

DESCRIPTION

Title of Invention

REFRIGERATOR

5 Technical Field

[0001]

The present invention relates to a refrigerator, in particular, to a refrigerator that has a function of bringing objects to be cooled into a super-cooling state.

10 Background Art

[0002]

Generally, in storing food in a refrigerator to keep quality, maintaining the food at as low a temperature as possible without freezing the food is considered to be desirable. As a method for achieving such storage, a method for storing food in a super-cooling state has been proposed. Here, the super-cooling state means a state in which while reaching or falling to or below the freezing point, the food remains unfrozen without starting to freeze. However, when food is stored at or below the freezing point (e.g., 0 degrees C or below), there is a possibility that the refrigerator is no longer in the super-cooling state due to a shock or some other factors, and ice crystals are formed in the food. Then, if the refrigerator remains in a state where it is no longer in the super-cooling state, freezing of the food will proceed, resulting in degradation of food quality due to cell damage caused by freezing.

25 [0003]

To avoid such a problem, a method has been proposed in which temperature is allowed to change periodically, to thereby cause ice crystals formed to be melted when the refrigerator is not in a super-cooling state. For example, a refrigerator has been disclosed in which super-cooling operation starts again if, after super-cooling operation that brings food into a

super-cooling state, a cycle of start and stop of a cooling unit is repeated more than once at a temperature setting for refrigeration operation (see, for example, Patent Literature 1). In the refrigerator described in Patent Literature 1, even if freezing of food begins to proceed as a result of super-cooling operation, if refrigeration operation is performed at a set temperature higher than a set temperature for super-cooling operation, it is possible to prevent the food from being frozen completely.

[0004]

Also, a refrigerator has been disclosed that repeatedly carries out a low-temperature step and a warm-up step. In this refrigerator, in the low-temperature step, an inside temperature is set to a temperature lower than the freezing point of food and in the warm-up step, the inside temperature is set to a temperature higher than the freezing point (see, for example, Patent Literature 2). With the refrigerator of Patent Literature 2, even if the refrigerator is no longer in the super-cooling state in the low-temperature step and freezing starts with ice crystals being formed in the food, if the warm-up step is started with a predetermined timing, the ice crystals formed when the refrigerator is out of the super-cooling state can be melted. Subsequently, by carrying out the low-temperature step again, it is possible to bring about a super-cooling state and stably maintain the food in a super-cooling state.

[0005]

On the other hand, in a refrigerator provided with a storage compartment switchable from a low-temperature compartment to a super-cooling storage compartment, a structure that uses a heat insulating element right under a top plate of the super-cooling storage compartment has been disclosed (see, for example, Patent Literature 3). The refrigerator of Patent Literature 3 increases insulation capability and cooling capability of the super-cooling storage compartment and enables preventing dew formation in the super-cooling storage compartment.

[0006]

Also, a refrigerator structured to contain a regenerating agent right under a top plate of a super-cooling storage compartment is disclosed (see, for example, Patent Literature 4). According to Patent Literature 4, the regenerating agent receives heat when the temperature in the storage compartment is equal to or higher than a set temperature and generates heat when the temperature in the storage compartment is equal to or lower than a set temperature. This makes it possible to keep the air temperature in the storage compartment constant, i.e., curb air temperature changes in the storage compartment and prevent quality deterioration of perishable foods.

Citation List

Patent Literature

[0007]

Patent Literature 1: Japanese Patent No. 4647047

Patent Literature 2: Japanese Patent No. 4948562

Patent Literature 3: Japanese Unexamined Patent Application
Publication No. 2013-083364

Patent Literature 4: Japanese Unexamined Patent Application
Publication No. 2015-038391

Summary of Invention

Technical Problem

[0008]

For example, the super-cooling storage compartment in which objects to be cooled is stored in a super-cooling state is required to be more convenient in the future, and the refrigerators disclosed in the above-mentioned patent literature have problems as described below.

[0009]

For example, with the refrigerator of Patent Literature 1, a duration for which refrigeration operation is performed is equal to a duration for which one or more cycles of normal refrigeration operation are repeated. This

time period is not determined by considering a relationship with a duration for which super-cooling operation is performed and a relationship with an amount of heat during each operation. Therefore, for example, if the duration for which refrigeration operation is performed is too short compared to the duration for which super-cooling operation is performed, ice crystals in the food cannot be melted sufficiently and freezing of the food may proceed. Also, if the duration for which refrigeration operation is performed is too long compared to the duration for which super-cooling operation is performed, an average temperature during storage period of the food will increase and food quality may be degraded.

[0010]

Also, with the refrigerator of Patent Literature 2, a duration of the low-temperature step is set for the purpose of completely melting the ice crystals formed in the food in the low-temperature step. Specifically, with the refrigerator of Patent Literature 2, the duration of the low-temperature step is set such that latent heat Q_1 released when water is changed to ice, latent heat Q_2 drawn from water during a progress of freezing, and heat Q_3 transferred to the ice during a progress of thawing will satisfy the relationship of $Q_3 \geq Q_1 + Q_2$. This makes it possible to completely melt the ice crystals formed in the low-temperature step. However, the refrigerator of Patent Literature 2 requires fine temperature control. Consequently, for example, if the height of the super-cooling storage compartment is increased in order to increase the volume of the super-cooling storage compartment, a temperature difference is generated between an upper region and a lower region, making it impossible to perform temperature control as desired, and as a result, food quality may be degraded.

[0011]

Also, with the refrigerator of Patent Literature 3, the heat insulating element is used right under the top plate in the upper part of the super-cooling storage compartment. This makes it possible to improve the

insulation capability and cooling capability of the super-cooling storage compartment and increase the volume of the super-cooling storage compartment. However, since the heat insulating element is used right under the top plate, even if glass or other transparent elements are used for the top plate, an interior of the super-cooling storage compartment cannot be checked visually from a side closer to the top plate. This is inconvenient since contents of the super-cooling storage compartment cannot be checked unless the super-cooling storage compartment is opened.

[0012]

Also, the refrigerator of Patent Literature 4 enables super-cooling storage using a regenerating agent in the super-cooling storage compartment. However, use of the regenerating agent results in a cost increase. Also, even if glass or other transparent elements are used for the top plate, a problem arises that the regenerating agent placed right under the top plate deteriorates visibility inside the super-cooling storage compartment.

[0013]

The present invention has been made to solve at least one of the above problems, and has an object to provide a refrigerator equipped with a super-cooling storage compartment that is more convenient than existing ones.

Solution to Problem

[0014]

To solve the problems regarding existing refrigerators mentioned above, a refrigerator according to an embodiment of the present invention comprises: a refrigerator compartment set to a refrigeration temperature zone; a super-cooling storage compartment provided on a lower side in the refrigerator compartment and adapted to cool an object to be cooled such that the object to be cooled reaches a super-cooling temperature equal to or lower than a freezing temperature below the refrigeration temperature zone; and a top plate made up of a plurality of flat-plate transparent elements and

configured to serve as a top face of the super-cooling storage compartment, the plurality of transparent elements enclosing a gas by facing one another.

Advantageous Effects of Invention

[0015]

5 Since the top plate serving as a top face of the super-cooling storage compartment is made up of a plurality of transparent elements enclosing a gas, the refrigerator according to an embodiment of the present invention has high heat insulation performance while allowing conditions in the super-cooling storage compartment to be checked visually. This makes it possible
10 to increase the inner volume of the super-cooling storage compartment by expanding the super-cooling storage compartment in a height direction, and thereby improving convenience of the super-cooling storage compartment.

Brief Description of Drawings

[0016]

15 [Fig. 1] Fig. 1 is a front view schematically illustrating external appearance of a refrigerator 1 according to Embodiment 1 of the present invention.

 [Fig. 2] Fig. 2 is an internal configuration diagram schematically illustrating a configuration inside the refrigerator 1 including a first air
20 passage 10 according to Embodiment 1 of the present invention.

 [Fig. 3] Fig. 3 is an internal configuration diagram schematically illustrating a configuration inside the refrigerator 1 including a second air
 passage 12 according to Embodiment 1 of the present invention.

25 [Fig. 4] Fig. 4 is a diagram illustrating a positional relationship among elements and parts around a super-cooling storage compartment 5 in the refrigerator 1 according to Embodiment 1 of the present invention.

 [Fig. 5] Fig. 5 is a schematic diagram illustrating a configuration of a top plate 18 provided in the refrigerator 1 according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a schematic diagram of the top plate 18 provided in the refrigerator 1 according to Embodiment 1 of the present invention as viewed from above the super-cooling storage compartment 5.

[Fig. 7] Fig. 7 is a diagram illustrating results of cooling in the super-cooling storage compartment 5 when the top plate 18 provided in the refrigerator 1 according to Embodiment 1 of the present invention is used.

[Fig. 8] Fig. 8 is a schematic diagram illustrating a configuration of a top plate 18 provided in a refrigerator 1 according to Embodiment 2 of the present invention.

[Fig. 9] Fig. 9 is a schematic diagram of the top plate 18 provided in the refrigerator 1 according to Embodiment 2 of the present invention as viewed from above the super-cooling storage compartment 5.

Description of Embodiments

[0017]

The present invention is aimed at improving heat insulation performance of a top plate of a super-cooling storage compartment and increasing the volume of the super-cooling storage compartment by expanding the super-cooling storage compartment in a height direction, where the super-cooling storage compartment is provided in a refrigerator compartment, set at a lower temperature than the refrigerator compartment, and adapted to supercool objects to be cooled. In so doing, an interior of the super-cooling storage compartment is made visible through the top plate.

[0018]

Therefore, the top plate is made up of plural flat-plate transparent elements placed by being spaced away from one another such that air gaps will be provided among the transparent elements. The presence of the air gaps improves heat insulation performance.

[0019]

Furthermore, the top plate includes ribs to maintain spacing among the transparent elements. Wire heaters serving as heating devices are run

inside the ribs. Use of the wire heaters makes it possible to install heating devices in the top plate without significantly impairing visibility. Besides, the wire heaters prevent dew formation in the top plate as well as prevent objects to be cooled stored near the top plate from freezing.

5 [0020]

Embodiments of the present invention will be described below with reference to the drawings. In the drawings, the same or equivalent components are denoted by the same reference numerals, and description thereof will be omitted or simplified as appropriate. Also, the shapes, sizes, layouts, and other geometries of the components shown in the drawings can be changed as appropriate without departing from the scope of the present invention. Also, herein the description of the positional relationships (e.g., a vertical positional relationship) among the components assumes that a refrigerator 1 is installed in a ready-for-use condition. Here, in the following drawings including Figs. 1 to 3, components may not be shown in their actual size relations, shapes, or the like.

15 [0021]

Embodiment 1

Fig. 1 is a front view schematically illustrating external appearance of the refrigerator 1 according to Embodiment 1 of the present invention. Fig. 2 is an internal configuration diagram schematically illustrating a configuration inside the refrigerator 1 including a first air passage 10 according to Embodiment 1 of the present invention. Fig. 3 is an internal configuration diagram schematically illustrating a configuration inside the refrigerator 1 including a second air passage 12 according to Embodiment 1 of the present invention.

25 [0022]

[Configuration of refrigerator 1]

As shown in Fig. 1, the refrigerator 1 of Embodiment 1 includes a heat insulating box-like body open in a front (front face) and provided with a

storage space formed inside. Although not illustrated in detail, the box-like body includes an outer box made of steel, an inner box made of resin, and a heat insulating material filling a space between the outer box and inner box.

However, as described later, no heat insulating material exists between a

5 refrigerator compartment 2 and a vegetable compartment 3. A storage space formed in the heat insulating box-like body is partitioned by plural partition elements into plural storage compartments adapted to store objects to be cooled. For example, as shown in Fig. 1, as the plural storage compartments, the refrigerator 1 of Embodiment 1 includes the refrigerator compartment 2 placed on an uppermost tier, the vegetable compartment 3 placed under the refrigerator compartment 2, and a freezer compartment placed on a lowermost tier. Here, in a structure in which the vegetable compartment 3 is installed in a lower region of the refrigerator compartment 2, the types and number of storage compartments provided in the refrigerator 1 are not limited to these described above. Also, an explanation is given below assuming that objects to be cooled are food.

[0023]

As shown in Fig. 2, on a back side of the refrigerator 1, as an example of a cooling device adapted to cool the storage compartments, a compressor 6 adapted to compress and discharge refrigerant, a cooler 8 adapted to cool air by functioning as an evaporator, and a fan 9 adapted to move cold air generated by the cooler 8 are provided. Furthermore, the refrigerator 1 includes a first air passage 10 through which cold air flows and in which the cooler 8, the fan 9, and other components are installed. The compressor 6 is connected to a condenser (not shown) on a side from which refrigerant is discharged and connected to the cooler 8 on a side from which refrigerant is suctioned. The cooler 8 functions as an evaporator and generates cold air by exchanging heat between the refrigerant passing through the cooler 8 and the air in the first air passage 10. The compressor 6 and the cooler 8 make up a refrigeration cycle circuit in conjunction with the condenser (not shown)

and an expansion unit (not shown). The fan 9 supplies cold air to the refrigerator compartment 2, the vegetable compartment 3, and the freezer compartment 4 through the first air passage 10.

[0024]

5 The first air passage 10 is provided along a vertical direction in an inner wall panel formed in a casing 50, extending from a lower side to an upper side in the refrigerator 1. More particularly, the first air passage 10 is provided on a back side of the refrigerator compartment 2, the vegetable compartment 3, and the freezer compartment 4. The first air passage 10 includes a first air passage 10a adapted to send cold air into the super-cooling storage compartment 5 and a first air passage 10b adapted to send cold air into a space in the refrigerator compartment 2 except the super-cooling storage compartment 5. The first air passage 10a is provided with a damper 11a. Also, the first air passage 10b is provided with a damper 11b. 10 The damper 11a varies its opening degree, thereby adjusting an air flow rate of cold air passing through the first air passage 10a. Also, the damper 11b varies its opening degree, thereby adjusting an air flow rate of cold air passing through the first air passage 10b.

[0025]

20 After being cooled by exchanging heat with the refrigerant in the cooler 8 through operation of the refrigeration cycle circuit, the cold air is supplied to storage compartments such as the refrigerator compartment 2 and freezer compartment 4 by the fan 9 through the first air passage 10 on the back side of the refrigerator 1. The cold air passing through the refrigerator compartment 2 and other compartments is returned to the cooler 8 through the second air passage 12 as shown in Fig. 3, cooled again, and sent to the storage compartments.

[0026]

Also, the refrigerator 1 includes a controller 100. Temperatures of the storage compartments are detected by temperature sensors (not shown)

installed in respective storage compartments. The controller 100 controls various devices in the refrigerator 1 such that the temperatures detected by the temperature sensors will become equal to temperatures set for the respective storage compartments. For example, the controller 100 controls the opening degrees of the damper 11a installed in the first air passage 10a and the damper 11b installed in the first air passage 10b, output of the compressor 6, output of a heater 16, a supplied air flow rate of the fan 9, and other variables.

[0027]

<Refrigerator compartment 2>

The refrigerator compartment 2 is a storage compartment set to a refrigeration temperature zone (e.g., approximately 3 to 5 degrees C) and adapted to store food. As shown in Fig. 2, shelves 21 and other structures used to place food and other objects thereon are provided in the refrigerator compartment 2. An opening formed in the front of the refrigerator 1 is provided with hinged doors (e.g., double doors) used to open and close the opening. Here, the refrigerator compartment 2 may have a hinged single door rather than double doors. Also, the inner wall panel serves as a rear wall in the refrigerator compartment 2. Besides, as shown in Figs. 2 and 3, in the refrigerator 1 of Embodiment 1, the super-cooling storage compartment 5 is provided in lowermost part of the refrigerator compartment 2. In the space inside the refrigerator compartment 2, the super-cooling storage compartment 5 is partitioned from other space by the top plate 18.

[0028]

The super-cooling storage compartment 5 stores food in a super-cooling state at temperatures lower than in the refrigerator compartment 2 (e.g., at super-cooling temperatures of approximately 0 to -3 degrees C, which corresponds to the freezing point (freezing temperature) of food). Therefore, the super-cooling storage compartment 5 is suitable as a storage chamber for storing food such as meat, fish, and processed products thereof.

A storage container 14 and a front wall 13 are provided in the super-cooling storage compartment 5. Also, on its far side, the super-cooling storage compartment 5 has a super-cooling storage compartment air inlet 15 adapted to lead air in the super-cooling storage compartment 5 to the second air passage 12. Here, the super-cooling storage compartment air inlet 15 and a refrigerator compartment air inlet 22 described later at least partially overlap each other in planar view. Consequently, air passing through the super-cooling storage compartment air inlet 15 and air passing through the refrigerator compartment air inlet 22 join in the second air passage 12 and return to the cooler 8. It means that the two currents of air are not returned separately to the cooler 8. Also, the super-cooling storage compartment 5 includes the top plate 18 that can maintain temperatures lower than in the refrigerator compartment 2.

[0029]

The storage container 14 is a container configured to store food to be stored in the super-cooling storage compartment 5. The storage container 14 is a drawer-type container movable in a back and forth direction along rails (not shown) provided, for example, on inner sides of side walls of the super-cooling storage compartment 5. Here, the rails may be provided on a bottom wall of the super-cooling storage compartment 5. Besides, the rails do not necessarily have to be installed. A user can draw the storage container 14 from the super-cooling storage compartment 5 and take food in and out of the storage container 14 through an upper opening of the storage container 14. As a material for the storage container 14, for example, polystyrene or other similar materials are used, as in the case of storage containers of common refrigerators. However, this is not restrictive.

[0030]

The front wall 13 is provided in an opening of space in the upper front part of the super-cooling storage compartment 5 by being pivotally attached

to the top plate 18. When the storage container 14 is pulled out, the front wall 13 pivots, and the door is opened.

[0031]

Here, for temperature adjustment of the refrigerator compartment 2, the controller 100 controls the opening degrees of the damper 11b, thereby adjusting a flow rate of air supplied to the refrigerator compartment 2.

Furthermore, for temperature adjustment of the super-cooling storage compartment 5, the controller 100 controls the opening degrees of the damper 11a, thereby adjusting a flow rate of air supplied to the super-cooling storage compartment 5, and adjusts output of the heater 16 described later.

[0032]

<Vegetable compartment 3>

The vegetable compartment 3 is a storage compartment whose temperature is set to a refrigeration temperature zone (e.g., approximately 3 to 7 degrees C) higher than the refrigerator compartment 2. The vegetable compartment 3 has a space for use to store a stock and is a storage compartment particularly suitable for refrigerating vegetables among food. As shown in Figs. 2 and 3, the vegetable compartment 3 is provided below the refrigerator compartment 2. Therefore, the vegetable compartment 3 is placed next to the super-cooling storage compartment 5 via a boundary wall 7 described later. The vegetable compartment 3 is provided with a drawer door. With opening and closing of the door, a space in the vegetable compartment 3 contacts or is isolated from the outside of the refrigerator 1.

[0033]

<Boundary wall 7>

As shown in Fig. 2, the boundary wall 7 is provided between the vegetable compartment 3 and the super-cooling storage compartment 5. The boundary wall 7 serves as a partition between the vegetable compartment 3 and the super-cooling storage compartment 5. In a configuration in which the vegetable compartment 3 is located under the

boundary wall 7, the vegetable compartment 3 is not cooled by heat transfer from the super-cooling storage compartment 5. Therefore, the boundary wall 7 does not need to contain a heat insulating material. Also, as shown in Fig. 3, the boundary wall 7 includes the refrigerator compartment air inlet 22 connected directly to the second air passage 12 and used to draw cold air from inside the refrigerator compartment 2 toward the second air passage 12. The refrigerator compartment air inlet 22 is formed on a far side of the refrigerator compartment 2.

[0034]

<Heater 16>

As shown in Figs. 2 and 3, the heater 16 is installed on the boundary wall 7 supporting the super-cooling storage compartment 5 from below. The heater 16 is a heating mechanism (heating unit) adapted to heat and thereby raise the temperature of the food in the super-cooling storage compartment 5. The heater 16 is provided for use in heating food and used for a warm-up step in a super-cooled storage process. In the super-cooling storage process, it is necessary to avoid excessive cooling and freezing the food. Therefore, the food cooled excessively is heated using the heater 16. Since the heater 16 is installed under the super-cooling storage compartment 5, the food in the super-cooling storage compartment 5 can be heated efficiently.

[0035]

<Freezer compartment 4>

The freezer compartment 4 is a storage compartment set to a freezing temperature zone lower than 0 degrees C (e.g., -18 degrees C or lower).

As shown in Figs. 2 and 3, the freezer compartment 4 is provided under the vegetable compartment 3 and adapted to store food to be frozen. The freezer compartment 4 is provided with a drawer door. With opening and closing of the door, a space in the freezer compartment 4 contacts or is isolated from the outside of the refrigerator 1.

[0036]

[Maintaining super-cooling state]

Here, description will be given of a temperature environment in which the food in the super-cooling storage compartment 5 is maintained in a super-cooling state. For water to turn into ice, it is necessary for ice crystals to grow. The ice crystals are small ice nuclei at a molecular level. It is considered that, in a super-cooling liquid, molecules repeat clustering and scattering due to fluctuations, producing molecular assemblies (clusters) of various sizes. When clusters are very small, the molecules of ice inside the clusters are in a bonded state. However, molecules on surfaces cannot have bonds and remain unstable, and hence some of the molecules on surfaces separate from the clusters.

[0037]

Unless a certain critical radius is exceeded, the clusters cannot exist stably and do not turn into ice crystals. Therefore, even after falling to or below the solidifying point, the clusters do not start freezing. This state is the super-cooling state. If even one cluster equal to or larger than the critical radius is produced, an ice crystal is produced using the cluster as a nucleus, thereby breaking the super-cooling state. The probability that the super-cooling state will be stopped increases with decreases in temperature. Also, disturbances such as physical shocks increase fluctuations in the liquid, producing clusters equal to or larger than the critical radius and thereby breaking the super-cooling state.

[0038]

Here, food is a mixture of substances, which often serve as nuclei around which ice crystals are produced. When food is stored at or below the freezing point (e.g., 0 degrees C or below), the refrigerator may no longer be in the super-cooling state by a shock or some other factors and ice crystals may form in the food. Then, if the refrigerator remains in a state where it is no longer in the super-cooling state, freezing of the food will

proceed, resulting in degradation of food quality due to cell damage caused by freezing.

[0039]

Thus, the refrigerator 1 of Embodiment 1 includes a low-temperature
5 step in which an inside temperature is set to a temperature lower than the freezing point of food and a warm-up step in which the inside temperature is set to a temperature higher than the freezing point. Then, the food is maintained in a super-cooling state by securing an appropriate temperature environment in the super-cooling storage compartment 5, which is a food
10 storage space and cooling the food without stimuli such as a sudden temperature fall. Specifically, in maintaining the super-cooling state, preferably a "temperature range" of the super-cooling storage compartment 5 is -4 to 0 degrees C. Also, in maintaining the super-cooling state, preferably a "temperature distribution" in the super-cooling storage
15 compartment 5 is made uniform.

[0040]

[About flows of cold air]

Next, flows of cold air produced by the cooler 8 will be described with reference to Figs. 2 and 3. Here, the arrows in Figs. 2 and 3 indicate flows
20 of cold air. The cold air produced by the cooler 8 passes through the fan 9 and is divided there into cold air sent to the refrigerator compartment 2 and cold air sent to the freezer compartment 4. The cold air being sent to the refrigerator compartment 2 passes through the first air passage 10 and is divided by the damper 11a and damper 11b into cold air being sent to the
25 super-cooling storage compartment 5 and cold air being sent to the refrigerator compartment 2. Then, the cold air being sent to the refrigerator compartment 2 passes over the shelves 21, flows down from above ahead of the refrigerator compartment 2, and is sent to the second air passage 12.

[0041]

Fig. 4 is a diagram illustrating a positional relationship among elements and parts around the super-cooling storage compartment 5 in the refrigerator 1 according to Embodiment 1 of the present invention. Fig. 4 shows the refrigerator 1 by focusing on a cross section along a plane containing line Y-Z shown in Figs. 2 and 3. As shown in Figs. 2 and 4, the cold air being sent to the super-cooling storage compartment 5 is blown out of an outlet air passage 17 directly connected to the damper 11a. Part of the cold air blown out flows out to a space on a side closer to the front of the super-cooling storage compartment 5 through a gap between the front wall 13 and top plate 18. The cold air flowing out to the space on a side closer to the front joins the cold air flowing downward of the refrigerator compartment 2 and passes through a gap between the super-cooling storage compartment 5 and an undersurface of the refrigerator compartment 2. Then, as shown in Fig. 3, the cold air flows out from the refrigerator compartment air inlet 22 to the second air passage 12. After flowing out, the air returns to the first air passage 10.

[0042]

As described above, since the vegetable compartment 3 higher in set temperature than the refrigerator compartment 2 is placed next to the super-cooling storage compartment 5, the inside of the super-cooling storage compartment 5 is not cooled by heat transfer from the vegetable compartment 3. Therefore, unlike existing super-cooling storage compartments, for example, the super-cooling storage compartment 5 is not affected by temperature, such as being cooled by heat transfer from an adjacent freezer compartment 4. As a result, the super-cooling storage compartment 5 is not cooled excessively, and heating capacity of the heater 16 used for the super-cooling storage of food in the super-cooling storage compartment 5 can be reduced. This makes it possible to reduce a duty factor and size of the heater 16, resulting in efficient super-cooling storage.

[0043]

Also, in a configuration in which the super-cooling storage compartment 5 is adjacent to the vegetable compartment 3 which is higher in temperature than the super-cooling storage compartment 5 as with Embodiment 1, the super-cooling storage compartment 5 is not cooled by transmitted heat. Consequently, the boundary wall 7 does not need to contain a heat insulating material configured to prevent heat transmission to the super-cooling storage compartment 5. This results in cost reduction.

[0044]

Furthermore, because the temperature of the boundary wall 7 does not fall below the temperature of the super-cooling storage compartment 5, there is no fear that water will freeze. Besides, because there is no need to consider heat insulation performance of the boundary wall 7 and the boundary wall 7 does not contain a heat insulating material, the boundary wall 7 can be locally reduced in thickness. These structural features make it possible to house an ice-making water tank 19 in the boundary wall 7, for example, as shown in Figs. 2 and 3. Consequently, as a water tank placed in the refrigerator compartment so far is placed in the boundary wall 7, the refrigerator 1 of Embodiment 1 can increase an inner volume of the refrigerator compartment 2 including the super-cooling storage compartment 5, whereby convenience is improved.

[0045]

[About top plate 18]

Fig. 5 is a schematic diagram illustrating a configuration of the top plate 18 provided in the refrigerator 1 according to Embodiment 1 of the present invention. Fig. 6 is a schematic diagram of the top plate 18 provided in the refrigerator 1 according to Embodiment 1 of the present invention as viewed from above the super-cooling storage compartment 5. Next, a configuration of the top plate 18 will be described with reference to Figs. 5 and 6.

[0046]

As shown in Fig. 5, the top plate 18 is made up of plural flat-plate transparent elements 24 arranged such that they face and are spaced away from one another. The transparent elements 24 are made of a material such as glass or resin. The transparent elements 24 form air gaps among themselves. Air in the air gaps serves to maintain a state of rest by inhibiting convection and other phenomena even in case of thermal variation in the top plate 18. Consequently, the top plate 18 has high heat insulation performance. Here, the space between the transparent elements 24 does not need to contain air gaps as a whole. For example, spacers (not shown) may be provided to keep distances among the transparent elements 24 and maintain durability. Hereinafter the air gaps enclosing air will be referred to as stationary air layers 23. Although it is assumed here that air is enclosed, another transparent gas may be enclosed.

[0047]

Also, a resin frame 27 is mounted around the top plate 18. To assemble the top plate 18 into the refrigerator 1, it is necessary to mount the resin frame 27 around the top plate 18. In so doing, the top plate 18 is configured as follows such that air will not flow into the stationary air layers 23 from outside: the plural transparent elements 24 are arranged, being spaced away from one another and surroundings of the transparent elements 24 are covered and sealed with a rubber or silicon element, ensuring sealing. Here, before being enclosed, moisture content of the air may be reduced by dehumidification or another method. Also, if the stationary air layers 23 have such airtightness as to keep outside air from flowing in, a resin frame may be attached directly to a stacked structure.

[0048]

Desirably a thickness T2 of each stationary air layer 23 is 3 mm or below. This is because if the thickness of the stationary air layer 23 is longer than 3 mm, it becomes easier for the air to flow, reducing the heat insulation performance ensured by stationary air. There is no particular

limit to a thickness T1 of each transparent element 24. However, in actual use, increases in the thickness of the transparent elements 24 result in increases in the weight of the top plate 18. Therefore, the thickness T1 of transparent elements 24 is desirably 3 mm or below.

[0049]

Here, although Fig. 5 shows a configuration in which two stationary air layers 23 are formed by three transparent elements 24, this is not restrictive. For example, the number of stationary air layers 23 may be one, or three or more.

[0050]

Thus, even if the number of stationary air layers 23 is increased by configuring the top plate 18 as mentioned above, the food stored in the storage container 14 can be examined by visually checking the inside of the super-cooling storage compartment 5 from above the top plate 18. This makes it possible to increase the heat insulation performance of the top plate 18 over existing top plates, and consequently, the inner volume of the super-cooling storage compartment 5 can be increased by expanding the super-cooling storage compartment 5 in a height direction.

[0051]

[Effect of top plate 18 on cooling capability]

Fig. 7 is a diagram illustrating results of cooling in the super-cooling storage compartment 5 when the top plate 18 provided in the refrigerator 1 according to Embodiment 1 of the present invention is used. As shown in Fig. 7, approximately equal cooling capability is exhibited by air temperature at a height of around 20 mm in an existing configuration that does not use the top plate 18 shown in Embodiment 1 and air temperature at a height of around 70 mm in Embodiment 1 that uses the top plate 18. This indicates superiority, in the height direction, of configuration that uses the top plate 18. Also, when the top plate 18 is used, a difference between the air temperature at a height of 20 mm and air temperature at a height of 70 mm is within

approximately 1 to 1.5 degrees C, indicating that the temperature distribution is not poor.

[0052]

Basically, the temperature distribution in the super-cooling storage compartment 5 needs to be kept uniform in both a horizontal direction and the height direction. Temperature distribution characteristics in the horizontal direction mainly depend on a flow rate in the outlet air passage 17 that supplies cold air to the super-cooling storage compartment 5. On the other hand, temperature distribution characteristics in the height direction depend on heat insulation performance of the super-cooling storage compartment 5, and in particular on heat insulation on an upper side. This is because cold air generally tends to collect in lower part, and upper part is more liable to be affected by heat outside the super-cooling storage compartment 5.

[0053]

For example, existing refrigerators have a configuration in which a chilling compartment provided in the refrigerator compartment is divided into an upper chilling compartment and lower chilling compartment and the lower chilling compartment is used as a super-cooling storage compartment. This is a structure used to prevent the super-cooling storage compartment and the refrigerator compartment higher in temperature than the super-cooling storage compartment from being placed directly next to each other.

[0054]

Basically, heat transfer from a location having a greater heat amount to a location having a smaller heat amount, tending to maintain balance of heat amounts (concentrating on a side lower in heat flux). Therefore, heat propagation forms a flow tending to equalize temperature. When the refrigerator compartment and super-cooling storage compartment are located adjacent to each other in the vertical direction, heat propagates from the side of the refrigerator compartment to the side of the super-cooling storage

compartment and the temperature in an upper region of the super-cooling storage compartment tends to increase. Consequently, a temperature difference is generated between upper and lower regions of the super-cooling storage compartment, making it difficult to maintain a uniform temperature distribution in the height direction.

[0055]

Thus, the refrigerator 1 of Embodiment 1 can curb temperature rises in the upper region of the super-cooling storage compartment 5 by enhancing the heat insulation performance of the top plate 18 of the super-cooling storage compartment 5, thereby preventing heat flux from entering the super-cooling storage compartment 5 from the side of the refrigerator compartment 2. This eliminates the need of providing an upper chilling compartment in an intermediate temperature range between the refrigerator compartment and super-cooling storage compartment like existing refrigerators.

Therefore, for example, if a space volume allocated to an upper chilling compartment so far is divided or otherwise allocated as an inner volume of the refrigerator compartment or super-cooling storage compartment, the inner volume of the super-cooling storage compartment 5 can be increased.

[0056]

Embodiment 2

Fig. 8 is a schematic diagram illustrating a configuration of a top plate 18 provided in a refrigerator 1 according to Embodiment 2 of the present invention. Fig. 9 is a schematic diagram of the top plate 18 provided in the refrigerator 1 according to Embodiment 2 of the present invention as viewed from above a super-cooling storage compartment 5. Next, a configuration of the top plate 18 in Embodiment 2 will be described with reference to Figs. 8 and 9.

[0057]

As shown in Fig. 8, the top plate 18 of Embodiment 2 has rib elements 26 in the stationary air layer 23 between each pair of transparent elements

24, where the rib elements 26 form a lattice shape when viewed from above. Although this is not restrictive in particular, it is assumed that the rib elements 26 of Embodiment 2 have an inverted U-shaped cross-section to ensure visibility and stability. A wire heater 25 is contained in each rib element 26. As with the heater 16, the wire heater 25 is a top plate heating device adapted to heat and thereby raise the temperature of the food in the super-cooling storage compartment 5. Since the wire heaters 25 are contained in the rib elements 26, the wire heaters 25 can be incorporated into the top plate 18 without significantly impairing visibility from above the top plate 18.

[0058]

It is assumed that the wire heaters 25 are around 2 to 3 mm in diameter ϕ . Besides, desirably the overall thickness of each rib element 26 is around 5 to 7 mm. Also, although in Fig. 8, the wire heaters 25 are incorporated into the rib elements 26 in each stationary air layer 23, the wire heaters 25 may be incorporated in only one stationary air layer 23.

[0059]

By incorporating the wire heaters 25 into the top plate 18, it becomes possible to supply heat to the food in the super-cooling storage compartment 5 in the warm-up step to assist the heater 16. This makes it possible to reliably prevent the food from being frozen in the height direction of the super-cooling storage compartment 5 as well as to prevent dew formation on the transparent elements 24 inside the top plate 18.

[0060]

Here, in Embodiment 2, it is assumed that the controller 100 controls the temperature of the super-cooling storage compartment 5 by controlling the dampers 11, the heater 16, and the wire heaters 25, but this is not restrictive. For example, the controller 100 may heat the inside of the super-cooling storage compartment 5 by controlling only the wire heaters 25 without controlling the dampers 11.

[0061]

Also, although an example in which the wire heaters 25 are heating equipment in the super-cooling storage compartment 5 has been described, this is not restrictive. For example, a heat exchanger, Peltier element, or other device may be used for heating as long as visibility can be ensured.

[0062]

Embodiment 3

Also, the super-cooling storage compartment 5 may be a versatile compartment that allows switching among a partial freezing compartment whose inside temperature is set to a subzero temperature zone around -3 degrees C, chilling compartment whose inside temperature is set to a positive temperature zone around 1 degree C, and other similar compartment. This makes it possible to select a temperature zone suitable for the food to be stored and improve convenience of the user.

[0063]

Also, in the super-cooling storage compartment 5 of the refrigerator 1 in Embodiment 1 and Embodiment 2 described earlier, the objects to be cooled that are put in a super-cooling state are not limited to food. For example, objects may be those collected from the natural world, such as uncooked meat of non-edible small animals. Also, the objects to be cooled may be uncooked meat of laboratory animals such as cloned animals. Every object to be cooled that is stored in a super-cooling state is included.

Reference Signs List

[0064]

1 refrigerator 2 refrigerator compartment 3 vegetable compartment 4 freezer compartment 5 super-cooling storage compartment 6 compressor 7 boundary wall 8 cooler 9 fan 10, 10a, 10b first air passage 11, 11a, 11b damper 12 second air passage 13 front wall 14 storage container 15 super-cooling storage compartment air inlet 16 heater 17 outlet air passage 18 top

plate 19 water tank 21 shelf 22 refrigerator compartment air inlet
23 stationary air layer 24 transparent element 25 wire
heater 26 rib element 27 resin frame 50 casing100 controller

CLAIMS

[Claim 1]

A refrigerator comprising:

a refrigerator compartment set to a refrigeration temperature zone;

5 a super-cooling storage compartment provided on a lower side in the refrigerator compartment and adapted to cool an object to be cooled such that the object to be cooled reaches a super-cooling temperature equal to or lower than a freezing temperature below the refrigeration temperature zone; and

10 a top plate made up of a plurality of flat-plate transparent elements and configured to serve as a top face of the super-cooling storage compartment, the plurality of transparent elements enclosing a gas by facing one another, wherein the top plate includes a top plate heating device.

[Claim 2]

15 The refrigerator of claim 1, further comprising:

a vegetable compartment placed under the refrigerator compartment and set to a temperature higher than in the refrigerator compartment;

a boundary wall configured to serve as a partition between the vegetable compartment and the super-cooling storage compartment provided
20 on the lower side in the refrigerator compartment; and

a heating device installed in the boundary wall and adapted to heat an inside of the super-cooling storage compartment.

[Claim 3]

The refrigerator of claim 2, further comprising a refrigerator
25 compartment air inlet configured to suck air from the refrigerator compartment, wherein the refrigerator compartment air inlet at least partially overlaps a super-cooling storage compartment air inlet in planar view, the super-cooling storage compartment air inlet being configured to suck air from the super-cooling storage compartment.

[Claim 4]

The refrigerator of claim 2 or 3, wherein an ice-making water tank is housed in the boundary wall.

[Claim 5]

5 The refrigerator of any one of claims 1 to 4, wherein the super-cooling storage compartment is switchable between a partial freezing compartment in a subzero temperature zone lower than the super-cooling temperature and a chilling compartment in a positive temperature zone higher than the super-cooling temperature.

[Claim 6]

10 The refrigerator of any one of claims 1 to 5, wherein the top plate heating device is a wire heater.