

REFRIGERATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of
5 priority from Japanese Patent Application No. 2007-197511,
filed on July 30, 2007, the entire contents of which are
incorporated herein by reference.

BACKGROUND OF THE INVENTION

10 1. Field

This invention relates to a refrigerator or storage house
having a duct for guiding the cold air created in a cooler to
a divided storing compartment.

2. Description of the Related Art

15 A traditional refrigerators includes a plurality of
storing compartments such as a refrigerator compartment, a
freezer compartment, a vegetable compartment and a convertible
compartment. By driving a fan, the cold air created in the
cooler is sent to e.g. the convertible compartment through a
20 single duct. If the temperature within the convertible
compartment, which is detected by a convertible compartment
sensor provided therein, is not higher than a prescribed
temperature, a convertible compartment damper for controlling
the quantity of cold air flowing toward the convertible
25 compartment is closed; and if the temperature detected by the
convertible compartment sensor is higher than a prescribed
temperature, the convertible compartment damper is opened. In

this way, the convertible compartment permits the temperature zone to be changed. In some refrigerators, a convertible compartment heater is provided for changing the temperature therein to a higher temperature side. JP-A-2006-258322
5 discloses this kind of refrigerator.

In the traditional refrigerator, a cold air blowout port (also simply referred to as a blowout port) is provided at a specific place constituting the wall such as the inner side of the convertible compartment or ceiling thereof; from the
10 cold air blowout port, the cold air blows into the convertible compartment. Therefore, only the portion near the blowout port is abruptly cooled, whereas the cold air is not relatively likely to reach the center and this (front) side of the convertible compartment which is farther than the inner side
15 and ceiling from the cold air blowout port. This is likely to generate temperature changes at some areas in the convertible compartment and makes it difficult to cool foods and others at a uniform temperature.

For this reason, even if "slow freezing" is carried out
20 to super-cooling refrigerate the foods, because of difficulty of cooling the foods at the uniform temperature due to the temperature changes, the super-cooling was not successful. Further, where an indirect cooling structure is adopted for the slow freezing, since the cold air blowout port is not
25 provided in a vessel, the temperature therein could not be changed to a freezing temperature zone in the vicinity of -18°C and the freezing such as fast freezing could not also carried

out.

The refrigerator disclosed in JP-A-2006-258322 permits the temperature within a convertible compartment to be precisely controlled by controlling the convertible compartment heater and a convertible compartment damper. This refrigerator, however, offered a problem that power consumption is much because both heater and damper are used.

SUMMARY OF THE INVENTION

One aspect of the invention has been accomplished to solve the above problems, and an object thereof is to permit both direct cooling and indirect cooling to be performed in a storing compartment. Another object is to provide a refrigerator or storage house having a storing compartment permitting the freezing to be selectively changed among fast freezing, normal freezing and super-cooling freezing. Still another object is to carry out the super-cooling freezing effectively. Still another object is to provide a refrigerator or storage house with less power consumption which does not use the heater. Still another object is to provide a refrigerator or storage house capable of super-cooling freezing with high freezing quality giving a small quantity of drip in unfreezing by selectively changing the indirect cooling and the direct cooling. Still another object is to provide a refrigerator permitting the convertible compartment to be used as a high humidity vegetable compartment to be used by selectively changing the indirect cooling and the direct cooling.

According to a first aspect of the invention, there is provided a refrigerator including a plurality of divided storing compartments to which a cold air created by a cooler is sent, wherein a cold air duct for sending the cold air from the cooler to at least one of the storing compartments includes two ducts of a direct cooling duct and indirect cooling duct.

According to a second aspect of the invention, there is also provided a refrigerator including a plurality of divided storing compartments to which a cold air created by a cooler is sent, wherein a cold air duct for sending the cold air from the cooler to at least one of the storing compartments is composed of two ducts of a direct cooling duct and indirect cooling duct, comprising a direct cooling duct connected to at least one of the storing compartments and opened at a position where the cold air from the cooler is directly applied to the food within the storing compartment; an indirect cooling duct connected to at least one of the storing compartments and opened at a position where the cold air is not directly applied to food within the storing compartment or the cold air is indirectly applied to the food; and an air quantity regulating means capable of changing two cooling ducts of the direct cooling duct and the indirect cooling duct into an either state of both opened, one opened or both closed, wherein the two cooling ducts are selectively changed so that the storing compartment is a storing compartment capable of executing the super-cooling freezing of freezing by way of a super-cooled state.

According to an aspect of the invention, since at least one of the storing compartments has both direct cooling duct and indirect cooling duct, a refrigerator or storage house capable of selecting fast freezing, normal freezing or
5 super-cooling freezing can be provided.

According to another aspect of the invention, since changes in the temperature distribution within a divided storing compartment of the refrigerator can be reduced, a refrigerator or storage house permitting high quality food
10 preserving can be provided.

According to still another aspect of the invention, since changes in the temperature distribution of the food or the like preserved within the storing compartment of the refrigerator can be reduced, a refrigerator or storage house permitting high
15 quality food preserving can be provided.

According to still another aspect of the invention, as a high quality freezing function, a super-cooling freezing function is adopted in place of conventional fast freezing. Therefore, the high quality freezing with less energy than
20 before, i.e. energy saved freezing as an earth environment measure can be realized.

Further, the refrigerator according to still another aspect of the invention adopts a temperature-controlled cooling structure in which the cold air is introduced in the
25 space causing the super-cooling and the cooling temperature can be changed to plural values. Thus, in the structure and control of the refrigerator which is not greatly different from

that of the conventional refrigerator, the super-cooling of the meat or like can be realized.

According to still another aspect of the invention, since an infrared sensor is used as the temperature detecting means, the surface temperature of the food can be measured, thereby permitting the temperature nearer to the food (e.g. surface temperature) to be detected and the success probability of the super-cooling freezing to be enhanced. Thus, the freezing preserving (super-cooling freezing) giving the good food quality can be provided.

According to still another aspect of the invention, which has a super-cooling freezing function of freezing by way of the super-cooled state, the high quality freezing in which the size or shape of the ice crystals created in freezing is not prone to destroy the essential structure of the food. Further, since the ice crystals created are minute, even if the ice crystals are broken, the state close to the original state can be obtained. Thus, when the food is unfrozen, the food quality such as its taste, texture or preserved state becomes satisfactory. Because of the super-cooling freezing by way of the super-cooled state, the ice nuclei are minute and fine and uniformly distributed over the entire material to be frozen. Thus, as compared with the normal freezing or fast freezing, the resultant food quality is satisfactory.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a front view of a refrigerator illustrating the

first embodiment of this invention;

Fig. 2 is a side sectional view of a refrigerator illustrating the first embodiment of this invention;

Fig. 3 is a sectional view around the convertible
5 compartment of a refrigerator illustrating the first
embodiment of this invention;

Fig. 4 is a control chart during the normal freezing of
a refrigerator illustrating the first embodiment of this
invention;

10 Fig. 5 is a view showing a liquid crystal display panel
according to the first embodiment of this invention;

Fig. 6 is a control chart during the super-cooling
freezing of a refrigerator illustrating the first embodiment
of this invention;

15 Fig. 7 is a sectional view around the convertible
compartment of the refrigerator showing the first embodiment
of this invention;

Fig. 8 is a front view around a convertible compartment
damper of the refrigerator illustrating the first embodiment
20 of this invention;

Fig. 9 is a sectional view around the convertible
compartment of the refrigerator showing the first embodiment
of this invention; and

Fig. 10 is a control chart during the super-cooling
25 freezing of a refrigerator illustrating the first embodiment
of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiment 1

Fig. 1 is a front view of a refrigerator illustrating the first embodiment of this invention. Fig. 2 is a side sectional view of a refrigerator illustrating the first embodiment of this invention. In these figures, a refrigerator body 1 includes a double-doored refrigerator compartment 2 at the uppermost stage, and an ice-making compartment 3 and a convertible compartment 4 right and left below the refrigerator compartment 2, The refrigerator body 1 also includes a freezer compartment 6 at the lowermost stage and a vegetable compartment 5 above the freezer compartment 6. The vegetable compartment 5 is placed below the ice-making compartment 3 and convertible compartment 4 arranged left and right and also above the freezer compartment 6.

It is needless to say that the arrangement of the respective compartments should not limit this invention. For example, a "mid-freezer type" refrigerator may be adopted in which the freezer compartment 6 is arranged between the ice-making compartment 3 and convertible compartment 4 arranged left and right and the vegetable compartment 5. In the mid-freezer type refrigerator, the ice-making compartment 3 and convertible compartment 4 are arranged left and right below the refrigerator compartment 2 at the upper stage, and the freezer compartment 6 is arranged below the ice-making compartment 3 and convertible compartment 4 arranged left and right and also above the vegetable compartment 5 arranged at

the lower stage.

At the front side opening portion of the refrigerator compartment 2, a refrigerator compartment door 7 is double-doored which can be freely opened or closed. The refrigerator compartment door 7 is double-doored by a left refrigerator compartment door 7A and a right refrigerator compartment door 7B. The door 7 may not be double-doored type door but may be a single rotary type door. The ice-making compartment 3, convertible compartment 4, vegetable compartment 5 and freezer compartment 6, which are storing compartments, have a drawble ice-making compartment door 8 capable of freely opening/closing an opening of the ice-making compartment 3, a drawable convertible compartment door 9 capable of freely opening/closing an opening of the convertible compartment 4, a drawable vegetable compartment door 10 capable of freely opening/closing an opening of the vegetable compartment 5, and a drawable door 11 capable of freely opening/closing an opening of the freezer compartment 6, respectively. Either one of the left and right doors of the refrigerator compartment 2 which is the storing compartment is provided with an operating switch for setting e.g. the temperature within the refrigerator compartment and a display panel 60 for displaying the temperature information such as the temperature within the refrigerator and setting temperature. Further, the operating information by the operating switch, displayed information by the liquid crystal display portion and temperature information within the

refrigerator compartment are controlled by a control device 30 such as a microcomputer provided at the upper portion of rear side of the refrigerator body (rear side of the refrigerator compartment).

5 Within a machine compartment 1A at the lowermost portion of the rear side of the refrigerator body 1, a compressor 12 is arranged. The refrigerator body 1 has a freezing cycle. The compressor 12 serves as a component of the freezing cycle and has a function of compressing the refrigerant within the
10 freezing cycle. The refrigerant compressed by the compressor 12 is condensed by a condenser (not shown). The refrigerant being condensed is pressure-reduced by a capillary tube (not shown) or expansion valve serving as a pressure reducer. A cooler 13 serves as a component of the freezing cycle. The
15 refrigerant pressure-reduced is evaporated by the cooler 13 and the gas in the vicinity of the cooler 13 is cooled by the heat absorbing function in the evaporation. A cold air circulating fan 14 serves to send the cold air cooled around the cooler 13 to the respective compartments (refrigerator
20 compartment 2, ice-making compartment 3, convertible compartment 4, vegetable compartment 5 and freezer compartment 6) of the refrigerator body 1. A convertible compartment damper 15 serving as an air quantity regulating means serves to regulate the quantity of the cold air to the convertible
25 compartment 4 sent by the cold air circulating fan 14, thereby controlling the temperature within the convertible compartment 4 to a prescribed temperature. The cold air cooled by the

cooler 13 is sent into the convertible compartment 4 through a convertible compartment cooling doubled duct 16. This convertible compartment cooling doubled duct 16 is arranged downstream of the convertible compartment damper 15.

5 Fig. 3 is a sectional view of the main part around the convertible compartment of the refrigerator showing the first embodiment of this invention. As seen from Fig. 3, a convertible compartment case 17 is arranged within the convertible compartment 4. One baffle 15A of the convertible
10 compartment damper 15 serving as the air quantity regulating means can regulate the quantity of the cold air sent to the convertible compartment 4 by opening/closing regulation (regulation of the opening/closing angle) and can select one of the two ducts constituting the convertible compartment
15 cooling doubled duct 16. Now, the convertible compartment cooling doubled duct 16 consists of two cooling ducts inclusive of a direct cooling duct 16A and an indirect cooling duct 16B (In Fig. 3, the convertible compartment cooling doubled duct 16 is branched into two cooling ducts (direct cooling duct 16A
20 and indirect cooling duct 16B) through the air quantity regulating means 15 from a cooler room connected duct 16C connected to a cooler room. In such a configuration, the convertible compartment cooling doubled duct 16 selects one of the two cooling ducts and regulates the air quantity through
25 the air quantity regulating means 15). The direct cooling duct 16A serves to directly send the cold air to the convertible compartment 4. The indirect cooling duct 16B is provided

within a convertible compartment ceiling heat insulator 18 arranged on the ceiling of the convertible compartment 4, thereby sending the cold air. Because the blowout port for jetting the cold air is not provided on the ceiling of the convertible compartment 4, by the cold air passing the indirect cooling duct 16B, the interior of the convertible compartment 4 is cooled indirectly from the ceiling.

In the direct cooling duct 16A, a rear blowout port 4A is provided on the rear side within the convertible compartment 4. From the rear blowout port 4A, the cold air is directly jet into the convertible compartment 4. In this case, where a convertible compartment case 17 serving as a storing compartment case is provided within the convertible compartment 4, the cold air jet from the rear blowout port 4A is jet into the convertible compartment case 17 from an opening or notch made on a rear wall of the convertible compartment case 17 at the position opposite to the rear blowout port 4A, thereby directly cooling the food within the convertible compartment case 17. It is needless to say that even where the convertible compartment 4 is not provided so that the food is directly stored within the convertible compartment 4, because the cold air can be jet from the rear blowout port 4A, the food can be directly cooled.

In Fig. 3, in the indirect cooling duct 16B, the cold air blowout port into the convertible compartment 4 is not provided. However, the cold air having passed the indirect cooling duct 16B is returned to the cooler room through a convertible

compartment returning duct provided on the lower surface or side face of the convertible compartment 4. In this case, in the indirect cooling duct 16B, the blowout port jetting the cold air into the convertible compartment 4 may be provided as long as the air of a very small quantity or with a low cooling speed is jet. If the air of a very small quantity or at a low cooling speed is jet to give the cooling level identical to the indirect cooling to the inside of the convertible compartment 4, the blowout port jetting the cold air into the convertible compartment 4 or convertible compartment case 17 may be provided in the indirect cooling duct 16B. The slow cooling in which the cold air naturally falls can be regarded as the indirect cooling. Within the convertible compartment 4, a convertible compartment thermistor 19 is provided which serves as a convertible compartment temperature detecting means for detecting the temperature within the convertible compartment 4. On the basis of the temperature detected by the convertible compartment temperature detecting means 19, the temperature within the convertible compartment 4 is controlled to a prescribed temperature by the control device (e.g. a microcomputer).

The cold air cooled by the cooler 13 is sent to the respective storing compartments through the cold air ducts by the cold air circulating fan 14. The cold air cooled by the cooler 13 passes the cold air duct 16C through the cold air circulating fan 14. By controlling the opening/closing angle of the one baffle 15A of the convertible compartment damper

15, the direct cooling duct 16A and the indirect cooling duct 16B arranged in parallel are selectively changed. Further, by controlling the opening/closing angle of the one baffle 15A for controlling the flow rate in each of the ducts, the cold air with a prescribed flow rate or at a prescribed speed is sent to the convertible compartment 4. In this case, if the opening/closing angle of the baffle 15A is zero (substantially horizontal: $\pm 20^\circ$, preferably $\pm 10^\circ$), a substantially fully closed status (both of the direct cooling duct and the indirect cooling duct are in a closed status) is provided. In this status, since both direct cooling duct 16A and indirect cooling duct 16B are closed, the cold air is not sent to both direct cooling duct 16A and indirect cooling duct 16B. As a result, the inside of the convertible compartment 4 is not cooled by the cold air passing the direct cooling duct 16A and indirect cooling duct 16B.

If the opening/closing angle of the baffle 15A is substantially 90° (substantially vertical: 70° to 110° , preferably 80° to 100°), a substantially fully opened status is provided. In this status, since both direct cooling duct 16A and indirect cooling duct 16B are opened, the cold air is sent to both direct cooling duct 16A and indirect cooling duct 16B. As a result, owing to the cooling by both the indirect cooling and direct cooling, a prescribed set temperature can be reached quickly. In this case, although the flow path areas of the direct cooling duct 16A and indirect cooling duct 16B may be substantially equal to each other, they may be different

according to the using purposes such as the frequency of using the direct cooling and indirect cooling, size and cooling setting temperature of the storing compartment to be cooled or presence/absence of the super-cooling freezing (In Fig. 3, the flow path area of the direct cooling duct 16A is made larger than that of the indirect cooling duct 16B so that when the baffle is fully opened, a larger quantity of the cold air flows into the direct cooling duct 16A, thereby emphasizing the effect of the direct cooling. Preferably, if the flow path area of the direct cooling duct 16A is twice or more as large as that of the indirect cooling duct 16B, when the baffle is fully opened, the cold air is likely to flow into the direct cooling duct 16A so that the effect of the direct cooling can be easily obtained).

15 If the opening/closing angle of the baffle 15A is substantially 45° (20° to 70° , preferably 35° to 55°), a one-side open status is provided. In this status, the direct cooling duct 16A is substantially closed whereas the indirect cooling duct 16B is opened so that the cold air is sent to the indirect cooling duct 16B. Thus, the inside of the convertible compartment 4 is indirectly cooled by the cold air passing the indirect cooling duct 16B from the ceiling and others. An explanation has been given of an example in which the indirect cooling duct 16B is provided on the ceiling of the convertible compartment 4. However, as long as the cooling identical to the indirect cooling can be done, it may be provided in not the ceiling but the side wall or bottom wall (partition wall

of the bottom of the convertible compartment). Similarly, the blowout port 4A of the direct cooling duct 16A may be also provided on the ceiling wall, side wall or bottom wall).

Hitherto, in this embodiment, as regards the opening/closing pattern of the direct cooling duct 16A and the indirect cooling duct 16B, it was explained that using the one baffle, one of three patterns of (1) substantially fully closed, (2) substantially fully opened and (3) the direct cooling duct 16A substantially closed and indirect cooling duct 16B substantially closed can be selected. However, one of three patterns of (1) substantially fully opened, (2) substantially fully opened and (3) either one of the direct cooling duct 16A and indirect cooling duct 16B being opened and the other being closed may be selected, thereby attaining the same effect. Further, using a twin damper or triple damper equipped with two or more baffles, the direct cooling duct 16A and indirect cooling duct 16B may be individually opening/closing controlled. In this case, the cold air quantity of the direct cooling and that of the indirect cooling can be separately controlled so that the cold air quantity can be controlled precisely. Further, since the direct cooling and indirect cooling can be selected separately, controlling the temperature and changing the prescribed temperature can be precisely done.

Fig. 4 is a control chart during the normal freezing of the convertible compartment damper 15 of the refrigerator showing the first embodiment of this invention. In step S1,

it is determined whether or not the running condition of the compressor 12 is satisfied. Satisfaction of the running condition of the compressor 12 means that the temperature detected by the freezer compartment temperature detecting means (not shown) provided for detecting the temperature of e.g. the freezer compartment 6 is a prescribed temperature or higher. Namely, step S1 determines the compressor running condition and determines whether or not the temperature detected by e.g. the freezer compartment temperature detecting means being a temperature detecting means is the prescribed temperature or higher. In step S1, if it is determined that the temperature detected by the freezer compartment temperature detecting means is lower than the prescribed temperature (NO), the control returns to step S1. If the temperature detected by the freezer compartment temperature detecting means is the prescribed temperature or higher (YES), the control proceeds to step S2.

Step S2 is determines whether or not the temperature detected by the convertible compartment thermistor 19 being a convertible compartment temperature detecting means is a prescribed temperature T_0 or higher. In step S2, if it is determined that the temperature detected by the convertible compartment thermistor 19 is lower than the prescribed temperature T_0 (NO), the control returns to step S2. In step S2, if it is determined that the temperature detected by the convertible compartment thermistor 19 is the prescribed temperature T_0 or higher (YES), the control proceeds to step

S3.

In step S3, the convertible compartment damper 15 is opened at a predetermined angle θ_0 (substantially fully opened state at substantially 90° (substantially vertical: 70° to 110°)) from the fully closed state (substantially 0°). The control proceeds to step S4. Step S4 determines whether or not the convertible compartment damper 15 has been opened for a predetermined time t_0 or longer. In step S4, if it is determined that the convertible compartment damper 15 has not been opened for a predetermined time t_0 or longer, the control returns to step S4. In step 4, if it is determined that the convertible compartment damper 15 has been opened for a predetermined time t_0 or longer, the control proceeds to step S5. In step S5, the convertible compartment damper 15 is opened at a predetermined angle θ_1° (one side opened at substantially 45° (20° to 70°) being a middle angle). The control proceeds to step S6.

Step S6 determines whether or not the temperature detected by the convertible compartment thermistor 19 is a prescribed temperature $T_1^\circ\text{C}$ or lower. In step S6, if it is determined that the temperature detected by the convertible compartment thermistor 19 is higher than the prescribed temperature $T_1^\circ\text{C}$ (NO), the control proceeds to step S8. Step S8 determines whether or not the convertible compartment damper 15 has been opened for a prescribed time t_1 or longer. In step S8, if it is determined that the convertible compartment damper 15 has not been opened for a prescribed time t_1 or longer (NO), the control returns to step S6. In step S8, if it is determined

that the convertible compartment damper 15 has been opened for a prescribed time t_1 or longer (YES), the control proceeds to step S9. In step S9, the convertible compartment damper 15 is opened at the predetermined angle θ_0° (substantially fully opened state, substantially vertical). The control returns to step S6. In step S6, if it is determined that the temperature detected by the convertible compartment thermistor 19 is the prescribed temperature $T_1^\circ\text{C}$ or lower (YES), the convertible compartment damper 15 is closed (substantially 0° , substantially horizontal).

Now, the prescribed angle θ_0° is e.g. substantially 90° . At this angle, the cold air for the convertible compartment 4 is sent to both direct cooling duct 16A and indirect cooling duct 16B. Therefore, the inside of the convertible compartment 4 is cooled more quickly to the degree that the cold air directly flows therein. The prescribed angle θ_1° is e.g. substantially 45° . At this angle, the direct cooling duct 16A can be substantially closed by the baffle 15A. Therefore, almost of the cold air for the convertible compartment 4 is sent to the indirect cooling duct 16B. Therefore, the inside of the convertible compartment 4 is cooled gently from the ceiling side of the convertible compartment 4 (or from the side or the bottom side). Because the inside of the convertible compartment 4 is gently cooled, the temperature distribution within the convertible compartment 4 becomes substantially uniform owing to natural convection of the cold air so that the food can be preserved or frozen in a super-cooled state.

The opening degree of the convertible compartment damper 15 at the prescribed time t_0 is changed for the purpose of making the temperature distribution within the convertible compartment 4 substantially uniform without reducing the cooling speed within the convertible compartment 4. Where the opening time of the convertible compartment damper 15 becomes the prescribed time t_1 or longer because of opening/closing of the convertible compartment door 9, by returning the opening degree to θ_0° (substantially 90° , fully opened), the cooling time is not extremely delayed and so the preserving quality of the food will not be impaired.

In this way, in accordance with the refrigerator according to the first embodiment of this invention, since the temperature distribution within the convertible compartment 4 can be made substantially uniform without reducing the cooling speed, the super-cooling preserving or super-cooling freezing can be done. Further, if the display panel 60 shown in Fig. 1 is equipped with a select switch or a select button, where the mode of fast cooling (fast cooling or fast freezing) is selected by this switch or button, by opening the convertible compartment damper 15 at substantially 90° (fully opened), the cooling within the convertible compartment 4 can be done in a short time, thereby realizing the fast cooling (fast cooling or fast freezing).

In accordance with this invention, which is provided with the direct cooling duct 16A and the indirect cooling duct 16B, in addition to the normal freezing, the super-cooling freezing

or fast freezing can be done. First, taking water as an example, an explanation will be given of the super-cooled state and freezing by way of the super-cooled state. The super-cooled state refers to the state where when water is cooled, the state of water of 100 % is kept even if the temperature becomes below 0°C being a freezing point. The water once fallen in the super-cooled state can be frozen into ice. However, in order to realize this, any stimulus is required. This stimulus may be either a temperature stimulus or a physical stimulus. Either temperature stimulus and physical stimulus can start the freezing. The time taken from the super-cooled state from the start of freezing is several seconds to be instantaneous. The percentage of ice instantaneously frozen at the start of freezing is several % of the entire quantity. In the case of water, sherbet is created. In order that the sherbet becomes ice in 100 %, further cooling is required to take a cooling time. The freezing by way of the super-cooled state refers to super-cooling freezing.

Next, another remarkable difference between the normal freezing or super-cooling freezing resides in the state when the freezing starts. Now, taking, as an example, the water contained in a PET bottle, the phenomenon occurring when freezing starts will be explained. In the case of the normal freezing, when freezing starts, the water start to freeze from the vicinity of the surface of the PET bottle, which results in the state as if thin ice spread on the surface. Thereafter, the ice extends toward the interior and eventually the entire

water will be frozen. The growth of ice occurs around the ice nuclei in which water molecules have created a cluster with a certain or larger size. The ice nuclei are created when freezing starts. Thus, in the case of the normal freezing, most
5 of the ice nuclei are created on the surface and the ice grows from there toward the portion in the state of water. As a result, the ice nuclei are created in a certain direction thereby to create larger needle-like ice crystals.

On the other hand, in the case of the super-cooling
10 freezing, the entire PET bottle inclusive of the interior (center portion of the water) of the PET bottle is substantially uniformly cooled in a non-frozen state. When the super-cooled state is cancelled by the temperature stimulus or physical stimulus, the freezing starts and ice nuclei are created
15 uniformly over the entire PET bottle. Further, the ice grows in any portion within the PET bottle inclusive the surface and interior so that it will not grow toward a certain direction. Thus, substantially uniform minute granular ice crystals are obtained. As a result, the difference between the normal
20 freezing and super-cooling freezing resides in the following point owing to the difference in their cooling process. Namely, in the case of the normal freezing, the large needle-like ice crystals oriented from the surface to the interior are created, whereas in the super-cooling freezing, the substantially
25 uniform minute granular ice crystals. Owing to the difference in the frozen state, the foods frozen via the super-cooled state will not be impaired in their preserving quality.

Now, the super-cooling freezing will be explained in more detail. The refrigerator according to this embodiment includes a control mechanism for keeping the stable temperature environment necessary to stably realize the super-cooling and regulating the temperature and cold air such as the temperature, wind speed, wind quantity and jetting timing of the cold air to be directly jetted to the food; a structure such as the cases for housing the foods; a device or control mechanism for determining the completion of the super-cooling necessary to surely cancel the super-cooling; and a device or control mechanism for giving the stimulus necessary to cancel the super-cooling. The refrigerator also includes a function of cooling and preserving for keeping satisfactory freezing after the super-cooling has been cancelled.

First, the super-cooling freezing can be classified into the following five states according to the temperature of the food.

(1) non-frozen state: the food temperature is a freezing point of the food or higher.

(2) super-cooled state: the food temperature is a freezing point or lower and the food is not frozen. Since the food temperature continues to fall, it can be known that the food is in the super-cooled state.

(3) state where the super-cooling has been canceled: the food temperature has returned to the freezing point from the temperature lower than it.

(4) state from the start of freezing to the completion

thereof: the food reaches its freezing point to make their phase change (in the case of water, liquid water changes into solid ice) and is kept at a certain temperature.

(5) state where the freezing has been completed and food has
5 been frozen and preserved: the food has been frozen by way of the step of (4).

Now, the freezing point of main foods will be explained. It is -1.7°C for beef/pork; -1.3°C for tuna; -1.7°C for a potato; -1.2°C for a strawberry; and -2.0°C for an apple (Reference
10 Document: Yoshito Sakurai, "Sougou Shokuryou Kougyou (General Food Industry)," Japan, Koseisha Koseikaku Co., Ltd., 1975, p. 922).

For the state of (1) to (2), there are a condition necessary for rushing in the super-cooling (the food is placed
15 at the temperature of the freezing point or lower in their non-frozen state) and a condition for deepening the super-cooling (lowering the temperature which is reached in the super-cooling state). For the state of (3), there is a condition for canceling the super-cooled state and starting
20 freezing. For the states of (4) and (5), there is a condition for keeping the goodness of the food super-cooling frozen. If a sufficiently deep super-cooling degree (temperature difference between the freezing point of the food and the temperature reached after the super-cooling) can be obtained
25 by controlling the states of (1) to (3), the effect of super-cooling will not be lost by the states of (4) and (5). However, if the door is opened for a long time owing to take

in/out of the foods in the super-cooled state, or if the setting temperature is raised to the freezing point or higher so that the temperature within the super-cooling compartment becomes 0°C or higher to cancel the super-cooled state, control will
5 be re-started from the state of (1).

Next, the steps of (1) to (3) will be explained. First, they will be explained on the basis of the investigation result when as a food, the beef with a thickness of 15 mm and weight of 150 g is put in. An explanation will be given of the
10 super-cooling condition for a super-cooling compartment (identical to a super-cooling space) of the refrigerator according to this invention. In setting the condition of the super-cooling, an attention is paid to the cooling speed and a difference between the lowest reaching point (temperature
15 reached in the super-cooled state) of the core temperature of the food and its freezing point. If the cooling speed is too high, the entire food is cooled in a nonuniform temperature state (there is a large difference between the surface temperature of the food and the core temperature thereof),
20 thereby providing a frozen portion and non-frozen portion. Since the ice crystal grows around the ice nucleus, if even a portion of the food is frozen, the ice crystal will grow taking in water from the non-frozen portion. As a result, the needle-like and ice crystals will be created. The needle-like
25 ice crystals created among cells or large ice crystals give rises to flow-out of water in the cells and breakage of the cells and further drip flow-out in unfreezing.

Accordingly, the essential taste of the food will be reduced, nutritious contents such as liberated amino acid will be reduced, or feeling of the food will be deteriorated. On the other hand, if the cooling speed is too low, the maintenance
5 of the super-cooled state is not problematic, but lengthening of the non-frozen state may lead to deterioration of the food quality owing to bacteria bleeding and oxidation promotion. In view of these facts, until the temperature reaches the freezing point, the food should be cooled so as to reduce the
10 difference between the surface temperature and core temperature. Once the temperature has reached the freezing point or lower (super-cooled state), the cooling speed should be increased to quickly reach the lowest reaching point of the core temperature and the super-cooled state should be cancelled
15 to prevent the non-frozen state from being lengthened. In this way, the temperature control or cold air regulation is carried out continuously or stepwise at the respective states where the food is cooled to the freezing point; further cooled to the super-cooled state lower than the freezing point;
20 super-cooling-cancelled; and completely frozen. In order to solve the above problem, there is a technique of giving an antibacterial function to the super-cooled space. The antibacterial function can be obtained by using ultraviolet rays or ozone. However, the provision of the antibacterial
25 function, which is costly, is problematic.

First, the cooling speed for the condition of rushing into the super-cooling will be explained. The food is cooled from

the surface and the center of the food is cooled by thermal conduction according to the kind and thickness of the food. This is because the cooling speed of the food center is determined after the cooling speed of the food surface is determined. Further, actually, where the temperature change in the food is controlled in a home-use refrigerator, it is general to detect the surface temperature of the food so that the surface temperature is first defined. The temperatures at the food surface and food center fall in a similar tendency in a time passage when the food is super-cooled. In the case of the beef having a thickness of 15 mm and a weight of 150 g, the environmental air of the food reaches a prescribed temperature, e.g. -5°C , -7°C or -10°C in about 30 minutes. On the other hand, the food surface is late to reach the freezing point late by 120 minutes, 80 minutes or 60 minutes, respectively. There is a small difference in temperature between the food center and food surface, 0.5 to 3.0 degrees (K).

However, as the air setting temperature is higher, there is a smaller temperature difference between the surface and center. As the air setting temperature is lower, the degree of super-cooling, i.e. energy in freezing becomes smaller. The cooling speed is calculated in a range in which the food surface temperature is 3°C to 0°C . The cooling speed in this temperature zone is related to success or failure of rushing in the super-cooling. If the setting temperature around the food is -5°C , the cooling speed of the food surface is about 3.5°C/h ;

if the setting temperature around the food is -7°C , the cooling speed of the food surface is about 5°C/h ; and if the setting temperature around the food is -10°C (the degree of super-cooling is shallow), the cooling speed of the food surface is about 10°C/h . Thus, as a condition of rushing into the super-cooling, if there is a certain distance between the food surface and food center, it is defined that the cooling speed of the food surface is 10°C/h , preferably 5°C/h .

In this case, there are changes in the temperature difference between the food surface and food center. At the setting temperature of -5°C , there is a temperature difference of about 1 degree (K) between the food surface and food center (the cooling speed at the food center is about 3.5°C/h); and at the setting temperature of -7°C , there is a temperature difference of about 2 degrees (K) between the food surface and food center (the cooling speed at the food center is about 5°C/h). On the other hand, at the setting temperature of -10°C where the degree of super-cooling is shallow, there is a temperature difference of about 3 degrees (K) between the food surface and food center (the cooling speed at the food center is about 10°C/h). Accordingly, as a condition for rushing in the super-cooling, it is defined that the temperature difference between the food surface and food center is 3 degrees (K) or less, preferably 2 degrees (K) or less. Where the distance between the food surface and food center is short, i.e. the thermal capacity of the food is small, for example, thin meat, even if the setting temperature is lower than -10°C , for example

-15°C, the degree of super-cooling dose not become shallow, thereby providing a good frozen food.

In view of the above facts, it seems that the condition of the cooling speed for the food surface is that the temperature difference between the food surface and food center is 3 K or lower. Under this condition, the following phenomena may be avoided. A) If the temperature difference between the food surface and food center increases, the density of the water contained in the food changes and owing to the density difference, convection of water contained in the food is generated. Thus, the ratio of association of water molecules increases to promote the growth of ice nuclei, thereby facilitating canceling of the super-cooling. B) If the food surface is frozen early, with the food surface being fixed at the freezing point, a stabilized environment will be generated over the entire food. Thus, the food is preserved stably at the freezing point and the cooling heat conducted from the food surface will be used as latent heat so that the freezing will advance.

For this reason, if the food surface is frozen, the entire food will not be super-cooled. On the other hand, as regards the air temperature around the food, in order that the food is made at the temperature lower than the freezing point without being frozen, it is desired that the air temperature around the food is -10°C or higher although it varies according to the kind or thickness of the food. It is apparent that the upper limit of the air temperature around the food is the freezing

point or lower of the food to be super-cooled. For example, for the beef or pork, it is -1.7°C , and for most of the foods, it is set at -2°C . The cooling speed for limiting the temperature to 3 degree (K) or less is desirably about 3.5°C/h to 10°C/h , particularly desirably 5°C/h or lower. However, in the case of the thin meat having a thickness of 10 mm or less, at the cooling speed of 5°C/min or less, it rushes into the super-cooling. In the case of a meat lump having a thickness of 40 mm to 50 mm, the cooling speed of about 2 to 3°C/h is required. In any food, the temperature difference between the food surface and food center may be limited to about 3 degree. However, in a gelled uniform food such as yogurt in which water is likely to be held at a certain position and which is easily super-cooled, it is super-cooled at the cooling speed of about 3.5°C/h to 10°C/h . However, at the setting temperature of -18°C , it will be super-cooled even at the temperature difference of 5 to 10 degree.

Against the temperature change around the food which is a factor which obstructs the rush in the super-cooling and maintenance of the super-cooled state, it is desired to restrict changes in the cooling speed, or decrease the cooling speed around the food. Further, in the refrigerator, in order to control the air temperature at a certain temperature, the air temperature around the food inevitably changes owing to the influence from various device operations such as on/off of the compressor, on/off of the fan within the refrigerator and opening/closing of the damper. Changes in the air temperature

give a great temperature change to the interior of the foods. Thus, the convention of water is promoted within the food. Namely, the probability of the association of water molecules becomes high so that the super-cooling is likely to be cancelled.

5 In order to avoid this and to cause the food to rush in the super-cooled state, the temperature changing width required until the freezing point of the food is exceeded (for example, -1.7°C), i.e. the food rushes in the super-cooled state was experimentally about 6 degrees (K) or less. Regardless of the
10 size and kind of the foods, any stimulus of canceling the super-cooling of the food surface must not given. Thus, the change in the air temperature around the food is desirably 6 K or less as described above.

However, even if the super-cooling speed is slightly
15 retarded or the probability of occurrence of the super-cooling becomes low, the super-cooled state can be created. In the environment where for example, in the vicinity of the blowout port, the temperature change is 6K or higher, e.g. 15K, the rush in the super-cooling can be made and the super-cooling
20 of the food which is likely to be super-cooled can be deepened. In order to cause the food to rush in the super-cooled state and deepen its super-cooling, it is not necessary to cool the food at the fixed temperature. If the food is being cooled at the fixed temperature, the temperature of the food surface drops
25 so that the temperature difference between itself and the air temperature around the food decreases. The temperature of the food surface will be stabilized at the air temperature around

the food. Thus, in order to deepen the super-cooling, it is desired that the food is cooled with the temperature difference between the food surface and the air temperature around the food being kept at a certain value or more.

5 For this purpose, the air temperature around the food may be reduced according to the temperature at the food surface or food center. In the process of deepening the super-cooling in the home use refrigerator, the setting temperature may be reduced by 1°C every prescribed times (time whenever the food
10 temperature drops by 1°C, previously experimentally investigated, e.g. 0.5 hour) after a prescribed time (time elapsed from when the food is put in to when the temperature at the food center reaches -1°C, previously experimentally investigated, e.g. 2 hours). In this way, with the temperature
15 difference between the food surface temperature and the air temperature around the food being kept, the food can be cooled so that the super-cooling can be deepened. Inversely speaking, if unevenness or change in the air temperature is great, a great temperature distribution is generated on the food surface or
20 the thermal conductivity of the food surface is increased so that crystallization will start from the surface position likely to be cooled, thus leading to canceling of the super-cooling.

 As well known, if the ice crystals internally created when
25 meat or fish is frozen are large, the cells will be broken and the quantity of drip after unfreezing is increased. In comparison of the quantity of drip of a beef round or tuna

between the super-cooling freezing and normal freezing, there is a tendency that the drip quantity in the super-cooling is limited to half or less of that in the normal freezing. It has been considered that potato or taro is the food not suitable to freezing. It is usually done in a general household that when a cooked curry is frozen-preserved and re-heated after the next day to be eaten. In this case, to freeze the curry with only the potato removed or and crushed was considered to be a common sense for freezing the curry deliciously. This is because if the potato is frozen and then unfrozen, it can not retain moisture, thereby making the texture poor.

However, if the curry is frozen by the super-cooling freezing, the texture of the potato after unfrozen will not almost alerted from that before freezing, i.e. will not be dried or soggy. The starch which is the main component of potato is composed of amylose and amylopectin. The conventional freezing destroys these three-dimensional structure by the growth of the ice crystal. The structure once broken will not be restored to the original state even when unfrozen, so that the water in the potato unfrozen is lost. On the other hand, because the ice crystals created by the super-cooling freezing are very minute, the three-dimensional structure of starch will not be almost deformed. Even after the unfreezing, the original three-dimensional structure can be probably maintained.

Thus, it seems that the texture of the potato unfrozen after super-cooling freezing will not become bad. As the case

may be, such a theory can be applied to the other foods which have been considered to be not suitable to freezing. Accordingly, it is suggested that by adopting the super-cooling freezing, the foods which have been considered to be not
5 suitable to freezing can be frozen. Thus, it is known that where the food is frozen after the super-cooled state, minute ice crystals are created so that the essential food structure such as cells or protein can be kept without being changed. There is a possibility that even if freezing and unfreezing
10 are repeated, e.g. the food unfrozen after freezing is frozen again, the food quality will not be extremely deteriorated unlike the conventional freezing. Hitherto, the explanation has been given of the merits of use in the general households. However, also in food processing, the super-cooling freezing
15 can be effectively used. It has been confirmed that the minuteness of the ice crystals created in the super-cooling freezing is more excellent than the freezing at -60°C . Thus, from the viewpoint of realizing the high quality freezing, the refrigerator according to this embodiment can be substituted
20 for an industrial refrigerator. Since the refrigerator according to this embodiment has no need to create the cold air at an extremely low temperature by using great energy unlike the industrial refrigerator, a merit of energy saving can be obtained.

25 In the investigation hitherto described, it is assumed that the wind speed of the cold air flowing around the food is about 0.5 m/s. The cooling speed for the food is determined

by the temperature difference between the food surface and the air around the food and the convection heat conducting coefficient. This is because the smaller the convection heat conducting coefficient is, the smaller becomes the temperature difference between the food surface and the food center, and it is desired that the super-cooled state is realized at a higher speed. Incidentally, although the cooling speed is defined by a time passage change in the food surface temperature, in an actual product, as the means for detecting the food surface temperature, an infrared sensor or thermopile is employed. This means detects the food surface temperature in a non-contact manner by receiving the radiation heat of infrared rays emitted from the food surface. In this way, by guessing the temperature and area of the food from the temperature detected by the thermopile when the food is put in e.g. the convertible compartment of the refrigerator and further by guessing the thermal capacity of the food put in from the time passage change in the temperature detected by the thermopile, the control time for each step can be extended or shortened according to the food put in.

The super-cooling is essentially an unstable state and will be cancelled when any stimulus is given. Generally, it is said that vibration cancels the super-cooling. However, for example, where a sealed vessel is filled with water with no gap, for example, even if the vessel is waved severely, the super-cooling will not be cancelled. Where water is put in the drawable compartment, e.g. convertible compartment of the

refrigerator, even if opening/closing of the door is repeated several tens of times in a manner of full-opening/full-closing, the super-cooling will not be cancelled. However, where water is put in the sealed vessel by about 1/2, the super-cooling is cancelled all at once. From these facts, it is thought that in order to cancel the super-cooling by vibration, a space is required in which liquid freely flows. In the case of the food such as meat, fish or fruits, since water is filled within each cell and among the cells with no gap, the food is identical to the sealed vessel filled with water with no gap. Actually, for the convertible compartment in which the meat super-cooled is put, even if door opening/closing is repeated in the manner of full-opening/full closing, the super-cooling is not cancelled. Further, the percentage of the water contained in the entire food of creating ice nuclei when the super-cooling is cancelled depends on the degree of super-cooling. For example, in the case of the super-cooling degree of 4 degree (K), it is apparent from the following equation for a freezing rate that the ice nuclei will be created in 5 % of water contained in the entire food.

$$\text{A freezing rate (\%)} = (\text{Cp} \times \text{rV} \times \Delta\text{T}) / \text{L} \times \text{rV} \times 100$$

where Cp: specific heat (kJ/kgK)

r: density (kg/m³)

V: volume (m³)

L: latent heat (kJ/kg)

ΔT : temperature difference (K)

In the case of the super-cooling degree of 4 degrees, the

ice crystals created are in a minute and grain shape. From when the food temperature returns to the freezing point from the temperature lower than the freezing point (the temperature difference at this time refers to the super-cooling degree) after the super-cooling has been cancelled to when freezing starts in the next step and is completed, the food has reached the freezing point to make a phase shift (in the case of water, it changes from liquid water into solid ice) to be kept at a fixed temperature. Thereafter, the freezing is completed so that the food is freezing-preserved at a setting temperature. As long as the super-cooling is caused, the subsequent freezing speed does not influence the ice crystal shape; and if the minute ice nuclei during the super-cooling are created and distributed over the entire food, the ice crystals of the entire food becomes minute. In this way, the percentage of the water contained in the entire food of creating ice nuclei when the super-cooling is cancelled can be calculated from the freezing rate. According to the experimental data, in the case of the super-cooling degree of 0.8 degree, the freezing rate was about 1 % and the ice crystals were in a larger needle shape. If the super-cooling degree increases to 2.6 degree, the ice crystals become very minute and the freezing rate was about 3 %. Further, If the super-cooling degree increases 4.1 degree, the ice crystals becomes so minute that they cannot be distinguished by naked eyes and the freezing rate was about 5 %. Thus, the ice nuclei created when the super-cooling is cancelled is only several % of water of the entire food. However, since the ice

nuclei are created uniformly over the entire food, they influence the state of the ice crystals during the freezing-preserving. Further, the energy stored in the super-cooled state is employed as the energy for creating the ice nuclei. For this reason, the larger the super-cooling degree and the more the quantity of stored energy, the more become the number of the ice nuclei created when the super-cooling is cancelled and the smaller the diameter of the ice crystals. This will reduce the damage to the food due to the ice crystals.

As understood from the description, in order to place the food housed in the refrigerator in the super-cooled state, to cool the food with a cooling capability in a certain range is the necessary condition. This means that even if the cooling capability of cooling the food is too low or too high, the super-cooled state cannot be realized, or the super-cooled state will be immediately cancelled. If the cooling capability is too low, the food is likely to enter the super-cooled state, but the cooling capability around the food is low, i.e. the temperature is high. So, the reaching point of the food temperature in the super-cooled state is also high so that the super-cooling will be cancelled without being deepened (lower temperature). Generally, as the depth of super-cooling increases, larger energy is generated so that the minute crystals are created in the food to provide the high quality freezing. As a result, to deepen the super-cooling cannot be realized by only reducing the cooling capability. As regards

the depth of the super-cooling, if it is 3K (for example, after the food reaches -4°C (the lowest reaching point) in the super-cooled state, by canceling the super-cooling, the temperature instantaneously rises to -1°C of the freezing point) or more, this provides a large difference in the quantity of drip flow-out in unfreezing the meat. Therefore, it is necessary to fall the food in the super-cooling with 3K or more (The larger the depth of super-cooling (difference between the freezing point to the lowest reaching temperature) being 3K or more, the less the quantity of drip flow-out becomes, thereby improving the freezing quality.

Inversely, if the cooling capability is too high, when the freezing point of the food is reached, the food may be frozen as it is, or otherwise, even if the food is fallen in the super-cooled state, the high cooling capability serves as a stimulus to cancel the super-cooling. Thus, the high degree of the super-cooling cannot be obtained. Accordingly, to cool the food with the cooling capability in a certain range is the necessary condition. As described above, if the cooling capability is low (i.e. the compartment temperature is high), when the food is put in the refrigerator, the compartment temperature progresses at about -3 to -4°C . Even if the food is cooled with this temperature being kept, as long as the compartment temperature is about -3 to -4°C , the food temperature naturally does not drop from this temperature so that the deep super-cooling cannot be obtained. In order to obviate this, the compartment temperature is gradually reduced,

but the super-cooling will be eventually cancelled when the food temperature reaches about -3°C . In this way, if the cooling capability is too low (i.e. the compartment temperature is high), the food enters the super-cooled state but does not enter deeply so that a user does not almost feel the significant difference as the food. Inversely, if the cooling capability is too high (the compartment temperature is low), the food will not enter the super-cooled state but starts to freeze when the freezing point is reached.

It should be noted that where the air temperature is set at -10°C or higher, the compartment temperature can only be reduced to the level of -7 to -8°C , but the depth of super-cooling of 3K or more can be sufficiently realized at this temperature. Further, in lowering the setting temperature, if the temperature is reduced from the vicinity of the freezing point (about -1°C) of the food, the super-cooling can be further deepened. Further, in lowering the temperature, it is desirable to gradually reduce the temperature so that any strong stimulus is not given to the food. For example, where if the setting temperature is reduced by the unit of 2°C , the super-cooling is cancelled, if the setting temperature is reduced by the unit of 1°C , the stimulus due to the temperature gradient is relaxed so that the super-cooling is not cancelled.

As described already, another necessary condition for super-cooling is the air temperature distribution (unevenness) in the vicinity of the food to be super-cooled. This is attributable to occurrence of the phenomenon that if the food

is not placed in the air temperature distribution in a certain range, it does not enter the super-cooled state, or its super-cooling is immediately cancelled. Further, this is because the freezing or the cancel of super-cooling occurs from a lower temperature position in the temperature unevenness of the food and this resultantly influences the food at a higher temperature position so that the food is correspondingly frozen or cancelled in its super-cooling. As a result, to cool the food in the temperature distribution in a certain temperature range (unevenness) is the necessary condition. Concretely, although the air temperature unevenness is preferably as possible as small, it is desired in view of various factors of a variation in actual products of the refrigerator and size or shape of the food to be housed that the temperature unevenness is about 2 K or less. If the experimental result on the temperature unevenness and depth of super-cooling is statistically summarized regardless of the compartment temperature, it can be seen that if the temperature unevenness becomes 2K or less, the occurrence probability of super-cooling increases. By multiplying this condition by the above setting temperature, the occurrence probability of super-cooling can be made brought near to 100 %.

Within the refrigerator, the temperature is kept constant by ON/OFF of the compressor mounted in the refrigerator to regulate the strength of cooling and the damper regulated by the temperature sensor placed in each compartment. Therefore, there are necessarily times while the cold air is supplied and

not supplied to each compartment (ON/OFF of the cold air). Thus, in order to regulate the compartment to a setting temperature, the cold air at the temperature lower than the compartment temperature must be supplied. However, in order to realize the super-cooling, the food must be placed in the super-cooled state at the temperatures described above. In this case, it is desired that the food is cooled constantly at the temperature of -15°C or higher, preferably -10°C or higher which is the necessary condition for the air temperature nearer to the food, but actually it is difficult to realize the environment with less temperature hunting in the home use refrigerator. So, the cold air temperature around the food to be super-cooled is controlled. In order to realize this, two means are proposed. The first means is to bring the temperature of the cooling air cooling the compartment nearer to a super-cooling optimum temperature. Generally, where the compartment whose temperature can be set at a freezing temperature zone in the refrigerator is cooled, the cold air temperature reaches about -25°C at the cold air supplying port (blowout port). This temperature is an extremely far value apart from the super-cooling optimum temperature. Controlling the temperature of the supplying source of the cold air is an efficient means. This means is first to raise the cold air temperature by reducing the freezing capability of the compressor.

However, since the essential capability other than the super-cooling must be assured, by not reducing the capability

of the compressor itself but reducing the number of revolutions of the compressor through inverter control, the freezing capability is reduced to raise the temperature of the supplied cold air. Actually, if the number of revolutions of the compressor is reduced by the level of 10 rps, the blowout temperature is expected to rise by about 3 to 5 K. Further, also by changing the number of revolutions of the duct fan supplying the cold air within the refrigerator, the temperature of the supplied cold air can be controlled. If the number of revolutions of the fan is actually decreased, the flowing speed of the cold air is reduced to restrict the convection heat conduction so that the temperature of the supplied cold air falls. Therefore, inversely, by increasing the number of revolutions of the fan, heat exchange is promoted so that the temperature of the supplied cold air rises. Actually, if the number of revolutions of the fan within the refrigerator increases by 300 to 400 rpm, the temperature rise in the cold air is expected by about 2 to 3 K. Further, by providing a temperature keeping heater around the blowout port of the supplied cold air, the cold air temperature can be raised.

The second means is not to raise the supplied cold air temperature but raise the cold air temperature before the cold air hits against the food so that if possible, the cold air at the low temperature does not directly hit against the vicinity of the food. The means for realizing this is to lengthen the cold air reaching distance from the cold air supplying port to the food. This can be realized for example,

by a structure in which a cold air rectifying guide is provided around the cold air supplying port or an obstacle is placed between the blowout port and a food located position. Thus, the temperature of the cold air reaching the vicinity of the food can be raised by heat exchange on the way. Further, because the spraying speed of the cold air for the food can be reduced, the food can be slowly cooled without giving any strong stimulus. As one example of placing the obstacle between the blowout port and the food located position, a structure can be proposed in which a cover shape is added above a food housing case. By adding the cover shape, it is possible to assure the distance from the cold air blowout port on the rear side of the refrigerator to the opening of the case on the door side to half or more of the length of the case. From the analysis of the air flow in this case, the addition of the cover shape permits the cold air temperature around the food to be raised or the wind speed to be lowered. Further, the damper arranged between the air ducting fan circulating the cold air in the refrigerator and the blowout port thereby to control the supplied air serves, by angle regulation, as a shutter for the supplied cold air of e.g. throttling the quantity of the cold air. The damper is not only fully closed or fully opened but regulated at the angle on the way to throttle the quantity of the cold air, thereby restricting the wind speed of the cold air to be sprayed on the food. The wind speed at the cold air blowout port is set at 1.0 to 1.2 m/s by regulating the opening degree of the damper, and the cover is added to

the case. The cold air is supplied from the door side into the case so that the wind speed within the case is set at 0.1 to 0.5 m/s thereby to keep the super-cooled state. The first means and second means may be individually realized, but by combining
5 them, the temperature in the vicinity of the food can be set at the temperature convenient to super-cooling.

The means for improving the temperature unevenness is to reduce the number of times of ON/OFF of supplying the cold air, thereby restricting the temperature unevenness or hunting. As
10 describe above, by reducing the number of revolutions of the compressor 10 by the control device 16 to supply the cold air at a higher temperature so that the time taken to reach the setting temperature is lengthened, the above means can be linked to reduction of the number of times of ON/OFF and improvement
15 of the temperature unevenness and hunting. In this way, the means of reducing the number of times of ON/OFF leads to reduction of the cooling capability so that throttling the quantity of the cold air by regulation of the damper angle can be also employed. Further, the cold air temperature and wind
20 speed can be regulated by the shape of the air guide at the blowout port and the shape of the obstacle placed between the cold air blowout port and the food.

Next, an explanation will be given of the case of the fast freezing. In the case of the fast freezing, the states when
25 the freezing is started and when the freezing is completed are the same as in the case of the normal freezing from the point of view of (quickly) freezing the food by applying the cold

air to the surface thereof. In the case of the fast freezing, as compared with the normal freezing, the cold air at a low temperature is quickly applied to the surface of the food to abruptly lower the temperature of the surface. In the case of the fast freezing also, the food starts to freeze from the surface as in the case of the normal freezing. However, the fast freezing is different from the normal freezing in that since the cold air at the low temperature is quickly applied to the surface of the food, the speed of cooling the food to the interior thereof is increased so that ice nuclei are likely to be created in the interior also as compared with the normal freezing. In the fast freezing, as compared with the normal freezing, large crystals are not created and the food quality is not impaired. However, as compared with the super-cooling freezing by way of the super-cooled state, the ice nuclei are large and not uniform so that the food quality is inferior.

In the food freezing, the size and shape of the ice crystal after the freezing is completed greatly influence the food quality in unfreezing. In most cases, the food is composed of the cells, protein and starch so that once their structure is destroyed by the ice crystals, mostly, it is not completely restored to the original state. For this reason, if the size and shape of the ice crystals created in the freezing does not break the essential structure of the food, the freezing with good quality can be realized. If the ice crystals are smaller, even if the ice crystals are destroyed, the state close to the original state can be obtained. Thus, when unfrozen, the food

quality such as the taste, texture and preserved state of the food is more excellent. Therefore, in the case of the super-cooling freezing by way of the super-cooled state, the ice nuclei are minute and substantially uniform over the object
5 to be frozen such as the food. Accordingly, the super-cooling freezing, which gives the excellent food quality as compared with the normal freezing and fast freezing, is more suitable to the freezing.

Next, an explanation will be given of the merit and novelty
10 of freezing the food by the super-cooling freezing. The greatest merit of freezing the food by the super-cooling freezing is that the freezing with the good quality can be realized. As described hitherto, in the case of the super-cooling freezing by way of the super-cooled state, the
15 food is sufficiently cooled to the interior thereof within a prescribed temperature difference from the surface in the process of reaching the super-cooled state so that the ice nuclei are substantially uniformly created over the entire food to grow into the minute granular ice crystals. Further, the
20 larger the temperature between the lowest temperature (lowest reaching temperature) reached in the super-cooled state without being frozen and the freezing point, the more is the number of the ice nuclei created when the freezing starts. Thus, the ice crystals become more minute and the ratio of the ice
25 instantaneously created when the super-cooling is cancelled becomes large, thereby providing the excellent freezing quality. Accordingly, if the super-cooling occurs

sufficiently (the temperature reached in the super-cooled state is lower), also in the unfreezing after the super-cooling freezing, the state closer to the state before the freezing can be kept, thus making the freezing quality good.

5 As regards the relationship between the food cooling and the size and shape of the ice crystals, it is necessary to consider the time passing the temperature zone of -1°C to -5°C which is the greatest ice crystal creating zone. In the normal freezing and fast freezing, if the greatest ice crystal creating
10 temperature zone is passed in a short time, the ice crystals become minute. In the super-cooling freezing, however, as long as the super-cooled state not frozen is being kept, even if the time passing the temperature zone (vicinity of -1°C to -10°C) inclusive of the greatest ice crystal creating temperature zone
15 (-1°C to -5°C) and in the vicinity thereof is long, the freezing quality of the food will not be impaired.

In the case of the super-cooling freezing, the time of being kept in the not frozen and super-cooled state in the temperature zone (vicinity of -1°C to -10°C) inclusive of the
20 greatest ice crystal creating zone (-1°C to -5°C) and in the vicinity thereof, i.e. time passing this temperature zone is longer than in the normal freezing and fast freezing. In the super-cooled state, however, even if the time passing the temperature zone (vicinity of -1°C to -10°C) inclusive of the
25 greatest ice crystal creating zone (-1°C to -5°C) is long, the ice crystals after freezing will not become large and the minute ice crystals can be substantially uniformly created. Among the

kinds of freezing using the temperature zone inclusive of the greatest ice crystal creating temperature zone and in the vicinity thereof, the idea of the super-cooling freezing according to this invention provides an entirely new freezing technique from the point of view of creating many small crystals to realize the freezing with good quality. Further, in the super-cooling freezing according to this invention, the freezing starts when the super-cooled state is cancelled, and is completed by way of the phase shift state with no temperature change. As long as the super-cooled state is experienced, in the subsequent freezing process, even if the time passing the greatest ice crystal creating temperature zone is long (the temperature is kept in the greatest ice crystal creating zone for a long time), the ice crystals will not become large and the minute ice crystals are created substantially uniformly over the entire food, thereby realizing the super-cooling freezing. This has been confirmed already. In this point also, the freezing according to this invention is new.

As long as the super-cooled state is experienced, even if a long time is taken in the subsequent freezing process, this does not almost influence the ice crystal state and so is not problematic. However, when the freezing process is entered after the super-cooled state has been cancelled, if abrupt cooling is done, the possibility of the ice crystals being enlarged is further reduced so that the good food quality can be obtained. Further, the causes of deteriorating the food quality other than the matters on the ice crystals (e.g.

breeding of bacteria) can be avoided, thereby realizing the freezing with better quality.

Hitherto, the explanation has been given of the merits in the case where the food entered the super-cooled state is frozen after its super-cooling has been cancelled. However, the food entered the super-cooled state is not necessarily required to be frozen. The merit of super-cooling preserving of keeping the food in the super-cooled state without being frozen is that although the food is preserved at the temperature lower than the freezing point, i.e. at such a temperature as being frozen if usual, the food is not in the state where the food is frozen in 100 % and no ice crystal is created so that although it is preserved at the low temperature, it is not almost subjected to changes in the food structure owing to the ice crystal. To preserve the food at a lower temperature, by which various chemical changes of the food can be restrained, is effective to keep its freshness. In this invention providing the super-cooling preserving and super-cooling freezing, both merits of the low temperature preserving and the non-freezing can be enjoyed. Further, since the food is in the super-cooled but not frozen state, it is not required to be unfrozen. However, because the super-cooled state means the non-frozen state, the water not frozen contained in the food may be used for various changes such as bleeding of bacteria. However, as in this invention, if the super-cooling freezing of freezing by way of the super-cooled state is done, the food quality can be kept in the good state. Accordingly, although preserving

in the super-cooled state (super-cooling preserving) may be inferior to freezing by way of the super-cooling (super-cooling freezing) in the food quality (attention must be paid), it is not problematic as long as the food is preserved for a relatively short period (e.g. one to three weeks).

Next, an explanation will be given of the operation of the display panel 60 and control device 30. The convertible compartment 4 which is a cooling compartment capable of placing the food stored in the super-cooled state can be changed into a plurality of temperature zones of e.g. refrigerating (about 3°C), chilled (about 0°C), soft-freezing (about -5, -7, -9°C), freezing (about -17°C). These temperatures are selectively set in such a manner that the control device 30 such a microcomputer provided on the upper part on the back side of the refrigerator body controls the damper, compressor, blower, etc. An example of the display panel 60 provided on the door surface is shown in Fig. 5.

Fig. 5 is a view showing a liquid crystal display panel according to an embodiment of this invention. In Fig. 5, the display panel 60 has a compartment selecting switch 60a for selecting either one of the refrigerator compartment, vegetable compartment, freezer compartment and convertible compartment; a temperature regulating/fast freezing switch 60b for selecting the temperature regulating of the compartment selected (storing compartment) or fast freezing; a super-cooling freezing (instantaneous freezing) switch 60c for selecting the super-cooling freezing (instantaneous

freezing); and an ice-making changing switch 60d for selecting an ice-making mode from "normal", "transparent", "fast " and "stopping" (Now, since the super-cooling freezing instantaneously realizes freezing, in this invention, it is also referred to as "instantaneous freezing"). The display panel 60 may show the setting temperature and present temperature of each of the compartments (refrigerator compartment, freezer compartment, convertible compartment, vegetable compartment, super-cooling compartment, etc.) in the corresponding temperature zones. Further, where the food temperature or food surface temperature is measured by the non-contacted infrared sensor or thermopile, if the measured food temperature or food surface temperature is displayed on the liquid crystal display panel 60, it is convenient because the super-cooled state or the food surface temperature can be known at a glance so that it is not necessary to ascertain the time passage in the refrigerator for a user and open the door to confirm to what degree the food has not been cooled.

Now, where it is desired that the fast freezing is done, the temperature regulating/fast freezing switch 60b is pushed for a prescribed time (3 seconds) so that the fast freezing mode is entered to do the fast freezing. Further, where it is desired that the super-cooling freezing (instantaneous freezing) is done, the super-cooling freezing (instantaneous freezing) switch 60c so that the super-cooling mode is entered to do the super-cooling cooling or the super-cooling freezing. The refrigerator according to this invention has an ice-making

plate cleaning mode. By continuing to push the ice-making changing switch 60d for a prescribed time (about 5 seconds), the ice-making plate cleaning mode is entered to clean the ice-making plate. The temperature regulation of the selected
5 compartment (storing compartment) is realized by the temperature regulating/fast freezing switch 60b. In this embodiment, the temperature is displayed at three levels of "high", "medium" and "low". In this temperature display, the setting temperatures may be directly displayed on the display
10 panel 60.

Further, the setting temperature of the cooling compartment will be changed stepwise or continuously in order according to where the super-cooled state is realized, where the super-cooled state is cancelled, and where the super-cooled
15 state is cancelled and the freezing-preserving is done. The setting temperatures can be changed to automatically preset temperatures on the basis of the time intervals preset by a timer. However, by providing a switch to the liquid crystal panel 60 on the door of the refrigerator compartment 2, these
20 setting temperatures can be manually changed. The temperature of the cooling compartment (e.g. convertible compartment 4) where the super-cooled state is cancelled and further the super-cooling freezing is done is controlled by detecting the compartment temperature by the thermister 19 or the food surface
25 temperature and by using the cold air regulating means such as a damper so that the detected temperature becomes the prescribed value. It is needless to say that the compressor

12 and damper 15 may be controlled by using the infrared sensor 22 for measuring the food temperature instead of the thermistor 19 for measuring the compartment temperature.

As described above, as regards the super-cooled state,
5 by setting the temperature of the freezer compartment or cooling compartment at the first temperature so that the food is placed in the super-cooled state by the cold air introduced into the cooling compartment. Next, the temperature difference is previously stored and the super-cooled state of the food is
10 cancelled at the second temperature lower than the first temperature by the temperature difference. When it is decided from the temperature state of the food surface that the super-cooled state has been cancelled, the cold air is regulated according to the third temperature set by the changing switch
15 on the refrigerator so that the food is freezing-preserved. In this way, the first setting temperature, second setting temperature and third setting temperature are successively changed at time intervals or on the basis of the measurement of the food temperature so that by regulating the cold air by
20 a simple structure of software stored by a microcomputer, even if the fast freezing is not executed or even if the compartment is not placed at a very low temperature of -60°C , freezing-preserving of food freezing with good quality can be realized with less energy. Where the time intervals are set,
25 they may be the time intervals previously stored, or may be set on the liquid crystal panel 60 on the door surface. Thus, fast processing can be done according to the kinds of the food.

Further, since the cancellation of super-cooling is determined by measuring the food temperature, the degree of the super-cooling can be deepened.

Further, where the food to be housed is placed on the super-cooled state, by setting the temperature of the freezer compartment or cooling compartment of housing the food at the first temperature stored in the microcomputer and regulating the quantity of the cold air to be introduced in the cooled compartment at this temperature, the food is caused to rush in the super-cooled state, and the super-cooled state thereof is continued. Next, after the time set as the time necessary for the super-cooling has elapsed, the super-cooled state of the food is cancelled by supplying the cold air at the temperature lower than the first temperature. The resultant food is freezing-preserved at the third temperature set by the temperature setting device provide on the door surface. If the first temperature to be set is previously stored, the third temperature can be easily changed manually, these temperatures can be set irrespectively of each other. However, also where the first temperature is set, it may be changed by the temperature setting device provided on the door surface on the refrigerator or side of the cooling compartment so that it can be changed according to the kinds of food.

The states of these set temperatures and detected temperature of the food surface can be displayed on the liquid crystal display panel 60. The setting temperatures can be also changed while seeing the display. Setting the third

temperature may be realized in such a structure that it is changed in a deep temperature zone of -30°C to -60°C considering long period preserving for several months or more; a weak freezing temperature zone of -5°C to -15°C which causes minute ice crystals in the food and permits a user to cut the food by a kitchen knife; and a middle freezing-preserving temperature zone between the above temperature zones. If the temperature setting is done, in order that the temperature detected by the sensor falls in the changed/set temperature zone, on/off control such as the number of revolutions of the compressor 12 and opening/closing of the damper 15 is executed by the control device 30. As described above, the first temperature and third temperature can be set irrespectively of each other. In addition, the setting temperatures can be changed according to the time of continuing the necessary super-cooled state or depth of super-cooling according to the preserving period and using state, or the season and the kinds of the food to be housed, thereby permitting flexible freezing-preserving.

Further, where the temperature of the cooling compartment by indirect cooling is set, by measuring the compartment temperature using the sensor provided in the cooling compartment or estimating the compartment temperature from the elapsed time at the wall cooled, it can be determined whether or not the food is at the first temperature set for the super-cooled state. By lowering the temperature of the cold air for indirect cooling to the temperature lower than the first

temperature at which the food to be housed in the cooling compartment is placed in the super-cooled state, the wall temperature is lowered, and the super-cooling can be cancelled. Otherwise, the super-cooling may be cancelled by increasing
5 the number of revolutions of the blowing fan in the sealed cooling compartment to increase the wind speed so that the thermal conductivity of the food surface is enhanced. As the temperature distribution on the food surface becomes more non-uniform, the super-cooling is more likely to be cancelled.
10 The food may be freezing-preserved using the cold air directly introduced into the compartment by opening the port of the cooling compartment in which the super-cooling has been cancelled by the super-cooling canceling means for canceling the super-cooled state of the food. Otherwise, by further
15 lowering or keeping the wall temperature in the indirect cooling, the food may be freezing-preserved. In this way, the freezing-preserving with less energy can be realized in a simple structure.

Fig. 6 shows another control example of the damper for
20 the convertible compartment according to the first embodiment of this invention, which is a control chart when the super-cooling freezing is executed. The structure of the refrigerator is identical to that shown in Figs. 1, 2 and 3. Now, the super-cooling freezing will be explained. The
25 super-cooling freezing refers to a freezing mode of realizing the super-cooled state. The super-cooled state refers to the state where although the material such as the food is at the

temperature of its freezing point or lower, it is not frozen in 100 %. The freezing point is the temperature where the material starts to freeze. Namely, the super-cooled state refers to the state where although the material such as the food is at the temperature where it should start to freeze, it is not entirely frozen. For example, the freezing point of water is 0°C. The freezing point differs according to the material. The food with a higher salt density or sugar grade has a tendency of the freezing point being lower than 0°C.

Now referring to the flowchart of Fig. 6, an explanation will be given of the control method for realizing the super-cooled state. In step S11 of starting the super-cooling mode, the super-cooling mode starts. The main means for starting the super-cooling mode is a display panel (e.g. button) or switch (not shown) provided on the refrigerator door. When the user operates these devices (button, switch, etc.), the super-cooling mode starts. After the super-cooling mode starts in step S11, the control proceeds to compressor running state confirming step S12 of determining whether or not the compressor 12 is running. In step S12, if it is determined that the compressor 12 is stopping (NO), the control returns to step S11. In step S12, if it is determined that the compressor 12 is operating (YES), the control proceeds to a first convertible compartment damper opening step S13. In the first convertible compartment damper opening step S13, the convertible compartment damper 15 is opened by a prescribed angle θ_{10} .

Step S14 is a first convertible compartment temperature

determining step of determining whether or not the convertible compartment thermistor 19 serving as the convertible compartment temperature detecting means is at a prescribed temperature $T_{10}^{\circ}\text{C}$ or lower. In step S14, if it is determined
5 that the temperature detected by the convertible compartment thermistor 19 is higher than the prescribed temperature $T_{10}^{\circ}\text{C}$ (NO), the control returns to step S13. If it is determined that the temperature detected by the convertible compartment thermistor 19 is the prescribed temperature $T_{10}^{\circ}\text{C}$ or lower (YES),
10 the control proceeds to a second convertible compartment damper opening step S15. In step S15, the convertible compartment damper 15 is opened by a prescribed angle θ_{11} . Step S16 is a step of determining whether or not the temperature detected by the convertible compartment thermistor 19 is a prescribed
15 temperature $T_{11}^{\circ}\text{C}$ or lower. In step S16, if it is determined that the temperature detected by the convertible compartment thermistor 19 is higher than the prescribed temperature $T_{11}^{\circ}\text{C}$ (NO), the control returns to step S15. In step S16, if it is determined that the temperature detected by the convertible
20 compartment thermistor 19 is the prescribed temperature $T_{11}^{\circ}\text{C}$ or lower (YES), the control proceeds to step S17. In a third convertible compartment damper opening step S17, the convertible compartment 15 is opened by the prescribed angle θ_{10} . The control proceeds to step S18. Step S18 is a
25 super-cooling mode ending step where the super-cooling mode is ended.

Now, the prescribed angle θ_{10} is substantially 90°

(substantially vertical: 70° to 110° , preferably 80° to 100°). At this angle, the cold air for the convertible compartment 4 is sent to both direct cooling duct 16A and indirect cooling duct 16B. Thus, the interior of the convertible compartment 4 is cooled more quickly to the degree that the cold air directly flows into the convertible compartment 4. The prescribed temperature $T_{10}^\circ\text{C}$ is the freezing point of the food, mainly about -1°C which is the freezing point of meat, but not limited to this temperature. In step S14, after the detected temperature reaches the prescribed temperature, the control proceeds to the second convertible compartment damper opening step S15 where the convertible compartment damper 15 is opened by the prescribed angle θ_{11} . The prescribed angle θ_{11} is e.g. substantially 45° (20° to 70° , preferably 35° to 55°). At this angle, the direct cooling duct 16A can be substantially closed by the baffle 15A. Therefore, while the baffle 15A is opened by substantially 45° , the food within the convertible compartment 4 is indirectly cooled by the cold air flowing through the indirect cooling duct 16B. The cold air for direct cooling from the direct cooling duct 16A is not sent so that the food can be fallen in the super-cooled state without suffering from a strong stimulus by the direct cooling. Now, the prescribed temperature $T_{11}^\circ\text{C}$ is a temperature for determining the shift from the super-cooled state to the frozen state, e.g. -5°C . Although it depends on the size and shape of the meat, in the case of bone rib of pork of 100 g or so, if the super-cooled state can be kept to -5°C or lower, the meat

can be fallen in the frozen state in 100 % (frozen state by way of the super-cooling), thereby providing the super-cooling frozen state with high quality.

Fig. 7 is a sectional view of the main part around the convertible compartment, showing the first embodiment of this invention. The convertible compartment case 17 has a convertible compartment case cover 20 and the convertible compartment ceiling heat insulator 18 has a ceiling blowout port 18A. Although the ceiling blowout port 18A is a blowout port for jetting the cold air from the indirect cooling duct 16B into the convertible compartment 4, the provision of the convertible compartment case cover 20 realizes an indirect cooling system in which the cold air is not directly applied to the food within the convertible compartment case 17. If the user hopes quicker freezing (fast freezing), it can be dealt with by removing the convertible compartment case cover 20. If the convertible compartment case cover 20 is removed in a structure in which the convertible compartment case cover 20 is removable, duct resistance for the cold air from the indirect cooling duct 16B is reduced by the degree of the convertible compartment case cover 20 so that a larger quantity of the cold air flows in the convertible compartment case 17 at plural points (at least the back side and ceiling) from the direct cooling duct 16A and the indirect cooling duct 16B, thereby realizing the freezing at an earlier timing. Inversely, if the super-cooling (or super-cooling freezing) is desired, the convertible compartment case cover 20 may be attached. Further,

when the convertible compartment case cover 20 is removed, if there is difficulty of assuring the place where it is put, a structure may be adopted in which the convertible compartment case cover 20 is shifted to the inner part of the convertible compartment case 17. Specifically, only the convertible compartment case 17 may be pulled out in the structure in which when the convertible compartment case cover 17 is pulled out, the convertible compartment case cover 20 is left within the convertible compartment 4, for example, by fixing the convertible compartment case cover 20 on the ceiling or side wall of the convertible compartment 4 when pulling out the convertible compartment 17 or providing a case cover stopper on the ceiling or side wall of the convertible compartment 4.

Further, in Fig. 7, the convertible compartment case cover 20 is structured to overlies the upper opening of the convertible compartment case 17, but the convertible compartment case cover 20 is not required to overlies the entire upper opening of the convertible compartment case 17. The convertible compartment case cover 20 may be provided to overlies only the rear side of the convertible compartment case 17 so that the cold air for direct cooling jet from the back blowout port 4A of the direct cooling duct 16A is difficult to enter the convertible compartment case 17 from the upper opening. Namely, the convertible compartment case cover 20 may be structured to have a front opening so that when it is established in the convertible compartment case 17, the front side of the refrigerator is opened. Further, the blowout port 18A of the

indirect cooling duct 16B may be provided at such a position that the cold air for indirect cooling enters the convertible compartment case 17. In the case of the indirect cooling, it is desired that the cold air does not enter the convertible compartment case 17. However, the cold air entering the convertible compartment case 17, as long as it is the degree of natural drop, is identical to the case in the indirect cooling and so not problematic. In this embodiment, the port 4A of the direct cooling duct 16A is opened at the position nearer to the air quantity regulating means 15 whereas the blowout port 18A of the indirect cooling duct 16B is opened at the position farther from the air quantity regulating means 15. In such a structure, as regards the cold air passed the indirect cooling duct 16B, when it is jet from the blowout port 18A, its wind speed is reduced due to duct resistance so that wind speed and air quantity suitable to the indirect cooling can be obtained. As regards the cold air jet from the port 4A of the direct cooling duct 16A, since it can be immediately jet into the convertible compartment 4 and the convertible compartment case 17, the wind speed and air quantity suitable to the fast freezing can be obtained.

Fig. 8 is a detailed view of the main part around the convertible compartment damper shown in the first embodiment of this invention. The convertible compartment damper hitherto explained was a single damper system having the single baffle 15A. Now, an explanation will be given of an example of providing a convertible compartment twin damper 21 in the

direct cooling duct 16A and the indirect cooling duct 16B. The convertible compartment twin damper 21 has a direct cooling frame 21A and an indirect cooling frame 21B. The direct cooling frame 21A is connected to the direct cooling duct 16A whereas the indirect cooling from 21B is connected to the indirect cooling duct 16B. The direct cooling frame 21A and indirect cooling frame 21B have baffles 21C and 21D for opening/closing the corresponding frames, respectively. By opening/closing these baffles 21C and 21D, the opening/closing control of the direct cooling duct 16A and indirect cooling duct 16B can be individually done. In this embodiment, since the convertible compartment damper is the twin damper, two frames are provided, thereby permitting the air quantity to be precisely controlled. In the case of the single damper, the opening degree is regulated/controlled using the single baffle so that although the direct cooling duct 16A closed and the indirect cooling duct 16B opened could be realized, the direct cooling duct 16A opened and the indirect cooling duct 16B closed could not be realized.

Specifically, except that both the direct cooling duct 16A and the indirect cooling duct 16B are closed, the opening/closing of the direct cooling duct 16A could be controlled whereas the indirect cooling duct 16B was always placed in the opened state. On the other hand, if the twin damper 21 is employed as in this embodiment, the opening/closing control of the direct cooling duct 16A and the indirect cooling duct 16B can be done individually and precisely. For example,

where the super-cooling freezing is unnecessary and the freezing at a higher speed than the normal freezing is desired, namely, in the case of the fast freezing mode, if the indirect cooling frame 21B remains closed, the cold air in 100 % flows
5 into the direct cooling duct 16A so that the fast freezing can be executed effectively. On the other hand, the merit of using the single damper is that since the number of the frames is few, the production cost is relatively low and the establishing space may be relatively small; correspondingly the large
10 capacity of the storing compartment or refrigerator can be realized.

Fig. 9 is a side sectional view around the convertible compartment of the refrigerator, showing the first embodiment of this invention. On the ceiling of the convertible
15 compartment 4, an infrared sensor 22 serving as the convertible compartment temperature detecting means is provided to measure the surface temperature of the food housed in the convertible compartment 4 (or the convertible compartment case 17). As its locating position, the ceiling 4A of the convertible
20 compartment 4 offering a broad view of the interior of the convertible compartment case 17 is suitable. However, it may be the side or bottom as long as the surface of the food can be measured even indirectly. The surface temperature of the food stored in the convertible compartment 4 (or the convertible
25 compartment case 17) may be measured through the convertible compartment case cover 20. If the infrared sensor 22 is employed as the temperature detecting means, as compared with

the case of using the convertible compartment thermistor 19 for detecting the air temperature, the temperature nearer to the food (e.g. the surface temperature of the food) can be detected, thereby enhancing the success probability of the super-cooling. In the case of using the convertible compartment thermistor 19, only the temperature nearest to the convertible compartment thermistor 19 can be detected. On the other hand, the infrared sensor 22, which is characterized by detecting the infrared rays emitted from the surface of a material remote therefrom, can detect the temperature nearer to the food (surface temperature of the food). Because the quantity of infrared rays emitted from the food increases as the temperature becomes high, the temperature can be detected on the basis of the quantity of infrared rays detected.

Now, in order to execute the super-cooling preserving or the super-cooling freezing, it is desired that the temperature difference between the surface temperature and center temperature of the food is smaller so that the entire food is substantially uniformly cooled. So, in the embodiment, the center temperature is experimentally estimated from the surface temperature measured according to the kind, size, thickness and weight of the food stored in the convertible compartment 4 (or the convertible compartment case 17) to estimate the temperature difference between the surface temperature and the center temperature, thereby determining whether or not the super-cooled state is being kept. In this embodiment, it has been experimentally confirmed that if the

temperature difference is 5 degree or less, desirably 3 degree or less, the super-cooled state can be kept and the quality of the food when unfrozen is satisfactory.

Fig. 10 is another super-cooling freezing flowchart in the refrigerator according to the first embodiment of this invention which realizes the super-cooled state. In super-cooling mode starting step S21, the super-cooling mode starts. The main means for starting the super-cooling mode is a display panel (e.g. button) or switch (not shown) provided on the refrigerator door. When the user operates these devices (button, switch, etc.), the super-cooling mode starts. After the super-cooling mode starts in step S21, the control proceeds to compressor running state confirming step S22 of determining whether or not the compressor 12 is running. In step S22, if it is determined that the compressor 12 is stopping (NO), the control returns to step S21. In step S22, if it is determined that the compressor 12 is operating (YES), the control proceeds to a first convertible compartment temperature determining step S23.

In step S23, it is determined whether or not the convertible compartment thermistor 19 is at a prescribed temperature $T_{20}^{\circ}\text{C}$ or lower. In step S23, if it is determined that the convertible compartment thermistor 19 serving as the temperature detecting means is at a temperature higher than the prescribed temperature $T_{20}^{\circ}\text{C}$ (NO), the control proceeds to a first convertible compartment damper opening step S24. In step S24, the convertible compartment damper 15 is opened by

a prescribed angle θ_{10} . Thereafter, the control returns to step S23. In step S23, if it is determined that the convertible compartment thermistor 19 is at the prescribed temperature $T_{20}^{\circ}\text{C}$ or lower (YES), the control proceeds to a first infrared sensor temperature determining step S25. In step S25, it is determined whether or not the infrared sensor 22 serving as the temperature detecting means is at a prescribed temperature $T_{21}^{\circ}\text{C}$ or lower. In step S25, if it is determined that the infrared sensor 22 serving as the temperature detecting means is at a temperature higher than the prescribed temperature $T_{21}^{\circ}\text{C}$ (NO), the control returns to step S25.

In step S25, if it is determined that the infrared sensor 22 serving as the temperature detecting means is at the prescribed temperature $T_{21}^{\circ}\text{C}$ or lower (YES), the control proceeds to a second convertible compartment damper opening step S26. In step S26, the convertible compartment damper 15 is opened by a prescribed angle θ_{11} . Thereafter, in a second infrared sensor temperature determining step S27, it is determined whether or not the infrared sensor 22 is at a prescribed temperature $T_{22}^{\circ}\text{C}$ or lower. In step S27, if it is determined that the infrared sensor 22 is at a temperature high than the prescribed temperature $T_{22}^{\circ}\text{C}$ (NO), the control returns to step S27. In step S27, if it is determined that the infrared sensor 22 is at the prescribed temperature $T_{22}^{\circ}\text{C}$ or lower (YES), the control proceeds to a second convertible compartment damper opening step S28. In step S28, the convertible compartment damper 15 is opened by the angle θ_{10}° . After the convertible

compartment damper 15 is opened by the angle θ_{10} , in a super-cooling mode ending step S29, the super-cooling mode is ended.

In step S23, if the temperature detected by the convertible compartment thermistor 19 is higher than the prescribed temperature $T_{20}^{\circ}\text{C}$, the convertible compartment damper 15 is opened by the prescribed angle θ_{10} (fully opened). This intends to determine that the interior of the convertible compartment 4 is not in a normal temperature zone owing to e.g. opening of the door for a long time. Namely, if it is determined that the cooling within the convertible compartment is insufficient (the convertible compartment thermistor 19 is at the temperature higher than the prescribed temperature $T_{20}^{\circ}\text{C}$), the convertible compartment damper 15 is fully opened to send the cold air to both the direct cooling duct 16A and the indirect cooling duct 16B. Without executing the cooling from the direct cooling duct 16A, if slow freezing (slow direct cooling at a low speed or cooling or freezing by the indirect cooling) is immediately started with the cooling from the indirect cooling duct 16B only, owing to the possibility of shortage of cooling based on determination that the cooling is insufficient, the freshness of the food may be deteriorated. The first convertible compartment temperature determining step S23 is a determining step for avoiding such a circumstance. When the interior of the convertible compartment 4 has been cooled to the prescribed temperature or so by cooling from the direct cooling duct 16A, in step S25, it is determined whether

or not the infrared sensor 22 is at the prescribed temperature $T_{21}^{\circ}\text{C}$ or lower. The prescribed temperature $T_{21}^{\circ}\text{C}$ is e.g. -1°C .

From when -1°C is reached, in order to start the slow freezing, the convertible compartment damper 15 is opened by the angle θ_{11} (half opened, about 45°). The angle θ_{11} is an angle of opening the indirect cooling duct 16B but substantially closing the direct cooling duct 16A. Thus, an entire quantity of the cold air headed for the convertible compartment 4 flows in the indirect cooling duct 16B. The food is cooled by the slow freezing based on the indirect cooling. When the temperature of the infrared sensor 22 has become the prescribed temperature $T_{22}^{\circ}\text{C}$ or lower, the convertible compartment damper 15 is opened by the prescribed angle θ_{10} (fully opened). The prescribed temperature $T_{22}^{\circ}\text{C}$ is e.g. -5°C . For example, in order that the round of 150 g is caused to pass the temperature of -5°C from -1°C , it takes about one hour if there is not opening/closing of the door. The prescribed angle, as described above, is the angle of sending the cold air to the direct cooling duct 16A also so that the interior of the convertible compartment 4 will be cooled at a stretch (fast). Owing to this thermal shock (temperature shock), the super-cooled state of the food within the convertible compartment 4 (or within the convertible compartment case 17) is cancelled so that the ice crystals do not become fat unlike the case of the normal freezing. Further, since the infrared sensor 22 is employed, the temperature nearer to the food (e.g. the surface temperature of the food) can be detected, thereby

enhancing the success probability of the super-cooling freezing. Thus, the freezing preserving (super-cooling freezing) giving the good food quality can be provided.

As understood from the description hitherto made, in this invention, in the refrigerator including a plurality of divided storing compartments (for example, the refrigerator compartment 2, ice-making compartment 3, convertible compartment 4, vegetable compartment 5 and freezer compartment 6) to which the cold air created by the cooler is sent, the cold air duct for sending the cold air from the cooler to at least one of the storing compartments (for example, the convertible compartment 4, freezer compartment 6 or vegetable compartment 5) is composed of two ducts of the direct cooling duct 16A and indirect cooling duct 16B. For this reason, the fast freezing or slow freezing can be set according to the using circumstance of the user. The super-cooling freezing can be also done. Setting for the vegetable compartment capable of keeping high humidity can be also done.

In the refrigerator including a plurality of sectioned storing compartments (for example, the refrigerator compartment 2, ice-making compartment 3, convertible compartment 4, vegetable compartment 5 and freezer compartment 6) to which the cold air created by the cooler is sent, it includes two cooling ducts of the direct cooling duct 16A and the indirect cooling duct 16B which are connected to at least one of the storing compartments (for example, the convertible compartment 4) to send the cold air to the storing compartment

(for example, the convertible compartment 4), an air quantity regulating means 15 capable of changing the two cooling ducts into the state of at least both opened, one opened or both closed. For this reason, the fast freezing or slow freezing can be set according to the using circumstance of the user. The super-cooling freezing can be also done.

Further, the air quantity regulating means 15 includes a single inlet and two outlets. The inlet is connected to the duct 16C from the cooler room where the cooler is located. The one of the two outlets is connected to the indirect cooling duct 16B and the other thereof is connected to the direct cooling duct 16A. The direct cooling duct 16A is opened at the position where the cold air is directly applied to the food within the storing compartment (e.g. convertible compartment). The indirect cooling duct 16B is opened at the position where the cold air is not directly applied to the food within the storing compartment (e.g. convertible compartment) or the cold air is indirectly applied to the food. At least one of the storing compartments is a storing compartment capable of executing the super-cooling freezing permitting the freezing by way of the super-cooled state, thereby enhancing the success probability of the super-cooling freezing. Thus, the freezing preserving (super-cooling freezing) giving the good food quality can be provided.

Further, in the refrigerator according to this invention, at least one of the storing compartments can be changed into the convertible compartment 4 or a super-cooling freezer

compartment. The refrigerator according to this invention includes the storing compartment case 17 established in at least one of the storing compartments (the convertible compartment 4 or the super-cooling compartment 4) and the cover member 20 covering at least a part of the upper opening of the storing compartment case 17. The indirect cooling duct 16B is opened at the position where the cold air is directly applied to the cover member 20 so that the cold air is not applied to the food within the storing compartment case 17.

Otherwise, the refrigerator according to this invention includes the storing compartment case 17 established in at least one of the storing compartments (the convertible compartment 4 or the super-cooling compartment 4) and the cover member 20 covering at least a part of the upper opening of the storing compartment case 17. In this case, the indirect cooling duct 16B is opened at the position of the upper opening of the storing compartment case 17 not covered with the cover member 20 covering at least a part of the upper opening thereof so that the food within the storing compartment 17 can be cooled like the indirect cooling by the cold air at a low cooling speed substantially equal to natural drop.

For this reason, the success probability of the super-cooling freezing will be enhanced. Thus, the freezing preserving (super-cooling freezing) giving the good food quality can be provided.

Further, the refrigerator according to this invention includes a temperature detecting means 19 for detecting the

food temperature within at least one of the storing compartments (the convertible compartment 4 or the super-cooling compartment 4) and the control means 30 for controlling the baffle opening degree of the air quantity regulating means 15
5 on the basis of the temperature detected by the temperature detecting means 19. If it is determined that the temperature detected by the temperature detecting means 19 is higher than a first prescribed temperature T_0 , both the direct cooling duct 16A and the indirect cooling duct 16B are opened. When a
10 prescribed time t_0 elapses after both the direct cooling duct 16A and the indirect cooling duct 16B have been opened, the direct cooling duct 16A is substantially closed, thus executing the indirect cooling.

Further, the refrigerator according to this invention
15 includes a temperature detecting means 22 for detecting the food temperature within at least one of the storing compartments (the convertible compartment 4 or the super-cooling compartment 4) and the control means 30 for controlling the baffle opening degree of the air quantity regulating means 15
20 on the basis of the temperature detected by the temperature detecting means 22. If it is determined that the temperature detected by the temperature detecting means 22 is a second prescribed temperature $T_{21}^{\circ}\text{C}$ or lower, the direct cooling duct 16A is substantially closed, thereby executing the indirect
25 cooling. Further, if it is determined that the temperature detected by the temperature detecting means 22 is a third prescribed temperature $T_{22}^{\circ}\text{C}$ or lower, the direct cooling duct

16A is opened, thereby executing the direct cooling for fast cooling. (In this case, the indirect cooling duct 16B may be either opened or closed according to the specification of the air quantity regulating means 15 (single baffle or two baffles)).
5 Specifically, in the case of the single baffle, the indirect cooling duct is opened. In the case of two baffles, the indirect cooling duct may be either closed or opened. In short, only the direct cooling may be done, or both direct cooling and indirect cooling may be done). In this way, since the
10 infrared sensor is used as the temperature detecting means 22 thereby to measure the surface temperature of the food, the temperature nearer to the food (e.g. surface temperature) can be detected, and the success probability of the super-cooling freezing will be enhanced. Thus, the freezing preserving
15 (super-cooling freezing) giving the good food quality can be provided.

Further, the refrigerator according to this invention has a plurality of divided storing compartments to which the cold air created in the cooler is sent. Such a refrigerator includes
20 a direct cooling duct which is connected to at least one of the plurality of storing compartments and is opened at the position where the cold air supplied from the cooler is directly applied to the food within the storing compartment; an indirect cooling duct which is connected to at least one of the plurality
25 of storing compartments and is opened at the position where the cold air supplied from the cooler is not directly applied to the food within the storing compartment or indirectly applied

to the food; and an air quantity regulating means capable of at least selecting either one of both opened, one opened and both closed of the two cooling ducts of the direct cooling duct and the indirect cooling duct. By selectively changing the two
5 cooling ducts, the storing compartment is made capable of executing the super-cooling freezing permitting the freezing by way of the super-cooled state. Therefore, the temperature nearer to the food (e.g. surface temperature) can be detected, and the success probability of the super-cooling freezing will
10 be enhanced. Thus, the freezing preserving (super-cooling freezing) giving the good food quality can be provided.

In accordance with this invention, since at least one of the storing compartments has both direct cooling duct 16A and indirect cooling duct 16B, a refrigerator or storage house
15 capable of selecting fast freezing, normal freezing or super-cooling freezing can be provided. Further, since the indirect cooling and direct cooling can be selectively changed, by selecting the indirect cooling, the refrigerator or storage house which can be employed as a vegetable storage compartment
20 can be provided.

In accordance with this invention, since changes in the temperature distribution within a sectioned storing compartment of the refrigerator can be reduced, a refrigerator or storage house permitting high quality food preserving can
25 be provided.

In accordance with this invention, since changes in the temperature distribution of the food or the like preserved

within the storing compartment of the refrigerator can be reduced, a refrigerator or storage house permitting high quality food preserving can be provided.

5 In accordance with this invention, as a high quality freezing function, a super-cooling freezing function is adopted in place of conventional fast freezing. The high quality freezing with less energy than before, i.e. energy saved freezing as an earth environment measure can be realized.

10 Further, the refrigerator according to this invention adopts a temperature-controlled cooling structure in which the cold air is introduced in the space causing the super-cooling and the cooling temperature can be changed to plural values. Thus, in the structure and control of the refrigerator which is not greatly different from that of the conventional
15 refrigerator, the super-cooling of the meat or like can be realized.

In accordance with this invention, since an infrared sensor is used as the temperature detecting means, the surface temperature of the food can be measured, thereby permitting
20 the temperature nearer to the food (e.g. surface temperature) to be detected and the success probability of the super-cooling freezing to be enhanced. Thus, the freezing preserving (super-cooling freezing) giving the good food quality can be provided.

25 In accordance with this invention, which has a super-cooling freezing function of freezing by way of the super-cooled state, the high quality freezing in which the size

or shape of the ice crystals created in freezing is not prone to destroy the essential structure of the food. Further, since the ice crystals created are minute, even if the ice crystals are broken, the state close to the original state can be obtained.

5 Thus, when the food is unfrozen, the food quality such as its taste, texture or preserved state becomes satisfactory. Because of the super-cooling freezing by way of the super-cooled state, the ice nuclei are minute and fine and uniformly distributed over the entire material to be frozen. Thus, as
10 compared with the normal freezing or fast freezing, the resultant food quality is satisfactory.

In accordance with this invention, by modifying the specification of a general refrigerator, the refrigerator capable of executing the super-cooling freezing can be provided.

15 The explanation has been mainly given of the structure of the home use refrigerator. The idea of this invention resides in the control, for example, that after the food is stored, the temperature is lowered at a prescribed cooling speed to its freezing point; while the temperature is gradually lowered
20 using the air flow entirely uniformly distributed, cooling keep the super-cooled state at a higher freezing temperature is done for the food to be frozen; after a prescribed time elapses, the cold air at a further lower temperature is directly applied to the food to fast freeze the food, thereby canceling the
25 super-cooling; and thereafter, the food is preserved at a temperature lower than the temperature of providing the super-cooled state, e.g. at the freezing temperature of -18°C .

This idea can be also applied to a large scale very low-temperature industrial freezing house. Thus, the energy can be greatly saved. Further, it is more effective that while the food is carried by a low-temperature carrying vehicle as a refrigerator, it is caused to rush in the super-cooled state, and the cold air at a lower temperature is directly applied to the food during the super-cooled state to cancel the super-cooling so that the food can be freezing-preserved. Specifically, meat or fish, in which water is contained with no gap in each of the cells and among the cells, corresponds to a vessel filled with water with no gap. So, its super-cooled state will not be cancelled by vibration during carrying. In addition, the food may be stored at a normal temperature and cooled at a temperature not excessively low. The final freezing temperature may be at most -20°C but not at a very extremely low temperature of -60°C adopted in the industrial freezing house. Thus, without using energy as the carrying vehicle and by using the carrying time, the super-cooling freezing can be done, thereby contributing to energy saving before and after the carrying. Accordingly, the food with good freezing quality can be delivered to a consignee.

As regards the food subjected to the super-cooling freezing in the refrigerator according to this invention, its super-cooled state is given at a low cooling speed. Therefore, after the temperature uniformly drops to the interior of the food, simultaneously, the ice crystals start to be created. The ice crystal created partially will not grow non-uniformly

and the size of the ice crystals created within the food becomes minute, thereby keeping the food quality. As regards the relationship between the cooling speed and the size of the ice crystals, as the cooling speed increases, the size of the ice crystals created within the food tends to increase.

The refrigerator according to this invention includes a freezer compartment capable of continuously or stepwise regulating the temperature of the food to be stored from 0°C to the temperature in a freezing temperature zone by the cold air circulated from a cooler; a cooling compartment arranged in the freezer compartment, for taking in the cold air jet from a cold air blowout port of the freezer compartment and sucked therein to keep the food in its super-cooled state where the food is not frozen even at a temperature of the freezing point or lower; a temperature setting means for setting the temperature of the freezer compartment at the temperature between -2°C or lower and -15°C or higher so that the food stored in the cooling compartment falls in the super-cooled state; and a cold air regulating means for restricting the wind speed around the food stored in the cooling compartment thereby to regulate the cold air jet in the freezer compartment to be taken in the cooling compartment so that the food stored in the cooling compartment is kept in its super-cooled state. In such a configuration, the high quality freezing can be realized with saved energy.

The refrigerator according to this invention includes a super-cooling compartment for keeping the food stored in its

not-frozen super-cooled state at the setting temperature between the freezing point or lower and the -15°C or higher by the cold air supplied from the cooler; a cold air regulating means for changing the temperature of the cold air jet into
5 the super cooling compartment and circulating therein; a super-cooling canceling means for canceling the super-cooled state of the food by supplying the cold air at the temperature lower than the setting temperature by about 2 to 5 degree to the food stored in the super-cooling compartment and kept in
10 the super-cooled state by way of the cold air regulating means. In such a configuration, the frozen food with good quality can be easily obtained.

The temperature setting means for setting the freezer compartment or cooling compartment in this invention sets the
15 cooling speed in a range from -3.5°C/hr to -10°C/hr when the food at compartment temperature stored in the cooling compartment is cooled so that the surface temperature of the food drops to a range from 3°C to 0°C , thereby causing the food to surely rush in the super-cooled state.

20 The cold air regulating means 15 is provided in either one of the cold air blowout port from which the cold air is jet into the cooling compartment being the freezer compartment or storing compartment in this invention, a cold air take-in port from which the cold air is taken in the cooling compartment
25 and the duct between the cold air blowout port and the cold air take-in port. By regulating the cold air using the cold air regulating means thereby to restrict the wind speed around

the food to be fallen in the super-cooled state to 0.1 to 0.5 m/s. Thus, the super-cooled state can be kept.

The cold air regulating means 15 and duct 16 in this invention constitute plural curves in the indirect cooling duct 5 16B or provide a duct length corresponding to the depth of a convertible compartment serving as the storing compartment or cooling compartment. Otherwise, using the baffle 15A, the cold air regulating means restricts the wind speed of the cold air at the cold air blowout port from which the cold air is jet 10 into the freezer compartment or cooling compartment to 1.0 to 1.2 m/s. Thus, the super-cooled state can be kept.

Additionally, in this embodiment, as an example of the storing compartment capable of executing the super-cooling cooling, super-cooling freezing or fast freezing, the 15 convertible compartment 4 was employed. However, the other stock compartment such as the freezer compartment 6 or vegetable compartment 5, as long as it is provided with the direct cooling duct and indirect cooling duct which can be selectively changed, can also execute the super-cooling freezing or fast freezing. 20 In this way, in any storing compartment, according to the user's liking, a desired storing compartment can be set at a desired temperature zone or super-cooling freezing. Accordingly, the refrigerator or storage house with good operability for the user can be provided.

WHAT IS CLAIMED IS:

1. A refrigerator comprising:

a plurality of divided storing compartments to which a cold air created by a cooler is sent; and

a cold air duct for sending the cold air from the cooler to at least one of the storing compartments,

wherein the cold air duct comprises two ducts of a direct cooling duct and indirect cooling duct.

2. A refrigerator comprising:

a plurality of divided storing compartments to which a cold air created by a cooler is sent;

two cooling ducts of a direct cooling duct and an indirect cooling duct which are connected to at least one of said storing compartments to send the cold air from the cooler to said storing compartment; and

an air quantity regulating means capable of changing said two cooling ducts into the state of at least both opened, one opened or both closed.

3. The refrigerator according to claim 2, wherein said air quantity regulating means includes a single inlet and two outlets, the inlet being connected to a duct connected to a cooler room in which said cooler is arranged, the one of said two outlets being connected to said indirect cooling duct and the other thereof being connected to said direct cooling duct.

4. The refrigerator according to any one of claims 1 to 3, wherein said direct cooling duct is opened at a position where the cold air is directly applied to food within said storing compartment.

5. The refrigerator according to any one of claims 1 to 4, wherein said indirect cooling duct is opened at a position where the cold air is not directly applied to food within said storing compartment or the cold air is indirectly applied to the food.

6. The refrigerator according to any one of claims 1 to 5, wherein said at least one of the storing compartments is a storing compartment capable of executing super-cooling freezing of freezing by way of a super-cooled state.

7. The refrigerator according to any one of claims 1 to 5, wherein said at least one of the storing compartments is a convertible compartment.

8. The refrigerator according to any one of claims 1 to 7, further comprising:

a storing compartment case established within said at least one of the storing compartments; and

a cover member for covering at least a part of an upper opening of said storing compartment case,

wherein said indirect cooling duct is opened to directly

apply the cold air to said cover member so that the cold air is not directly applied to the food within said storing compartment case.

9. The refrigerator according to any one of claims 1 to 8, further comprising:

a temperature detecting means for detecting the food temperature within said at least one of the storing compartments; and

a control means for controlling said air quantity regulating means on the basis of the temperature detected by said temperature detecting means,

wherein if it is determined that the temperature detected by said temperature detecting means is higher than a first prescribed temperature previously set, both the direct cooling duct and the indirect cooling duct are opened, and then where a prescribed time or longer elapses from when both the direct cooling duct and indirect cooling duct are opened, said direct cooling duct is substantially closed to execute indirect cooling.

10. The refrigerator according to any one of claims 1 to 8, further comprising:

a temperature detecting means for detecting the food temperature within said at least one of the storing compartments; and

a control means for controlling said air quantity

regulating means on the basis of the temperature detected by said temperature detecting means,

wherein if it is determined that the temperature detected by said temperature detecting means is a second prescribed temperature previously set or lower, said direct cooling duct is substantially closed to execute indirect cooling.

11. A refrigerator comprising:

a plurality of divided storing compartments to which a cold air created by a cooler is sent;

a cold air duct for sending the cold air from the cooler to at least one of the storing compartments including two ducts of a direct cooling duct and indirect cooling duct, said direct cooling duct being connected to at least one of the storing compartments and opened at a position where the cold air from said cooler is directly applied to the food within said storing compartment, and said indirect cooling duct being connected to at least one of the storing compartments and opened at a position where the cold air is not directly applied to food within said storing compartment or the cold air is indirectly applied to the food; and

an air quantity regulating means capable of changing two cooling ducts of said direct cooling duct and said indirect cooling duct into an either state of both opened, one opened or both closed,

wherein said two cooling ducts are selectively changed so that said storing compartment is a storing compartment

capable of executing the super-cooling freezing of freezing
by way of a super-cooled state.