the heat medium conveyed from the pump.

8. The refrigeration cycle apparatus of claim 7, wherein the controller is configured to:

control an opening degree of the expansion device so that a target discharge refrigerant temperature of the compressor is approached when the controller does not determine that the scale has adhered in the first flow path; and
increase the opening degree of the expansion device when the controller determines that scale has adhered in the first flow path.

9. The refrigeration cycle apparatus of claim 7 or 8, wherein the controller is configured to set a maximum value of a target discharge refrigerant temperature of the compressor to 70 degrees Celsius when the controller determines that scale has adhered in the first flow path.

10. The refrigeration cycle apparatus of any one of claims 7 to 9, further comprising:

an inlet temperature detection sensor configured to detect a heat medium temperature at an inlet of the first flow path; and
an outside air temperature detection sensor configured to detect an outside air temperature,
wherein the controller is configured to control the compressor based on a temperature detected by the outside air temperature detection sensor and a temperature detected by the inlet temperature detection sensor.

11. The refrigeration cycle apparatus of claim 8, further comprising an outside air temperature detection sensor configured to detect an outside air temperature, wherein the controller is configured to calculate the target discharge refrigerant temperature based on a temperature detected by the outside air temperature detection sensor and a predetermined target outlet temperature of the first flow path.

12. The refrigeration cycle apparatus of any one of claims 7 to 9, further comprising an inlet temperature detection sensor configured to detect a heat medium temperature at an inlet of the first flow path,
wherein the controller is configured to calculate the calculated flow rate based on a temperature detected by the inlet temperature detection sensor and a predetermined target outlet temperature of the first flow path.

FIG. 1

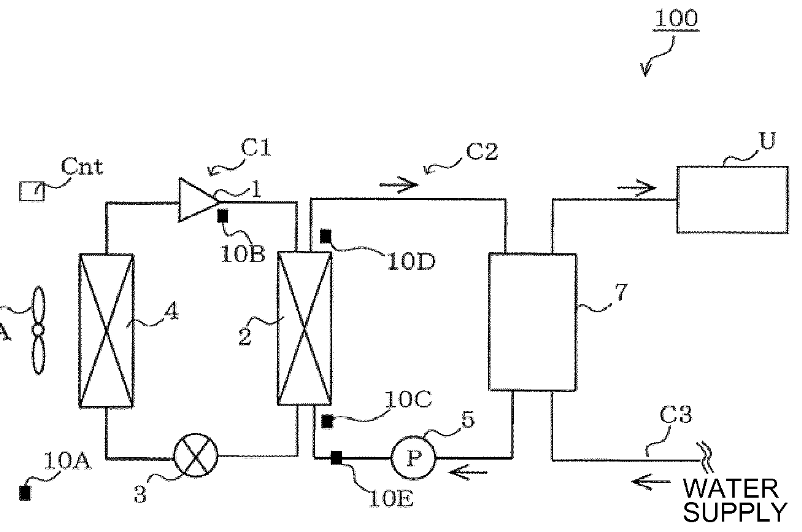


FIG. 2A

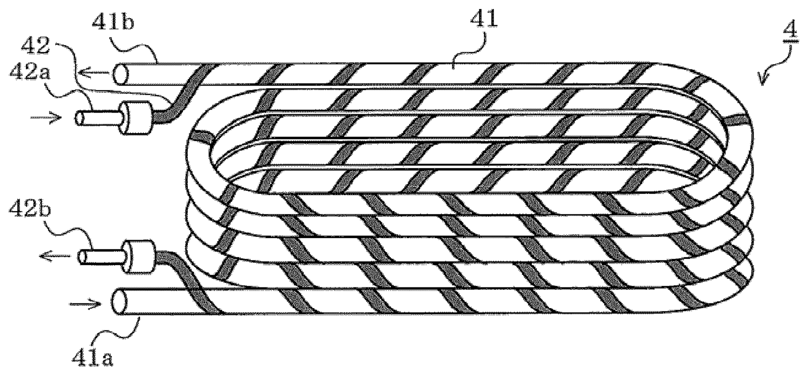


FIG. 2B

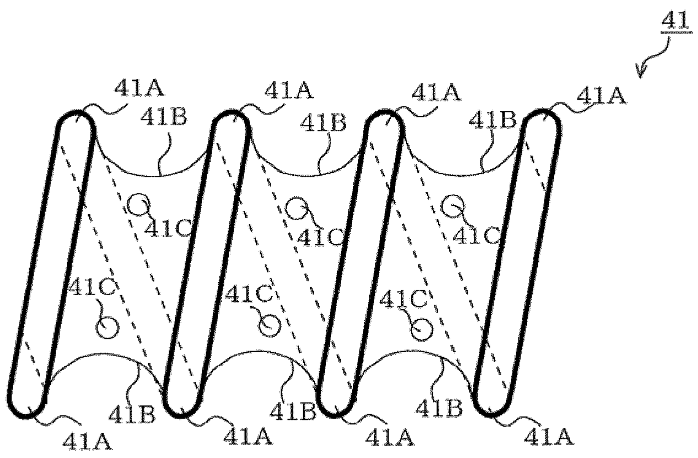


FIG. 2C

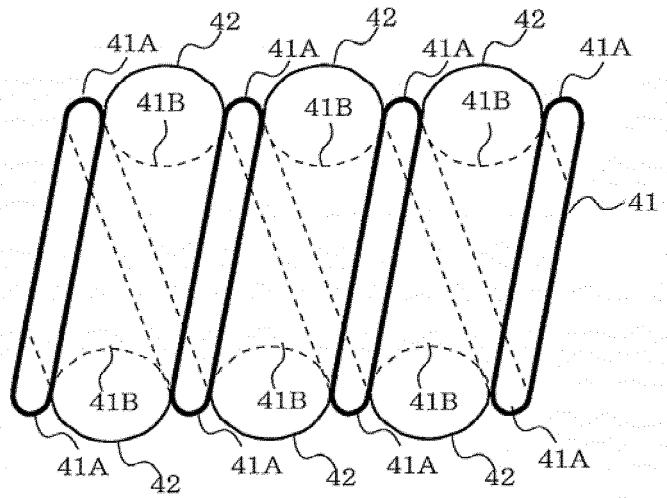

41A
42
41A
42
41A
42
41A
41B
41B
41B
41
41B
41B
41B
41A
42
41A
42
41A
42
41A

FIG. 2D

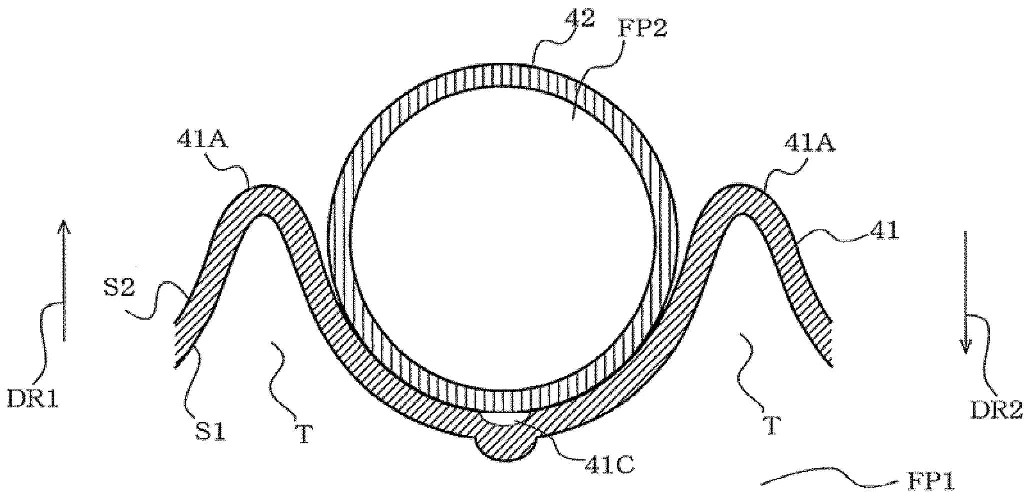

42
FP2
41A
41A
41
S2
DR1
S1
T
41C
T
DR2
FP1

FIG. 2E

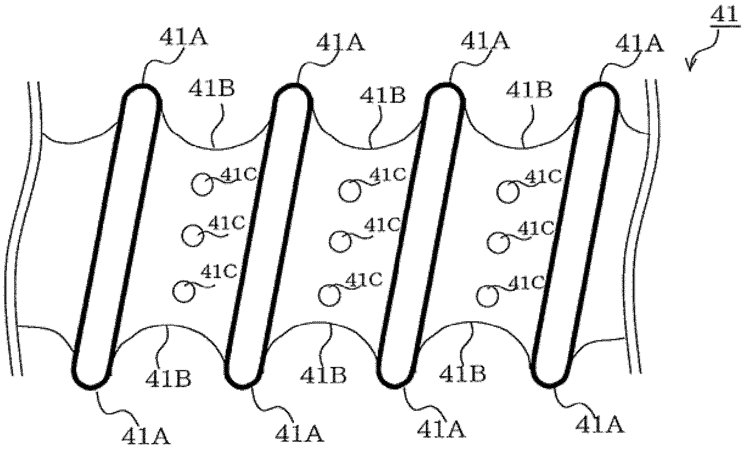


FIG. 2F

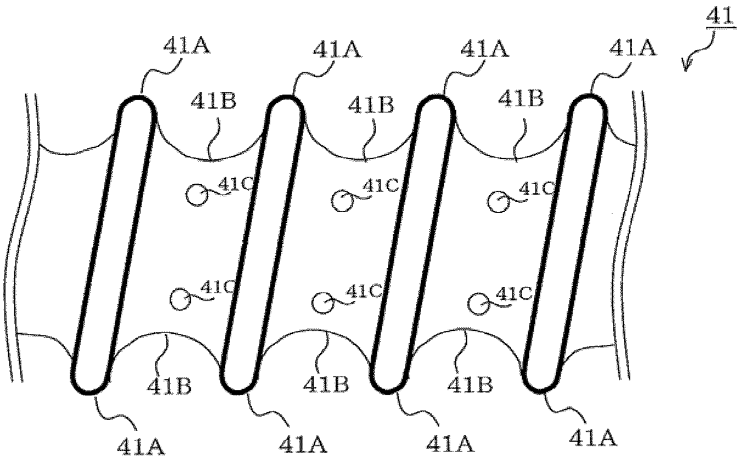


FIG. 2G

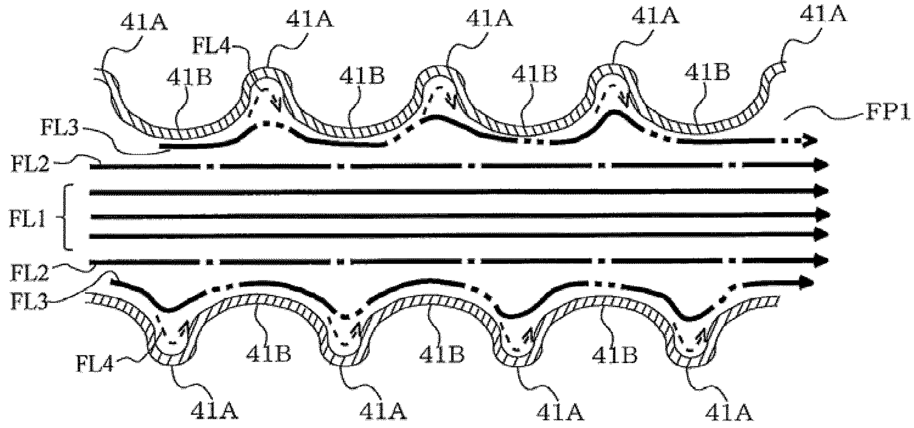


FIG. 2H

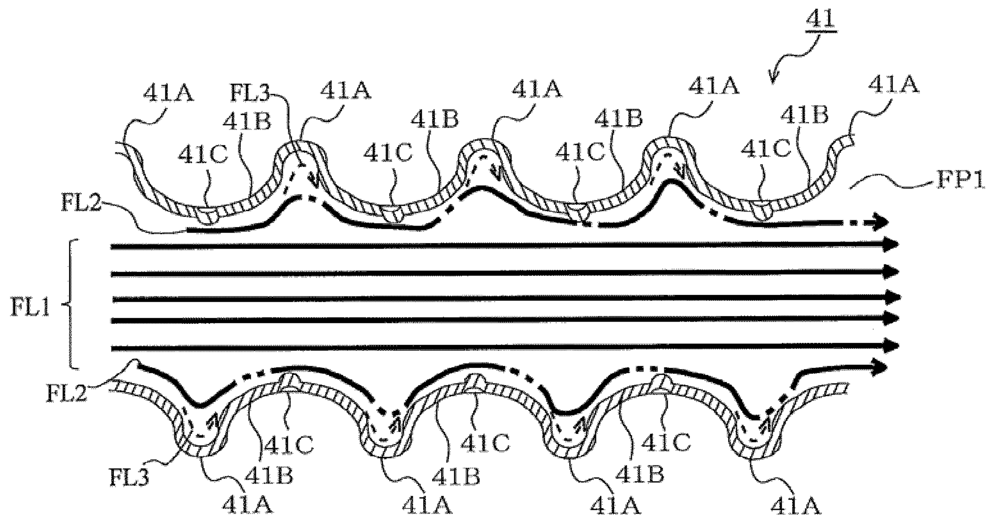
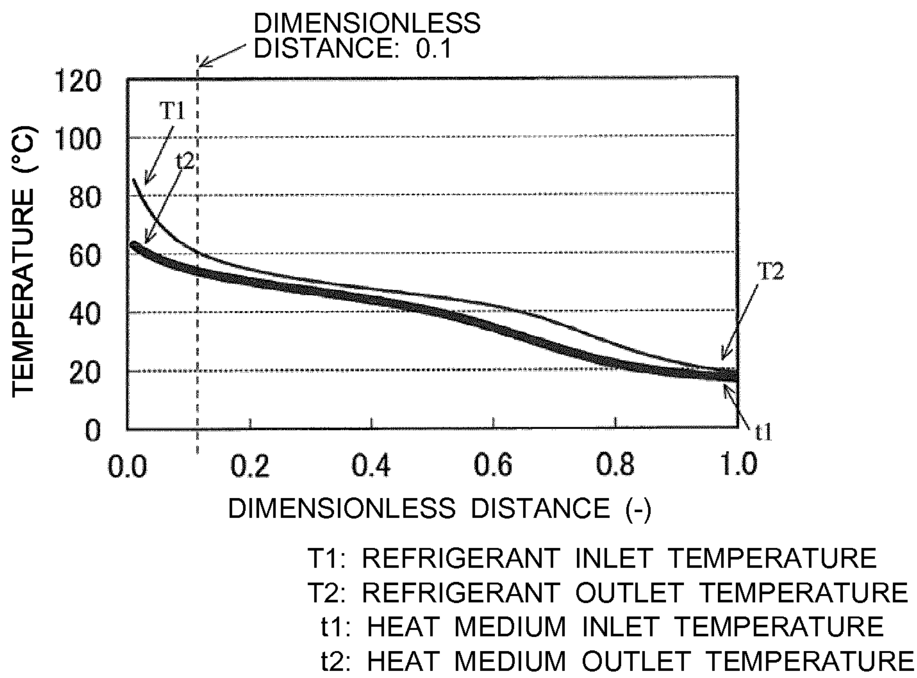

41
41A
FL3
41B
41C
FL2
FP1
FL1

FIG. 3A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100
80
60
40
20
0
T1
t2
T2
t1
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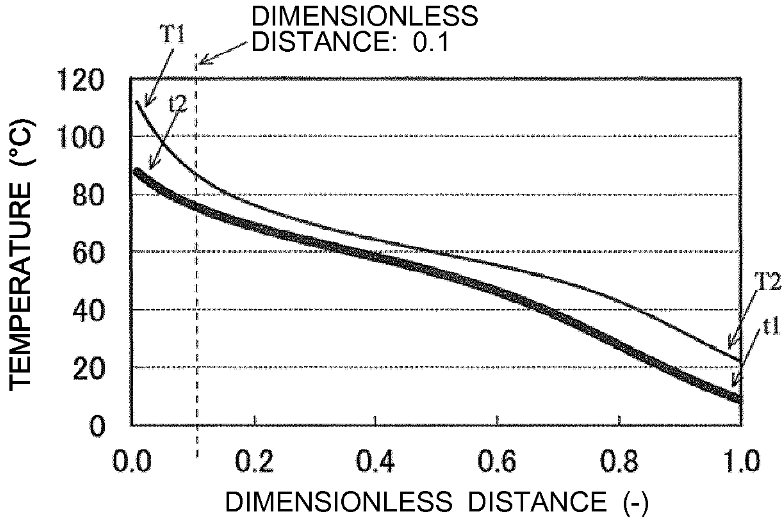
0.2
0.4
0.6
0.8
1.0
DIMENSIONLESS DISTANCE (-)
T1: REFRIGERANT INLET TEMPERATURE
T2: REFRIGERANT OUTLET TEMPERATURE
t1: HEAT MEDIUM INLET TEMPERATURE
t2: HEAT MEDIUM OUTLET TEMPERATURE

FIG. 3B



T1: REFRIGERANT INLET TEMPERATURE
T2: REFRIGERANT OUTLET TEMPERATURE
t1: HEAT MEDIUM INLET TEMPERATURE
t2: HEAT MEDIUM OUTLET TEMPERATURE

FIG. 3C

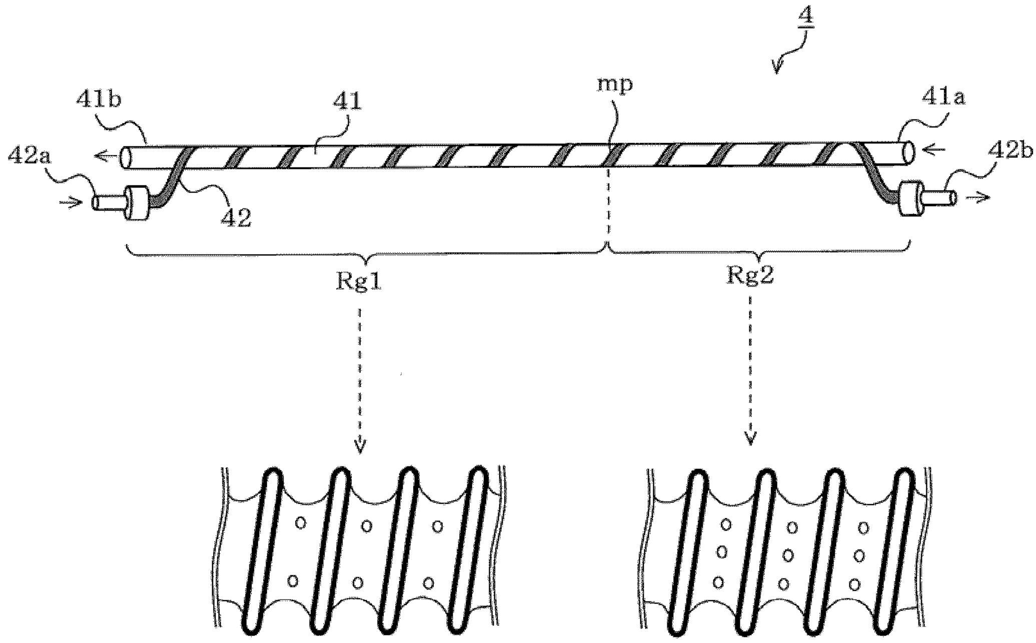
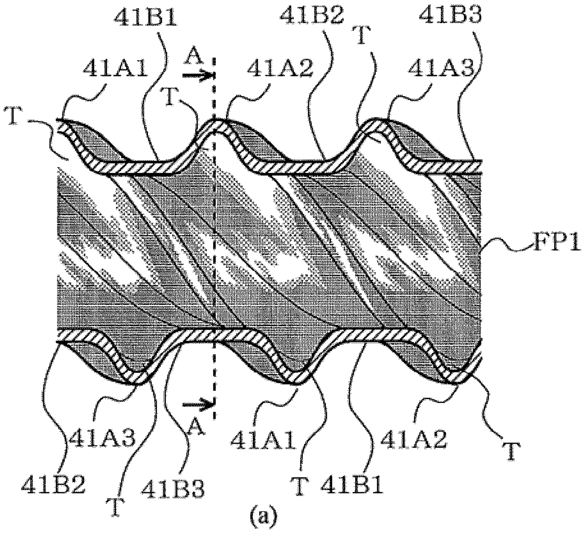


FIG. 4A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41B2
41B3
T
41A1
A
41A2
41A3
T
T
T
FP1
41A3
A
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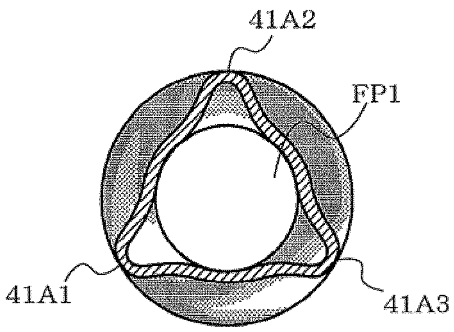
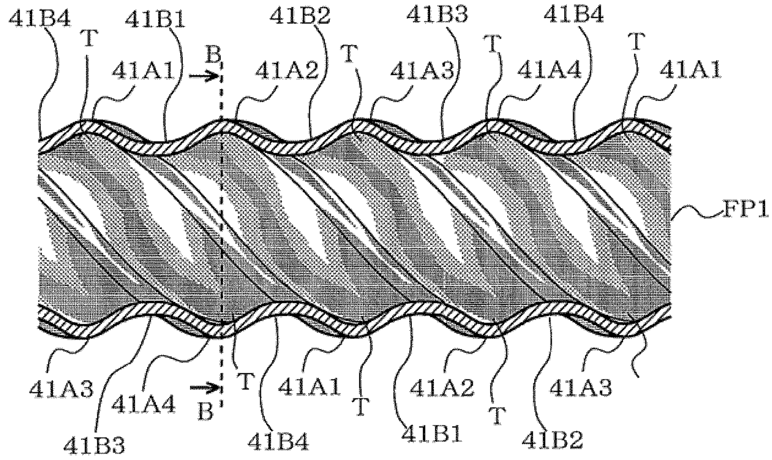
41B3
T
41B1

(a)

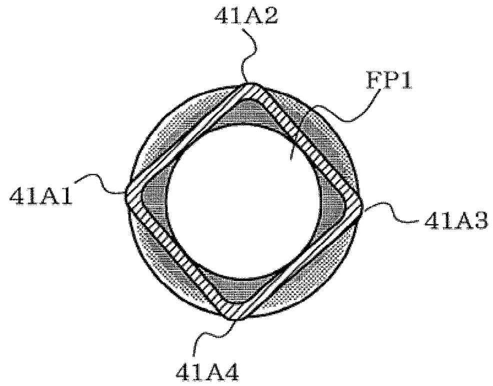

41A2
FP1
41A1
41A3

(b)

FIG. 4B



(a)



(b)

FIG. 4C

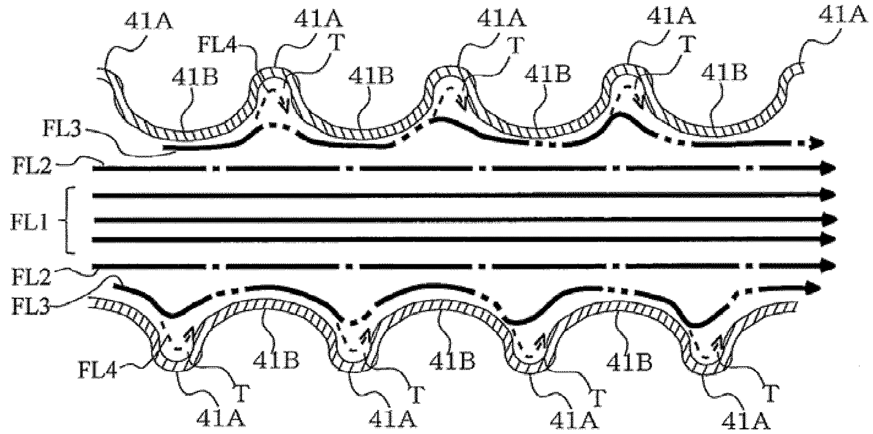
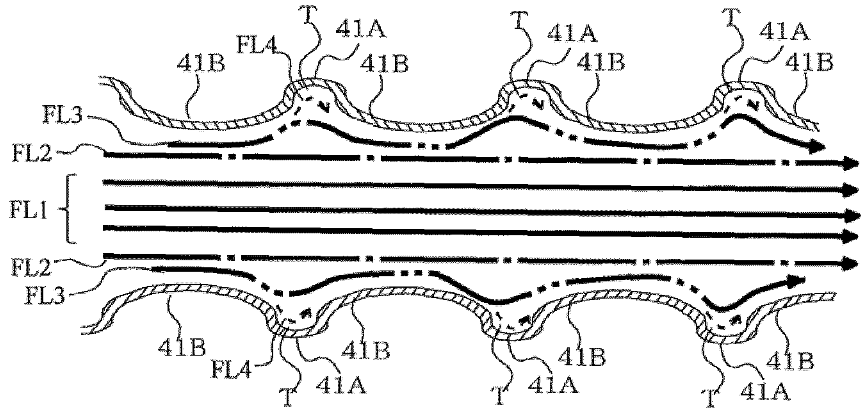


FIG. 4D


41B
FL4
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41A
41B
FL3
FL2
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FL2
FL3
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FL4
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41B
T
41A
41B
T
41A
41B

FIG. 5

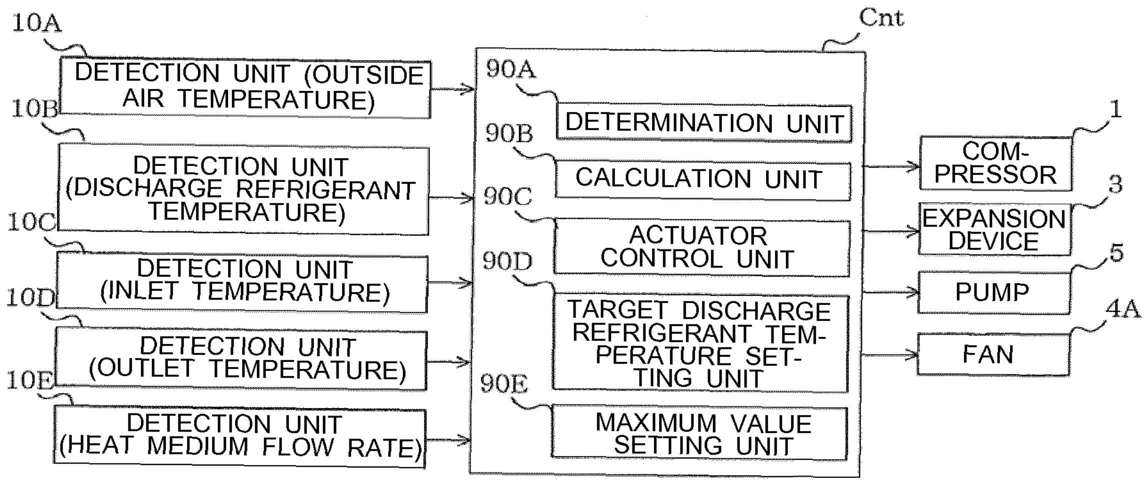
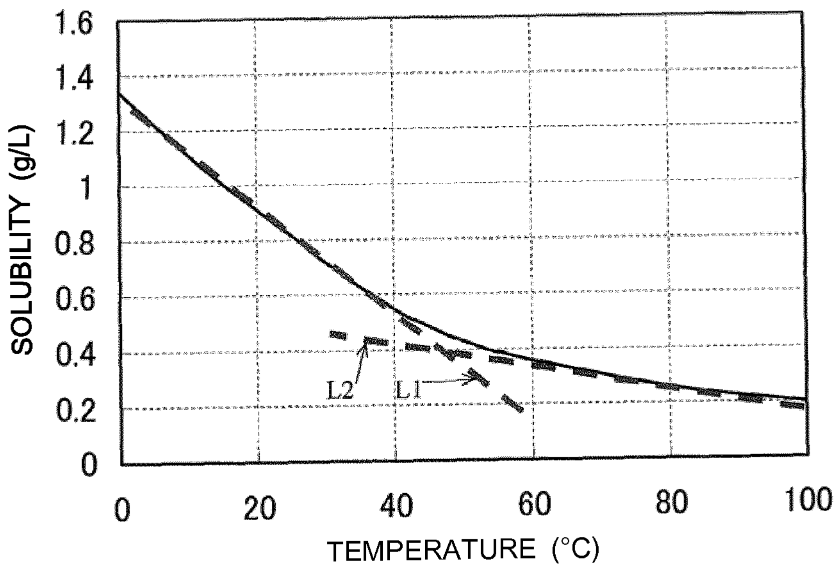

10A
DETECTION UNIT (OUTSIDE AIR TEMPERATURE)
10B
DETECTION UNIT (DISCHARGE REFRIGERANT TEMPERATURE)
10C
DETECTION UNIT (INLET TEMPERATURE)
10D
DETECTION UNIT (OUTLET TEMPERATURE)
10E
DETECTION UNIT (HEAT MEDIUM FLOW RATE)
Cnt
90A
DETERMINATION UNIT
90B
CALCULATION UNIT
90C
ACTUATOR CONTROL UNIT
90D
TARGET DISCHARGE REFRIGERANT TEMPERATURE SETTING UNIT
90E
MAXIMUM VALUE SETTING UNIT
1
COMPRESSOR
3
EXPANSION DEVICE
5
PUMP
4A
FAN

FIG. 6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0.2
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L1
0
20
40
60
80
100
TEMPERATURE (°C)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/073070

A. CLASSIFICATION OF SUBJECT MATTER
F28D7/02(2006.01)i, *F24H1/18*(2006.01)i, *F24H4/02*(2006.01)i, *F25B1/00*(2006.01)i, *F25B49/02*(2006.01)i, *F28D1/047*(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)
F28D7/02, F24H1/18, F24H4/02, F25B1/00, F25B49/02, F28D1/047

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	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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 A	JP 2012-122686 A (Mitsubishi Electric Corp.), 28 June 2012 (28.06.2012), paragraphs [0008], [0013] to [0016], [0024] to [0028]; fig. 5 to 7 (Family: none)	1 2-3,7-12 4-6
Y A	JP 2008-249163 A (Daikin Industries, Ltd.), 16 October 2008 (16.10.2008), paragraphs [0027] to [0042]; fig. 1 to 4 (Family: none)	2-3 4-6
Y	JP 2009-250461 A (Panasonic Corp.), 29 October 2009 (29.10.2009), paragraphs [0009], [0013] to [0030]; fig. 1 to 3 (Family: none)	7-12

☒ 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
19 October 2016 (19.10.16)	01 November 2016 (01.11.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/073070

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 2011-252676 A (Hitachi Appliances, Inc.), 15 December 2011 (15.12.2011), paragraphs [0027] to [0056]; fig. 1 to 4 & WO 2011/151933 A1 & CN 102918332 A & KR 10-2013-0010484 A	8
Y	JP 2014-043963 A (Mitsubishi Electric Corp.), 13 March 2014 (13.03.2014), paragraphs [0016] to [0017]; fig. 1 (Family: none)	10
Y	JP 2008-241173 A (Matsushita Electric Industrial Co., Ltd.), 09 October 2008 (09.10.2008), paragraph [0021]; fig. 1 (Family: none)	10-11
Y	JP 2006-266592 A (Hitachi Home & Life Solution, Inc.), 05 October 2006 (05.10.2006), paragraph [0065]; fig. 1 (Family: none)	11
Y	JP 2012-197956 A (Mitsubishi Electric Corp.), 18 October 2012 (18.10.2012), paragraphs [0012] to [0013], [0034]; fig. 1 (Family: none)	12

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Patent documents cited in the description

- JP 2008249163 A **[0003]**