

DESCRIPTION

TITLE OF THE INVENTION: REFRIGERATOR

TECHNICAL FIELD

[0001] The present invention relates to a refrigerator including a cooling device.

BACKGROUND ART

[0002] The following refrigerator has been known. A cooling device (heat exchanger) is mounted on a back side of a partition formed of a wall of a freezer compartment and a wall of a refrigerator compartment, and a fan provided in an air pathway sends air cooled by the cooling device to each of the freezer compartment and the refrigerator compartment. In such a refrigerator, the cold air whose temperature is increased due to a thermal load in each compartment is caused to return to the cooling device so that the cold air circulates in the air pathway inside the refrigerator.

[0003] In the related-art refrigerator as described above, the surface temperature of the cooling device decreases to about -25°C. Therefore, when the cooling device exchanges heat with the cold air returning from each compartment and containing water vapor, frost is formed on the surface of the cooling device.

[0004] As compared to the freezer compartment, the refrigerator compartment is generally opened and closed at a higher frequency. Therefore, as compared to the cold air returning from

the freezer compartment, the cold air returning from the refrigerator compartment tends to contain a larger amount of moisture due to entry of outside air containing a large amount of moisture. The cold air returning from the refrigerator compartment contains a large amount of moisture and has a large temperature difference from the cooling device, and is thus a main cause of frost formation. When frost is formed, an air pathway resistance of the cooling device is increased. Thus, performance reduction or other adverse effects may be caused, and the energy consumption may be increased.

[0005] The cooling device disclosed in Patent Literature 1 has an object to suppress reduction in performance and improving resistance to frost formation of the cooling device described above, and includes a first cooling section located on a back surface side of the cooling device and a second cooling section located on a front surface side of the cooling device and adjacent to the first cooling section. The first cooling section is formed of flat tubes without a fin. The second cooling section is formed of a refrigerant pipe having a large number of fins. The cold air returning from the refrigerator compartment and containing a large amount of moisture is caused to pass through the first cooling section without the fin to exchange heat in the first cooling section. In this manner, it is intended to suppress occurrence of clogging due to frost formation.

[0006] The cooling device disclosed in Patent Literature 2 has

an object to suppress reduction in performance and improving resistance to frost formation of the cooling device described above, and is configured such that a fin pitch in a lower part of the cooling device is smaller than a fin pitch in an upper part in a height direction of the cooling device. With use of this configuration, it is intended to promote the frost formation concentratedly in the lower part of the cooling device so that the upper part of the cooling device may be effectively used.

CITATION LIST

PATENT LITERATURE

[0007] [PTL 1] JP 2014-20736 A

[PTL 2] JP 2008-202823 A

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0008] The cooling device disclosed in Patent Literature 1 uses the flat tubes. The flat tubes generally have high manufacturing cost, and power for a compressor may be increased (energy consumption may be increased) along with increase in pressure loss on a refrigerant side. Therefore, there are problems toward practical use.

[0009] In the cooling device disclosed in Patent Literature 2, when the frost formation concentrates on the lower part of the cooling device, obstruction may be caused due to the frost

formation, and the air pathway resistance may be increased for the air returning from the lower side of the cooling device. Therefore, the air flow of the entire refrigerator may be reduced. Thus, the cooling device performance may be reduced, and the energy consumption may be increased.

[0010] The present invention has been made in order to solve the above-mentioned problems, and has an object to provide a refrigerator in which a frost resistance of a cooling device is improved.

MEANS FOR SOLVING THE PROBLEM

[0011] According to one embodiment of the present invention, there is provided a refrigerator including: a refrigerator compartment; a freezer compartment; a cooling device compartment including a cooling device configured to cool refrigerator compartment air sent from the refrigerator compartment and freezer compartment air sent from the freezer compartment; and a circulation fan configured to send cooled air cooled by the cooling device to the refrigerator compartment and the freezer compartment, the cooling device compartment further including: a pre-cooling device arranged on an upstream side of the cooling device and configured to perform dehumidification; a defrost heater configured to heat the pre-cooling device; a freezer compartment return port formed at a position at which the freezer compartment air sent from the freezer compartment to the cooling device compartment directly

flows toward the cooling device; and a refrigerator compartment return port formed at a position at which the refrigerator compartment air sent from the refrigerator compartment to the cooling device compartment flows toward the pre-cooling device.

EFFECTS OF THE INVENTION

[0012] According to the refrigerator of the present invention, the air discharged through the freezer compartment return port and the air discharged through the refrigerator compartment return port flow separately. The air returning from the refrigerator compartment and containing a large amount of moisture is dehumidified by the pre-cooling device and then cooled by the cooling device. Thus, the frost resistance of the cooling device is significantly improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a front view of a refrigerator according to Embodiment 1 of the present invention.

FIG. 2 is a sectional view of the refrigerator according to Embodiment 1 of the present invention.

FIG. 3 is a refrigerant circuit diagram of the refrigerator according to Embodiment 1 of the present invention.

FIG. 4 is a schematic structural view of a cooling device compartment in Embodiment 1 of the present invention.

FIG. 5 is a partially enlarged sectional view of a freezer

compartment return port in Embodiment 1 of the present invention.

FIG. 6 are partially enlarged sectional views of an outlet port and a return port in Embodiment 1 of the present invention.

FIG. 7 are front views of the cooling device compartment in which a width of a refrigerator compartment return port is increased to a width of a pre-cooling device in Embodiment 1 of the present invention.

FIG. 8 are schematic views for illustrating a radiant heater and a heater roof in Embodiment 1 of the present invention.

FIG. 9 is a sectional view of a dimensionless water-vapor density distribution of the cooling device compartment, which is obtained through analysis.

FIG. 10 is a schematic structural view of the cooling device compartment in which a vertical dimension of the freezer compartment return port is increased in Embodiment 1 of the present invention.

FIG. 11 is an explanatory diagram of short cycle evaluation results depending on the vertical dimension of the freezer compartment return port.

FIG. 12 is a sectional view of the dimensionless water-vapor density distribution of the cooling device compartment in which the vertical dimension of the freezer compartment return port is increased, which is obtained through analysis.

FIG. 13 is a schematic structural view of a cooling device compartment in Embodiment 2 of the present invention.

FIG. 14 is a sectional view of a cooling device compartment

in Embodiment 3 of the present invention.

FIG. 15 is a front view of a cooling device compartment in Embodiment 4 of the present invention.

FIG. 16 is a schematic view for illustrating a dehumidification capacity testing device in a pre-cooling device 10.

FIG. 17 is a bar graph for showing a dehumidification capacity ratio of a pre-cooling device of Embodiments 1 to 4 to that of Comparative Example 1.

DESCRIPTION OF EMBODIMENTS

[0014] Now, details of refrigerators according to embodiments of the present invention are described with reference to the accompanying drawings. The embodiments described below are merely examples, and the present invention is not limited to those embodiments.

[0015] Embodiment 1

<Overall Configuration of Refrigerator>

FIG. 1 is a front view of a refrigerator 100 according to Embodiment 1 of the present invention. As illustrated in FIG. 1, the refrigerator 100 includes a refrigerator compartment 1 located in an uppermost part and a vegetable compartment 5 located in a lowermost part. The refrigerator 100 further includes a freezer compartment 4 located above the vegetable compartment 5, and, between the freezer compartment 4 and the refrigerator compartment

1, a convertible compartment 2 located on a right side as viewed from the front and an ice making compartment 3 located on a left side as viewed from the front.

[0016] In the example illustrated in FIG. 1, a door portion 6 of the refrigerator compartment 1 is constructed of a double door of a side-by-side type (French type), but the door portion 6 of the refrigerator compartment 1 is not particularly limited thereto, and may be constructed of a single door of a single-swing type.

[0017] <Outline of Cooling Inside Refrigerator>

FIG. 2 is a sectional view of the refrigerator 100 according to Embodiment 1 of the present invention. FIG. 2 is a sectional view of the inside of the refrigerator 100 as viewed from the lateral side. The inside of the refrigerator is insulated from the outside (outside air) of the refrigerator by the door portion 6 of each compartment and a heat-insulating wall 7.

[0018] The refrigerator 100 separately includes a compartment for refrigerating and a compartment for freezing. The refrigerator 100 further includes a cooling device 9 configured to cool air sent from each compartment, a circulation fan 8 configured to send the cooled air cooled by the cooling device 9 to each compartment, a pre-cooling device 10 located below the cooling device 9, a radiant heater 24 configured to heat and remove frost formed on the pre-cooling device 10, and a compressor 12 located at a lowermost portion of a back surface of the refrigerator 100. The cooling device 9, the pre-cooling device 10, and the radiant heater 24 are

accommodated in a cooling device compartment 200 mounted on the back surface side of the freezer compartment 4 or the like.

[0019] The cooled air cooled by the cooling device 9 is sent to each compartment by the circulation fan 8 to contribute to maintenance of low temperature inside the refrigerator. After that, the cooled air sent to each compartment is caused to return to the cooling device 9 from each compartment so as to be cooled, and thus the cooled air is circulated inside the refrigerator. Further, in the cooling device compartment 200, the air flows from the lower side to the upper side of the cooling device 9. The air cooled in the cooling device compartment 200 passes through a duct so as to be supplied through an outlet port to each compartment.

[0020] When the door portion 6 is opened and closed, outside air containing a large amount of moisture may enter the inner side of the door portion 6. As compared to the freezer compartment 4, the refrigerator compartment 1 is generally opened and closed at a higher frequency by a user. Therefore, as compared to the cold air returning from the freezer compartment 4, the cold air returning from the refrigerator compartment 1 may contain a larger amount of moisture. Therefore, when the refrigerator 100 is operated for a long period of time, and the cooling device 9 exchanges heat with the cold air returning from the refrigerator compartment 1 and containing a large amount of moisture, frost may be formed on the surface of the cooling device 9.

[0021] In the refrigerator 100 according to Embodiment 1, the

pre-cooling device 10 is arranged below the cooling device 9, and the cold air returning from the refrigerator compartment 1 exchanges heat with the pre-cooling device 10 ahead of the cooling device 9. With use of this configuration, frost is formed on the pre-cooling device 10 ahead of the cooling device 9, and thus the frost resistance of the cooling device 9 is improved. Further, the frost formed on the cooling device 9 and the frost formed on the pre-cooling device 10 are removed regularly by the radiant heater 24. With this configuration, reduction in performance of the refrigerator 100 due to frost formation is suppressed. Further, a place in the cooling device compartment 200 to which the air returns from the refrigerator compartment 1 and a place in the cooling device compartment 200 to which the air returns from the freezer compartment 4 are separated so that almost only the air returning from the refrigerator compartment 1 is dehumidified by the pre-cooling device 10.

[0022] The compressor 12 located at the lowermost portion of the back surface of the refrigerator 100 is a component for constructing a refrigeration cycle of the refrigerator 100, and has a function of compressing refrigerant.

[0023] <Refrigerant Circuit>

FIG. 3 is a refrigerant circuit diagram of the refrigerator 100 according to Embodiment 1 of the present invention. As illustrated in FIG. 3, the refrigerator 100 includes the compressor 12, a pipe group 13, an expansion device 14, the pre-cooling device

10, and the cooling device 9 as the refrigerant circuit.

[0024] The compressor 12 adiabatically compresses the refrigerant of, for example, isobutene to obtain high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant flows into the pipe group 13 embedded in the heat-insulating wall 7 of a refrigerator casing so that the refrigerant rejects heat in the pipe group 13 to transition to liquid refrigerant. After that, the liquid refrigerant is expanded by the expansion device 14, for example, a capillary tube, to thereby transition to two-phase gas-liquid refrigerant. The expanded low-temperature two-phase gas-liquid refrigerant passes through the cooling device 9 and the pre-cooling device 10, and thus exchanges heat with air 15 returning from each compartment in the refrigerator. With the heat exchange, the two-phase gas-liquid refrigerant receives heat of the returning air 15 to transition to a gas, and then returns to the compressor 12. The air whose temperature is decreased through heat removal by the cooling device 9 and the pre-cooling device 10 is sent to each compartment by the circulation fan 8. As described above, the refrigerant circuit of the refrigerator 100 performs a cooling operation of circulating the air inside the refrigerator to cool the air.

[0025] <Outline of Structure of Cooling Device Compartment>

FIG. 4 a schematic structural view of the cooling device compartment 200 in Embodiment 1 of the present invention. FIG. 4 (a) is a front view, and FIG. 4 (b) is a sectional view taken along

the line A-A' of FIG. 4 (a). FIG. 4 (b) is a view of the A-A' cross section of FIG. 4 (a) as viewed from the right side to the left side of the drawing sheet. The cooling device compartment 200 refers to a part that accommodates the circulation fan 8, the cooling device 9, the pre-cooling device 10, and the radiant heater 24.

[0026] <Cooling Device>

As illustrated in FIG. 4, the cooling device 9 includes a plurality of fins 16 and a plurality of refrigerant pipes 17. In order to increase the heat transfer area to improve the cooling performance, the plurality of fins 16 are stacked so that an interval between one fin 16 and another fin 16 has a constant fin pitch. In consideration of quality with respect to, for example, clogging between the fins (increase in air pathway resistance) due to frost formation, the fin pitch is desired to fall within a range of 5 mm or more and 10 mm or less. For example, in an air flowing direction in which the air flows, frost is formed more notably on the upstream side of the cooling device 9 as compared to the downstream side of the cooling device 9. The amount of moisture contained in the returning air 15 is reduced as the air flows to the downstream side because frost is formed due to heat exchange with the fins 16. Therefore, the fin pitch on the upstream side may be set wider. For example, the fin pitch on the downstream side may be 5 mm, and the fin pitch on the upstream side may be 7.5 mm or more and 10 mm or less.

[0027] The fin pitch of the cooling device 9 is not

particularly limited as long as the fin pitch is within a range that does not depart from the gist of the present invention. The fin pitch may be changed as appropriate, for example, both the upstream side and the downstream side may have a constant fin pitch of 5 mm. The shape of the fin 16 is also not particularly limited. A plate fin, a corrugated fin, a louver fin, a slit fin, or other fins can be used.

[0028] <Pre-cooling Device>

As illustrated in FIG. 4, similarly to the cooling device 9, the pre-cooling device 10 includes a plurality of fins 16 and a plurality of refrigerant pipes 17. Similarly to the cooling device 9, the plurality of fins 16 of the pre-cooling device 10 are stacked so that an interval between one fin 16 and another fin 16 has a constant fin pitch. The pre-cooling device 10 is arranged on the upstream side of the cooling device 9 in the air flowing direction. Therefore, frost is formed more notably on the pre-cooling device 10 as compared to the cooling device 9. Therefore, the fin pitch of the pre-cooling device 10 is larger than the fin pitch (5 mm or more and 10 mm or less) of the cooling device 9. The fin pitch of the pre-cooling device 10 is desired to fall within a range of, for example, 10 mm or more and 15 mm or less. The fin pitch of the pre-cooling device 10 is not particularly limited as long as the fin pitch is within a range that does not depart from the gist of the present invention, and can be changed as appropriate. Further, the shape of the fin 16 of the pre-cooling device 10 is also not

particularly limited, and a plate fin, a corrugated fin, a louver fin, a slit fin, or other fins can be used. It is preferred that the cooling device 9 and the pre-cooling device 10 be mounted with a slight interval therebetween. Air flows from the lower side to the upper side in the cooling device compartment 200, and hence it is preferred that the pre-cooling device 10 be mounted below the cooling device 9 with a slight distance, for example.

Further, the fin shape of the pre-cooling device 10 may be changed as appropriate. For example, the fin inclination angle may be changed along the flow of refrigerator compartment air 23, the fin may have a rhombic lower end to promote a leading edge effect, or the fin may have a sharp lower end so that water smoothly drops when the frost is removed.

[0029] <Frost Removing Device>

The refrigerator 100 includes, as a frost removing device, in addition to the radiant heater 24 arranged below the cooling device 9 and used for frost removal, a plurality of electric heating-wire heaters, that is, cord heaters 18 that are brought into close contact with the fins 16 of the cooling device 9. The radiant heater 24 is configured to heat the pre-cooling device 10 by radiation heat, and may be mounted to have a slight interval with respect to the pre-cooling device 10 as illustrated in FIG. 4 (b). The cord heaters 18 are arranged on the front surface side and the back surface side of the cooling device 9. Further, each of the cord heaters 18 is inserted between the fins 16 of the cooling

device 9 so as to be brought into close contact with the fins 16, to thereby heat the fins 16 mainly by heat conduction.

<Arrangement of Pre-cooling Device and Frost Removing Device>

The pre-cooling device 10 is arranged in parallel to the radiant heater 24 serving as a defrost heater in a horizontal direction, and is arranged on the back surface side of the cooling device compartment 200. This is because the refrigerator compartment air 23 mainly flows on the back surface side of the cooling device compartment 200, and this arrangement is optimal for removing moisture contained in the refrigerator compartment air 23. The pre-cooling device 10 is desired to be arranged in accordance with the passage of the flow of the refrigerator compartment air 23. For example, when the refrigerator compartment air 23 mainly flows on the front side of the cooling device compartment 200, the pre-cooling device 10 is arranged on the front side of the cooling device compartment, and the radiant heater 24 serving as the defrost heater is arranged on the back surface side.

Further, the pre-cooling device 10 and the radiant heater 24 are arranged in parallel in the horizontal direction. As a result, when the pre-cooling device 10 is obstructed due to frost formation, the refrigerator compartment air 23 flows to a space secured on the radiant heater 24 side. Thus, reduction in volume of the refrigerator compartment air 23 can be suppressed.

[0030] The refrigerator 100 causes the radiant heater 24 and the cord heater 18 to simultaneously generate heat, to thereby melt

the frost adhering on the cooling device 9 and the pre-cooling device 10.

[0031] When the frost is removed, water dropping off from the cooling device 9 may hit the radiant heater 24. Therefore, a heater roof 25 is arranged above the radiant heater 24 so as to prevent a situation in which the water dropping off from the cooling device 9 directly hits the radiant heater 24. The water dropping off from the cooling device 9 and the pre-cooling device 10 is received by a drain pan 26 located at a lower portion of the cooling device compartment 200, and is discharged through a drainage conduit 27.

[0032] <Arrangement of Freezer Compartment Return Port and Refrigerator Compartment Return Port>

In the refrigerator 100 according to Embodiment 1 of the present invention, as illustrated in FIG. 4, a lower edge of an inlet (freezer compartment-side end portion) of a freezer compartment return port 20 is formed above a lower end of the cooling device 9, and a refrigerator compartment return port 22 is formed below the inlet lower end of the freezer compartment return port 20. Further, an outlet port 28 for sending the air cooled by the cooling device 9 and the air cooled by the pre-cooling device 10 to each compartment is arranged at a position across the freezer compartment return port 20 with respect to the refrigerator compartment return port 22. The freezer compartment return port 20 is formed at a position at which air from the freezer compartment 4 directly flows to the lower end of the cooling device 9. Further,

the refrigerator compartment return port 22 is formed at a position at which air from the refrigerator compartment 1 first flows toward the pre-cooling device 10 and then flows toward the cooling device 9. For example, when the pre-cooling device 10 is arranged on the back surface side of the cooling device compartment 200, the refrigerator compartment return port 22 is preferred to be formed so that the refrigerator compartment air 23 flows from the front side of the cooling device compartment 200 in order to send the refrigerator compartment air 23 to the back surface side.

[0033] FIG. 5 is a partially enlarged sectional view of the freezer compartment return port 20 in Embodiment 1 of the present invention. In an inflow portion of the freezer compartment return port 20, as illustrated in FIG. 5, a plurality of airflow control ribs 29 are provided for the purpose of preventing direct contact of a hand or a finger, or preventing entry of the stock in the freezer compartment 4 to the cooling device compartment 200. The pitch of the plurality of airflow control ribs 29 is set so that a constant interval is obtained.

[0034] The shape, the pitch, and the angle of the airflow control rib 29 can be changed as appropriate as long as the shape, the pitch, and the angle are within ranges that do not depart from the above-mentioned purpose. Further, the freezer compartment return port 20 is desired to have an inclination angle from the freezer compartment 4 side to the cooling device compartment 200 in order to prevent a situation in which water generated during

frost removal drops off from the cooling device 9 to enter the inside of the compartment. The inclination angle is desired to be from 5° to 20° in view of the balance with the increase in pressure drop in the air pathway. In the above, the inlet lower edge of the freezer compartment return port 20 is formed above the lower end of the cooling device 9. As long as the freezer compartment 4 side is formed above the lower end of the cooling device 9 as illustrated in FIG. 4 (b), the outlet side, that is, the cooling device compartment 200 side may be formed slightly below the lower end of the cooling device 9. Further, the inclination of the freezer compartment return port 20 is an inclination declining from the freezer compartment 4 side to the cooling device compartment 200 side. A smooth inclination is superior and desired in terms of water discharge, but the inclination may have a small step.

[0035] When the freezer compartment return port 20 has the above-mentioned inclination angle, freezer compartment air 21 discharged through the freezer compartment return port 20 flows slightly downward to the lower end portion of the cooling device 9, and then flows to the upper side of the cooling device 9 by the circulation fan 8. Therefore, an air curtain of the freezer compartment air 21 is generated at a front portion of the lower end of the cooling device 9. The generated air curtain can prevent a situation in which the refrigerator compartment air 23 discharged through the refrigerator compartment return port 22 enters the front-side lower end portion of the cooling device 9, and the

refrigerator compartment air 23 having no place to go flows toward the pre-cooling device 10 located below the cooling device 9 on the back surface side.

[0036] The arrangement difference in the height direction of the freezer compartment return port 20 and the refrigerator compartment return port 22 generates an air curtain effect of the freezer compartment air 21 discharged through the freezer compartment return port 20, to thereby prevent a situation in which the refrigerator compartment air 23 discharged through the refrigerator compartment return port 22 enters the front-side lower end of the cooling device 9. Therefore, the freezer compartment air 21 flows through a freezer compartment air flow passage 111 (FIG. 9) formed on the front surface side of the cooling device 9, and the refrigerator compartment air 23 flows through a refrigerator compartment air flow passage 112 (FIG. 9) formed at a position opposed to the freezer compartment air flow passage 111 with respect to the cooling device 9, that is, the refrigerator compartment air flow passage 112 formed on the back surface side of the pre-cooling device 10 and the cooling device 9. In this manner, the freezer compartment air 21 and the refrigerator compartment air 23 in the cooling device compartment 200 can flow separately. In order to obtain such an air curtain effect, the air flow is desired to be increased to some extent. For example, it is preferred that the air flow of the freezer compartment air 21 discharged through the freezer compartment return port 20 be larger

than the air flow of the refrigerator compartment air 23 discharged through the refrigerator compartment return port 22 because the air curtain effect can be enhanced.

[0037] <Freezer Compartment Short-cycle Suppression Mechanism>

When a distance between the lower edge of the outlet port 28 and the upper edge of the freezer compartment return port 20 is reduced, the temperature of the freezer compartment 4 may rise due to the short cycle of the freezer compartment air 21. The short cycle here refers to a phenomenon in which the cooled air blown out through the outlet port 28 flows directly to the freezer compartment return port 20 without circulating inside the compartment. When the short cycle occurs, for example, a cooling time (compressor operation time) may be extended, the cooling efficiency may be degraded, and the energy consumption may be increased.

[0038] FIG. 6 is a partially enlarged sectional views of the outlet port 28 and the return port 20 in Embodiment 1 of the present invention. FIG. 6 is an illustration of an example of a suppression mechanism configured to suppress the short cycle in the freezer compartment 4.

[0039] As illustrated in FIG. 6, on the lower side of the outlet port 28 and the upper side of the freezer compartment return port 20, that is, between the outlet port 28 and the freezer compartment return port 20, there are arranged the airflow control rib 29

provided in the vicinity of the outlet port 28 and the airflow control rib 29 provided in the vicinity of the freezer compartment return port 20. Those airflow control ribs 29 have a role of blocking the cooled air blown out through the outlet port 28 from directly flowing toward the freezer compartment return port 20 without circulation due to the short cycle. The outlet port 28 is located above the freezer compartment return port 20, and hence each of the airflow control ribs 29 is desired to be a structure configured to block at least a part of air, if possible, the entire air that flows from the upper side to the lower side along the back surface. The length of the airflow control rib 29 may be set within a range that does not cause interference with a freezer compartment case 30, and is desired to be from 5 mm to 10 mm, for example.

[0040] The arrangement angle of the airflow control rib 29 is not particularly limited. The arrangement angle of the airflow control rib 29 is desired to be from 15° to 30° downward with respect to a horizontal plane as illustrated in FIG. 6 (b) unless there is no restriction in terms of structure.

[0041] The arrangement location of the airflow control rib 29 is not particularly limited. For example, as illustrated in FIG. 6 (c), the airflow control rib 29 may be arranged in a space formed between the freezer compartment case 30 and the compartment wall surface.

[0042] The short-cycle suppression mechanism is not limited to the mounting of the airflow control rib 29. For example, as

illustrated in FIG. 6 (d) or (e), there may be employed a configuration in which one of the outlet port 28 and the freezer compartment return port 20 is extended to the inside of the compartment.

[0043] As the short-cycle suppression mechanism, there is also a method of narrowing the space between the freezer compartment case 30 and the compartment wall surface by forming the compartment wall surface so as to bulge to the freezer compartment 4 side, to thereby increase the air pathway resistance. As illustrated in FIG. 6 (f), the entire surface between the outlet port 28 (FIG. 6-f) and the freezer compartment return port 20 may bulge, or as illustrated in FIG. 6 (g), the outlet port 28 side may bulge in a tapered manner. Further, as illustrated in FIG. 6 (h), the return port 20 side may bulge in a tapered manner, or as illustrated in FIG. 6 (i), the freezer compartment case 30 may extend toward the lower end of the outlet port 28.

[0044] With the short-cycle suppression mechanism as described above, it is possible to suppress the short cycle in which the cooled air blown out through the outlet port 28 directly flows to the freezer compartment return port 20 without circulating inside the compartment, and the cooling efficiency of the freezer compartment 4 can be improved.

[0045] <Width of Refrigerator Compartment Return Port>

In the example illustrated in FIG. 4, the refrigerator compartment return port 22 is partially opened with respect to the

width of the pre-cooling device 10. In this case, the frost formation may start from a part of the pre-cooling device 10 in the vicinity of this opening portion, and a local frost formation distribution may be caused.

[0046] FIG. 7 is a front view of the cooling device compartment 200 in which the width of the refrigerator compartment return port 22 is increased to the width of the pre-cooling device 10 in Embodiment 1 of the present invention. FIG. 7 (a) is a front view of the cooling device compartment 200 in which the width of the refrigerator compartment return port 22 is increased to the width of the pre-cooling device 10, and FIG. 7 (b) is a partial enlarged view of the cooling device compartment 200 in which the width of the refrigerator compartment return port 22 is increased to the width of the pre-cooling device 10. As illustrated in FIG. 7, the width of the refrigerator compartment return port 22 is desired to be increased to be the same as the width of the pre-cooling device 10. This is because, when the width of the refrigerator compartment return port 22 is increased to be equivalent to the width of the pre-cooling device 10, the refrigerator compartment air 23 uniformly flows to the entire pre-cooling device 10. This uniform flow can contribute to a further improvement of the dehumidification capacity of the pre-cooling device 10.

[0047] <Shape of Heater Roof>

FIG. 8 is a schematic view for illustrating the radiant heater 24 and the heater roof 25 in Embodiment 1 of the present invention.

FIG. 8 is an illustration of the semicircular-arc heater roof 25, the flow of the freezer compartment air 21 indicated by the solid line with the arrow, and the flow of the refrigerator compartment air 23 indicated by the broken line with the arrow. As illustrated in FIG. 8, the radiant heater 24 and the heater roof 25 are arranged at positions shifted from the pre-cooling device 10 in the horizontal direction below the pre-cooling device 10. The heater roof 25 is located closer to the freezer compartment return port 20 with respect to the pre-cooling device 10, and is located immediately below the freezer compartment return port 20.

[0048] In order to cause the water that drops due to melting of the frost formed on the cooling device 9 during frost removal to fall into the drain pan 26, the heater roof 25 has a semicircular-arc shape about the radiant heater 24. When the freezer compartment air 21 flows to the front portion of the lower end of the cooling device 9, a small amount of freezer compartment air 21 flows into the pre-cooling device 10 along the heater roof 25. Therefore, as illustrated in FIG. 8 (a), the refrigerator compartment air 23 is pushed to the back surface side of the cooling device 9, and thus is introduced to flow to the lower end portion of the pre-cooling device 10.

[0049] In order to block the freezer compartment air 21 from flowing into the pre-cooling device 10, as illustrated in FIG. 8 (b), the heater roof 25 may have a smooth straight-line shape, that is, a flat shape, and may be inclined from the cooling device 9

to the freezer compartment return port 20 side. Thus, the refrigerator compartment air 23 flows to the entire pre-cooling device 10. This flow can contribute to a further improvement of the dehumidification capacity of the pre-cooling device. The heater roof 25 is desired to have an inclination angle within a range of from 10° to 30°, and to incline in a direction from the pre-cooling device 10 to the freezer compartment return port 20 side.

[0050] <Frost Resistance Improvement Effect>

In order to understand the flow of the freezer compartment air 21 and the flow of the refrigerator compartment air 23 in the air pathway structure of the refrigerator 100 according to Embodiment 1 described above, numerical analysis was performed with a vertical dimension of the freezer compartment return port 20 being set to 28 mm. When the numerical analysis was performed, the freezer compartment return port 20 and the refrigerator compartment return port 22 were set as air flow determinations (actual measurement results), and the exit side of the circulation fan 8 was set to have an external opening static pressure of 0 Pa. Further, in order to trace the flow by schematically expressing the water vapor of the refrigerator compartment air 23 contributing to frost formation, the dimensionless water-vapor density (ratio) of the refrigerator compartment return port 22 was set to 1[-], and the dimensionless water-vapor density (ratio) of the freezer compartment return port 20 was set to 0[-].

[0051] There are two reasons why the dimensionless water-vapor density is set only to the refrigerator compartment air 23. The first reason is that high-temperature and high-humidity outside air more frequently flows into the refrigerator compartment air 23 along with the opening and closing of the door portion 6 as compared to the freezer compartment air 21. The second reason is that the temperature difference between the temperature of the cooling device 9 ($T_{eva} = -23^{\circ}\text{C}$) and the temperature of the refrigerator compartment air 23 ($T_{\text{refrigerator compartment return}} = 0^{\circ}\text{C}$) is 23°C , which is larger than the temperature difference between the temperature of the cooling device 9 and the temperature of the freezer compartment air 21. Thus, the frost formation is liable to be induced onto the surface of the cooling device 9. Because of those two reasons, it is generally considered that the refrigerator compartment air 23 is the main cause of frost formation.

[0052] FIG. 9 is a sectional view of the dimensionless water-vapor density distribution of the cooling device compartment 200, which is obtained through analysis. A region having a black contour represents the freezer compartment air 21, and a region having a white contour represents the refrigerator compartment air 23. In this manner, both of the flows are visualized.

[0053] When the freezer compartment air 21 and the refrigerator compartment air 23 were joined at the inflow portion of the cooling device 9 as illustrated in FIG. 9 (a), the

refrigerator compartment air 23 was less likely to flow to the pre-cooling device 10, and tended to flow preferentially to the front surface side of the cooling device 9. Meanwhile, in the refrigerator 100 according to Embodiment 1, as illustrated in FIG. 9 (b), the refrigerator compartment air 23 tended to flow preferentially to the pre-cooling device 10 and the back surface side of the cooling device 9. That is, it was confirmed that, in the air pathway structure in Embodiment 1, the freezer compartment air 21 flowed through the freezer compartment air flow passage 111 formed on the front surface side of the cooling device 9, the refrigerator compartment air 23 flowed through the pre-cooling device 10 and the refrigerator compartment air flow passage 112 formed on the back surface side of the cooling device 9, and the freezer compartment air 21 and the refrigerator compartment air 23 flowed separately.

[0054] In the refrigerator 100 according to Embodiment 1, the air flow of the freezer compartment air 21 is about four times as large as the air flow of the refrigerator compartment air 23. Therefore, the freezer compartment air 21 plays the role of the air curtain so as to prevent a situation in which the refrigerator compartment air 23 enters the front surface side of the cooling device 9. Thus, the freezer compartment air 21 discharged through the freezer compartment return port 20 and the refrigerator compartment air 23 discharged through the refrigerator compartment return port 22 flow separately.

[0055] The refrigerator compartment air 23 containing a large amount of moisture preferentially flows to the pre-cooling device 10. Thus, as compared to the related-art refrigerator, the refrigerator 100 according to Embodiment 1 can be improved in dehumidification capacity of the pre-cooling device 10, and can be improved in frost resistance of the cooling device 9. Further, with the improvement of the frost resistance of the cooling device 9, it is possible to suppress reduction in cooling performance of the cooling device 9 due to the frost formation. In this manner, the refrigerator 100 according to Embodiment 1 can maintain high cooling performance even when frost is formed.

[0056] <Vertical Dimension of Freezer Compartment Return Port>

FIG. 10 is a schematic structural view of the cooling device compartment 200 in which the vertical dimension of the freezer compartment return port 20 is increased in Embodiment 1 of the present invention. FIG. 10 (a) is a front view of the cooling device compartment 200, and FIG. 10 (b) is a sectional view of the cooling device compartment 200 taken along the line A-A' of FIG. 10 (a). The vertical dimension of the freezer compartment return port 20 is desired to be increased as illustrated in FIG. 10 as compared to the cooling device compartment 200 illustrated in FIG. 4, to thereby increase the opening area of the freezer compartment return port 20. Regarding the specific vertical dimension, the freezer compartment short cycle is required to be considered.

[0057] <Parameter Evaluation of Vertical Dimension of Freezer
Compartment Return Port>

FIG. 11 is an explanatory diagram of short cycle evaluation results depending on the vertical dimension of the freezer compartment return port. In FIG. 11 (a), a testing method for short cycle evaluation is illustrated. The temperatures of the outlet port 28 and the freezer compartment return port 20 when a vertical dimension B of the freezer compartment return port 20 was increased were measured with a thermocouple located at positions illustrated in FIG. 11 (a), and the influence of the short cycle was evaluated based on the temperature difference between the outlet port 28 and the freezer compartment return port 20. The short cycle here refers to a phenomenon in which the blown-out cooled air flows directly to the return port without circulating inside the compartment as described above. Therefore, when the short cycle occurs, the temperature difference between the outlet port 28 and the freezer compartment return port 20 tends to decrease. The airflow control rib 29 is arranged at the lower portion of the outlet port 28 of the freezer compartment 4, and the airflow control rib 29 is arranged also to the upper portion of the freezer compartment return port 20. Thus, the short cycle is suppressed.

[0058] <Conditions of Parameter Evaluation of Vertical
Dimension of Freezer Compartment Return Port>

As the refrigerator, a French-type refrigerator of 600 L was used. As outside air conditions, outside air having a temperature

of 30 °C and a relative humidity of 70% was used. The power consumption during the steady operation was measured simultaneously with the measurement of the temperature. As the vertical dimension of the freezer compartment return port 20, refrigerators having the vertical dimensions of 28 mm, 56 mm, 84 mm, 100 mm, 115 mm, and 130 mm were prepared.

[0059] <Results of Parameter Evaluation of Vertical Dimension of Freezer Compartment Return Port>

In FIG. 11 (b), a relationship among the vertical dimension of the freezer compartment return port 20, the temperature difference between the outlet port 28 and the freezer compartment return port 20, and the power consumption [kWh/d] per day during the steady operation is shown. As shown in FIG. 11 (b), the power consumption was minimum when the vertical dimension was 84 mm. When the vertical dimension was larger than 100 mm, the power consumption had a degradation tendency. The temperature difference between the outlet port 28 and the freezer compartment return port 20 was decreased when the vertical dimension was larger than 100 mm, and the sign of the short cycle was observed. It is considered that, when the vertical dimension is larger than 100 mm, the short cycle is caused to lead to the power consumption degradation. Therefore, considering the adverse effect on the power consumption, the vertical dimension of the freezer compartment return port 20 is desired to be 100 mm or less with the lower end of the cooling device 9 serving as a reference. However, the vertical dimension of the

freezer compartment return port 20 is not particularly limited to 100 mm or less, and may be changed as appropriate within a range that does not depart from the gist of the present invention while considering quality, for example, entry of heat into the compartment during frost removal and fan noise due to rigidity change.

[0060] When the opening area of the freezer compartment return port 20 is increased, the flow rate of the freezer compartment air 21 is decreased. When the wind velocity [m/s] of the freezer compartment air 21 discharged through the freezer compartment return port 20 was calculated with use of the air flow [m³/s] of the freezer compartment 4 (measurement value of actual machine) and the opening area [m²] of the freezer compartment return port 20, it was confirmed that the wind velocity of the freezer compartment air 21 was 1.3 m/s in the refrigerator 100 in which the vertical dimension of the freezer compartment return port 20 was 28 mm, the wind velocity of the freezer compartment air 21 was 0.7 m/s in the refrigerator 100 in which the vertical dimension of the freezer compartment return port 20 was 84 mm, and the wind velocity of the freezer compartment air 21 was reduced by about half when the vertical dimension was increased threefold.

[0061] FIG. 12 is a sectional view of the dimensionless water-vapor density distribution of the cooling device compartment 200 in which the vertical dimension of the freezer compartment return port 20 is increased, which is obtained through analysis. In FIG. 12A, the dimensionless water-vapor density distribution

of the cooling device compartment 200 of the refrigerator 100 in which the vertical dimension of the freezer compartment return port 20 is 28 mm is shown. In FIG. 12B, the dimensionless water-vapor density distribution of the cooling device compartment 200 of the refrigerator 100 in which the vertical dimension of the freezer compartment return port 20 is 84 mm is shown. As illustrated in FIG. 12, when the vertical dimension of the freezer compartment return port 20 is 84 mm, as compared to the case of 28 mm, the dimensionless water-vapor density around the pre-cooling device 10 is increased. When the vertical dimension of the freezer compartment return port 20 is 84 mm, as compared to the case of 28 mm, the wind velocity of the freezer compartment air 21 is decreased. It is considered that the dimensionless water-vapor density around the pre-cooling device 10 is increased because the decrease of the wind velocity of the freezer compartment air 21 causes less flow of the freezer compartment air 21 to the pre-cooling device 10 side. As shown by the analysis results, when the flow of the freezer compartment air 21 into the pre-cooling device 10 side is suppressed, the dimensionless water-vapor density around the pre-cooling device 10 is increased. Therefore, a further improvement of the dehumidification capacity with use of the pre-cooling device 10 can be expected.

[0062] As described above, in the refrigerator 100 according to Embodiment 1, the refrigerator compartment return port 22 is arranged below the freezer compartment return port 20 with a

positional displacement in the height direction. Further, the freezer compartment air flow passage through which the freezer compartment air 21 discharged through the freezer compartment return port 20 flows is mainly on the front surface side, and the refrigerator compartment air flow passage through which the refrigerator compartment air dehumidified by the pre-cooling device 10 flows is mainly on the back surface side. Thus, the air streams flow separately. Therefore, it is possible to prevent the non-dehumidified refrigerator compartment air 23 discharged through the refrigerator compartment return port 22 from entering the cooling device 9. With this entry suppression effect, the dehumidification capacity of the pre-cooling device 10 can be effectively utilized, and the frost resistance of the cooling device 9 can be dramatically improved.

[0063] Embodiment 2

FIG. 13 is a schematic structural view of the cooling device compartment 200 in Embodiment 2 of the present invention. FIG. 13 (a) is a front view of the cooling device compartment 200, FIG. 13 (b) is a sectional view of the cooling device compartment 200, and FIG. 13 (c) is an enlarged view of the vicinity of the pre-cooling device 10 of the cooling device compartment 200. In Embodiment 2, unlike Embodiment 1, as illustrated in FIG. 13, the refrigerator compartment return port 22 is arranged on a lateral surface side with respect to the cooling device 9. Therefore, in Embodiment 2, unlike Embodiment 1, the refrigerator compartment air 23 flows from

the lateral surface side of the pre-cooling device 10. As described above, in Embodiment 2, the freezer compartment return port 20 is arranged on the front surface side of the cooling device compartment 200, and the refrigerator compartment return port 22 is arranged on the lateral surface side of the cooling device compartment 200.

[0064] The refrigerator 100 according to Embodiment 2 includes a refrigerator compartment returning air pathway 31 extending in a vertical direction along the lateral surface of the cooling device compartment 200. The refrigerator compartment air 23 passes from the refrigerator compartment returning air pathway 31 through the refrigerator compartment return port 22 formed in the lateral surface of the cooling device compartment 200, to thereby flow into the pre-cooling device 10 from the lateral surface side. In Embodiment 2, the refrigerator compartment air 23 flowing from the lateral surface into the cooling device compartment 200 flows so as to be opposed to the fin surfaces of the pre-cooling device 10 along the drain pan 26. The refrigerator compartment air 23 flows along the longitudinal direction (horizontal direction) of the pre-cooling device 10 through a gap secured between the lower portion of the pre-cooling device 10 and the drain pan 26. Then, the flow of the refrigerator compartment air 23 is deflected upward due to the collision with the fin surfaces in addition to the suction force of the circulation fan 8, and thus the refrigerator compartment air 23 passes through a gap between the fins to flow upward toward the cooling device 9. Therefore, heat transfer can

be promoted, and the dehumidification capacity of the pre-cooling device 10 can be further improved.

[0065] When the pre-cooling device 10 is to be further improved in dehumidification capacity, the upper end of the refrigerator compartment return port 22 is desired to be arranged below the upper end of the pre-cooling device 10. Further, when the refrigerator compartment air 23 flows into the cooling device compartment 200 from the lateral surface, side plates 32 (support plates) arranged on both ends of the refrigerant pipes 17 of the cooling device 9 so as to support the refrigerant pipes 17 become a flow resistance, and hence the lower portions of the side plates are desired to be cut.

[0066] Embodiment 3

FIG. 14 is a sectional view of the cooling device compartment 200 in Embodiment 3 of the present invention. In FIG. 14 (a) a sectional view of the schematic structural view of the cooling device compartment 200 is shown. In FIG. 14B, a schematic enlarged view in which the vicinity of the refrigerator compartment return port 22 and the pre-cooling device 10 is enlarged is shown. In FIG. 14 (c), a schematic enlarged view in which the vicinity of the pre-cooling device 10 and the refrigerator compartment return port 22 of the cooling device compartment 200 including a modification example of the refrigerator compartment return port 22 is enlarged is shown.

[0067] In Embodiment 3, as illustrated in FIG. 14, the width

of the drain pan 26 in a depth direction is smaller than that in Embodiment 1. The refrigerator 100 according to Embodiment 3 differs from the refrigerator 100 according to Embodiment 1 in that the refrigerator compartment return port 22 includes an extending portion 22a that is linearly extended, and the refrigerator compartment air 23 is discharged through the extending portion 22a to the vicinity of the pre-cooling device 10. In the cooling device compartment 200, the pre-cooling device 10 and the radiant heater 24 are arranged below the cooling device 9 at positions shifted in the horizontal direction. That is, the pre-cooling device 10 is located in the cooling device compartment 200 at a position shifted in the horizontal direction. Further, the refrigerator compartment return port 22 is connected to the inside of the cooling device compartment 200 from the lower side of the radiant heater 24. Therefore, the refrigerator compartment return port 22 is connected from a side opposite to the side on which the pre-cooling device 10 is shifted. Below the radiant heater 24, the refrigerator compartment return port 22 is formed so that an air pathway for allowing the refrigerator compartment air 23 to come close to the pre-cooling device 10 is formed.

[0068] In Embodiment 3, as illustrated in FIG. 14 (a), the refrigerator compartment air 23 discharged through the refrigerator compartment return port 22 via the extending portion 22a comes close to the pre-cooling device 10, and thus the distance for the refrigerator compartment air 23 to reach the pre-cooling device

10 is reduced. Therefore, the bypass flow of the refrigerator compartment air 23 toward a region other than the pre-cooling device 10 can be suppressed, and the refrigerator compartment air 23 can be caused to concentratedly flow into the pre-cooling device 10. This configuration can contribute to a further improvement of the dehumidification capacity of the pre-cooling device 10. The method of causing the refrigerator compartment return port 22 to come close to the pre-cooling device 10 side is not particularly limited. For example, as illustrated in FIG. 14 (b), the extending portion 22a may be formed along the drain pan 26 so that the refrigerator compartment air 23 flows from the lower portion of the pre-cooling device 10 along the airflow control rib 29 arranged at the lower portion of the pre-cooling device 10. In order to cause the water dropping off during frost removal to flow into the drainage conduit 27, the extending portion 22a is required to be provided so as not to overlap with the drainage conduit 27 in the vertical direction.

[0069] Embodiment 4

FIG. 15 is a front view of the cooling device compartment 200 in Embodiment 4 of the present invention. In Embodiment 4, unlike Embodiment 1, the airflow control rib 29 is arranged in a lateral surface bypass air pathway 41 of the cooling device 9.

[0070] Although description has been omitted in Embodiment 1, the lateral surface bypass air pathway 41 is formed between the wall surface of the cooling device compartment 200 and each of the side plates 32 arranged at both ends of the pipes of the cooling

device 9 to support the pipes. The fins are stacked in the cooling device 9, and the side plates 32 are provided on the outer sides of the fins in its stacking direction. There are spaces for connecting the refrigerant pipes 17 to each other on the outer sides of the side plates 32. Air also flows through those spaces, which correspond to the lateral surface bypass air pathways 41. A small amount of freezer compartment air 21 and a small amount of refrigerator compartment air 23 flow through the lateral surface bypass air pathways 41. In the lateral surface bypass air pathways 41, heat is exchanged only with the exposed refrigerant pipes 17. The refrigerant pipe 17 has an extremely smaller heat exchange area and lower cooling efficiency as compared to the stacked fins located at the center portion of the cooling device 9.

[0071] In Embodiment 4, the airflow control ribs 29 are arranged at the upper portions of the side plates 32 located at both ends of the cooling device 9. Thus, the air pathway resistance of the lateral surface bypass air pathways 41 is increased, and the freezer compartment air 21 and the refrigerator compartment air 23 are prevented from flowing through the lateral surface bypass air pathways 41. Through prevention of a situation in which cold air flows into the lateral surface bypass air pathways 41, heat exchange loss in the lateral surface bypass air pathways 41 can be reduced. Further, the air flow of the refrigerator compartment air 23 flowing into the cooling device 9 and the pre-cooling device 10 can be increased. Therefore, this configuration can contribute

to a further improvement of the heat exchange performance of the cooling device 9 and a further improvement of the dehumidification capacity of the pre-cooling device 10. The material of the airflow control rib 29 of the lateral surface bypass air pathway 41 is not particularly limited, and may be, for example, aluminum, which is the same as the material of the fin. Further, the method of suppressing flow of the cold air into the lateral surface bypass air pathway 41 is not particularly limited as long as the method is within a range that does not depart from the gist of the present invention. For example, the lateral surface bypass air pathway 41 may be completely sealed with foamed polystyrene or the like.

[0072] <Effect of Improving Dehumidification Capacity of Pre-cooling Device>

The improvement of the dehumidification capacity of the pre-cooling device in Embodiments 1 to 4 of the present invention is discussed. With use of Comparative Example 1 in which the freezer compartment air 21 and the refrigerator compartment air 23 flow after being joined at the lower portion of the cooling device compartment 200, and Embodiments 1 to 4 of the present invention in which the freezer compartment air 21 and the refrigerator compartment air 23 flow separately, the dehumidification capacity (frost amount [g]) in the pre-cooling device 10 was measured with a test. The percentages of the dehumidification capacity ratio of the present invention to Comparative Example 1 were compared based on the measurement results.

[0073] <Testing Device and Method of Measuring Frost Formation Amount>

FIG. 16 is a schematic view for illustrating a dehumidification capacity testing device in the pre-cooling device 10. FIG. 16 is an illustration of the dehumidification capacity testing device and a method of measuring a frost amount. As illustrated in FIG. 16, water was evaporated by the heat generated by a heater 51 placed in the refrigerator compartment 1 to forcibly form frost on the cooling device 9. The frost amount [g] in the pre-cooling device 10 was measured and compared.

[0074] As the method of measuring the frost amount in the pre-cooling device 10, an acrylic plate 52 was placed between the cooling device 9 and the pre-cooling device 10, and warm air 54 of a dryer 53 was applied only to the pre-cooling device 10. Thus, only the frost formed on the pre-cooling device 10 was melted, and the measurement was performed.

[0075] In Comparative Example 1, the refrigerator as illustrated in FIG. 9 (a) is used, and the freezer compartment air 21 and the refrigerator compartment air 23 are caused to flow after being joined at the lower portion of the cooling device compartment 200.

[0076] In Embodiment 1, the refrigerator 100 as illustrated in FIG. 9 (b) in which the vertical dimension of the freezer compartment return port 20 is 28 mm is used. The lower edge of the freezer compartment return port 20 is arranged above the lower end

of the cooling device 9, and the refrigerator compartment return port 22 is arranged below the lower end of the freezer compartment return port 20. Therefore, the freezer compartment air 21 and the refrigerator compartment air 23 in the cooling device compartment 200 are caused to flow separately. In Embodiment 1a of the present invention, the width of the refrigerator compartment return port 22 in Embodiment 1 is increased so that the width of the refrigerator compartment return port 22 is equal to the width of the pre-cooling device 10. In Embodiment 1b of the present invention, the vertical dimension of the freezer compartment return port 20 in Embodiment 1 is set to 84 mm. In Embodiment 1c of the present invention, the heater roof 25 of Embodiment 1 has a smooth straight-line shape, and has an inclination declining from the cooling device 9 to the freezer compartment return port 20 side. In Embodiment 2, the refrigerator compartment return port 22 in Embodiment 1 is arranged on the lateral surface side with respect to the cooling device 9. In Embodiment 3, the refrigerator compartment return port 22 of Embodiment 1 includes the extending portion 22a that is linearly extended, and the refrigerator compartment air 23 is discharged via the extending portion 22a to a place close to the pre-cooling device 10 side. In Embodiment 4, the airflow control ribs 29 are mounted in the lateral surface bypass air pathways 41 of the cooling device 9 in Embodiment 1.

[0077] Common setting was employed for Comparative Example 1 and Embodiments 1 to 4 so that the mass of water to be evaporated

by the heater became 300 cc, and the above-mentioned comparing test of the dehumidification capacity was performed.

[0078] <Effect (Dehumidification Amount of Pre-cooling Device)>

FIG. 17 is a bar graph for showing a dehumidification capacity ratio of the pre-cooling device 10 of Embodiments 1 to 4 to that of Comparative Example 1. FIG. 17 is a graph for showing the ratio of the dehumidification capacity of the present invention to that of Comparative Example 1, which is obtained based on the results of measuring the dehumidification capacity of the pre-cooling device 10.

[0079] As shown in FIG. 17, the dehumidification capacity ratio of the pre-cooling device 10 was 125% in Embodiment 1, 158% in Embodiment 1a, 167% in Embodiment 1b, 133% in Embodiment 1c, 175% in Embodiment 2, 133% in Embodiment 3, and 142% in Embodiment 4. Dehumidification capacities higher than that of Comparative Example 1 (100%) were shown. Therefore, the refrigerators 100 according to Embodiments 1 to 4 of the present invention are capable of actively causing the refrigerator compartment air to flow into the pre-cooling device 10, and are capable of dramatically improving the dehumidification capacity of the pre-cooling device 10 and the cooling capacity of the cooling device 9.

Reference Signs List

[0080] 1 refrigerator compartment, 2 convertible compartment,

3 ice making compartment, 4 freezer compartment, 5 vegetable compartment, 6 door portion, 7 heat-insulating wall, 8 circulation fan, 9 cooling device, 10 pre-cooling device, 12 compressor, 13 pipe group, 14 expansion device, 15 returning air, 16 fin, 17 refrigerant pipe, 18 cord heater, 100 refrigerator, 20 freezer compartment return port, 21 freezer compartment air, 22 refrigerator compartment return port, 23 refrigerator compartment air, 24 radiant heater (defrost heater), 25 heater roof, 26 drain pan, 27 drainage conduit, 28 freezer compartment outlet port, 29 airflow control rib, 200 cooling device compartment, 30 freezer compartment case, 31 refrigerator compartment returning air pathway, 32 side plate of cooling device, 41 lateral surface bypass air pathway, 51 heater, 52 acrylic plate, 53 dryer, 54 warm air

Claims

[Claim 1]

A refrigerator, comprising:

a refrigerator compartment;

a freezer compartment;

a cooling device compartment comprising a cooling device configured to cool refrigerator compartment air sent from the refrigerator compartment and freezer compartment air sent from the freezer compartment; and

a circulation fan configured to send cooled air cooled by the cooling device to the refrigerator compartment and the freezer compartment,

wherein, in the cooling device compartment, the freezer compartment air and the refrigerator compartment air flow from a lower side to an upper side of the cooling device compartment,

the cooling device compartment further comprising:

a pre-cooling device arranged on an upstream side of the cooling device and configured to perform dehumidification;

a defrost heater configured to heat the pre-cooling device and arranged at a position at which the defrost heater is shifted from the pre-cooling device in a horizontal direction in the cooling device compartment, a heater roof being arranged above the defrost heater;

a freezer compartment return port formed at a position at which the freezer compartment air sent from the freezer compartment to the cooling device compartment directly flows toward the cooling device; and

a refrigerator compartment return port formed at a position at which the refrigerator compartment air sent from the refrigerator compartment to

the cooling device compartment flows toward the pre-cooling device,

wherein the heater roof is located closer to the freezer compartment return port with respect to the pre-cooling device 10, and is located below the freezer compartment return port,

wherein the freezer compartment return port is inclined so that the cooling device side of the freezer compartment return port is lower, and

wherein the freezer compartment air is discharged above the heater roof through the freezer compartment return port.

[Claim 2]

The refrigerator according to claim 1, wherein the pre-cooling device is arranged at the same height as the defrost heater in a horizontal direction, and is arranged on a back surface side of the cooling device compartment with respect to the defrost heater.

[Claim 3]

The refrigerator according to claim 1 or 2,

wherein a lower end of the freezer compartment return port is arranged above a lower end of the cooling device, and

wherein the refrigerator compartment return port is arranged below the lower end of the freezer compartment return port.

[Claim 4]

The refrigerator according to any one of claims 1 to 3, wherein the freezer compartment air and the refrigerator compartment air flow into the cooling device from the same direction.

[Claim 5]

The refrigerator according to any one of claims 1 to 4, wherein an air flow

of the freezer compartment air sent through the freezer compartment return port to the cooling device compartment is larger than an air flow of the refrigerator compartment air sent through the refrigerator compartment return port to the cooling device compartment.

[Claim 6]

The refrigerator according to any one of claims 1 to 5,

wherein the cooling device compartment comprises, above the freezer compartment return port, an outlet port for allowing the cooled air to be blown out, and

wherein the refrigerator further comprises an airflow control rib, which is arranged between an upper portion of the freezer compartment return port on the freezer compartment side and a lower portion of the outlet port, and is configured to block at least a part of flow of the cooled air blown out through the outlet port.

[Claim 7]

The refrigerator according to any one of claims 1 to 6, wherein the freezer compartment air discharged through the freezer compartment return port flows downward and then flows upward.

[Claim 8]

The refrigerator according to any one of claims 1 to 7, wherein the refrigerator compartment return port and the pre-cooling device have equivalent widths.

[Claim 9]

The refrigerator according to any one of claims 1 to 8,

wherein the freezer compartment return port is arranged on a front surface side of the cooling device compartment, and

wherein the refrigerator compartment return port is arranged on a lateral surface side of the cooling device compartment.

[Claim 10]

The refrigerator according to any one of claims 1 to 9,

wherein the defrost heater comprises a radiant heater, and

wherein the heater roof has a flat shape that is placed below the freezer compartment return port, and is inclined so that the freezer compartment return port side of the heater roof is lower.

[Claim 11]

The refrigerator according to any one of claims 1 to 10, wherein a vertical dimension of the freezer compartment return port is equal to or less than 100 mm.

[Claim 12]

The refrigerator according to any one of claims 1 to 11,

wherein the refrigerator compartment return port comprises an air pathway, which is formed below the defrost heater, and comes close to the pre-cooling device.

[Claim 13]

The refrigerator according to any one of claims 1 to 12,

wherein the cooling device comprises stacked fins and side plates located on outer sides in a stacking direction of the stacked fins, and

wherein the refrigerator further comprises a lateral-portion airflow control rib configured to block air flowing through a lateral surface bypass air pathway formed between each of the side plates and a wall surface of the cooling device compartment.