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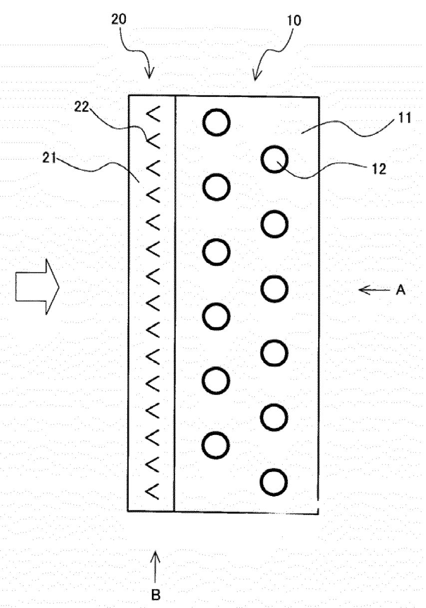
(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus according to the present invention includes: an evaporator including heat transfer tubes through which refrigerant flows, and heat transfer fins connected to the heat transfer tubes, the evaporator being provided to cool air with the refrigerant; a fan which supplies air to the evaporator; and a vortex generator formed independent of the evaporator and provided upstream of the evaporator in a flow direction of the air.

FIG. 2



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Description

Technical Field

[0001] The present invention relates to a refrigeration cycle apparatus in which the heat exchange performance of a heat exchanger is improved.

Background Art

[0002] In the past, a refrigeration cycle apparatus employing a fin-and-tube heat exchanger has been known. The fin-and-tube heat exchanger includes heat transfer tubes through which refrigerant flows, and heat transfer fins connected to the heat transfer tubes. Of fin-and-tube heat exchangers for use in such a refrigeration cycle apparatus, a fin-and-tube heat exchanger whose heat exchange performance is improved is proposed.

[0003] For example, Patent Literature 1 describes a fin-and-tube heat exchanger including a plurality of rectangular heat transfer fins and a plurality of heat transfer tubes. The plurality of heat transfer fins are disposed such that their longitudinal direction coincides with a vertical direction. The plurality of heat transfer fins are arranged side by side at predetermined intervals in a lateral direction substantially perpendicular to the flow direction of air which is sent by a fan. Furthermore, the heat transfer tubes are arranged side by side at predetermined intervals in the vertical direction (the longitudinal direction of the heat transfer fins) and extend through the heat transfer fins in the direction in which the fins are arranged side by side. In addition, in each of heat transfer fins of the heat exchanger described in Patent Literature 1, a plurality of triangular cut and raised pieces which are called winglets are formed in part of each heat transfer fin which is located in the vicinity of an end portion located on an upstream side in the flow direction of air. According to Patent Literature 1, when air flowing into space between the heat transfer fins impinges on the winglets, a vortex is generated, thus disturbing the flow of air in the vicinity of the surfaces of the heat transfer tubes and the heat transfer fins. As a result, the heat exchange performance of the heat exchanger is improved.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. Hei 11-108575

Summary of Invention

Technical Problem

[0005] There is a case where a fin-and-tube heat exchanger of a refrigeration cycle apparatus is used as an evaporator which cools air flowing into the heat exchanger using refrigerant flowing through heat transfer tubes. To be more specific, the heat transfer tubes and heat transfer fins are cooled by the refrigerant flowing through the heat transfer tubes to a temperature lower than that of the air flowing into the heat exchanger. Therefore, the air flowing into the heat exchanger is cooled by the heat transfer tubes and the heat transfer fins having the temperature lower than that of the air. When the air flowing into the heat exchanger is cooled to a temperature lower than or equal to a dew-point temperature, dew condensation occurs on surfaces of the heat transfer tubes and the heat transfer fins. That is, the vicinity of an end portion of the heat transfer fin that is located on an upstream side in the flow direction of air is a region from which cooling of the air flowing into the heat exchanger is started. Therefore, dew condensation easily occurs at this region. Furthermore, when the temperature of the air flowing into the heat exchanger is low, the temperature of the heat transfer fin is far lower than that of the air. Therefore, dews adhering to the vicinity of the end portion of the heat transfer fin that is located on the upstream side in the flow direction of air are frozen to form frost in the vicinity of the end portion.

[0006] In the heat exchanger described in Patent Literature 1, winglets which function as vortex generating units are formed at respective heat transfer fins. To be more specific, in the heat exchanger described in Patent Literature 1, the vortex generating units and the heat transfer fins are formed integrally with each other. Therefore, in the case where the heat exchanger described in Patent Literature 1 is used as the evaporator, the winglets functioning as the vortex generating units are cooled by the refrigerant flowing through the heat transfer tubes to a temperature equal to that of part of the heat transfer fins which is other than part of the heat transfer fins in which the winglets are formed. Furthermore, the part of the heat transfer fins in which the winglets are formed is the vicinity of end portions of the heat transfer fins that are located on an upstream side in the flow direction of air, that is, a region in which dew condensation easily occurs. Therefore, in the case where the heat exchanger described in Patent Literature 1 is used as the evaporator under a condition in which the temperature of the air flowing into the heat exchanger is low, frost is formed on the winglets functioning as the vortex generating units. Thus, it is hard to generate a vortex with the winglets. Accordingly, the heat exchanger described in Patent Literature 1 cannot improve the heat exchange performance in the case where the heat exchanger is used as the evaporator. That is, the conventional refrigeration cycle apparatus cannot improve the heat exchange performance of the evaporator.

[0007] The present invention has been made to solve the above problem, and an object of the invention is to obtain a refrigeration cycle apparatus in which the heat exchange performance of an evaporator can be improved.

Solution to Problem

[0008] A refrigeration cycle apparatus according to an embodiment of the present invention includes: an evaporator including heat transfer tubes through which refrigerant flows, and heat transfer fins connected to the heat transfer tubes, the evaporator being provided to cool air with the refrigerant; a fan which sends air to the evaporator; and a vortex generator formed independent of the evaporator and provided upstream of the evaporator in a flow direction of the air. Advantageous Effects of Invention

[0009] In the refrigeration cycle apparatus according to the embodiment of the present invention, the vortex generator functioning as a vortex generating unit is formed independently of the evaporator. Therefore, cooling of the vortex generator by refrigerant flowing through the heat transfer tubes of the evaporator can be reduced compared with the conventional heat exchanger. That is, in the refrigeration cycle apparatus according to the embodiment of the present invention, formation of frost on the vortex generator can be reduced compared with the conventional heat exchanger. Thus, in the refrigeration cycle apparatus according to the embodiment of the present invention, an air flow with vortexes generated at the vortex generator can be supplied to the evaporator even the temperature of air flowing into the evaporator is low. Therefore, the heat exchange performance of the evaporator can be improved compared with the conventional heat exchanger.

Brief Description of Drawings

[0010]

Fig. 1 is a refrigerant circuit diagram illustrating an air-conditioning apparatus 100 according to embodiment 1 of the present invention.
Fig. 2 is a side view illustrating a heat exchanger 10 and a vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 1 of the present invention.
Fig. 3 is a view taken as seen from a direction indicated by an arrow A in Fig. 2.
Fig. 4 is a view taken as seen from a direction indicated by an arrow B in Fig. 2.
Fig. 5 is a side view illustrating another example of the heat exchanger 10 of the air-conditioning apparatus 100 according to embodiment 1 of the present invention.
Fig. 6 is a side view illustrating another example of the vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 1 of the present invention.
Fig. 7 is a side view illustrating the vicinity of a heat exchanger 10 and a vortex generator 20 of an air-conditioning apparatus 100 according to embodiment 2 of the present invention.
Fig. 8 is a view illustrating the temperatures of a heat transfer fin 11 of the heat exchanger 10 and the vortex generator 20 in the case where the heat exchanger 10 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention is used as an evaporator.
Fig. 9 is a side view illustrating another example of the vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention.
Fig. 10 is a side view illustrating another example of the heat exchanger 10 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention.
Fig. 11 is a side view illustrating an example of an air-conditioning apparatus 100 according to embodiment 3 of the present invention.
Fig. 12 is a view additionally illustrating a velocity distribution of air flowing to the vortex generator 20 in the air-conditioning apparatus 100 as illustrated in Fig. 11.
Fig. 13 is a side view illustrating another example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention.
Fig. 14 is a plan view illustrating a further example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention.
Fig. 15 is a side view of the air-conditioning apparatus 100 as illustrated in Fig. 14.
Fig. 16 is a plan view illustrating still another example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention.
Fig. 17 is a side view of the air-conditioning apparatus 100 as illustrated in Fig. 16.
Fig. 18 is a side view illustrating an example of arrangement of heat exchangers 10 and vortex generators 20 of an air-conditioning apparatus 100 according to embodiment 4 of the present invention.
Fig. 19 is a side view illustrating another example of the arrangement of the heat exchangers 10 and the vortex generators 20 of the air-conditioning apparatus 100 according to embodiment 4 of the present invention are disposed. Description of embodiments

Embodiment 1

[0011] With respect to embodiment 1, a refrigeration cycle apparatus according to the present invention will be described by referring to by way of example an air-conditioning apparatus which is a refrigeration cycle apparatus.

[0012] Fig. 1 is a refrigerant circuit diagram illustrating an air-conditioning apparatus 100 according to embodiment 1 of the present invention. It should be noted that outlined arrows in Fig. 1 indicate the flow direction of air.

[0013] The air-conditioning apparatus 100 includes a compressor 1, a heat exchanger 2 functioning as an indoor heat exchanger, a fan 2a which sends indoor air to the heat exchanger 2, an expansion device 3, a heat exchanger 10 functioning as an outdoor heat exchanger, a fan 30 which sends outdoor air to the heat exchanger 10, a flow switching device 4, etc. The compressor 1, the heat exchanger 2, the expansion device 3, the heat exchanger 10 and the flow switching device 4 are connected to each other by refrigerant pipes, whereby a refrigerant circuit is formed.

[0014] The compressor 1 compresses refrigerant. The refrigerant compressed by the compressor 1 is discharged, and sent to the flow switching device 4. For example, as the compressor 1, a rotary compressor, a scroll compressor, a screw compressor or a reciprocating compressor can be applied.

[0015] The heat exchanger 2 is an indoor heat exchanger; and functions as a condenser during a heating operation, and functions as an evaporator during a cooling operation. For example, the heat exchanger 2 is a fin-and-tube heat exchanger.

[0016] The expansion device 3 expands refrigerant having flowed out of the heat exchanger 2 or the heat exchanger 10 to reduce the pressure of the refrigerant. For example, as the expansion device 3, an electric expansion valve which can adjust the flow rate of the refrigerant is used. It should be noted that not only the electric expansion valve but for example, a mechanical expansion valve that employs a diaphragm as a pressure receiving portion or a capillary tube can be applied as the expansion device 3.

[0017] The heat exchanger 10 is an outdoor heat exchanger; and functions as an evaporator during the heating operation, and functions as a condenser during the cooling operation. The heat exchanger 10 is a fin-and-tube heat exchanger, and a detailed configuration thereof will be described later.

[0018] For example, the flow switching device 4 is a four-way valve, and switches the refrigerant passage to be used, between a refrigerant passage for the heating operation and that for the cooling operation. More specifically, during the heating operation, the flow switching device 4 switches the refrigerant passage in such a way as to connect a discharge port of the compressor 1 to the heat exchanger 2 and connect a suction port of the compressor 1 to the heat exchanger 10. During the cooling operation, the flow switching device 4 switches the refrigerant passage in such a way as to connect the discharge port of the compressor 1 to the heat exchanger 10 and connect the suction port of the compressor 1 to the heat exchanger 2.

[0019] The fan 2a is located close to the heat exchanger 2, and sends indoor air to the heat exchanger 2 as described above.

[0020] The fan 30 is located close to the heat exchanger 10, and sends outdoor air to the heat exchanger 10 as described above.

[0021] Various types of fans such as a propeller fan, a cross-flow fan, a sirocco fan and a turbofan can be used as the fan 2a and the fan 30.

[0022] The air-conditioning apparatus 100 according to embodiment 1 is provided with a vortex generator 20 which is located upstream of the heat exchanger 10 in the flow direction of air which is sent to the heat exchanger 10 by the fan 30. A detailed configuration of the vortex generator 20 will be described later together with that of the heat exchanger 10.

[0023] The above components of the air-conditioning apparatus 100 are provided in an outdoor unit 101 or an indoor unit 102. To be more specific, the compressor 1, the expansion device 3, the flow switching device 4, the heat exchanger 10, the vortex generator 20 and the fan 30 are provided in the outdoor unit 101. The heat exchanger 2 and the fan 2a are provided in the indoor unit 102.

[0024] Fig. 2 is a side view illustrating the heat exchanger 10 and the vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 1 of the present invention. Fig. 3 is a view taken as seen from a direction indicated by an arrow A in Fig. 2. Fig. 4 is a view taken as seen from a direction indicated by an arrow B in Fig. 2. It should be noted that outlined arrows in Figs. 2 and 4 indicate flow directions of air (outdoor air) which is sent by the fan 30.

[0025] A detailed configuration of the heat exchanger 10 will be described with reference to Figs. 2 and 3. Also, a detailed configuration of the vortex generator 20 will be described with reference to Figs. 2 and 4.

[0026] As illustrated in Figs. 2 and 3, the heat exchanger 10 is a fin-and-tube heat exchanger, and includes a plurality of heat transfer tubes 12 through which the refrigerant flows, and a plurality of heat transfer fins 11 connected to the heat transfer tubes 12. The heat transfer fins 11 are rectangular plate-shaped elements. For example, the plurality of heat transfer fins 11 are provided such that their longitudinal direction coincides with a vertical direction. Also, the plurality of heat transfer fins 11 are arranged side by side at predetermined intervals in a lateral direction substantially perpendicular to the flow direction of air from the fan 30. Furthermore, through holes are provided in the heat transfer fins 11, and allow the heat transfer tubes 12 to be inserted through the through holes. It should be noted that each heat transfer fin 11 may be formed into a corrugated shape to enhance the strength of each heat transfer fin 11.

[0027] The plurality of heat transfer tubes 12 are circular tubes. The heat transfer tubes 12 are inserted into the through holes formed in the heat transfer fins 11. To be more specific, the heat transfer tubes 12 extend through the heat transfer fins 11 in the direction in which the heat transfer fins 11 are arranged side by side. That is, each of the heat transfer tubes 12 and an outer edge of the through hole of an associated one of the heat transfer fins 11 are connected to each other. It should be noted that the heat transfer tubes 12 are not limited to the circular tubes. For example, as illustrated in Fig. 5, flat tubes having elongated cross sections may be used as the heat transfer tubes 12. The elongated cross section is a cross section which is long in a lateral direction and short in a vertical direction, for example, an oval cross section. It should be noted that Fig. 5 is a side view illustrating another example of the heat exchanger 10 of the air-conditioning apparatus 100 according to embodiment 1 of the present invention.

[0028] Incidentally, in some conventional fin-and-tube heat exchangers, cut and raised pieces called slits, louvers, winglets or the like are formed at heat transfer fins to improve the heat exchange performance. On the other hand, at the heat transfer fins 11 of the heat exchanger 10 according to embodiment 1, cut and raised pieces are not formed. There is because the heat exchange performance of the heat exchanger 10 is improved by providing the vortex generator 20 as described later, and cut and raised pieces thus do not need to be formed at the heat transfer fins 11.

[0029] As described above, the vortex generator 20 is located upstream of the heat exchanger 10 in the flow direction of air which is sent from the fan 30 to the heat exchanger 10. The vortex generator 20 is formed independently of the heat exchanger 10. More specifically, as illustrated in Figs. 2 and 4, the vortex generator 20 has a plurality of protrusions 22. In embodiment 1, a plurality of protrusions 22 are formed by cutting and raising respective portions of each of plate-shaped bases 21. That is, the protrusions 22 are cut and raised pieces. Furthermore, the bases 21 each formed to include protrusions 22 are provided side by side at predetermined intervals, thereby forming the vortex generator 20. Also, in embodiment 1, the vortex generator 20 is provided in contact with the heat transfer fins 11 of the heat exchanger 10. In the vortex generator 20 having the above configuration, vortexes are generated when air sent by the fan 30 flows into space between the bases 21 and impinges on the protrusions 22. Moreover, in embodiment 1, the thickness of the vortex generator 20 is smaller than that of the heat exchanger 10 in the flow direction of air which is sent by the fan 30. Since the vortex generator 20 and the heat exchanger 10 are formed as described above, the air-conditioning apparatus 100 can be made compact.

[0030] It should be noted that the configuration of the vortex generator 20 is not limited to the above configuration. For example, the cut and raised protrusions 22 may be each formed in a shape other than the triangular shape. Furthermore, for example, referring to Figs. 2 and 4, protrusions 22 are formed by cutting and raising each base 21 from the upstream side toward the downstream side in the flow direction of air which is sent by the fan 30. However, the direction in which the protrusions 22 are cut and raised is not limited to such a direction. For example, the protrusions 22 may be formed by cutting and raising the base 21 from the downstream side to the upstream side in the flow direction of air from the fan 30. Also, the method for forming the protrusions 22 is not limited to the above cutting and raising. For example, components formed independently of the base 21 may be attached to the base 21 by welding or the like, and used as protrusions 22. Furthermore, for example, in Figs. 2 and 4, the direction in which the plurality of bases 21 are arranged side by side coincides with the direction in which the heat transfer fins 11 are arranged side by side. However, these directions may differ from each other. In addition, for example, the plurality of bases 21 may be disposed in a lattice pattern.

[0031] Moreover, for example, as illustrated in Fig. 6, the vortex generator 20 may include a plurality of wires 23 disposed at predetermined intervals, instead of using the protrusions 22. For example, the plurality of wires 23 are arranged in a lattice pattern. The vortex generator 20 may be formed of wires 23a or wires 23b arranged at predetermined intervals in a single direction. This is because vortexes are generated when air sent by the fan 30 impinges on the wires 23. That is, it suffices that the vortex generator 20 has a structure in which vortexes can be generated when air sent by the fan 30 passes through the vortex generator 20. It should be noted that Fig. 6 is a side view illustrating another example of the vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 1 of the present invention, and also that Fig. 6 illustrates the example of the vortex generator 20 as seen in the flow direction of the air which is sent from the fan 30 to the vortex generator 20. That is, the direction from which the above example of the vortex generator 20 is seen in Fig. 6 is a direction in which the example of the vortex generator 20 is seen from a left side in Fig. 2.

[0032] Next, an operation of the air-conditioning apparatus 100 will be described. First, a heating operation of the air-conditioning apparatus 100 will be described. When the air-conditioning apparatus 100 performs the heating operation, the flow switching device 4 switches the refrigerant passage to be used to a refrigerant passage indicated by solid lines in Fig. 1. In this state, the compressor 1, the fan 2a and the fan 30 are driven to start the heating operation.

[0033] By driving the compressor 1, high-temperature and high-pressure gas refrigerant is discharged from the compressor 1. The high-temperature and high-pressure gas refrigerant discharged from the compressor 1 flows into the heat exchanger 2 which is the indoor heat exchanger, via the flow switching device 4. During the heating operation, the heat exchanger 2 functions as the condenser. Therefore, in the heat exchanger 2, the high-temperature and high-pressure gas refrigerant flowing in the heat exchanger 2 heats indoor air sent by the fan 2a, thereby heating a target space to be air-conditioned, for example, the inner space of a room. Further, when the high-temperature and high-pressure gas refrigerant flowing in the heat exchanger 2 exchanges heat with the indoor air sent by the fan 2a, the refrigerant is condensed into high-pressure liquid refrigerant.

[0034] The high-pressure liquid refrigerant having flowed out of the heat exchanger 2 is changed into low-temperature and low-pressure two-phase gas-liquid refrigerant by the expansion device 3. The low-temperature and low-pressure two-phase gas-liquid refrigerant flows into the heat exchanger 10 which is the outdoor heat exchanger. During the heating operation, the heat exchanger 10 functions as the evaporator. Therefore, in the heat exchanger 10, the refrigerant flowing in the heat transfer tubes 12 of the heat exchanger 10 removes heat from outdoor air sent by the fan 30. In other words, the refrigerant flowing in the heat transfer tubes 12 of the heat exchanger 10 cools the outdoor air sent by the fan 30. Furthermore, when the refrigerant flowing in the heat transfer tubes 12 of the heat exchanger 10 exchanges heat with the outdoor air sent by the fan 30, the refrigerant is evaporated into low-pressure gas refrigerant. Then, the low-pressure gas refrigerant having flowed out of the heat exchanger 10 is sucked into the compressor 1 via the flow switching device 4, and is compressed into high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant is re-discharged from the compressor 1.

[0035] In the air-conditioning apparatus 100 according to embodiment 1, as described above, the vortex generator 20 is located upstream of the heat exchanger 10 in the flow direction of air which is sent from the fan 30 to the heat exchanger 10. Therefore, vortexes are generated when the air sent by the fan 30 flows into the vortex generator 20 and impinges on the protrusions 22. Thus, an air flow with the vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10. Accordingly, an air flow in the vicinity of the surfaces of the heat transfer fins 11 and the heat transfer tubes 12 of the heat exchanger 10 is disturbed. As a result, the heat exchange performance of the heat exchanger 10 can be improved.

[0036] Incidentally, in a conventional heat exchanger, vortex generating units are formed by, for example, cutting and raising heat transfer fins, that is, they are formed integrally with the heat transfer fins, to improve the heat exchange performance. To be more specific, in the conventional heat exchanger, the vortex generating units are formed integrally portions of the heat transfer tubes are adjacent to end portions thereof which are located on an upstream side in the flow direction of air. In such a conventional heat exchanger, in the case where the heat exchanger is used as an evaporator, the heat exchange performance cannot be improved by the vortex generating units.

[0037] Specifically, in the evaporator, the heat transfer tubes and the heat transfer fins are cooled by refrigerant flowing through the heat transfer tubes to a temperature lower than that of air flowing into the evaporator. Therefore, the air flowing into the evaporator is cooled by the heat transfer tubes and the heat transfer fins having the temperature lower than that of the air. In this case, when the air flowing into the evaporator is cooled to a temperature lower than or equal to a dew-point temperature, dew condensation occurs on surfaces of the heat transfer tubes and the heat transfer fins. That is, the portions of the heat transfer fins that are adjacent to the end portions thereof on the upstream side in the flow direction of air are regions from which cooling of the air flowing into the heat exchanger is started. Therefore, dew condensation easily occurs at these regions. Further, when the temperature of the air flowing into the evaporator is low, the temperatures of the heat transfer fins are far lower than that of the air. Therefore, dews adhering to the above adjacent portions of the end portions of the heat transfer fins which are located on the upstream side in the flow direction of the air are frozen to form frost on these portions.

[0038] That is, in the case where the conventional heat exchanger in which the vortex generating units are formed integrally with the heat transfer fins is used as an evaporator, the vortex generating units is cooled by refrigerant flowing through the heat transfer tubes to a temperature equal to that of part of the heat transfer fins which is other than part of the heat transfer fins in which the vortex generating units are located. Furthermore, the portion of the above heat transfer fin in which the associated vortex generating unit is located is a portion of the heat transfer fin which is adjacent to an end portion thereof which is located on an upstream side in the flow direction of air, that is, a region where dew condensation easily occurs. Therefore, in the case where the conventional heat exchanger in which the vortex generating units are formed integrally with the heat transfer fins is used as the evaporator, frost is formed on the vortex generating units under a condition in which the temperature of air flowing into the heat exchanger is low. It is therefore hard to generate a vortex using the vortex generating units. Accordingly, in the conventional heat exchanger in which the vortex generating units are formed integrally with the heat transfer fins, the heat exchange performance cannot be improved.

[0039] In the air-conditioning apparatus 100 according to embodiment 1, the vortex generator 20 is formed independently of the heat exchanger 10. Therefore, although the vortex generator 20 is in contact with the heat transfer fins 11 of the heat exchanger 10, the rate of heat transfer between the heat transfer fins 11 and the vortex generator 20 is lower than that between the heat transfer fins and the vortex generating units of the conventional heat exchanger. That is, cooling of the vortex generator 20 by the refrigerant flowing through the heat transfer tubes 12 of the heat exchanger 10, which occurs when the heat exchanger 10 is used as the evaporator, can be reduced compared with the conventional heat exchanger. That is, in the air-conditioning apparatus 100 according to embodiment 1, formation of frost on the vortex generator 20 can be reduced as compared with the conventional heat exchanger. Thus, in the air-conditioning apparatus 100 according to embodiment 1, when the heat exchanger 10 is used as the evaporator, an air flow with vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10 even when the temperature of the air flowing into the heat exchanger 10 is low. It is therefore possible to improve the heat exchange performance of the heat exchanger 10.

[0040] Furthermore, as stated above, in the heat transfer fins 11 of the heat exchanger 10 according to embodiment 1, cut and raised pieces are not formed. If cut and raised pieces are formed at a heat transfer fin 11, the space between the heat transfer fin 11 having the cut and raised pieces and a heat transfer fin 11 adjacent to the heat transfer fin 11 is reduced. Therefore, if cut and raised pieces are formed at the heat transfer fin 11, the space between the adjacent heat transfer fins 11 is easily clogged by formed frost. In other words, in the heat exchanger 10 according to embodiment 1, it is possible to prevent or reduce clogging of the space between adjacent heat transfer fins 11, which would be caused by formed frost, because cut and raised pieces are not formed at the heat transfer fins 11. Furthermore, because of formation of no cut and raised pieces, dews adhering to the heat transfer fins 11 slide downward without being retained by surface tension or the like, and are thus easily discharged from the heat exchanger 10. On this point as well, in the heat exchanger 10 according to embodiment 1, it is possible to prevent or reduce clogging of the space between the adjacent heat transfer fins 11, which would be caused by formation of frost. Thus, the heat exchange performance of the heat exchanger 10 according to embodiment 1 can further be improved because cut and raised pieces are not formed at the heat transfer fins 11.

[0041] When the air-conditioning apparatus 100 performs the cooling operation, the flow switching device 4 switches the refrigerant passage to be used, to a refrigerant passage indicated by broken lines as indicated in Fig. 1. In this state, the compressor 1, the fan 2a and the fan 30 are driven to start the cooling operation.

[0042] By driving the compressor 1, high-temperature and high-pressure gas refrigerant is discharged from the compressor 1. The high-temperature and high-pressure gas refrigerant discharged from the compressor 1 flows into the heat exchanger 10 which is the outdoor heat exchanger, via the flow switching device 4. During the cooling operation, the heat exchanger 2 functions as the condenser. Therefore, in the heat exchanger 10, the refrigerant flowing in the heat transfer tubes 12 of the heat exchanger 10 transfers heat to outdoor air sent by the fan 30. Furthermore, when the high-temperature and high-pressure gas refrigerant flowing in the heat transfer tubes 12 of the heat exchanger 10 exchanges heat with the outdoor air sent by the fan 30, the refrigerant is condensed into high-pressure liquid refrigerant.

[0043] The high-pressure liquid refrigerant having flowed out of the heat exchanger 10 is changed into low-temperature and low-pressure two-phase gas-liquid refrigerant by the expansion device 3. The low-temperature and low-pressure two-phase gas-liquid refrigerant flows into the heat exchanger 2 which is the indoor heat exchanger. During the cooling operation, the heat exchanger 2 functions as the evaporator. Therefore, in the heat exchanger 2, the low-temperature and low-pressure two-phase gas-liquid refrigerant flowing in the heat exchanger 2 cools the indoor air sent by the fan 2a, thereby cooling the target space to be air-conditioned, such as the inner space of the room. Furthermore, when the low-temperature and low-pressure two-phase gas-liquid refrigerant flowing in the heat exchanger 2 exchanges heat with indoor air sent by the fan 2a, the refrigerant is evaporated into low-pressure gas refrigerant. Then, the low-pressure gas refrigerant having flowed out of the heat exchanger 2 is sucked into the compressor 1 via the flow switching device 4 and is compressed into high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant is re-discharged from the compressor 1.

[0044] It should be noted that in the air-conditioning apparatus 100 according to embodiment 1, as described above, the vortex generator 20 is located upstream of the heat exchanger 10 in the flow direction of air which is sent from the fan 30 to the heat exchanger 10 from the fan 30. Therefore, vortexes are generated when the air sent by the fan 30 flows into the vortex generator 20 and impinges on the protrusions 22. Thus, an air flow with the vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10. Accordingly, an air flow in the vicinity of the surfaces of the heat transfer fins 11 and the heat transfer tubes 12 of the heat exchanger 10 is disturbed, as a result of which the heat exchange performance of the heat exchanger 10 can be improved during the cooling operation as well.

[0045] As described above, the air-conditioning apparatus 100 according to embodiment 1 includes: the heat exchanger 10 which includes the heat transfer tubes 12 through which the refrigerant flows and the heat transfer fins 11 connected to the heat transfer tubes 12, and functions as the evaporator; the fan 30 which sends air to the heat exchanger 10; and the vortex generator 20 formed independently of the heat exchanger 10 located upstream of the heat exchanger 10 in the flow direction of air from the fan 30. Therefore, in the air-conditioning apparatus 100 according to embodiment 1, it is possible to reduce cooling of the vortex generator 20 by the refrigerant flowing in the heat transfer tubes 12 of the heat exchanger 10, which occurs when the heat exchanger 10 is used as the evaporator, as compared with the conventional heat exchanger. That is, in the air-conditioning apparatus 100 according to embodiment 1, it is possible to reduce formation of frost on the vortex generator 20 as compared with the conventional heat exchanger.

[0046] Thus, in the air-conditioning apparatus 100 according to embodiment 1, when the heat exchanger 10 is used as the evaporator, an air flow with vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10 continuously and stably even when the temperature of air flowing into the heat exchanger 10 is low. Therefore, the heat exchange performance of the heat exchanger 10 can be improved as compared with the conventional heat exchanger. In other words, the air-conditioning apparatus 100 according to embodiment 1 can be operated while saving energy because the heat exchange performance of the heat exchanger 10 which functions as the evaporator can be improved.

[0047] Furthermore, in the air-conditioning apparatus 100 according to embodiment 1, cut and raised pieces are not formed at the heat transfer fins 11 of the heat exchanger 10. Therefore, in the air-conditioning apparatus 100 according to embodiment 1, it is possible to reduce clogging of the space between the heat transfer fins 11, which would be caused by frost formation, when the heat exchanger 10 is used as the evaporator. Thus, the heat exchange performance of the heat exchanger 10 can further be improved.

[0048] It should be noted that in embodiment 1, the heat exchanger 10 is used as the outdoor heat exchanger, but may be used as the indoor heat exchanger. If it is used as the indoor heat exchanger, it suffices that the heat exchanger 2 is used as the outdoor heat exchanger. That is, it suffices that the heat exchanger 10, the vortex generator 20 and the fan 30 are provided in the indoor unit 102, and the heat exchanger 2 and the fan 2a are provided in the outdoor unit 101 instead. Furthermore, the vortex generator 20 may be located upstream of both the heat exchanger 2 and the heat exchanger 10 in the flow direction of air.

[0049] Furthermore, the air-conditioning apparatus 100 according to embodiment 1 is merely an example of the refrigeration cycle apparatus according to the present invention. The present invention can be adopted in general refrigeration cycle apparatuses each including a fin-and-tube heat exchanger as an evaporator. That is, the present invention can be put to practical use by providing the vortex generator 20 upstream of the fin-and-tube evaporator in the flow direction of air.

Embodiment 2

[0050] In embodiment 1, the vortex generator 20 is in contact with the heat transfer fins 11 of the heat exchanger 10. However, the arrangement of the vortex generator 20 and the heat exchanger 10 is not limited to such arrangement. The vortex generator 20 and the heat transfer fins 11 of the heat exchanger 10 may be provided, with space provided between the vortex generator 20 and the heat transfer fins 11. It should be noted that with respect to embodiment 2, matters which are not particularly described are the same as or similar to those of embodiment 1, and functions and components which are identical to those of embodiment 1 will be denoted by the same reference signs.

[0051] Fig. 7 is a side view illustrating the vicinity of the heat exchanger 10 and the vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention. Fig. 8 is a diagram illustrating the temperatures of the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20 when the heat exchanger 10 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention is used as the evaporator. It should be noted that outlined arrows in Figs. 7 and 8 indicate flow directions of air from the fan 30.

[0052] As illustrated in Fig. 7, in the air-conditioning apparatus 100 according to embodiment 2, spaces 41 each having a width L are provided between the heat transfer fins 11 in the heat exchanger 10 and the vortex generator 20. By disposing the heat exchanger 10 and the vortex generator 20 in this manner, when the heat exchanger 10 is used as the evaporator, the temperatures of the vortex generator 20 and each heat transfer fin 11 in the heat exchanger 10 vary from one location from another as indicated in Fig. 8.

[0053] Specifically, the heat transfer fins 11 of the heat exchanger 10 are cooled by the refrigerant flowing through the heat transfer tubes 12 connected to the heat transfer fins 11. Furthermore, air which is sent by the fan 30 to the spaces between the heat transfer fins 11 is cooled thereby, and the temperature of the air thus decreases as the air flows toward the downstream side. That is, the temperature of each heat transfer fin 11 varies from one location to another such that the closer part of the heat transfer fin 11 to the downstream side in the flow of air from the fan 30, the lower the temperature of the part of the heat transfer fin 11, since the part of the heat transfer fin 11 is harder to heat with the air as the part of the heat transfer fin 11 is closer to the downstream side. Thus, as shown by a straight line C indicated by a solid line in Fig. 8, the surface temperature of the heat transfer fin 11 decreases from the upstream side to the downstream side in the flow direction of air from the fan 30.

[0054] It should be noted that in the conventional heat exchanger in which the vortex generating unit is formed integrally with the portion of the heat transfer fin which is close to the end portion thereof located on the upstream side in the flow direction of air, in the case where the heat exchanger is used as the evaporator, the temperature of the vortex generating unit is close to or equal to that of the other portion of the heat transfer fin. That is, the vortex generating unit is cooled by the refrigerant flowing through the heat transfer tubes, and as shown by a straight line D indicated by a two-dot chain line in Fig. 8, the temperature of the vortex generating unit decreases from the upstream side to the downstream side in the flow direction of air, and the straight line D connects the straight line C.

[0055] By contrast, in embodiment 2, the space 41 is provided between each of the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20. Therefore, the vortex generator 20 is hardly cooled by the refrigerant flowing through the heat transfer tubes 12. Thus, as shown by a straight line E indicated by a solid line in Fig. 8, the temperature of the vortex generator 20 is equal to an outdoor air temperature (the temperature of air to be sent to the heat exchanger 10 by the fan 30, that is, that of air which has not yet flowed into the heat exchanger 10).

[0056] Therefore, in the air-conditioning apparatus 100 according to embodiment 2, in the case where the heat exchanger 10 is used as the evaporator, frost is hardly formed on the vortex generator 20 even when the temperature of the air flowing into the heat exchanger 10 is low. Thus, in the air-conditioning apparatus 100 according to embodiment 2, as in embodiment 1, in the case where the heat exchanger 10 is used as the evaporator, an air flow with vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10 continuously and stably even when the temperature of the air flowing into the heat exchanger 10 is low. As a result, the heat exchange performance of the heat exchanger 10 can be further improved as compared with the conventional heat exchanger.

[0057] It should be noted that preferably, the width L of each space 41 should be 1 mm to 5 mm. This is because if the width L is excessively long, a vortex flow generated at the vortex generator 20 does not reach the heat exchanger 10, and if the width L is excessively short, dews adhering to the heat transfer fin 11 of the heat exchanger 10 may adhere to the vortex generator 20.

[0058] It should be noted that in embodiment 1 in which the vortex generator 20 is in contact with the heat transfer fins 11 of the heat exchanger 10, the temperature of the vortex generator 20 is a temperature between the temperature of the vortex generator 20 in embodiment 2 (straight line E in Fig. 8) and the temperature of each of the vortex generating units of the conventional heat exchanger (straight line D in Fig. 8). That is, in the air-conditioning apparatus 100 according to embodiment 2, when the heat exchanger 10 is used as the evaporator, frost is not easily formed on the vortex generator 20, as compared with that of embodiment 1. Thus, in the air-conditioning apparatus 100 according to embodiment 2, an air flow with vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10 continuously and stably for a longer period than in embodiment 1. Therefore, the heat exchange performance of the heat exchanger 10 can be further improved.

[0059] The air-conditioning apparatus 100 according to embodiment 2 includes spacers 40 which are provided between the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20, and are formed independent of the heat transfer fin 11 and the vortex generator 20. To be more specific, the spaces 41 are provided between the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20 by interposing the spacers 40 between the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20. It is preferable that the spacers 40 be made of material such as a resin, which have a lower thermal conductivity than those of the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20. It should be noted that that the number and shapes of the spacers 40 are not particularly limited.

[0060] The width L of each of the spaces 41 can be more easily managed because the spaces 41 are provided by interposing the spacers 40 between the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20. To be more specific, the dimension of each of the spaces 41 can be prevented from differing from a set value due to, for example, an error in provision of the heat exchanger 10 and the vortex generator 20. Furthermore, the width L of each of the spaces 41 between the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20 is accurately set, whereby an air flow disturbed in a desired state by the vortex generator 20 can be supplied to the heat exchanger 10. Thus, the heat exchange performance of the heat exchanger 10 can be further improved.

[0061] Further, when the heat exchanger 10 is used as the evaporator, the cooling of the vortex generator 20 by the heat transfer fins 11 is reduced via the spacers 40, since the spacers 40 are made of material having a lower thermal conductivity than those of the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20. Therefore, frost is not easily formed on the vortex generator 20 as compared with embodiment 1 even if the heat transfer fins 11 are thermally connected to the vortex generator 20 via the spacers 40, as compared with embodiment 1. Thus, in the air-conditioning apparatus 100 according to embodiment 2, an air flow with vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10 continuously and stably for a longer time period than in embodiment 1. Accordingly, the heat exchange performance of the heat exchanger 10 can be further improved.

[0062] It should be noted that as illustrated in Fig. 9, each of the spacers 40 may be formed integral with the vortex generator 20. For example, end portions of the bases 21 in the vortex generator 20 that are closer to the heat exchanger 10 may be partially projected toward the heat exchanger 10, and be used as the spacers 40. Furthermore, for example, as illustrated in Fig. 10, the spacers 40 may be formed integral with the respective heat transfer fins 11 of the heat exchanger 10. That is, end portions of the heat transfer fins 11 that are located closer to the vortex generator 20 may be partially projected toward the heat exchanger 10, and used as the spacers 40.

[0063] Fig. 9 is a side view illustrating another example of the vortex generator 20 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention. Fig. 10 is a side view illustrating another example of the heat exchanger 10 of the air-conditioning apparatus 100 according to embodiment 2 of the present invention.

[0064] Even in the case where the spacers 40 are formed as illustrated in Fig. 9 or 10, the width L of each of the spaces 41 between the heat transfer fins 11 of the heat exchanger 10 and the vortex generator 20 can be set accurately. Thus, an air flow disturbed in a desired state by the vortex generator 20 can be supplied to the heat exchanger 10, thus further improving the heat exchange performance of the heat exchanger 10. Furthermore, in the case where the spacers 40 are formed as illustrated in Fig. 9 or 10, the heat transfer fins 11 of the heat exchanger 10 are in contact with the vortex generator 20 at locations corresponding to the spacers 40. The contact area between each of the heat transfer fins 11 and the vector generator 20 is smaller than that in embodiment 1. Therefore, in the case where the heat exchanger 10 is used as the evaporator, the vortex generator 20 is not easily cooled by the heat transfer fins 11 of the heat exchanger 10, as compared with embodiment 1. That is, frost is not easily formed on the vortex generator 20. Thus, in the air-conditioning apparatus 100 according to embodiment 2, even in the case where the spacers 40 are formed as illustrated in Fig. 9 or Fig. 10, an air flow with vortexes generated at the vortex generator 20 can be supplied to the heat exchanger 10 continuously and stably for a longer time period than in embodiment 1. Accordingly, the heat exchange performance of the heat exchanger 10 can be further improved.

Embodiment 3

[0065] As described above, various types of fans such as a propeller fan, a cross-flow fan, a sirocco fan and a turbofan can be used as the fan 30 which sends air to the heat exchanger 10 and the vortex generator 20 as described above with respect to embodiments 1 and 2. In this case, more stable vortexes can be generated at the vortex generator 20 by sending a comparatively regulated air flow to the vortex generator 20, and as a result the heat exchange performance of the heat exchanger 10 can be improved. In view of this point, with respect to embodiment 3, an example of a preferred arrangement of the heat exchanger 10 and the vortex generator 20, which varies in accordance with the type of the fan 30, will be described. It should be noted that with respect to embodiment 3, matters which are not particularly described are the same as or similar to those of embodiment 1 or 2, and functions and components which are identical to those of embodiment 1 or 2 will be denoted by the same reference signs.

[0066] Fig. 11 is a side view illustrating an example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention. It should be noted that an outlined arrow in Fig. 11 indicates the flow direction of air from the fan 30.

[0067] The air-conditioning apparatus 100 as illustrated in Fig. 11 employs a propeller fan 31 as the fan 30. An air flow on an outlet side of the propeller fan 31 flows while swirling about a rotation axis of the propeller fan 31. On the other hand, an air flow on an inlet side of the propeller fan 31 is regulated, as compared with the air flow on the outlet side. Therefore, in the case where the propeller fan 31 is employed as the fan 30, it is preferable that the propeller fan 31 be provided downstream of the heat exchanger 10 in the flow direction of air from the propeller fan 31. By providing the propeller fan 31 in this manner, a comparatively regulated air flow can be supplied to the vortex generator 20, as a result of which stable vortexes can be generated at the vortex generator 20, and the heat exchange performance of the heat exchanger 10 can be improved.

[0068] Fig. 12 is a view additionally illustrating a velocity distribution of an air flow flowing to the vortex generator 20 in the air-conditioning apparatus 100 as illustrated in Fig. 11. By providing the propeller fan 31 downstream of the heat exchanger 10 in the flow direction of air from the propeller fan 31, a comparatively regulated air flow can be supplied to the vortex generator 20. However, the velocity of the flow of air flowing to the vortex generator 20 varies from one location to another in the vortex generator 20. Specifically, the velocity of an air flow, that is, an air velocity, is lower at an area of the vortex generator 20 where an air flow to be sucked toward the outer periphery of the propeller fan 31 passes than at an area of the vortex generator 20 where an air flow to be sucked toward the center of the propeller fan 31 passes. Furthermore, a vortex is not easily generated in the area where the air velocity is low, as compared with in the area where the air velocity is higher than that of the area where the air velocity is low. That is, the number of generated vortexes is small in an air flow which passes through the area of the vortex generator 20 where the air velocity is low, and in an area of the heat exchanger 10 where the above air flow passes, the heat exchange performance is decreased, as compared with an area of the heat exchanger 10 where an air flow passes at a high velocity.

[0069] In view of the above, as illustrated in Fig. 12, a large number of protrusions 22 may be provided in a given area of the vortex generator 20 than in an area where the air velocity is higher than that at the given area. By virtue of this configuration, vortexes equivalent to vortexes which can be generated even in the area of the vortex generator 20 where the air velocity is high can be generated in the area of the vortex generator 20 where the air velocity is low. Thus, the heat exchange performance of the heat exchanger 10 can be further improved. It should be noted that in the case where the vortex generator 20 is formed of wires 23 as illustrated in Fig. 6, it is appropriate that a larger number of wires 23 are provided in a given area of the vortex generator 20 than in an area where the air velocity is higher than that at the given area. By virtue of this configuration, vortexes equivalent to vortexes which can be generated at the area of the vortex generator 20 where the air velocity is high can be generated even in the area of the vortex generator 20 where the air velocity is low. Thus, the heat exchange performance of the heat exchanger 10 can be further improved.

[0070] Fig. 13 is a side view illustrating another example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention. It should be noted that outlined arrows in Fig. 13 indicate flow directions of air which is sent by the fan 30.

[0071] The air-conditioning apparatus 100 as illustrated in Fig. 13 employs a cross-flow fan 32 as the fan 30. Specifically, the air-conditioning apparatus 100 as illustrated in Fig. 13 includes a housing 50 having an air outlet 51. The cross-flow fan 32 is provided in the housing 50 in such a way as to cover a region located above the air outlet 51. When the cross-flow fan 32 located in such a manner is rotated, air is taken from an upper portion of the cross-flow fan 32, and is blown out of a lower portion of the cross-flow fan 32 toward the air outlet 51. In this case, an air flow on an inlet side of the cross-flow fan 32 is regulated comparatively. Therefore, in the case where the cross-flow fan 32 is employed as the fan 30, it is preferable that the cross-flow fan 32 be provided downstream of the cross-flow fan 32 in the flow direction of air from the cross-flow fan 32. Because of provision of the cross-flow fan 32 in this manner, a comparatively regulated air flow can be supplied to the vortex generator 20, as a result of which stable vortexes can be generated at the vortex generator 20, and the heat exchange performance of the heat exchanger 10 can thus be improved.

[0072] In the case where the cross-flow fan 32 is employed as the fan 30, the velocity of an air flow which flows to the vortex generator 20 varies from one location to another at the vertex generator 20. Therefore, also in the air-conditioning apparatus 100 as illustrated in Fig. 13, it is preferable that a larger number of protrusions 22 or wires 23 be provided in a given area of the vortex generator 20 than in an area where the air velocity is higher than at this given area. Thereby, vortexes equivalent to vortexes which can be generated at the area of the vortex generator 20 where the air velocity is high can be generated even in the area of the vortex generator 20 where the air velocity is low, and the heat exchange performance of the heat exchanger 10 can thus be further improved.

[0073] Fig. 14 is a plan view illustrating a further example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention. Fig. 15 is a side view of the air-conditioning apparatus 100 illustrated in Fig. 14. It should be noted that outlined arrows in Figs. 14 and 15 indicate flow directions of the air which is sent by the fan 30. Furthermore, Figs. 14 and 15 each illustrate a cross section of a casing 52 in which a sirocco fan 33 is provided.

[0074] The air-conditioning apparatus 100 as illustrated in Figs. 14 and 15 employs the sirocco fan 33 as the fan 30. Specifically, in the air-conditioning apparatus 100 as illustrated in Figs. 14 and 15, the sirocco fan 33 is provided in, for example, the casing 52. In a lower surface of the casing 52, an air inlet 53 is formed at a position where the air inlet 53 faces a rotation shaft of the sirocco fan 33. Also, in a side surface of the casing 52, an air outlet 54 is formed to face an outer peripheral surface of the sirocco fan 33. When the sirocco fan 33 is rotated, air is sucked into the casing 52 through the air inlet 53, and is blown out of the casing 52 through the air outlet 54. At this time, an air flow on an outlet side of the sirocco fan 33 is regulated comparatively. Therefore, in the case where the sirocco fan 33 is employed as the fan 30, it is preferable that the sirocco fan 33 be located upstream of the vortex generator 20 in the flow direction of air which is sent by the sirocco fan 33. By providing the sirocco fan 33 in this manner, a comparatively regulated air flow can be supplied to the vortex generator 20, and stable vortexes can thus be generated at the vortex generator 20. Therefore, the heat exchange performance of the heat exchanger 10 can be improved.

[0075] Also, in the case where the sirocco fan 33 is employed as the fan 30, the velocity of an air flow flowing to the vortex generator 20 varies from one location to another at the vortex generator 20. Therefore, also in the air-conditioning apparatus 100 as illustrated in Figs. 14 and 15, it is preferable that a larger number of protrusions 22 or wires 23 be provided in a given area of the vortex generator 20 than in an area where the air velocity is higher than that at the given area. Thereby, vortexes equivalent to vortexes which can be generated at the area of the vortex generator 20 where the air velocity is high can be generated even in the area of the vortex generator 20 where the air velocity is low. Therefore, the heat exchange performance of the heat exchanger 10 can be further improved.

[0076] Fig. 16 is a plan view illustrating still another example of the air-conditioning apparatus 100 according to embodiment 3 of the present invention. Fig. 17 is a side view of the air-conditioning apparatus 100 as illustrated in Fig. 16. It should be noted that outlined arrows in Figs. 16 and 17 indicate flow directions of air from the fan 30.

[0077] The air-conditioning apparatus 100 as illustrated in Fig. 16 and Fig. 17 employs a turbofan 34 as the fan 30. When the turbofan 34 is rotated, the turbofan 34 takes in air in a rotation axial direction of the turbofan 34. Further, the turbofan 34 sends air toward the outer periphery of the turbofan 34. At this time, an air flow on an outlet side of the turbofan 34 is regulated comparatively. Therefore, in the case where the turbofan 34 is employed as the fan 30, it is preferable that the turbofan 34 be located upstream of the vortex generator 20 in the flow direction of air which is sent by the turbofan 34. Therefore, in the air-conditioning apparatus 100 as illustrated in Figs. 16 and 17, the vortex generator 20 is provided to surround the outer periphery of the turbofan 34. Further, the heat exchanger 10 is provided to surround the outer periphery of the vortex generator 20. By providing the turbofan 34 in this manner, a comparatively regulated flow of air can be supplied to the vortex generator 20, and stable vortexes can thus be generated at the vortex generator 20. Thus, the heat exchange performance of the heat exchanger 10 can be improved.

[0078] Also, in the case where the turbofan 34 is employed as the fan 30, the velocity of an air flow flowing to the vortex generator 20 varies from one location to another at the vortex generator 20. Therefore, also in the air-conditioning apparatus 100 as illustrated in Figs. 16 and 17, it is preferable that a larger number of protrusions 22 or wires 23 be provided in a given area of the vortex generator 20 than in an area where the air velocity is higher than that at the given area. Thus, vortexes equivalent to vortexes which can be generated in the area of the vortex generator 20 where the air velocity is high can be generated even in the area of the vortex generator 20 where the air velocity is low. Therefore, the heat exchange performance of the heat exchanger 10 can be further improved.

Embodiment 4

[0079] In each of the air-conditioning apparatuses 100 according to embodiments 1 to 3, one heat exchanger 10 and one vortex generator 20 are arranged in the flow direction of air which is sent by the fan 30. However, the arrangement of these components is not limited to such arrangement. As described below with respect to embodiment 4, a plurality of heat exchangers 10 and a plurality of vortex generators 20 may be arranged in the flow direction of air from the fan 30 in each of the air-conditioning apparatuses 100 according to embodiments 1 to 3. It should be noted that in embodiment 4, matters which are not particularly described are the same as or similar to those of embodiment 1, and functions and components which are identical to those of embodiment 1 will be denoted by the same reference signs.

[0080] Fig. 18 is a side view illustrating an example of arrangement of the heat exchangers 10 and the vortex generators 20 of the air-conditioning apparatus 100 according to embodiment 4 of the present invention. It should be noted that in Fig. 18, the flow direction of air which is sent by the fan 30 is indicated by solid arrows. Also, Fig. 18 schematically shows vortexes indicated by scroll patterns are generated on a downstream side of the vortex generator 20.

[0081] In embodiment 4, a plurality of groups each consisting of one heat exchanger 10 and one vortex generator 20 are arranged in a row in the flow direction of air which is sent by the fan 30. That is, in each group consisting of a heat exchanger 10 and a vortex generator 20, the vortex generator 20 is located upstream of the heat exchanger 10.

[0082] Referring to Fig. 18, a single group consisting of a heat exchanger 10 and a vortex generator 20 is defined as a heat exchange portion, and a heat exchange portion 80A and a heat exchange portion 80B are arranged in this order from a windward side. In the following description, the heat exchange portions are collectively referred to as a heat exchange unit 80.

[0083] The flow of air in the heat exchange unit 80 will be described.

[0084] When the fan 30 is rotated, air is sent to the heat exchange unit 80. The air is first supplied to the heat exchange portion 80A. In the heat exchange portion 80A, the air sent by the fan 30 passes through the vortex generator 20 before flowing into the heat exchanger 10. In the vortex generator 20, vortexes are generated in the flow of air by the functions of protrusions 22. That is, the flow of air sent by the fan 30 is converted into a vortex flow.

[0085] The flow of air converted into the vortex flow is supplied to the heat exchange portion 80B after passing through the heat exchanger 10 of the heat exchange portion 80A. When air which passes through the heat exchange portion 80A passes through the heat exchanger 10, it is regulated, and the vortex flow shrinks or disappears. In this case, there is a possibility that in the heat exchange portion 80B, improvement in the heat exchange performance by the vortex generator 20 cannot be achieved. In view of this point, in the heat exchange portion 80B as well, the vortex generator 20 is provided upstream of the heat exchanger 10, and air flowing from the heat exchange portion 80A is converted into a vortex flow by the vortex generator 20.

[0086] Since the above operation is performed by the entire heat exchange unit 80, improvement of the heat exchange performance by the vortex generators 20 can be promoted by the entire heat exchange unit 80. That is, even in the case where the heat exchange unit 80 is configured that a plurality of heat exchange portions each including a combination of a heat exchanger 10 and a vortex generator 20 are arranged in a row, it is possible to improve the heat exchange performance because the vortex generators 20 are provided in the respective heat exchange portions, that is, respective groups.

[0087] Fig. 19 is a side view illustrating another example of arrangement of the heat exchangers 10 and the vortex generators 20 of the air-conditioning apparatus 100 according to embodiment 4 of the present invention.

[0088] Referring to Fig. 19, one group consisting of a heat exchanger 10 and a vortex generator 20 is defined as a heat exchange portion, and a heat exchange portion 80A, a heat exchange portion 80B ... and a heat exchange portion 80N are arranged in this order from a windward side. That is, three or more groups of heat exchange portions each including a heat exchanger 10 and a vortex generator 20 may be provided. To be more specific, three or more heat exchange portions each including a heat exchanger 10 and a vortex generator 20 may be arranged in a row in the flow direction of air which is sent by the fan 30.

[0089] As illustrated in Fig. 19, even in the case where the heat exchange unit 80 includes three or more heat exchange portions, in each of the heat exchange portions, the vortex generator 20 is located upstream of the heat exchanger 10, as a result of which the heat exchange performance of the entire heat exchange unit 80 can be improved by the vortex generators 20.

[0090] Incidentally, in each of all the heat exchange portions, in the case where spaces 41 each having the width L is provided between the heat exchanger 10 and the vortex generator 20 as described with respect to embodiment 2, the widths L in all the heat exchange portions may be set to the same value, or the widths L in all the heat exchange portions may be set such that the closer the heat exchange portion to the downstream side, the greater (or smaller) the width L in the heat exchange portion. That is, the widths L in all the heat exchange portions may be set equal to or different from each other, or the widths L in some of all the heat exchange portions may be set equal to each other.

[0091] Further, it is not indispensable that in the heat exchange unit 80, all the vortex generators 20 are located upstream of the respective heat exchangers 10. It suffices that at least two of the vortex generator 20 are located upstream of respective at least two of the heat exchangers 10.

Reference Signs List

[0092] 1 compressor 2 heat exchanger 2a fan 3 expansion device 4 flow switching device 10 heat exchanger 11 heat transfer fin 12 heat transfer tube 20 vortex generator 21 base 22 protrusion 23 (23a, 23b) wire 30 fan 31 propeller fan 32 cross-flow fan 33 sirocco fan 34 turbofan 40 spacer 41 space 50 housing 51 air outlet 52 casing 53 air inlet 54 air outlet 80 heat exchange unit 80A heat exchange portion 80B heat exchange portion 80N heat exchange portion 100 air-conditioning apparatus 101 outdoor unit 102 indoor unit

Claims

1. A refrigeration cycle apparatus comprising:

an evaporator including heat transfer tubes through which refrigerant flows, and heat transfer fins connected to the heat transfer tubes, the evaporator being configured to cool air with the refrigerant;
a fan configured to supply the air to the evaporator; and
a vortex generator formed independently of the evaporator, and provided upstream of the evaporator in a flow direction of the air.

2. The refrigeration cycle apparatus of claim 1, wherein spaces are provided between the heat transfer fins of the evaporator and the vortex generator.

3. The refrigeration cycle apparatus of claim 2, further comprising spacers between the heat transfer fins of the evaporator and the vortex generator.

4. The refrigeration cycle apparatus of claim 3, wherein the spacers are formed independently of the evaporator and the vortex generator.

5. The refrigeration cycle apparatus of claim 3, wherein the spacers are formed integrally with the vortex generator or the heat transfer fins of the evaporator.

6. The refrigeration cycle apparatus of any one of claims 1 to 5, wherein the heat transfer fins have no cut and raised pieces.

7. The refrigeration cycle apparatus of any one of claims 1 to 6, wherein a plurality of heat exchange portions are provided in a row in the flow direction of the air, and each of the heat exchange portions includes a combination of the evaporator and the vortex generator.

8. The refrigeration cycle apparatus of any one of claims 1 to 7,
wherein the fan is a propeller fan, and
wherein the propeller fan is provided downstream of the evaporator in the flow direction of the air.

9. The refrigeration cycle apparatus of any one of claims 1 to 7,
wherein the fan is a cross-flow fan, and
wherein the cross-flow fan is provided downstream of the evaporator in the flow direction of the air.

10. The refrigeration cycle apparatus of any one of claims 1 to 7,
wherein the fan is a sirocco fan, and
wherein the sirocco fan is provided upstream of the vortex generator in the flow direction of the air.

11. The refrigeration cycle apparatus of any one of claims 1 to 7,
wherein the fan is a turbofan, and
wherein the turbofan is provided upstream of the vortex generator in the flow direction of the air.

12. The refrigeration cycle apparatus of any one of claims 1 to 11, wherein the vortex generator includes bases each including a plurality of protrusions.

13. The refrigeration cycle apparatus of claim 12, wherein part of the vortex generator includes a larger number of protrusions included in the protrusions of the bases than another part of the vortex generator where an air velocity is higher than that at the part of the vortex generator.

14. The refrigeration cycle apparatus of any one of claims 1 to 11, wherein the vortex generator includes a plurality of wires disposed at predetermined intervals.

15. The refrigeration cycle apparatus of claim 14, wherein part of the vortex generator includes a larger number of wires of the plurality of wires than another part of the vortex generator at which an air velocity is higher than at the part of the vortex generator.

FIG. 1

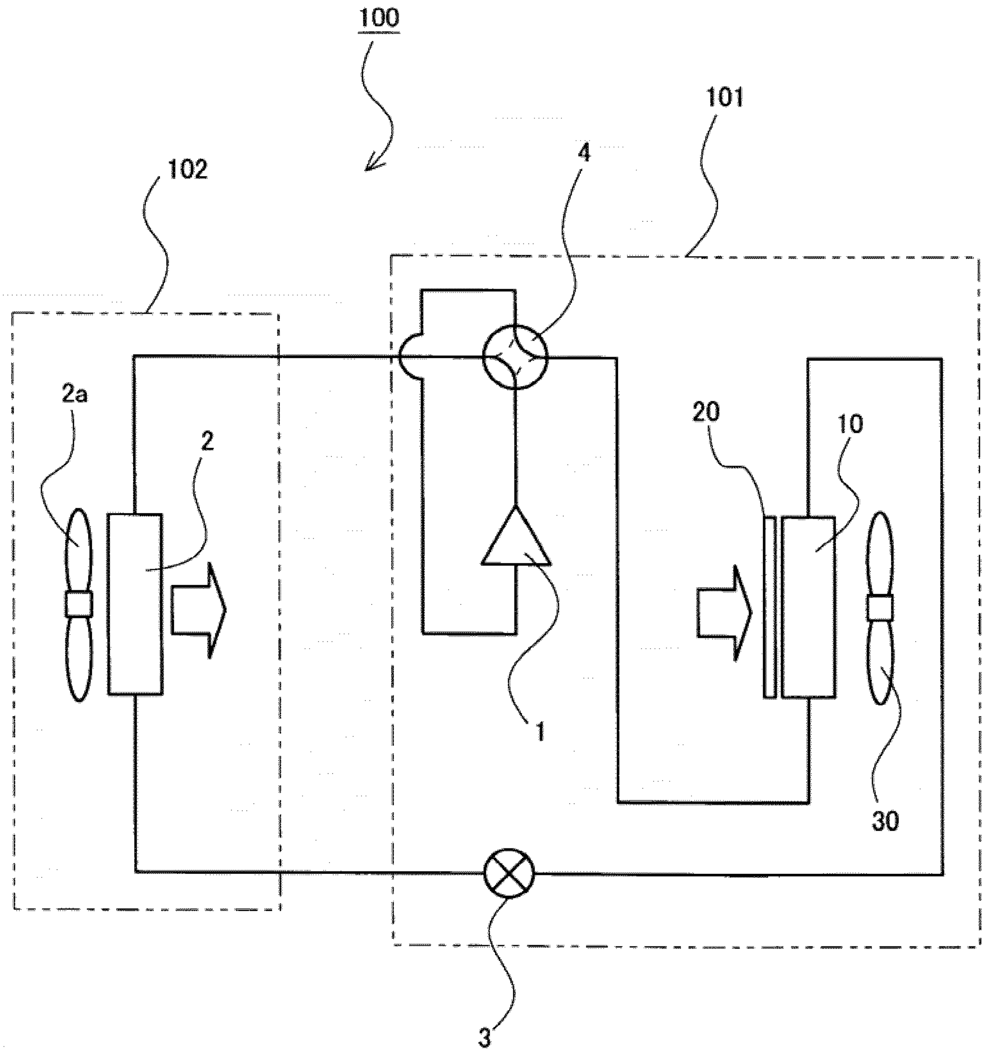


FIG. 2

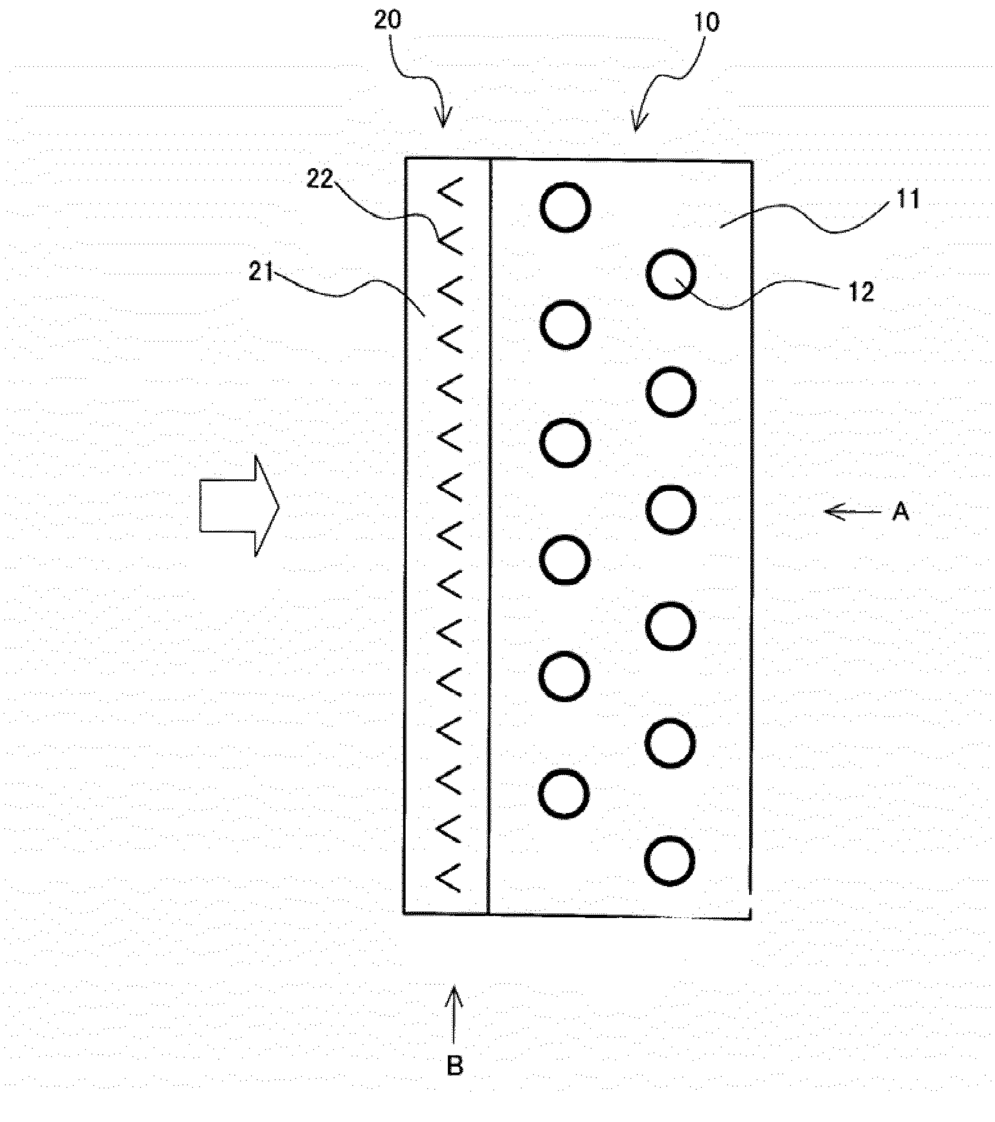


FIG. 3

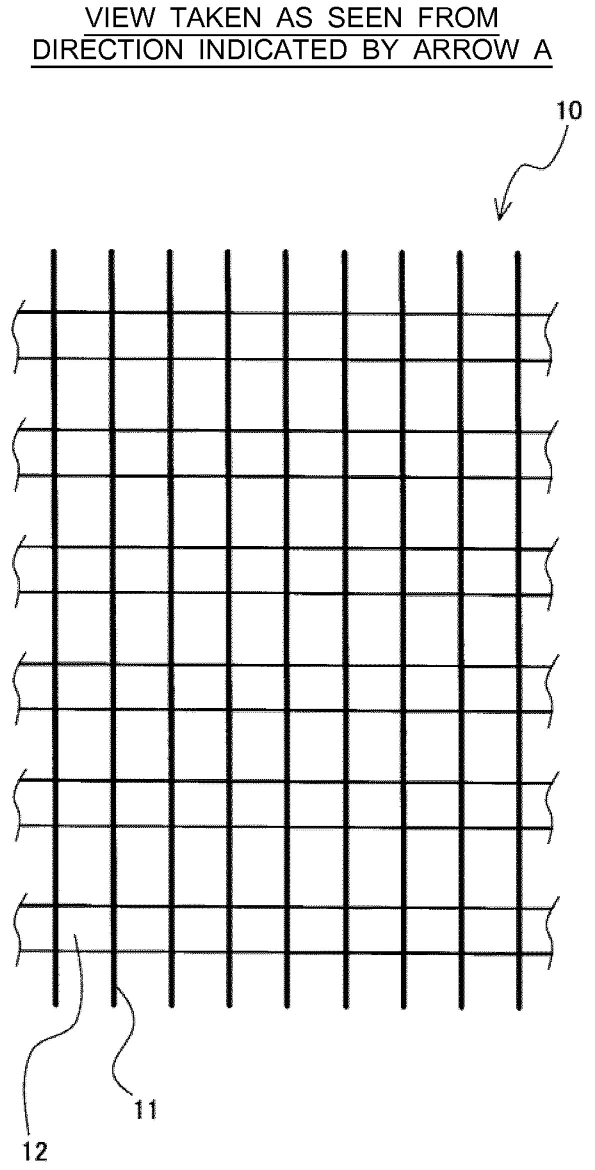
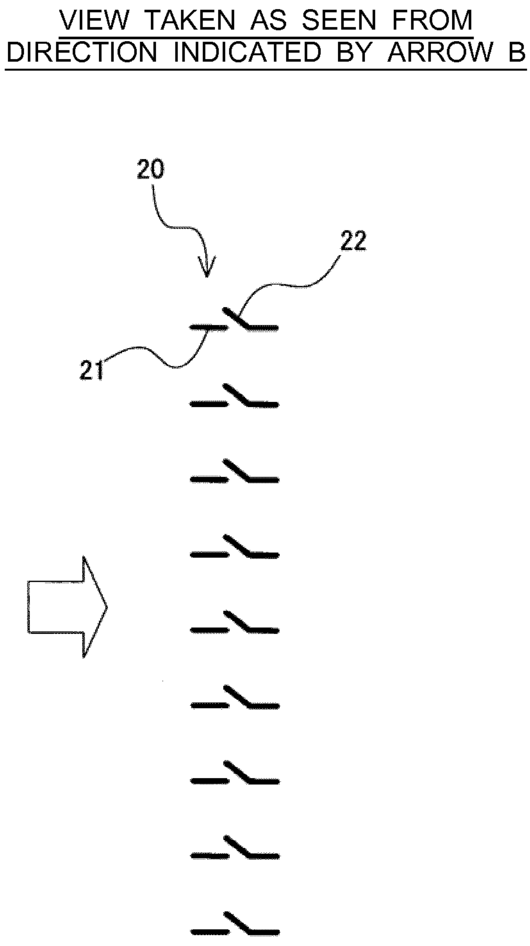

VIEW TAKEN AS SEEN FROM
DIRECTION INDICATED BY ARROW A
10
11
12

FIG. 4


VIEW TAKEN AS SEEN FROM
DIRECTION INDICATED BY ARROW B
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22
21

FIG. 5

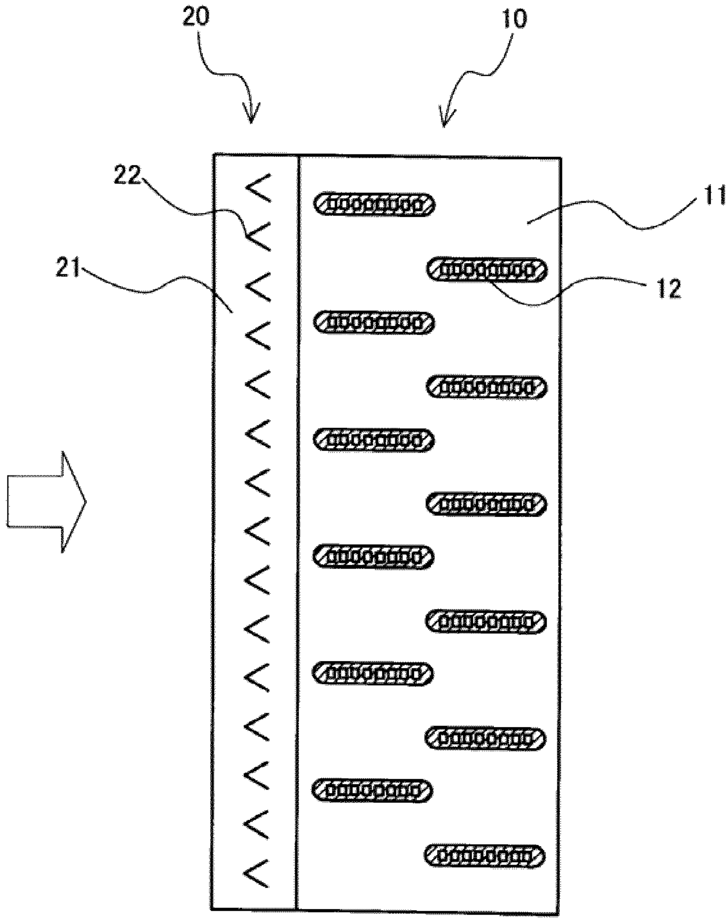


FIG. 6

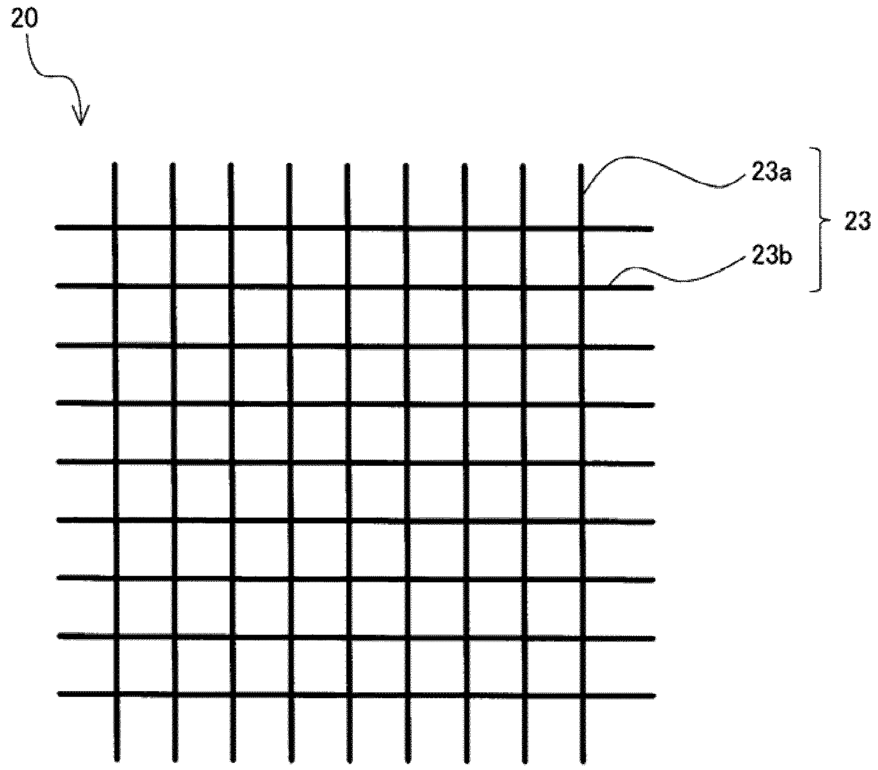


FIG. 7

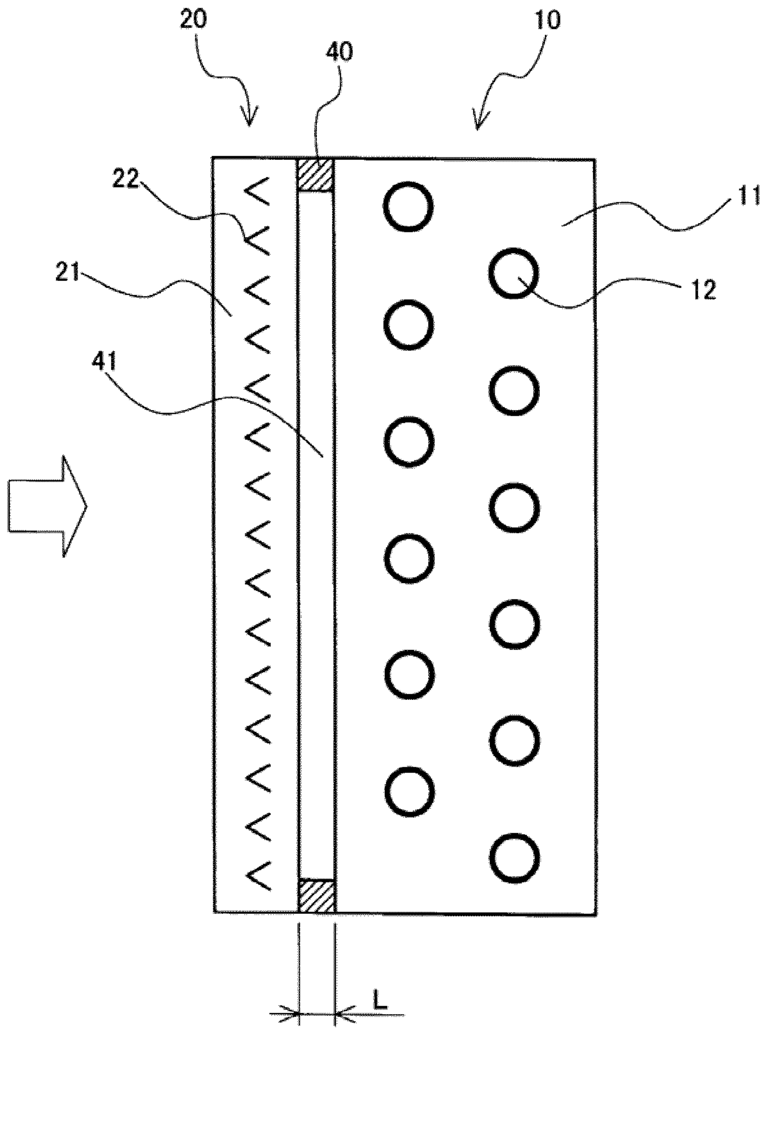
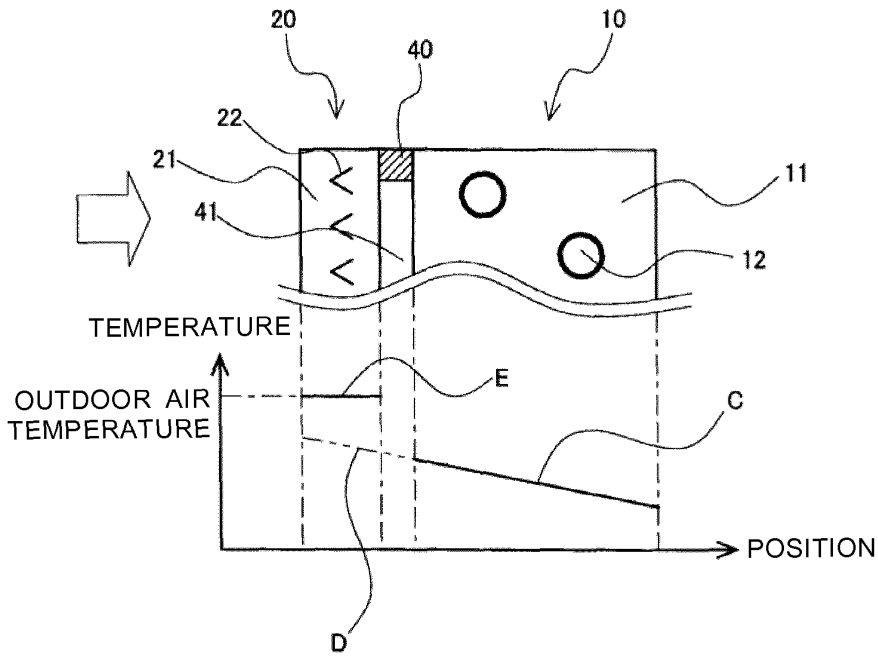


FIG. 8


20
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22
21
11
41
12
TEMPERATURE
E
OUTDOOR AIR
TEMPERATURE
C
POSITION
D

FIG. 9

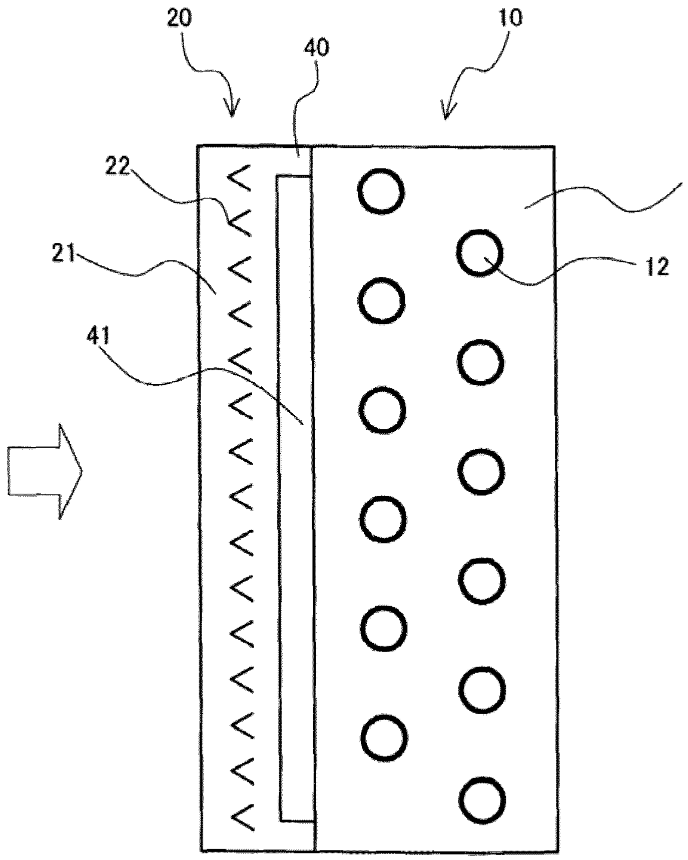
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FIG. 10

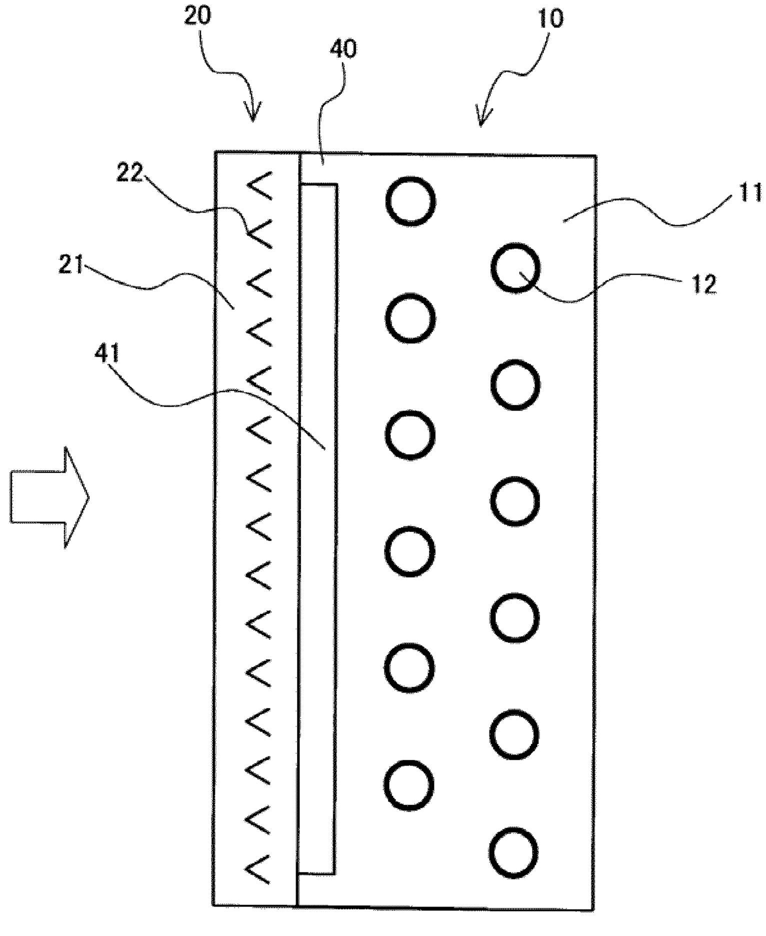


FIG. 11

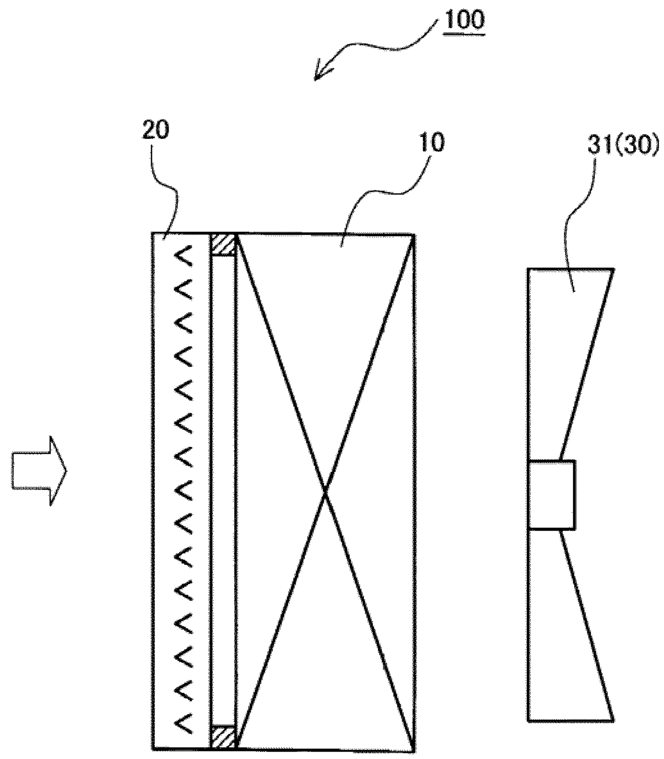


FIG. 12

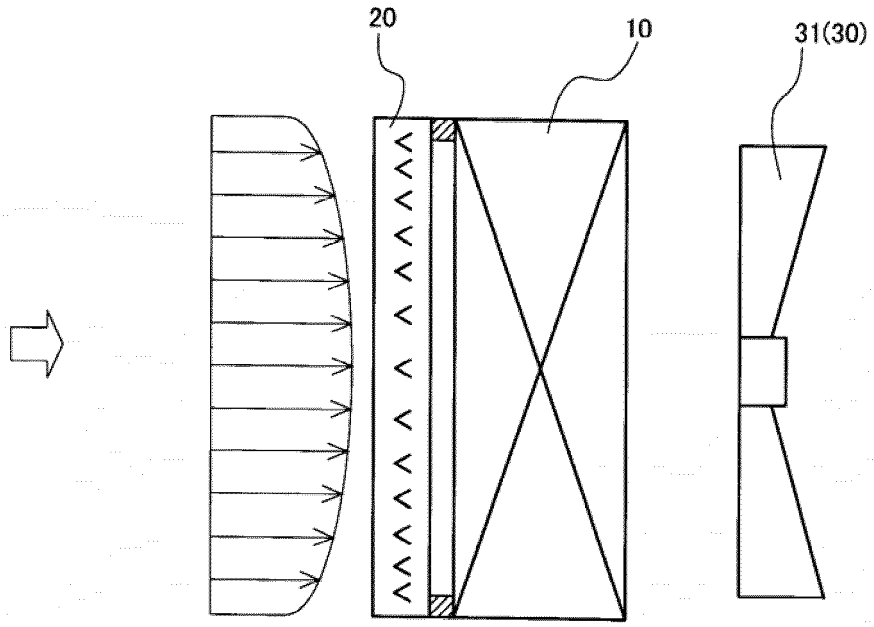


FIG. 13

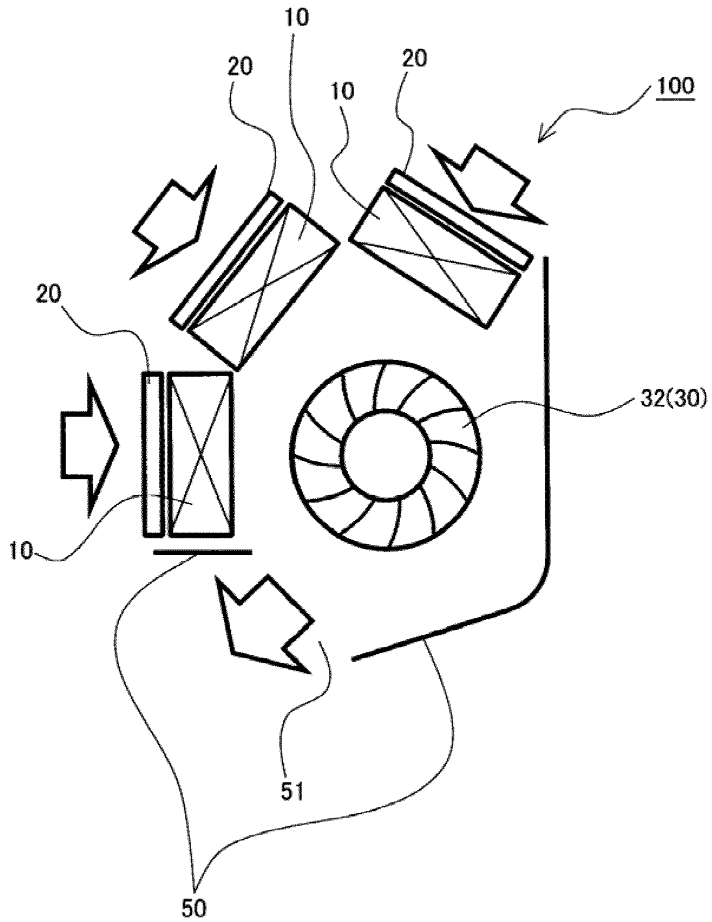


FIG. 14

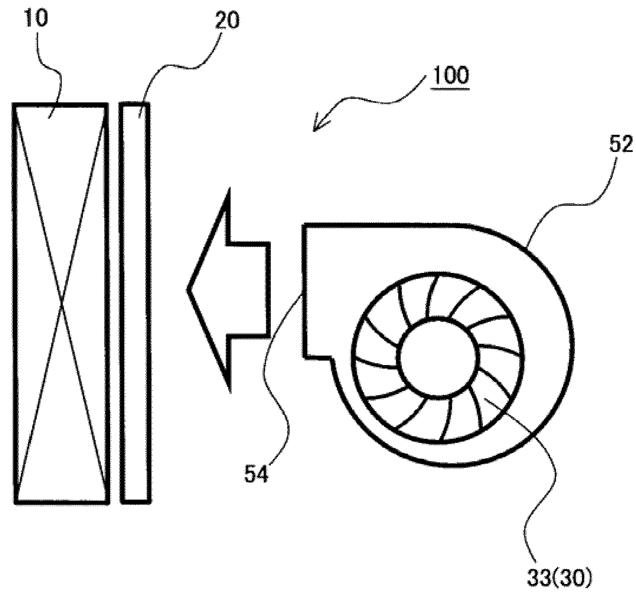


FIG. 15

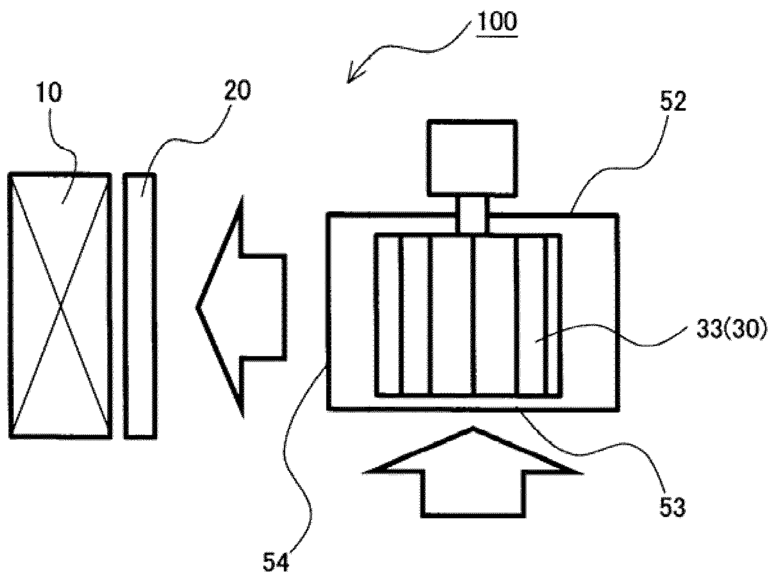


FIG. 16

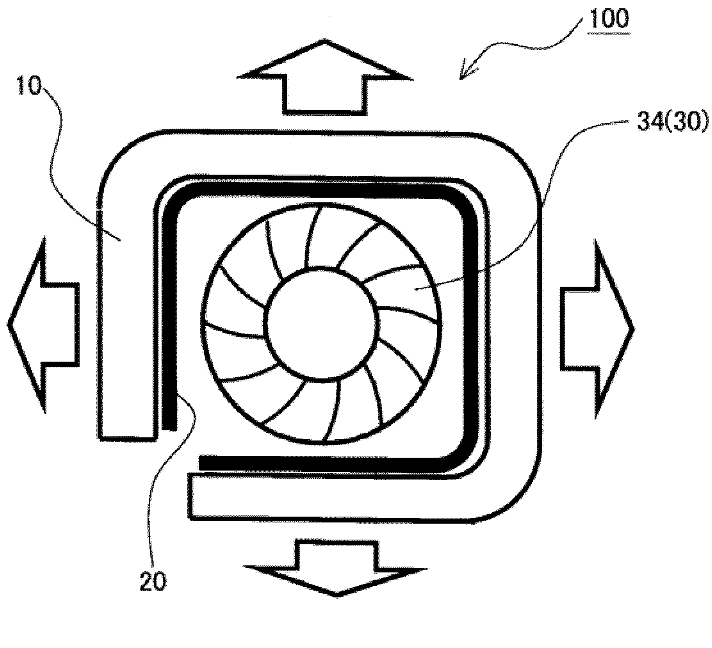


FIG. 17

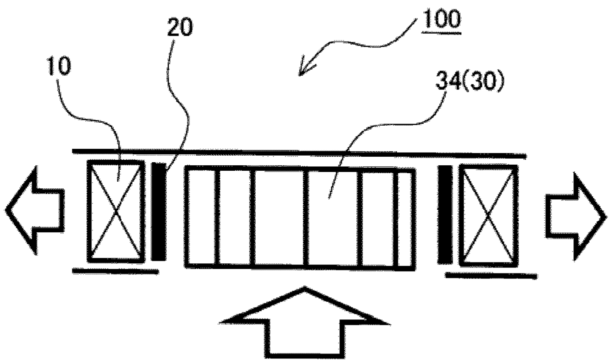


FIG. 18

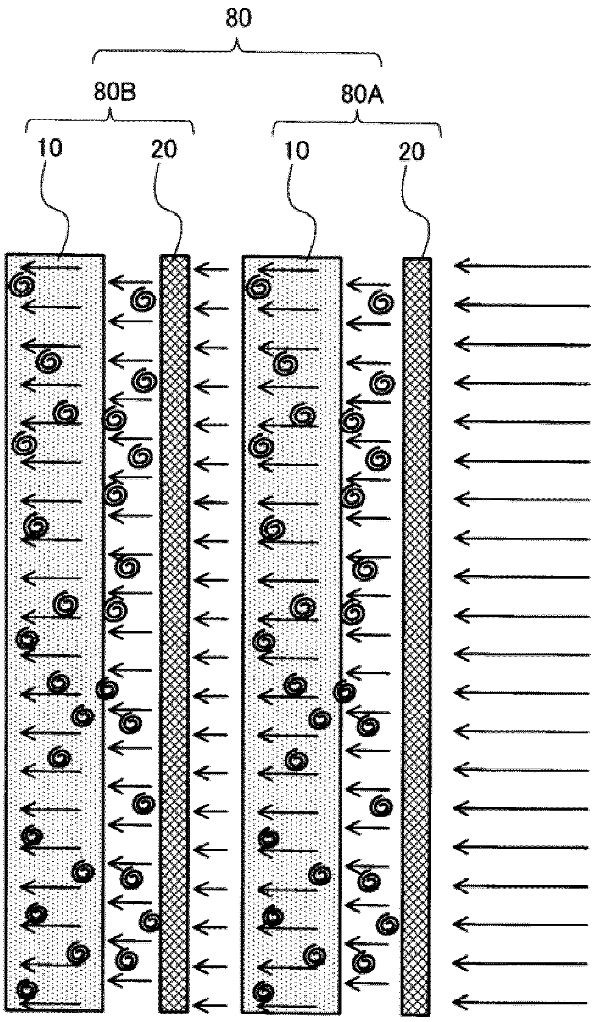
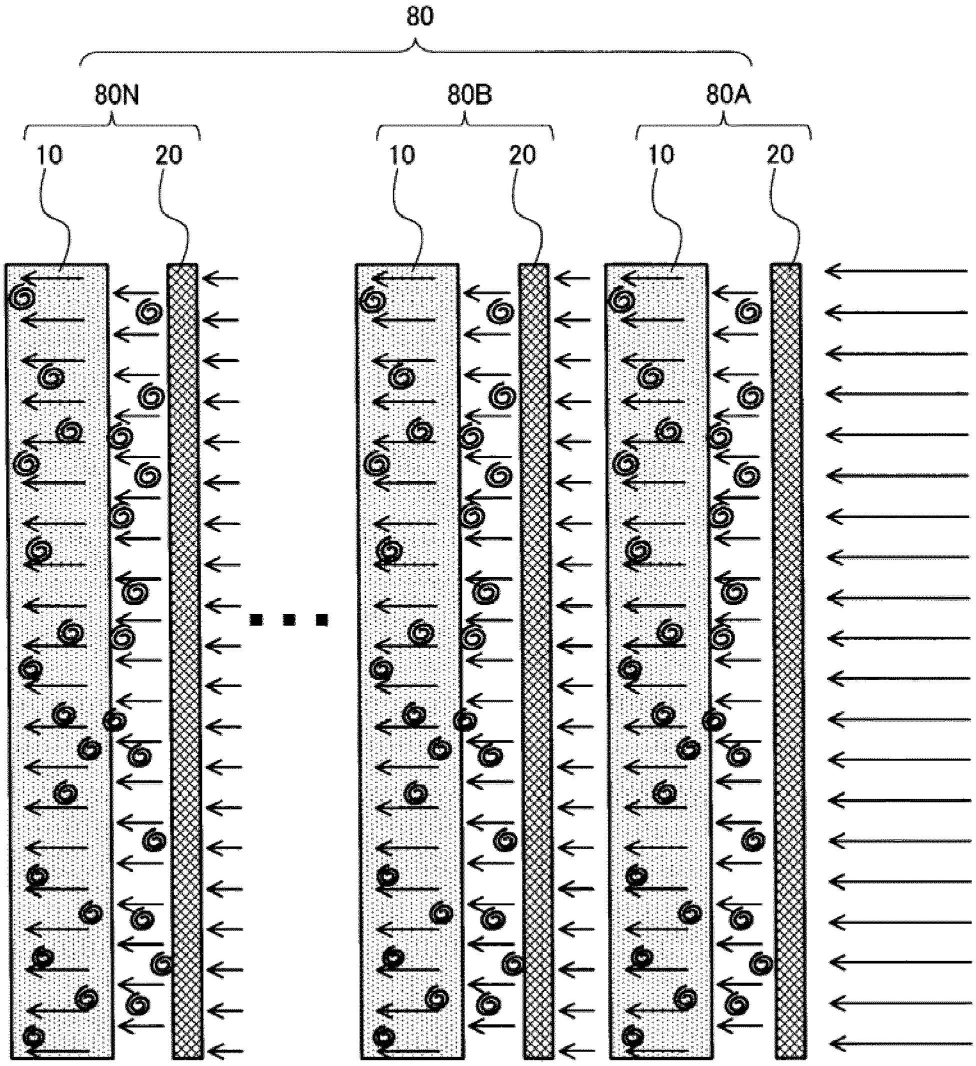


FIG. 19



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/079514

A. CLASSIFICATION OF SUBJECT MATTER
F28F13/12(2006.01)i, *F25B1/00*(2006.01)i, *F25B39/02*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F28F13/12, F25B1/00, F25B39/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
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.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 053863/1978(Laid-open No. 152363/1979) (Mitsubishi Electric Corp.), 23 October 1979 (23.10.1979), specification, page 3, line 19 to page 5, line 9; fig. 2 (Family: none)	1-15
Y	JP 2002-195675 A (Toshiba Carrier Corp.), 10 July 2002 (10.07.2002), paragraphs [0019] to [0026]; fig. 1 (Family: none)	1-15

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2016 (15.12.16)	27 December 2016 (27.12.16)

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/079514

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 57-134698 A (Tokyo Shibaura Electric Co., Ltd.), 19 August 1982 (19.08.1982), page 1, lower left column, line 19 to page 2, lower right column, line 3; fig. 1 to 4 (Family: none)	1-15
Y	JP 59-095391 A (Matsushita Electric Industrial Co., Ltd.), 01 June 1984 (01.06.1984), page 2, upper right column, lines 2 to 19; fig. 4 to 6 (Family: none)	1-15
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 139925/1978(Laid-open No. 056366/1980) (Tokyo Shibaura Electric Co., Ltd.), 16 April 1980 (16.04.1980), specification, page 5, lines 2 to 4; fig. 3 (Family: none)	7
Y	JP 2007-040611 A (Denso Corp.), 15 February 2007 (15.02.2007), paragraph [0025]; fig. 1 & CN 1908554 A	7
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 061284/1982(Laid-open No. 165570/1983) (Hitachi, Ltd.), 04 November 1983 (04.11.1983), specification, page 1, line 13 to page 2, line 5; fig. 1 (Family: none)	8
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 064688/1982(Laid-open No. 167824/1983) (Sanyo Electric Co., Ltd.), 09 November 1983 (09.11.1983), specification, page 4, lines 2 to 7; fig. 2 (Family: none)	9
Y	JP 2013-019596 A (Mitsubishi Electric Corp.), 31 January 2013 (31.01.2013), paragraphs [0028] to [0031]; fig. 6 to 7 (Family: none)	10-11

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/079514

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 152688/1977(Laid-open No. 079047/1979) (Mitsubishi Heavy Industries, Ltd.), 05 June 1979 (05.06.1979), specification, page 2, line 10 to page 3, line 2; fig. 1, 3 (Family: none)	13,15

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP HEI11108575 B **[0004]**