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CONTROL DEVICE FOR A REFRIGERATOR

The present invention is related to a control device
5 for a refrigerator.

In a conventional refrigerator, when a compressor is
driven, a timer is simultaneously energized to count an
operation period of the compressor. When the operation
period has reached a certain value, defrosting is made
10 (Japanese Unexamined Utility Model Publication No.
192377/1983).

Another conventional refrigerator has been proposed
as shown in Figure 36 (Japanese Unexamined Utility Model
Publication No. 106875/1989). In Figure 36, reference
15 numeral 101 designates a compressor. Reference numeral
102 designates a fan. Reference numeral 105 designates a
frozen food compartment. Reference numeral 103
designates a temperature sensor (hereinbelow, referred to
as the frozen food compartment thermister) for detecting
20 a temperature in the frozen food compartment 105.

Reference numeral 129 designates a power circuit.

Reference numeral 109 designates a control unit.

Reference numeral 131 designates a drive circuit. The control unit 109 detects a signal from the frozen food compartment 103 to control the drive circuit 131, thereby driving and stopping the compressor 101. The fan 102 is driven in synchronization with the compressor 101.

Because the conventional refrigerator control is made as stated above, when the compressor has been totally driven for a certain period, defrosting starts irrespectively of service conditions of the refrigerator. As a result, defrosting starts even when the refrigerator is frequently opened. It creates a problem in that stored food is adversely affected in terms of temperature.

The conventional refrigerator control maintains the revolution of the fan constant irrespectively of service conditions of the refrigerator. Because the fan has a constant revolution even when frequency of use is relatively low, a refrigerating capacity is used more than necessary even when the refrigerating capacity is in excess. It creates a problem in that the amount of power used is adversely affected.

It is an object of the present invention to solve these problems, and to provide a control device for a refrigerator wherein defrosting can be made while corresponding to a change in service conditions of the

refrigerator, without adverse effect on the temperature of food stored in the refrigerator.

It is another object of the present invention to provide a control device for a refrigerator capable of controlling the revolution of a fan while corresponding to a change in service conditions of the refrigerator, of minimizing power used, and of realising low noise operation.

According to a first aspect of the present invention, there is provided a control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator and a door; comprising:

- means for determining the total operating time of the compressor since the last defrosting operation;

- means for counting the number of openings of the door;

- means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods;

- means for selecting a defrosting timing based on a said period, after a predetermined compressor operating time, in which the door opening frequency has previously been determined to be low; and

- means for controlling defrosting based on the selected defrosting timing, in accordance with a predefined control rule for defrosting the evaporator.

According to a second aspect of the present invention, there is provided a control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator, and a door; comprising:

- means for determining the total operating time of the compressor since the last defrosting operation;

- means for counting the number of openings of the door;

- means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods;

means for determining, for each said period, an operation factor based on the total compressor operating time in said period since the last defrosting operation;

means for estimating a maximum permissible operating time based on the operation factors;

means for selecting a defrosting timing based on a said period, after a predetermined compressor operating time and before said maximum permissible operating time, in which the door opening frequency has previously been determined to be low; and

means for controlling defrosting based on the selected defrosting timing, in accordance with a predefined control rule for defrosting the evaporator.

According to a third aspect of the present invention, there is provided a control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator, and a door; comprising; detection means for detecting opening and closing of the door; means for counting the number of openings of the door;

means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods; and

means for determining the rate of revolution for the fan in each said period based on the stored frequencies, the determination being made in accordance with a predefined control rule.

According to a fourth aspect of the present invention, there is provided a control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator, and a door; comprising;

detection means for detecting opening and closing of the door; means for counting the number of openings of the door;

means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods; and

means for selecting a sub-cooling timing based on a said period immediately before the period determined to have the highest door opening frequency.

According to a fifth aspect of the present invention, there is provided a control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator and a door, comprising:

means for determining the total operating time of the compressor since the last defrosting operation;

means for determining the time for which the door has been closed;

a defrosting heater for the evaporator;

means for obtaining numerical values indicative of grades of the operating time and the door closing time in accordance with predefined membership functions for a fuzzy control;

means for selecting a conclusion part in accordance with a predefined control rule for defrosting;

means for calculating the grades selected at the conclusion part based on the conclusion part and the grades;

means for producing a final conclusion based on the selected grades; and

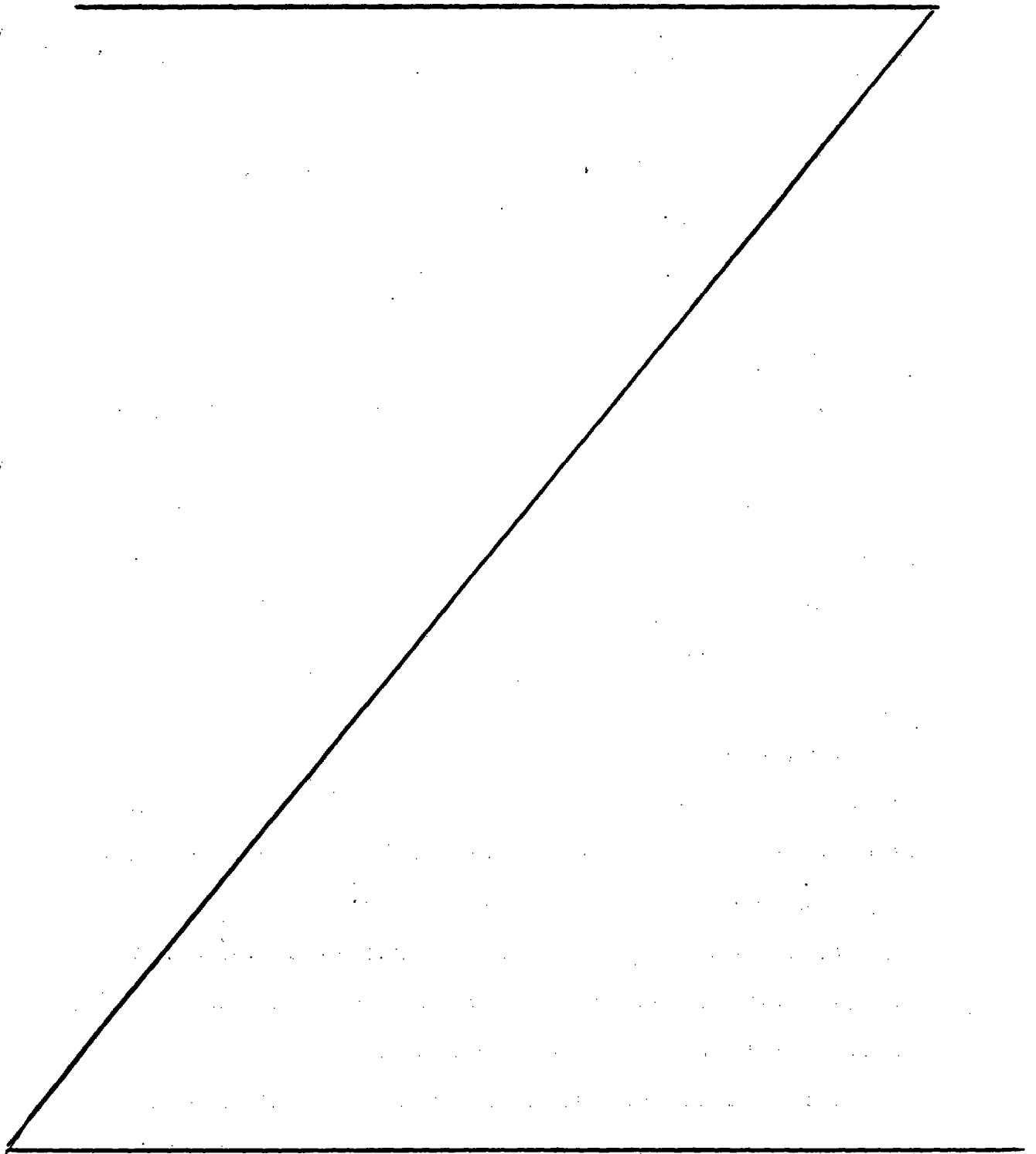
means for detecting a final control value for defrosting based on the produced value.

In accordance with the first aspect of the control device, timing wherein the door is opened and closed in low frequency can be selected to defrost the evaporator, thereby having no adverse effect to the temperature of food stored in the refrigerator.

In accordance with the second aspect of the control device, defrosting the evaporator is carried out based on the operation factor of the compressor and the frequency of opening and closing the door in accordance with the control rule, thereby having no adverse effect to food stored in the refrigerator.

In accordance with the third aspect of the control device, the revolution of the fan is controlled based on the frequency of opening and closing the door in accordance with the control rule to minimize power used, and to realise a low noise operation.

In accordance with the fifth aspect of the control device, the operating period of the compressor, and the door closing period are represented by minute numeric values indicative of grades, and the selected grades at



the conclusion part of the control rule are obtained by making the operation in accordance with the control rule. Finally, a total judgement is made to the selected grades of the respective control rules to carry out defrosting, thereby realizing defrosting without having no adverse effect to the temperature of food stored in the refrigerator.

In drawings:

Figure 1 is a schematic view of the entire structure of the refrigerator control device according to a first embodiment of the present invention;

Figure 2 is a circuit diagram of the refrigerator control device of the first embodiment;

Figure 3 is a block diagram of the refrigerator control device of the first embodiment;

Figure 4 is a flow chart of the refrigerator control device of the first embodiment;

Figure 5 is a flow chart of the refrigerator control device of the first embodiment;

Figure 6 is a block diagram of the refrigerator control device according to a second embodiment of the present invention;

Figure 7 is a flow chart of the refrigerator control device of the second embodiment;

Figure 8 is a flow chart of the refrigerator control device of the second embodiment;

Figure 9 is a flow chart of the refrigerator control

device of the second embodiment;

Figure 10 is a flow chart of the refrigerator control device of the second embodiment;

Figure 11 is a block diagram of the refrigerator control device according to a third embodiment of the present invention;

Figure 12 is a flow chart of the refrigerator control device of the third embodiment;

Figure 13 is a flow chart of the refrigerator control device of the third embodiment;

Figure 14 is a flow chart of the refrigerator control device of the third embodiment;

Figure 15 is a flow chart of the refrigerator control device of the third embodiment;

Figure 16 is a flow chart of the refrigerator control device according to a fourth embodiment of the present invention;

Figure 17 is a schematic view of the entire structure of the refrigerator control device according to a fifth embodiment of the present invention;

Figure 18 is a circuit diagram of the refrigerator control device of the fifth embodiment;

Figure 19 is a block diagram of the refrigerator control device of the fifth embodiment;

Figure 20 is a flow chart of the refrigerator control device of the fifth embodiment;

Figure 21 is a flow chart of the refrigerator control

device of the fifth embodiment;

Figure 22 is a flow chart of the refrigerator control device according to a sixth embodiment of the present invention.

5 Figure 23 is a schematic view showing a predefined operation manner in the refrigerator control device of the sixth embodiment;

Figure 24 is a flow chart of the refrigerator control device according to a seventh embodiment of the present
10 invention;

Figure 25 is a flow chart of the refrigerator control device according to an eighth embodiment of the present invention;

Figure 26 is a time chart to explain subcooling in
15 the refrigerator control device of the eighth embodiment;

Figure 27 is a schematic view of the entire structure of the refrigerator control device according to a ninth embodiment of the present invention;

Figure 28 is a circuit diagram showing the control
20 means of the ninth embodiment;

Figure 29 is a flow chart showing the control decision means of the ninth embodiment;

Figure 30 is a diagram showing membership functions to calculate grades based on a door closing period in
25 accordance with the ninth embodiment;

Figure 31 is a diagram of membership functions to calculate grades based on counted operation period of a

compressor in accordance with the ninth embodiment;

Figure 32 is a diagram showing control rules and conclusion parts in accordance with the ninth embodiment;

Figure 33 is a diagram to seek selected grades at the
5 conclusion parts based on goodness of fit to conditions in accordance with the ninth embodiment;

Figure 34 is a diagram to produce a final conclusion in accordance with the ninth embodiment;

Figure 35 is a diagram to determine a final control
10 value; and

Figure 36 is a schematic diagram of the entire structure of a conventional refrigerator control device.

Preferred embodiments of the present invention will be described with reference to the drawings.

15 EMBODIMENT 1

Now, a first embodiment of the present invention will be explained, referring to Figures 1 through 5. In Figure 1, there is shown a schematic view showing the entire structure of the refrigerator according to the
20 first embodiment of the present invention. Reference numeral 1 designates a compressor which compresses a refrigerant and circulates it. Reference numeral 2 designates an evaporator which evaporates the refrigerant. Reference numeral 3 designates a fan which
25 circulates cooled air produced by the evaporator 2. Reference numeral 5 designates a refrigerating compartment air path which directs a part of the cooled

air to a refrigerating compartment 4. Reference numeral 6 designates a damper which opens and closes the air path 5 to control the amount of the cooled air to the refrigerating compartment 4. Reference numeral 7 designates a defrosting heater which melts frost formed on the evaporator 2. Reference numeral 9 designates an F thermister which detects a temperature in a frozen food compartment 8. Reference numeral 10 designates an R thermister which detects a temperature in the refrigerating compartment 4. Reference numeral 11 designates a door detector which detects opening and closing a door. Reference numeral 12 designates an outside air thermister which detects an ambient temperature of the refrigerator. Reference numeral 13 designates a DEF thermister which detects a temperature of the evaporator 2 to finish defrosting. Reference numeral 14 designates a control unit which controls the operation of the refrigerator. The control unit 14 includes a control circuit 15 and control manner decision means 16. Next, the contents of the control circuit 15 will be explained, referring to Figure 2. In Figure 2, there are shown a first switch 18, a second switch 19, and a third switch 20 as means to turn on and off a power source 17 for the electrical parts. The first switch, the second switch and the third switch are contacts to turn on and off the compressor 1, the fan 3, the damper 6, and the defrosting heater 7, respectively. These

contacts are driven by a first coil 21, a second coil 22, and third coil 23, respectively. These coils are energized by a first driving circuit 24, a second driving circuit 25 and a third driving circuit 26. Which driving
5 circuit is energized is determined by a microcomputer 27.

In the case of defrosting, the third coil 23 is energized by the third driving circuit 26 to turn on the third switch 20. Power is supplied from the power source 17 to the defrosting heater 7 to carry out defrosting
10 (timing to start defrosting is determined by the control manner decision means 16). The microcomputer 27 receives inputs from the respective thermistors 9, 10, 12 and 13, and the door detector 11. Reference numerals 28 through 31 designate potential dividing resistors which share
15 voltages with the thermistors, respectively.

Now, the structure of control manner decision means for defrosting will be explained, referring to Figure 3. Compressor operating period counting means 32 counts an operating period of the compressor, and door detection
20 means 33 detects whether the door is opened or not, and inputs a signal indicative of the opening of the door into the control manner decision means to obtain the number of opening or closing the door in each time unit. In addition, door opening frequency calculation means 34
25 calculates frequencies of opening or closing the door in the respective time units, based on the counted number in the respective time units, and holds values indicative of

the calculated frequencies. On the other hand, when compressor operating period determination means 35 determines that the total length of the operating periods of the compressor which have been counted by the compressor operating period counting means 32 has reached a predetermined time period, defrosting time unit selection means 36 compares the frequencies in the respective time units to seek the order of priority according to the magnitudes of the compared frequencies, thereby determining in which time unit defrosting is carried out. In accordance with a predefined defrosting control rule, defrosting control value determination means 37 selects timing when defrosting should be started, and carries out ultimate determination about the control and start of defrosting.

Now, calculation of a frequency of opening or closing the door, and renewal of it will be described in detail, referring to a flowchart shown in Figure 4. At Step 38, the number x_i of opening or closing the door is calculated in each time unit T (Hr) which is obtained by dividing 24 hours. In each 24 hours, the number x_i of opening or closing the door in each time unit is transferred according to the following equation to add the number of opening or closing the door on the latest day in each time unit to a mean value in the past m days:

$$x_i = -(S_i/m) + x_i$$

At Step 39, values indicative of the frequencies (S_i)

of opening or closing the door are renewed according to the following equation:

$$S_i = S_i + x_i \quad (\text{The initial value of } S_i \text{ is } 0.)$$

$$i:1-n, n=24/T)$$

5 Referring to Figure 5, how to determine a time unit block to carry out defrosting among defrosting acceptable time units which have been selected by the presumption as stated above. At Step 40, all the time units are compared in terms of the magnitudes of the frequencies of opening
10 or closing the door. At Step 41, a block having the lowest frequency is selected. At Step 42, the block selected at Step 41 is finally determined as a time unit to carry out defrosting.

As explained, in accordance with the first
15 embodiment, a variable pattern of the door opening or closing frequencies in one day is held while being constantly refreshed based on the accumulated data on the door opening or closing frequencies in the past several days, and when it is a time unit having the lowest door
20 opening or closing frequency, defrosting can be carried out to avoid an adverse effect to stored food. In order to see how the refrigerator is used, there is provided the detector which detects the opening or closing of the door to count the number of opening or closing the door.
25 On the other hand, there is provided a counter to count the numbers of opening or closing the door in the respective blocks which are obtained by dividing 24 hours

of one day in such a way as to get blocks of 2 hours (The data for one day are obtained in such a manner). The data for one day are accumulated for several days (m days: for example 8 days), and weighted means of the accumulated data and the data newly counted for the latest day are obtained to be held as the door opening or closing pattern in one day (the number of opening or closing the door in each block of 2 hours). Based on the held door opening or closing pattern, it is determined which block has the lowest number of opening or closing the door in one day. When that block comes, defrosting is carried out. It usually takes 30-40 minutes to complete defrosting. In that manner, defrosting can be always carried out when the refrigerator is rarely opened.

EMBODIMENT 2

Next, a second embodiment of the present invention will be described in detail, referring to Figures 6-10. Now, the structure of control manner decision means 16 for defrosting will be explained, referring to Figure 6. Compressor operating period counting means 32 counts the operating period of a compressor 1. Means 43 for counting the operating period of the compressor accumulates the operating period of the compressor in each time unit block which is obtained by dividing 24 hours into time units. Door detection means 33 detects whether the door is opened or not, and inputs a signal

indicative of the opening of the door into the control manner decision means to obtain the number of opening or closing the door in each time unit. In addition, compressor operation factor calculation means 44 finds an operation factor in each time unit based on the compressor operating period accumulated in each time unit and holds a value indicative of the found operation factor. Further, door opening or closing frequency calculation means 34 calculates frequencies of opening or closing the door in the respective time units, based on the counted number in the respective time units, and holds values indicative of the calculated frequencies. On the other hand, when compressor operating period determination means 35 determines that the total length of the operating periods of the compressor 1 which have been counted by the compressor operating period counting means 32 has reached a predetermined time period, means 45 for presuming a range wherein defrosting is acceptable presumes a time unit range wherein defrosting is acceptable. This presumption is made, in accordance with a predefined control rule, based on the operation factor of the compressor in each time unit which is found by the compressor operation factor calculation means 44. Defrosting time unit selection means 36 compares the frequencies in the respective time units which have been presumed as being in the defrosting acceptable range, and seeks the order of priority according to the magnitudes

of the compared frequencies, thereby determining in which time unit block defrosting is carried out. In accordance with a predefined defrosting control rule, defrosting control value determination means 37 selects timing when
 5 defrosting should be started, and carries out ultimate determination about the control and start of defrosting.

Now, calculation of a frequency of opening or closing the door, and renewal of it will be described in detail, referring to Figure 7. At Step 38, the number x_i of
 10 opening or closing the door is calculated in each time unit T (Hr) which is obtained by dividing 24 hours. In each 24 hours, the number x_i of opening or closing the door in each time unit is transferred according to the following equation to add the number of opening or
 15 closing the door in each unit time on the latest day to a mean value in the past m days:

$$x_i = -(S_i/m) + x_i$$

At Step 39, values indicative of the frequencies (S_i) of opening or closing the door are renewed according to
 20 the following equation:

$$S_i = S_i + x_i \quad (\text{The initial value of } S_i \text{ is } 0.)$$

$$i: 1-n, n=24/T$$

Now, calculation of the operation factor of the compressor, and renewal of it will be described in
 25 detail, referring to Figure 8. At Step 46, an operating period t_i of the compressor is calculated in each time unit T (Hr) which is obtained by dividing 24 hours. In

each 24 hours, the operating period t_i in each time unit is transferred according to the following equation to add the operating period in each time unit on the latest day to a mean value in the past m days:

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$$t_i = -(R_i/m) + t_i$$

At Step 47, values indicative of the operation factor R_i are renewed according to the following equation:

$$R_i = R_i + t_i \quad (\text{The initial value of } R_i \text{ is } 0.)$$

$$i: 1-n, n=24/T$$

10 Referring to a flowchart shown in Figure 9, how to presume a time unit range to be able to accept defrosting based on the operation factors found as stated above will be described in detail. At Step 48, it is determined whether the total length S of the operating periods of
 15 the compressor has reached a predetermined value S_1 , or not. If affirmative, the program proceeds to Step 49, where the operation factor in each time unit found as stated above is added from that of the current time unit one after another. Whenever such addition is made, it is
 20 determined at step 50 whether a value found by the addition has been in the defrosting acceptable range S_2 , or not. At Step 51, a time unit range from the time unit when a value found by the addition has reached the predetermined value, and the time unit when the
 25 defrosting acceptable range has been exceeded is selected as a defrosting acceptable time unit range.

Referring to Figure 10, how to determine a time unit

block to carry out defrosting in the defrosting acceptable time unit range which have been selected by the presumption as stated above will be described in detail. At Step 40, all the time unit blocks in the
5 defrosting acceptable range are compared in terms of the magnitudes of the frequencies of opening or closing the door. At Step 41, a block having the lowest frequency is selected. At Step 42, the block selected at Step 41 is finally determined as a time unit to carry out
10 defrosting.

As explained, in accordance with the second embodiment, a variable pattern of the door opening or closing frequencies in one day is held while being constantly refreshed based on the accumulated data on the
15 door opening or closing frequencies in the past several days, and changes in the operation factors of the compressor are also held while being refreshed. When the accumulated operating period of the compressor has reached a predetermined first time (e.g. 8 hours), a
20 timing when the accumulated operating period of the compressor has reached a predetermined second time (e.g. 16 hours) is presumed based on the held operation factors. Defrosting is carried out in the time unit which is between the predetermined first time and the
25 predetermined second time, and which has the lowest frequency of opening or closing the door, thereby avoiding an adverse effect to stored food. The first

time is a time when it is advisable that defrosting is carried out after the time. The second time is a time when it is necessary to complete defrosting to prevent refrigeration performance from deteriorating. In order to see how the refrigerator is used, there is provided the detector which detects the opening or closing of the door to count the number of opening or closing the door. On the other hand, there is provided a counter to count the numbers of opening or closing the door in the respective blocks which are obtained by dividing 24 hours of one day in such a way as to get blocks of 2 hours. In addition, the operating period of the compressor is counted in each block (The data for one day are obtained in such a manner). The data for one day are accumulated for several days (m days: e.g. 8 days), and weighted means of the accumulated data and the data newly counted for the latest day are obtained to be held as the door opening or closing pattern in one day (the number of opening or closing the door in each block of 2 hours), and the compressor operation factor pattern in one day (the operating period in each block of 2 hours). When the total length of the operating periods of the compressor has the predetermined first time, e.g. 8 hours (The block in that time is called "a first block".), the operation factors (the operating periods) in the respective blocks which are after that time are added one after another. A block where a value obtained by such

addition has reached the predetermined second time, e.g. 16 hours is called "a second block". Based on the held door opening or closing pattern, it is determined which block between the first block and the second block has the lowest frequency of opening or closing the door in one day. When that block comes, defrosting is carried out. In that manner, even if the refrigerator has a low operation factor, defrosting can be carried out when it is the optimum timing and the refrigerator is rarely opened.

EMBODIMENT 3

Next, a third embodiment of the present invention will be described in detail, referring to Figures 11-15. Now, the structure of control manner decision means 16 for defrosting will be explained, referring to Figure 11. Compressor operating period counting means 32 counts the operating period of a compressor 1. Means 43 for accumulating the operating periods of the compressor accumulates the operating periods of the compressor 1 in each time unit block which is obtained by dividing 24 hours into time unites. Door detection means 33 detects whether the door is opened or not, and inputs a signal indicative of the opening of the door into the control manner decision means to obtain the number of opening or closing the door in each time unit. In addition, compressor operation factor calculation means 44 finds an operation factor in each time unit based on the

compressor operating period accumulated in each time unit and holds a value indicative of the found operation factor. Further, door opening or closing frequency calculation means 34 calculates frequencies of opening or closing the door in the respective time units, based on the counted number in the respective time units, and holds values indicative of the calculated frequencies. On the other hand, when compressor operating period determination means 35 determines that the total length of the operating periods of the compressor 1 which have been counted by the compressor operating period counting means 32 has reached a predetermined time period, means 45 for presuming a range wherein defrosting is acceptable presumes a time unit range wherein defrosting is acceptable. This presumption is made, in accordance with a predefined control rule, based on the operation factor of the compressor in each time unit which is found by the compressor operation factor calculation means 44. Defrosting time unit selection means 36 compares the frequencies in the respective time units which have been presumed as being in the defrosting acceptable range, and seeks the order of priority according to the magnitudes of the compared frequencies, thereby determining in which time unit block defrosting is carried out. In accordance with a predefined defrosting control rule, defrosting control value determination means 37 selects timing when defrosting should be started, and carries out ultimate

determination about the control and start of defrosting.

Now, calculation of a frequency of opening or closing the door, and renewal of it will be described in detail, referring to a flowchart shown in Figure 12. At Step 38, the number x_i of opening or closing the door is calculated in each time unit T (Hr) which is obtained by dividing 24 hours. In each 24 hours, the number x_i of opening or closing the door in each time unit is transferred according to the following equation to add the number of opening or closing the door in each time unit on the latest day to a mean value in the past m days:

$$x_i = -(S_i/m) + x_i$$

At Step 39, values indicative of the frequencies (S_i) of opening or closing the door are renewed according to the following equation:

$$S_i = S_i + x_i \text{ (The initial value of } S_i \text{ is 0.)}$$

$$i: 1-n, n=24/T$$

Now, calculation of the operation factor of the compressor, and renewal of it will be described in detail, referring to a flowchart shown in Figure 13. At Step 46, an operating period t_i of the compressor is calculated in each time unit T (Hr) which is obtained by dividing 24 hours. In each 24 hours, the operating period t_i in each time unit is transferred according to the following equation to add the operating period in each time unit on the latest day to a mean value in the

past m days:

$$t_i = -(R_i/m) + t_i$$

At Step 47, values indicative of the operation factor R_i are renewed according to the following equation:

5 $R_i = R_i + t_i$ (The initial value of R_i is 0.
 $i:1-n, n=24/T$)

Referring to a flowchart shown in Figure 14, how to presume a time unit range to be able to accept defrosting based on the operation factors found as stated above will be described in detail. At Step 48, it is determined whether the total length S of the operating periods of the compressor has reached a predetermined value S_1 , or not. If affirmative, the program proceeds to Step 49, where the operation factor in each time unit found as stated above is added from that of the current time unit one after another. Whenever such addition is made, it is determined at step 50 whether a value found by the addition has been in the defrosting acceptable range S_2 , or not. At Step 51, a time unit range from the time unit when a value found by the addition has reached the predetermined value, and the time unit when the defrosting acceptable range has been exceeded is selected as a defrosting acceptable time unit range.

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Referring to Figure 15, how to determine a time unit block to carry out defrosting in the defrosting acceptable time unit range which has been selected by the presumption as stated above will be described in detail.

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At Step 40, all the time unit blocks in the defrosting acceptable range are compared in terms of the magnitudes of the frequencies of opening or closing the door. At Step 41, a block having the lowest frequency is selected.

5 At Step 43, it is determined whether the block immediately after the selected block has the highest frequency among all the blocks, or not. If affirmative, a block which is located immediately before the block selected at Step 41 is selected at Step 44. At Step 42,

10 the block selected at Step 41 or 44 is finally determined as a time unit to carry out defrosting.

As explained, in accordance with the third embodiment, a variable pattern of the door opening or closing frequencies in one day is held while being

15 constantly refreshed based on the accumulated data on the door opening or closing frequencies in the past several days, and changes in the operation factors of the compressor are also held while being refreshed. When the accumulated operating period of the compressor has

20 reached a predetermined first time (e.g. 8 hours), a timing when the accumulated operating period of the compressor has reached a predetermined second time (e.g. 16 hours) is presumed based on the held operation factors. Defrosting is carried out in the time unit

25 which is between the predetermined first time and the predetermined second time, and which has the lowest frequency of opening or closing the door. If the time

unit immediately after the selected time unit with the lowest frequency has the highest frequency among the held frequencies, defrosting in the time unit with the lowest frequency is evaded, and defrosting is carried out in the time unit immediately before the the time unit with the lowest frequency, thereby avoiding an adverse effect to stored food. In order to see how the refrigerator is used, there is provided the detector which detects the opening or closing of the door to count the number of opening or closing the door. On the other hand, there is provided a counter to count the numbers of opening or closing the door in the respective blocks which are obtained by dividing 24 hours of one day in such a way as to get blocks of 2 hours. In addition, the operating period of the compressor is counted in each block (The data for one day are obtained in such a manner). The data for one day are accumulated for several days (m days: e.g. 8 days), and weighted means of the accumulated data and the data newly counted for the latest day are obtained to be held as the door opening or closing pattern in one day (the number of opening or closing the door in each block of 2 hours), and the compressor operation factor pattern in one day (the operating period in each block of 2 hours). When the total length of the operating periods of the compressor has the predetermined first time, e.g. 8 hours (The block in that time is called "a first block".), the operation factors (the

operating periods) in the respective blocks which are after that time are added one after another. A block where a value obtained by such addition has reached the predetermined second time, e.g. 16 hours is called "a second block". Based on the held door opening or closing pattern, it is determined which block between the first block and the second block has the lowest frequency of opening or closing the door in one day. In addition, the number of opening or closing the door in the block immediately after the block with the lowest frequency is checked, and if that block has the highest frequency, defrosting is carried out when the block immediately before the block with the lowest frequency comes. In that manner, even if the refrigerator has a low operation factor, defrosting can be carried out when it is the optimum timing and the refrigerator is rarely opened. Further, there is no possibility that when the refrigerator is frequently used, heat due to defrosting has an adverse effect to stored food.

EMBODIMENT 4

Next, a fourth embodiment of the present invention will be described in detail, referring to Figures 16. At Step 40, all the time unit blocks in the defrosting acceptable range are compared in terms of the magnitudes of the frequencies of opening or closing the door. At Step 41, a block having the lowest frequency is selected, and at Step 45, a block having the second lowest

frequency is selected as a second candidate. At Step 43, it is determined whether the block immediately after the block selected at Step 41 has the highest frequency among all the blocks, or not. If affirmative, the block which
5 has been selected as the second candidate at Step 45 is selected at Step 46. In that manner, the block which has been selected at Step 41 or 45 is finally determined at Step 42 as a time unit to carry out defrosting.

As explained, in accordance with the fourth
10 embodiment, a variable pattern of the door opening or closing frequencies in one day is held while being constantly refreshed based on the accumulated data on the door opening or closing frequencies in the past several days, and changes in the operation factors of the
15 compressor are also held while being refreshed. When the total length of the accumulated operating periods of the compressor has reached a predetermined first time (e.g. 8 hours), a timing when the total length of the operating periods of the compressor has reached a predetermined
20 second time (e.g. 16 hours) is presumed based on the held operation factors. Defrosting is carried out in the time unit which is between the predetermined first time and the predetermined second time, and which has the lowest frequency of opening or closing the door. If the time
25 unit immediately after the selected time unit with the lowest frequency has the highest frequency among the held frequencies, defrosting in the time unit with the lowest

frequency is evaded, and defrosting is carried out in the time unit with the second lowest frequency, thereby avoiding an adverse effect to stored food. In order to see how the refrigerator is used, there is provided a
5 detector which detects the opening or closing of the door to count the number of opening or closing the door. On the other hand, there is provided a counter to count the numbers of opening or closing the door in the respective blocks which are obtained by dividing 24 hours of one day
10 in such a way as to get blocks of 2 hours. In addition, the operating period of the compressor is counted in each block (The data for one day are obtained in such a manner). The data for one day are accumulated for several days (m days: e.g. 8 days), and weighted means of
15 the accumulated data and the data newly counted for the latest day are obtained to be held as the door opening or closing pattern in one day (the number of opening or closing the door in each block of 2 hours), and the compressor operation factor pattern in one day (the
20 operating period in each block of 2 hours). When the total length of the operating periods of the compressor has the predetermined first time, e.g. 8 hours (The block in that time is called "a first block".), the operation factors (the operating periods) in the respective blocks
25 which are after that time are added one after another. A block where a value obtained by such addition has reached the predetermined second time, e.g. 16 hours is called "a

second block". Based on the held door opening or closing pattern, it is determined which block between the first block and the second block has the lowest frequency of opening or closing the door in one day. In addition, the
5 number of opening or closing the door in the block immediately after the block with the lowest frequency is checked, and if that block has the highest frequency, defrosting is carried out when the block with the second lowest frequency comes. In that manner, even if the
10 refrigerator has a low operation factor, defrosting can be carried out when it is the optimum timing and the refrigerator is rarely opened. Further, there is no possibility that when the refrigerator is frequently used, heat due to defrosting has an adverse effect to
15 stored food.

EMBODIMENT 5

Next, a fifth embodiment of the present invention will be described. Referring not to Figure 17, there is shown a schematic diagram showing the entire structure of
20 the refrigerator according to the fifth embodiment. A refrigerant is compressed and circulated by a compressor 1. There are provided an evaporator 2 which evaporates the refrigerant, a fan 3 which circulates cooled air produced by the evaporator 2, a frozen food compartment
25 thermister 9 which detects a temperature in a frozen food compartment 8, and a control unit 14 which controls the operation of the refrigerator. The control unit 14

comprises control means 15 and control manner decision means 16. Now, the contents of the control means 15 will be described in, referring to Figure 18.

As shown in Figure 18, the control means 15 includes
5 a first switch 18 and a second switch 19 as means for turning on and off a power source 17 for electrical parts. These switches are to turn on and off the compressor 1 and the fan 3, respectively, and are driven by a coil 21 and a coil 22. Energization to these coils
10 is made by means of a first driving circuit 24 and a third driving circuit 26.

In addition, there are provided a photocoupler 47, and capacities 48 and 49 which control the revolution of the fan 3. Energization to the photocoupler 47 is made
15 by means of a second driving circuit 25. Which one of the first driving circuit 24, the second driving circuit 25 and the third driving circuit 26 should be energized is determined by a microcomputer 27. This determination is made by the control manner decision means 16. The
20 microcomputer 27 has the thermister 9 and a door detector 11 as inputs. Reference numeral 29 designates a potential dividing resistor which shares a voltage with the thermister.

Next, the contents of the control manner decision
25 means 16 for the revolution of the fan 3 will be described, referring to a control block diagram shown in Figure 19. Door opening input means 50 detects whether a

door of the refrigerator is opened or not. Door opening or closing frequency counting means 51 uses as input a signal indicative of the opening of the door to count the number of opening the door in each time unit. Door opening or closing frequency renewal means 52 constantly renews the number of opening the door in each time unit to hold new data on the opening of the door. Fan revolution decision means 53 determines the revolution of the fan 3 based on the frequency in each time unit in accordance with a predefined rule.

Next, the contents of the control manner decision means 16 for the revolution of the fan 3 will be described, referring to a flow chart shown in Figure 20. At Step 54, it is determined whether the door is opened or not, and if affirmative, a signal indicative of the opening of the door is inputted. At Step 55, signals indicative of the opening of the door inputted at Step 54 are used as input, and the numbers of opening the door in the respective time units which are obtained by dividing 24 hours are counted. At Step 56, the numbers of opening the door in the respective time units for a certain period are calculated to constantly hold new data on the numbers of opening the door for that certain period. At Step 57, the revolution of the fan 3 is determined based on the door opening or closing frequency in the respective time units in accordance with the predefined rule.

Now, calculation of the frequency of opening or closing the door, and renewal of it will be described in detail, referring to Figure 21. At Step 58, the number x_i of opening or closing the door is calculated in each time unit T (Hr) which is obtained by dividing 24 hours. In each 24 hours, the number x_i of opening or closing the door in each time unit is transferred according to the following equation to add the number of opening or closing the door in each time unit on the latest day to a mean value in the past m days:

$$x_i = -(S_i/m) + x_i$$

At Step 59, values indicative of the frequencies S_i of opening or closing the door are renewed according to the following equation:

$$S_i = S_i + x_i \quad (\text{The initial value of } S_i \text{ is } 0.)$$

$$i: 1-n, n=24/T$$

In accordance with priorities of the door opening or closing frequencies found at Step 59, the revolution of the fan is increased at a high priority, and the revolution is decreased at a low priority.

EMBODIMENT 6

Now, a sixth embodiment of the present invention will be described in detail, referring to Figures 22 and 23. In Figure 22, how to select a timing to carry out defrosting based on a defrosting acceptable range and door opening or closing frequencies numerically represented will be described in detail. At Step 60, the

magnitudes of the frequencies of opening or closing the door in the respective time unit are compared. At Step 61, the time units are ordered from "0" to "11". At Step 62, the data so ordered is combined with the defrosting acceptable range. In this case, "12" is allotted to the order of a block wherein defrosting is not acceptable, i.e. defrosting should be avoided, and combination of the data is made.

At Step 63, the order of the door opening or closing frequencies in the respective time units are calculated in accordance with the following equation, using predefined optimum parameters:

$$M_1 = F(I_1, I_2, \dots, I_1, \dots, I_{12})$$

$F(I_1, I_2, \dots, I_1, \dots, I_{12})$: function of I_1-I_{12}

I_1-I_{12} : combined data

At Step 64, the data obtained at Step 63 are calculated in accordance with the following equation, using predefined optimum parameters, and data for the respective time units are obtained:

$$O_1 = F(M_1, M_2, \dots, M_1, \dots, M_{12})$$

$G(M_1, M_2, \dots, M_1, \dots, M_{12})$: function of M_1-M_{12}

At Step 65, a block to carry out defrosting is selected based on the results obtained by the calculations stated above.

Referring now to Figure-23, the contents of the calculations will be described. The calculations comprise hierarchically related Steps (intermediate

position and output position). At first, the calculation at the intermediate position is made as follows, using as inputs the data I_1 - I_{12} ordered at Step 62:

$$M_1 = 1 / (1 + \exp(I_1 \cdot W_{2(1,1)} + I_2 \cdot W_{2(1,2)} + \dots + I_{11} \cdot W_{2(1,11)} + I_{12} \cdot W_{2(1,12)}))$$

$$M_2 = 1 / (1 + \exp(I_1 \cdot W_{2(2,1)} + I_2 \cdot W_{2(2,2)} + \dots + I_{11} \cdot W_{2(2,11)} + I_{12} \cdot W_{2(2,12)}))$$

10

$$M_{11} = 1 / (1 + \exp(I_1 \cdot W_{2(11,1)} + I_2 \cdot W_{2(11,2)} + \dots + I_{11} \cdot W_{2(11,11)} + I_{12} \cdot W_{2(11,12)}))$$

$$M_{12} = 1 / (1 + \exp(I_1 \cdot W_{2(12,1)} + I_2 \cdot W_{2(12,2)} + \dots + I_{11} \cdot W_{2(12,11)} + I_{12} \cdot W_{2(12,12)}))$$

15 Subsequently, the calculation at the output position is made as follows, using as inputs the data at the intermediate position:

$$O_1 = M_1 \cdot W_{1(1,1)} + M_2 \cdot W_{1(1,2)} + \dots + M_{11} \cdot W_{1(1,11)} + M_{12} \cdot W_{1(1,12)}$$

$$O_2 = M_1 \cdot W_{1(2,1)} + M_2 \cdot W_{1(2,2)} + \dots + M_{11} \cdot W_{1(2,11)} + M_{12} \cdot W_{1(2,12)}$$

20

$$O_{11} = M_1 \cdot W_{1(11,1)} + M_2 \cdot W_{1(11,2)} + \dots +$$

$$M_{11} \cdot W_{1(11,11)} + M_{12} \cdot W_{1(11,12)}$$

25

$$O_{12} = M_1 \cdot W_{1(12,1)} + M_2 \cdot W_{1(12,2)} + \dots +$$

$$M_{11} \cdot W_{1(12,11)} + M_{12} \cdot W_{1(12,12)}$$

A block which has a positive value at the final

output is selected as a block to carry out defrosting. This selection is made at Step 65. In the equations described above, $W_{1(1-12,1-12)}$ and $W_{2(1-12,1-12)}$ are optimum parameters by means of which the input position is
 5 related to the output position, and which are preset values (data tuned in advance in such a way to select the optimum block finally). In this specific case, there is shown a model wherein the intermediate position is single and includes 12 units. The intermediate position is not
 10 limited to be single, and the number of units in the intermediate position is not limited.

EMBODIMENT 7

Now, a seventh embodiment of the present invention will be described, referring to Figure 24. How to select
 15 a timing to reduce the revolution of a fan based on door opening or closing frequencies numerically represented will be described in detail, referring to Figure 24. At Step 71, the magnitudes of the frequencies of opening or closing the door in the respective time units are
 20 compared. At Step 72, the door opening or closing frequencies in the respective time units are ordered from "0" to "11". At Step 73, the order of the door opening or closing frequencies in the respective time units are calculated in accordance with the following equation,
 25 using predefined optimum parameters:

$$M_1 = F(I_1, I_2, \dots, I_1, \dots, I_{12})$$

$$F(I_1, I_2, \dots, I_1, \dots, I_{12}): \text{function of } I_1-I_{12}$$

At Step 74, the data obtained at Step 73 are calculated in accordance with the following equation, using predefined optimum parameters, and the data in the respective time units are obtained:

$$O_1 = F(M_1, M_2, \dots, M_1, \dots, M_{12})$$

$G(M_1, M_2, \dots, M_1, \dots, M_{12})$: function of M_1 - M_{12}

At Step 75, a block to rotate the fan at a low speed is selected based on the results found by the calculations stated above. The contents of the calculations are similar to those of the sixth embodiment.

EMBODIMENT 8

Now, an eighth embodiment of the present invention will be described, referring to Figures 25 and 26. How to determine a time unit block to carry out subcooling in a frozen food compartment will be described in detail, referring to Figure 25. At Step 80, the magnitudes of the frequencies of opening or closing the door in the respective time units are compared. A time unit block which has the highest frequency is selected at Step 81. Finally, at Step 82, the block which is located immediately before the block selected at Step 81 is determined as a time unit block to carry out subcooling. Subcooling is made in such a manner that the OFF temperature of a compressor 1 and a fan 3 is made lower than that at a normal time in the determined block to decrease the temperature in a refrigerator, thereby

preventing the temperature of stored food from increasing. On the other hand, the compressor 1 and the fan 3 may be driven for a certain period to carry out similar subcooling operation.

5 EMBODIMENT 9

Now, a ninth embodiment of the present invention will be described, referring to Figures 27-35. In Figure 27, there is shown a schematic diagram showing the entire structure of the refrigerator according to the ninth
10 embodiment. Reference numeral 1 designates a compressor which compresses and circulates a refrigerant. Reference numeral 2 designates an evaporator which evaporates the refrigerant. Reference numeral 3 designates a fan which circulates cooled air produced by the evaporator 2.
15 Reference numeral 5 designates an air path for directing a part of the cooled air to a refrigerating compartment 4. Reference numeral 6 designates a damper which opens and closes the air path 5 to control the amount of the cooled air to the refrigerating compartment 4. Reference
20 numeral 7 designates a defrosting heater which melts frost formed on the evaporator 2. Reference numeral 9 designates an F thermister which detects a temperature in a frozen food compartment 8. Reference numeral 10 designates an R thermister which detects a temperature in
25 the refrigerating compartment 4. Reference numeral 11 designates a door detector which detects whether a door of the refrigerator is opened or not. Reference numeral

12 designates an outside air thermister which detects an ambient temperature around the refrigerator. Reference numeral 13 designates a DEF thermister which detects a temperature of the evaporator 2 to complete defrosting.

5 Reference numeral 14 designates a control unit which controls the operation of the refrigerator, and which is constituted by control means 15 and control manner decision means 16.

Next, the contents of the control means 15 will
10 described, referring to Figure 28. In Figure 28, there are provided a first switch 18, a second switch 19 and a third switch 20 which are means for turning on and off a power source 17 for the electrical parts. These switches are contacts which turn on and off the compressor 1, the
15 fan 3, the damper 6 and the defrosting heater 7, respectively. The contacts 18, 19 and 20 are driven by a first coil 21, a second coil 22 and a third coil 23, respectively. Energization to the coils is made by means of a first driving circuit 24, a second driving circuit
20 25 and a third driving circuit 26. A microcomputer 27 determines which one of the driving circuits should be energized.

In the case of defrosting, the third coil 23 is energized by the third driving circuit 26, and the third
25 switch 20 turns on the power source 17 to feed power to the defrosting heater 7, thereby carrying out defrosting. (Determination of timing to carry out defrosting is made

by the control manner decision means 16.) The microcomputer 27 has the thermistors 9, 10, 12 and 13, and the door detector 11 as inputs. Reference numerals 28-31 designate potential dividing resistors which shares
5 voltages with the thermistors.

Next, the contents of the control manner decision means 16 for defrosting will be described, referring to Figure 29. At Step 32, the state of a door of the refrigerator is detected to input a signal indicative of
10 the state, and how long the door is closed is counted. A value obtained by the count is stored as a door closing period. At Step 33, the total length of the operating periods of the compressor 1 is counted. Such two kinds of data have their respective grades numerically
15 represented by use of fuzzy control membership functions predefined as shown in Figures 30 and 31 (Step 34), and conclusion parts are selected in accordance with control rules shown in Figure 32 (Step 35). Subsequently, at Step 36, the grades selected at the conclusion parts are
20 calculated based on goodness of fit to the condition parts of the rules as shown in Figure 33. The greatest one among the numerical values indicative of the grades selected at the respective rules in the same conclusion is selected to produce a final conclusion as shown in
25 Figure 34 (Step 37). Based on the selected value, a final control value is found as the center of gravity in an area as shown in Figure 35 (Step 38), and it is

determined based on the found control value whether defrosting should be carried out or not. Though, in the ninth embodiment the final control value is found based on the center of gravity in the area, the control value
5 can be found by weighted average to make a similar control.

CLAIMS:

1. A control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator and a door, comprising:

means for determining the total operating time of the compressor since the last defrosting operation;

means for counting the number of openings of the door;

means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods;

means for selecting a defrosting timing based on a said period, after a predetermined compressor operating time, in which the door opening frequency has previously been determined to be low; and

means for controlling defrosting based on the selected defrosting timing, in accordance with a predefined control rule for defrosting the evaporator.

2. A control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator, and a door, comprising: means for determining the total operating time of the compressor since the last defrosting operation;

means for counting the number of openings of the door;

means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods;

means for determining, for each said period, an operation factor based on the total compressor operating time in said period since the last defrosting operation;



means for estimating a maximum permissible operating time based on the operation factors;

means for selecting a defrosting timing based on a said period, after a predetermined compressor operating time and before said maximum permissible operating time, in which the door opening frequency has previously been determined to be low; and

means for controlling defrosting based on the selected defrosting timing, in accordance with a predefined control rule for defrosting the evaporator.

3. A control device for a refrigerator, as claimed in claim 2, in which the means for selecting defrosting time are operative to determine whether the period immediately following the said period of low door opening frequency has the highest door opening frequency, and in that case, to select as the period in which defrosting is to occur, the period immediately preceding the said period of low door frequency.

4. A control device for a refrigerator, as claimed in claim 2, in which the means for selecting defrosting time are operative to determine whether the period immediately following the said period of low door opening frequency has the highest door opening frequency, and in that case, to select as the period in which defrosting is to occur, the period in which the door opening frequency has been determined to be the second lowest.

5. A control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator, and a door, comprising;



detection means for detecting opening and closing of the door; means for counting the number of openings of the door;

means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods; and

means for determining the rate of revolution for the fan in each said period based on the stored frequencies, the determination being made in accordance with a predefined control rule.

6. A control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator, and a door; comprising:

detection means for detecting opening and closing of the door; means for counting the number of openings of the door;

means for determining the frequency of opening and closing the door based on the counted number of openings of the door and for thereby determining the variation of the said frequency over a repeating cycle of time periods; and

means for selecting a sub-cooling timing based on a said period immediately before the period determined to have the highest door opening frequency.

7. A control device for a refrigerator having a compressor and an evaporator, a fan for forcibly circulating cooled air produced by the evaporator and a door; comprising:

means for determining the total operating time of the compressor since the last defrosting operation;



means for determining the time for which the door has been closed;

a defrosting heater for the evaporator;

means for obtaining numerical values indicative of grades of the operating time and the door closing time in accordance with predefined membership functions for a fuzzy control;

means for selecting a conclusion part in accordance with a predefined control rule for defrosting;

means for calculating the grades selected at the conclusion part based on the conclusion part and the grades;

means for producing a final conclusion based on the selected grades; and

means for detecting a final control value for defrosting based on the produced value.

8. Control means for a refrigerator, substantially as herein described with reference to Figures 1 to 5, Figures 6 to 10, Figures 11 to 15, Figure 16, Figures 17 to 21, Figures 22 and 23, Figure 24, Figures 25 and 26, or Figures 27 to 35 of the accompanying drawings.

