

COOLING OPERATION CONTROL DEVICE FOR REFRIGERATOR

This invention relates to a cooling operation control device for a refrigerator including two evaporators for cooling an atmosphere in a freezing compartment and an atmosphere in a refrigerating compartment respectively.

In refrigerators of the above-described type, a freezing evaporator and a refrigerating evaporator are connected in series to each other in a refrigerant circuit. A throttle opening of the refrigerating evaporator is reduced so that a temperature of the refrigerating evaporator becomes higher than a temperature of the freezing evaporator. A temperature sensor is provided in either freezing or refrigerating compartment for sensing an atmospheric temperature therein. A compressor is controlled on the basis of the temperature sensed by the temperature sensor.

In the above-described refrigerator, however, only a small temperature difference is set between the refrigerating and freezing evaporators. Accordingly, the temperature of the refrigerating evaporator is extremely low. In this case, the atmosphere in the refrigerating compartment in which the temperature is relatively high is cooled by the refrigerant supplied from the refrigerating evaporator whose temperature is low. This results in a wasteful cooling operation such as over-cooling or cooling too much, reducing a cooling efficiency of a refrigerating cycle. Further, the temperature of the refrigerating evaporator becomes low while the atmosphere in the freezing compartment is being cooled. Since a humidity in the

refrigerating compartment is high at this time, frost tends to fall on the refrigerating evaporator. Upon frost formation on the refrigerating evaporator, its heat-exchange efficiency is reduced and the power consumption is increased.

5 Further, the compressor is controlled on the basis of the temperature sensed by the temperature sensor provided in either freezing or refrigerating compartment. Accordingly, when hot or high-temperature food etc. is accommodated in the other compartment in which the temperature sensor is not provided, this
10 compartment cannot be maintained at a suitable low temperature. Additionally, the circulation of cold air through the freezing compartment is not performed completely independent of the circulation of cold air through the refrigerating compartment or vice versa. Accordingly, when a door of one of the freezing
15 and refrigerating compartments is half-opened so slightly that an open state cannot be detected by a door switch, the interior of the other compartment is not almost cooled as well as the interior of the one compartment.

Therefore, an object of the present invention is to provide
20 a refrigerator in which the cooling efficiency of the refrigerating cycle can be improved and both freezing and refrigerating compartments can reliably be maintained at respective proper temperatures.

The present invention provides a refrigerator comprising
25 a compressor, a condenser, refrigerating throttling means, a refrigerating evaporator, a refrigerating blower supplying a cold air produced by the refrigerating evaporator into a refrigerating compartment, a freezing evaporator, a freezing

blower supplying a cold air produced by the freezing evaporator into a freezing compartment, a refrigerant circuit serially connecting the compressor, the condenser, the refrigerating throttling means, the refrigerating evaporator and the freezing evaporator sequentially, a refrigerant branch pipe diverged between the condenser and the refrigerating throttling means and connected at a downstream between the refrigerating evaporator and the freezing evaporator, freezing throttling means provided on the refrigerant branch pipe, and passage switching means for switching a flow direction of the refrigerant from the condenser between the refrigerating evaporator side and the refrigerant branch pipe side. Control means is provided for switching a cooling operation between a refrigerating compartment cooling mode in which the passage switching means is switched to the refrigerating evaporator side and the refrigerating blower is driven with the freezing blower being stopped and a freezing compartment cooling mode in which the passage switching means is switched to the refrigerant branch pipe side and the freezing blower is driven with the refrigerating blower being stopped.

The control means switches the cooling operation from the refrigerating compartment cooling mode to the freezing compartment cooling mode when a temperature in the freezing compartment has reached a predetermined freezing compartment upper limit temperature. The control means switches the cooling operation from the freezing compartment cooling mode to the refrigerating compartment cooling mode when a temperature in the refrigerating compartment has reached a predetermined refrigerating compartment upper limit temperature.

According to the above-described refrigerator, the provision of the refrigerant branch pipe and the passage switching means allows the refrigerating evaporator to be set at a relatively higher temperature. Since this prevents the refrigerating compartment from being over-cooled, the cooling efficiency can be improved. The control means compares the temperatures in the freezing and refrigerating compartments with the respective upper limit temperatures, thereby switching the refrigerator between the refrigerating compartment cooling mode and the freezing compartment cooling mode. Consequently, the temperatures in the freezing and refrigerating compartments can be maintained at respective proper values.

In a preferred form, the control means switches the cooling operation from the refrigerating compartment cooling mode to the freezing compartment cooling mode when the temperature in the refrigerating compartment has reached a predetermined refrigerating compartment lower limit temperature. On the other hand, the control means switches the cooling operation from the freezing compartment cooling mode to the refrigerating compartment cooling mode when the temperature in the freezing compartment has reached a predetermined freezing compartment lower limit temperature. Further, the control means preferably adjusts a compressing performance of the compressor based on a difference between the temperature of either the freezing or the refrigerating compartment and a predetermined reference temperature. The control means may adjust the compressing performance of the compressor when switching the passage switching means.

In another preferred form, the control means adjusts a rotational speed of either the freezing or refrigerating blower. In this case, the control means stops the compressor when the compressor is in operation with a minimum compressing performance in a case where the control means reduces the compressing performance of the compressor. Further, after the compressor has been stopped, the control means determines which of the temperatures in the freezing and refrigerating compartments has reached the respective upper limit temperature faster, so that the control means re-starts the cooling operation for either compartment in which the temperature has reached the upper limit temperature faster.

In further another preferred form, the control means obtains a difference between the temperature in the freezing compartment and the freezing compartment upper limit temperature and a difference between the temperature in the refrigerating compartment and the refrigerating compartment upper limit temperature when the temperatures in the freezing and refrigerating compartments have exceeded the respective upper limit temperatures, so that the control means performs the cooling operation first for either one of the compartments in which the difference is larger than in the other.

In further another preferred form, the control means drives the refrigerating blower with delay after having switched the passage switching means to finish the cooling operation in the refrigerating compartment cooling mode. In this case, the control means preferably obtains an accumulated time of the freezing compartment cooling mode and starts a defrosting

operation of the freezing evaporator when the accumulated time has exceeded a predetermined set time.

In further another preferred form, when the freezing compartment or refrigerating compartment cooling mode has been carried out continuously for a respective predetermined time, the control means switches the passage switching means so that the cooling operation is switched from the freezing compartment cooling mode to the refrigerating compartment cooling mode or from the refrigerating compartment cooling mode to the freezing compartment cooling mode.

In further another preferred form, the control means drives the compressor with a maximum compressing performance when the temperature in either freezing or refrigerating compartment has reached a respective freezing or refrigerating compartment forced cooling temperature. In this case, the cooling operation is executed with the maximum compressing performance being maintained until the temperature in the freezing or refrigerating compartment reaches the respective upper limit temperature. Further, the control means carries out an alarming operation and returns the compressor to a normal compressing performance when the temperature in the freezing or refrigerating compartment does not reach the respective upper limit temperature upon lapse of a predetermined time from start of drive of the compressor with the maximum compressing performance.

Other objects, features and advantages of the present invention will become clear upon understanding of the following description of one embodiment, made with reference to the

accompanying drawings, in which:

FIG. 1 is a front view of the interior of a refrigerator of one embodiment in accordance with the present invention;

FIG. 2 is a longitudinal section of the refrigerator;

5 FIG. 3 illustrates an arrangement of equipment constituting a refrigerating cycle of the refrigerator;

FIG. 4 illustrates a refrigerant circuit of the refrigerator;

FIG. 5 is a flowchart showing a control manner performed
10 by a control section;

FIG. 6 is a flowchart showing another control manner performed by the control section;

FIG. 7 is a time chart for explaining the control manner of the control section;

15 FIG. 8 is also a time chart for explaining the control manner of the control section;

FIG. 9 is further a time chart for explaining the control manner of the control section; and

FIG. 10 is a schematic block diagram showing an electrical
20 arrangement of the refrigerator.

One embodiment of the present invention will be described with reference to the accompanying drawings. Referring to FIG. 1, the interior of a refrigerator 10 of one embodiment in accordance with the present invention is shown. The
25 refrigerator 10 comprises a main body or cabinet 12 in which a refrigerating compartment 14, a vegetable compartment 16, a temperature-changeable compartment 18 and a freezing compartment 22 are defined in this order from the top. An

ice-making compartment 20 is provided on the left of the temperature-changeable compartment 18 as viewed in FIG. 1. A heat-insulating partition panel 24 is provided between the vegetable compartment 16 and the temperature-changeable and
5 ice-making compartments 18 and 20.

A chilling compartment 26 is defined in the lower interior of the refrigerating compartment 14. A temperature in the chilling compartment 26 is maintained at about 0°C. The vegetable compartment 16 is of a drawer type and includes a
10 vegetable container 28 provided to be drawn in and out. A vegetable compartment door (not shown) is mounted on a front of the vegetable compartment 26. The temperature-changeable compartment 18 is also of the drawer type and includes a temperature-changeable compartment container 30 provided to be
15 drawn in and out. A temperature-changeable compartment door (not shown) is mounted on a front of the container 30. Further, the freezing compartment 22 is also of the drawer type and includes a freezing container 32 provided to be drawn in and out. A freezing compartment door (not shown) is mounted on a front of
20 the freezing container 32. An ice maker 34 is provided near a ceiling of the ice-making compartment 20. An ice reservoir 36 is provided below the ice maker 34 to be drawn in and out. An ice-making compartment door (not shown) is mounted on a front of the ice reservoir 36. A water tank 44 from which water is
25 supplied to the ice maker 34 is provided on the left of the chilling compartment 26 in the refrigerating compartment 14 as viewed in FIG. 1.

The structure and arrangement of a refrigerating cycle of

the refrigerator 10 will now be described with reference to FIGS. 1 to 3. A compressor 46 is provided on the bottom of the cabinet 12 or more specifically, in an equipment compartment 48 defined at the lower rear of the freezing compartment 22. The refrigerator 10 is provided with two evaporators, that is, a refrigerating evaporator 50 and a freezing evaporator 52. The refrigerating evaporator 50 is disposed in the rear of the vegetable compartment 16, whereas the freezing evaporator 52 is disposed in the upper rear of the freezing compartment 22. A refrigerating blower 54 is provided over the refrigerating evaporator 50, whereas a freezing blower 56 is provided over the freezing evaporator 52. A defrosting heater 96 is provided below the refrigerating evaporator 50, whereas another defrosting heater 98 is provided below the freezing evaporator 52.

A flow of a refrigerant will be described with reference to FIG. 4. The refrigerant from the compressor 46 flows through a muffler 58, a radiating pipe 60, a condenser 62, a moisture condensation proof pipe 64 and a drier 66 into a three-way electromagnetic valve 68 serving as passage switching means. A refrigerant passage is diverged at the three-way valve 68. One passage leads to a refrigerating capillary tube 70 serving as refrigerating throttling means, whereas the other leads to a freezing capillary tube 72 connected to a refrigerant branch pipe 103 and serving as freezing throttling means. The former refrigerant passage leads from the refrigerating capillary tube 70 to the refrigerating evaporator 50 and further to the freezing evaporator 52. The refrigerant branch pipe 103 joins at its outlet side the refrigerant passage between the refrigerating

and freezing evaporators 50 and 52. The refrigerant passage further leads through an accumulator 74 and a suction pipe 76 to the compressor 46.

The refrigerator 10 is provided with two temperature sensors, namely, a freezing compartment temperature sensor 101 for sensing a temperature t_F in the freezing compartment 22 and a refrigerating compartment temperature sensor 102 for sensing a temperature t_R in the refrigerating compartment 14. Each temperature sensor delivers a temperature signal indicative of the respective temperature t_F or t_R . A control section 121 is provided for controlling an overall operation of the refrigerator 10 as shown in FIG. 10. The control section 121 thus serves as control means for controlling the aforesaid refrigerating cycle. The control section 121 comprises a microcomputer-based control circuit 123 and a drive circuit 125 as shown in FIG. 10. The temperature signals delivered by the respective temperature sensors 101 and 102 are supplied to the control circuit 123. The control circuit 123 controls via the drive circuit 125 the compressor 46, the three-way valve 68, the refrigerating compartment blower 54, the freezing compartment blower 56 and the defrosting heaters 96 and 98 individually. More specifically, the control circuit 123 controls the compressor 46 so that a running rotational speed of an electric motor thereof is varied. The control circuit 123 further controls the refrigerating and freezing compartment blowers 54 and 56 so that running rotational speeds of respective fan motors thereof are varied. For accomplishment of the variable speed control, the control circuit 123 incorporates an inverter

circuit etc. A compressor-condenser blower (not shown) is provided in the equipment compartment 48 for cooling the compressor 46 and the condenser 62. The control circuit 123 also controls the compressor-condenser blower via the drive circuit
5 125 so that a running rotational speed of a fan motor thereof is varied.

The control circuit 123 carries out, as a cooling operation, a refrigerating compartment cooling mode in which the three-way valve 68 is switched to the refrigerating evaporator 50 side
10 and the refrigerating blower 54 is driven with the freezing blower 56 being stopped. The control circuit 123 further carries out, as the cooling operation, a freezing compartment cooling mode in which the three-way valve 68 is switched to the refrigerant branch pipe 103 side and the freezing blower 56 is driven with
15 the refrigerating blower 54 being stopped. Switching the cooling operation between these cooling modes is executed by the control circuit 123 of the control section 121 on the basis of the temperatures t_F and t_R sensed by the respective freezing and refrigerating compartment temperature sensors 101 and 102.

20 A control manner for switching the cooling operation between the cooling modes will be described with reference to FIGS. 5 and 6. Assume now that the cooling operation is currently being carried out in the freezing compartment cooling mode. At step S1 in FIG. 5, the control circuit 123 compares, with a
25 predetermined refrigerating compartment upper limit temperature t_{Ru} , the temperature t_R in the refrigerating compartment 14 for which the cooling operation is not performed. When the refrigerating compartment temperature t_R is lower than the upper

limit temperature t_{Ru} , the control circuit 123 advances to step S2 to compare the freezing compartment temperature t_F with a predetermined freezing compartment lower limit temperature t_{Fl} . When the freezing compartment temperature t_F is above the lower
5 limit temperature t_{Fl} , the control circuit 123 continues the freezing compartment cooling mode and advances to step S3. Thereafter, the control circuit 123 carries out a forced switching process at step S3 and a forced cooling process at step S4. The control circuit 123 further carries out a running
10 rotational speed adjusting process for the compressor 46 at step S10 and a defrosting process at step S11, then returning to step S1. These processes will be described later.

On the other hand, when the refrigerating compartment temperature t_R is equal to or above the upper limit temperature
15 t_{Ru} , the control circuit 123 advances from step S1 to step S5. The control circuit 123 determines at step S5 whether the freezing compartment temperature t_F is equal to or above a predetermined freezing compartment upper limit temperature t_{Fu} . When the
20 freezing compartment temperature t_F is below the upper limit temperature t_{Fu} , the control circuit 123 advances to step S7 to switch the cooling operation to the refrigerating compartment cooling mode. The control circuit 123 then advances to step S11.

When the freezing compartment temperature t_F is equal to or above the upper limit temperature t_{Fu} at step S5, the control
25 circuit 123 advances to step S6 to compare a difference (a refrigerating compartment side difference) between the refrigerating compartment temperature t_R and the upper limit temperature t_{Ru} with a difference (a freezing compartment side

difference) between the freezing compartment temperature t_F and the upper limit temperature t_{Fu} . When the refrigerating compartment side difference is larger than the freezing compartment side difference, the control circuit 123 advances
5 to step S8 to switch the cooling operation to the refrigerating compartment cooling mode. Otherwise, the control circuit 123 advances to step S9 to continue the freezing compartment cooling mode. Thereafter, the control circuit 123 advances from step S8 or S9 to step S11.

10 The above-described control is applied to a case where the cooling operation is being carried out in the freezing compartment cooling mode upon start of the control. On the other hand, when the cooling operation is being carried out in the refrigerating compartment cooling mode upon start of control,
15 the control circuit 123 compares the freezing compartment temperature t_F with the upper limit temperature t_{Fu} at step S1 and further compares the refrigerating compartment temperature t_R with a predetermined refrigerating compartment lower limit temperature t_{Rl} at step S2.

20 In the forced switching process carried out at step S3, an elapsed time from the start of the freezing compartment cooling operation is counted. When the elapsed time becomes equal to a predetermined time (60 minutes, for example), the control circuit 123 forcibly switches the cooling operation from the
25 freezing compartment cooling mode to the refrigerating compartment cooling mode. Further, in a case where the cooling operation is being carried out in the refrigerating compartment cooling mode, the cooling operation is switched to the freezing

compartment cooling mode when the similar condition is met.

In the forced cooling process carried out at step S4, when the freezing compartment temperature t_F is increased to a large degree during the freezing compartment cooling mode up to a
5 predetermined freezing compartment forced cooling temperature (-12°C , for example), the control circuit 123 controls the compressor 46 so that it runs with its maximum compressing performance. The forced cooling operation is continued until the freezing compartment temperature t_F drops to the upper limit
10 temperature t_{Fu} . In a case where the temperature t_F does not drop to the upper limit temperature t_{Fu} even upon lapse of a predetermined time from the start of the forced cooling operation, the control circuit 123 actuates an alarm to inform a user of an abnormal condition and returns the compressor 46 from the
15 maximum compressing performance to a normal compressing performance. Further, in a case where the cooling operation is being carried out in the refrigerating compartment cooling mode, the control circuit 123 compares the refrigerating compartment temperature t_R with a refrigerating compartment forced cooling
20 temperature (10°C , for example) and carries out the similar process.

The running rotational speed adjusting process carried out at step S10 will be described in conjunction with step S29 later. The defrosting process carried out at step S11 will now be
25 described. With respect to the defrosting process for the freezing evaporator 52, the control section 121 obtains an accumulated time of the freezing compartment cooling operation. When the obtained accumulated time exceeds a predetermined set

time (10 hours, for example), the control circuit 123 stops the compressor 46 and energizes the defrosting heater 98 to heat the freezing evaporator 52 so that a defrosting operation is performed. The control circuit 123 finishes the defrosting operation when a temperature of the freezing evaporator 52 reaches a predetermined defrosting completion temperature.

With respect to the defrosting operation for the refrigerating evaporator 50, the control circuit 123 energizes the refrigerating blower 54 every time switching the three-way valve 68 to finish the refrigerating compartment cooling operation. In this case, since the refrigerant does not flow through the refrigerating evaporator 50, air in the refrigerating compartment 14, the temperature of which air is higher than 0°C, is blown against the refrigerating evaporator 50 so that the defrosting operation is carried out therefor. In this case, air circulated into the refrigerating compartment 14 has a proper amount of dampness, the interior of the compartment 14 is rendered suitable as a refrigerating space. The above-described defrosting operation is carried out for a predetermined time (5 minutes, for example) from the time of switch of the three-way valve 68. After the above-described defrosting operation is carried out at a predetermined number of times, the defrosting heater 96 is energized in a subsequent defrosting operation to heat the refrigerating evaporator 50 so that the defrosting is carried out therefor. The control circuit 123 finishes the defrosting operation when a temperature of the refrigerating evaporator 50 reaches a predetermined defrosting completion temperature.

The control circuit 123 advances to step S21 in FIG. 6 when the freezing compartment temperature t_F is equal to or below the freezing compartment lower limit temperature t_{Fl} at step S2. At step S21, the control circuit 123 determines whether the compressor 46 is in operation with its minimum compressing performance or whether a running rotational speed thereof is a minimum one. When the running speed of the compressor 46 is not the minimum, the control circuit 123 advances to step S29 to reduce the running speed of the compressor 46.

10 An example of a manner for determining an amount of reduction in the running speed of the compressor 46 will be described with reference to FIG. 9. First, consider a case where a freezing compartment cooling operation c_F is in progress. At time T_0 when the cooling operation is switched to the refrigerating compartment cooling operation, the control circuit 123 obtains by computation a difference e_{Ru} between the refrigerating compartment upper limit temperature t_{Ru} and the refrigerating compartment temperature t_R and a difference e_{Fl} between the freezing compartment lower limit temperature t_{Fl} and the freezing compartment temperature t_F . Using the obtained differences e_{Ru} and e_{Fl} , constants α , β and γ , and a running speed Fr' in a previously performed refrigerating compartment cooling operation, the control circuit 123 obtains the running speed Fr of a subsequent refrigerating compartment cooling operation from the following equation:

$$Fr = (\alpha \cdot e_{Ru} + \beta \cdot e_{Fl}) \cdot \gamma + Fr' \quad (1)$$

Consider then another case where a refrigerating compartment cooling operation c_R is started at time T_0 and is currently in

progress. At time T1 when the cooling operation is switched to the freezing compartment cooling mode, the control circuit 123 obtains by computation a difference eFu between the freezing compartment upper limit temperature tFu and the freezing compartment temperature tF and a difference eRl between the refrigerating compartment lower limit temperature tRl and the refrigerating compartment temperature tR. Using the obtained differences eFu and eRl, constants α , β and γ , and a running speed Ff' in a previously performed freezing compartment cooling operation, the control circuit 123 obtains the running speed Ff of a subsequent freezing compartment cooling operation from the following equation:

$$Ff = (\alpha \cdot eRl + \beta \cdot eFu) \cdot \gamma + Ff' . \quad (2)$$

The control circuit 123 then compares the obtained running speeds Fr and Ff with several stages (seven stages, for example) of running speed values which are set so as to avoid resonance points of vibration or oscillation and noise of the overall refrigerator, determining as the running speeds Fr and Ff the running speed values most approximate to them respectively. The running speeds Fr and Ff of the compressor 46 are thus varied stepwise. The aforesaid running speeds avoiding the resonance points are set on the basis of experimentally obtained data.

When reducing the running speed of the compressor 46 at step S29, the control circuit 123 also reduces the rotational speed of the refrigerating blower 54 accordingly (step S30). In this case, too, the running speed of the refrigerating blower 54 is varied in several stages (2 or 3 stages, for example) which are set so as to avoid the resonance points of vibration or

oscillation and noise of the overall refrigerator. Thereafter, the control circuit 123 returns from step S30 to step S5 in FIG. 5. Additionally, when the cooling operation is switched from the refrigerating compartment cooling mode to the freezing compartment cooling mode, the running speed of the freezing blower 56 is reduced in the same manner as described above.

The running speed adjusting process carried out at step S10 will now be described. In the running speed adjusting process, the three-way valve 68 is switched, and the running speed of the compressor 46 is obtained in the same manner as described above, upon lapse of a predetermined time (10 minutes, for example) from the start of the cooling operation, so that the compressing performance of the compressor 46 is adjusted. In this case, the control circuit 123 carries out the computation using equation (1) during the refrigerating compartment cooling mode, while carrying out the computation using equation (2) during the freezing compartment cooling mode.

When the compressor 46 is being driven at a minimum speed at step S21, the control circuit 123 advances to step S22 to compare the refrigerating compartment temperature t_R with the refrigerating compartment upper limit temperature t_{Ru} . This case is on the premise that the cooling operation is being carried out in the freezing compartment cooling mode. On the other hand, when the cooling operation is being carried out in the refrigerating compartment cooling mode, the control circuit 123 compares the freezing compartment temperature t_F with the freezing compartment upper limit temperature t_{Fu} at step S22.

The control circuit 123 returns to step S5 when the

refrigerating compartment temperature t_R is equal to or above the upper limit temperature t_{Ru} at step S22. On the other hand, when the refrigerating compartment temperature t_R is lower than the upper limit temperature t_{Ru} , the control circuit 123 advances
5 to step S23 to stop the compressor 46 and the blowers 54 and 56. When the compressor 46 is stopped in this manner, the control circuit 123 advances to step S24 to prohibit re-start of the compressor 46 until a predetermined time elapses. The purpose for the prohibition is to uniform pressure between the suction
10 side and the discharge side of the compressor 46.

Thereafter, the compressor 46 is re-started upon lapse of the re-start prohibition time. The control circuit 123 determines which of the cooling modes to be re-started in the following manner. The control circuit 123 compares the
15 refrigerating compartment temperature t_R with the upper limit temperature t_{Ru} at step S25. When the refrigerating compartment temperature t_R is equal to or above the upper limit temperature t_{Ru} , the control circuit 123 advances to step S27 to re-start the cooling operation in the refrigerating compartment cooling
20 mode. On the other hand, when the refrigerating compartment temperature t_R is below the upper limit temperature t_{Ru} , the control circuit 123 advances to step S26 to compare the freezing compartment temperature t_F with the freezing compartment upper limit temperature t_{Fu} . When the freezing compartment
25 temperature t_F is equal to or above the upper limit temperature t_{Fu} , the control circuit 123 advances to step S28 to re-start the cooling operation in the freezing compartment cooling mode. On the other hand, when the freezing compartment temperature t_F

is below the upper limit temperature t_{Fu} , the control circuit 123 returns to step S5. In other words, the cooling operation is performed for either refrigerating or freezing compartment in which the temperature has increased to the respective upper limit temperature t_{Ru} or t_{Fu} faster than in the other.

According to the above-described refrigerator, the temperature t_R or t_F in the refrigerating or freezing compartment for which the cooling operation is not performed is compared with the respective upper limit temperature t_{Ru} or t_{Fu} . The cooling operation is switched so as to be performed for the compartment in which the temperature t_R or t_F is equal to or above the respective upper limit temperature t_{Ru} or t_{Fu} . FIG. 7 shows changes in the temperatures in the refrigerating and freezing compartments.

Before the invention of the refrigerator 10, the inventors developed a refrigerator controlled so that the cooling operation was performed for the freezing compartment prior to the other compartments. In the developed refrigerator, what the refrigerating compartment temperature $t_{R'}$ was during the freezing compartment cooling operation was not taken into consideration. Accordingly, even when the refrigerating compartment temperature $t_{R'}$ had exceeded the refrigerating compartment upper limit temperature t_{Ru} at time T_1 , the freezing compartment cooling operation was continued until the freezing compartment temperature reached the freezing compartment lower limit temperature t_{Fl} at time T_2 , as shown by broken line in FIG. 7. Accordingly, since the refrigerating compartment temperature $t_{R'}$ exceeded the refrigerating compartment upper

limit temperature t_{Ru} , it was difficult to maintain a proper low temperature in the refrigerating compartment.

In the above-described refrigerator 10 of the embodiment, however, the cooling operation is switched from the freezing compartment cooling mode to the refrigerating compartment cooling mode at time T_1 when the refrigerating compartment temperature has exceeded the refrigerating compartment upper limit temperature t_{Ru} , as shown by solid line in FIG. 7. Consequently, the interiors of the refrigerating and freezing compartments 14 and 22 can be maintained at the respective proper low temperatures.

Further, in the refrigerator 10, in a case where the temperature t_R or t_F in the refrigerating or freezing compartment for which the cooling operation is currently being carried out has reached the respective lower limit temperature t_{Rl} or t_{Fl} , the cooling operation is switched even though the temperature t_F or t_R in the compartment for which the cooling operation is not performed has not exceeded the respective upper limit temperature t_{Fu} or t_{Ru} . FIG. 8 shows the changes in the temperatures in the refrigerating and freezing compartments in this control manner.

Now consider a refrigerator in which the cooling operation is switched on the basis of the determination only as to whether the refrigerating compartment temperature t_R' has exceeded the refrigerating compartment upper limit temperature t_{Ru}' during the freezing compartment cooling operation, for example. In this refrigerator, as shown by broken line in FIG. 8, the freezing compartment cooling operation is continued to time T_1' although

the freezing compartment temperature t_F' is sufficiently below the freezing compartment lower limit temperature t_{F1} . This results in a wasteful cooling operation.

In the refrigerator 10 of the embodiment, however, the cooling operation is switched to the refrigerating compartment cooling mode at time $T1$. Consequently, a wasteful cooling operation as described above is not performed. Further, in the refrigerator 10, the cooling operation is re-switched to the freezing compartment cooling mode at time $T2$ and thereafter, the cooling operation is switched to the refrigerating compartment cooling mode at time $T3$ when the freezing compartment temperature t_F has reached the freezing compartment lower limit temperature t_{F1} , as shown in FIG. 8. On the other hand, a wasteful cooling operation is carried out at about time $T2'$ in a refrigerator wherein the cooling operation is not controlled in the above-described manner.

The compressing performance of the compressor 46 is adjusted at step S29 in FIG. 6. The compressing performance of the compressor is considered too high when the temperature t_R or t_F in the refrigerating or freezing compartment for which the cooling operation is being carried out reaches the respective lower limit temperature t_{R1} or t_{F1} before the temperature t_F or t_R in the compartment for which the cooling operation is not being performed reaches the respective upper limit temperature t_{Fu} or t_{Ru} . In this case, the compressing performance of the compressor 46 is reduced. This is the reason for the aforesaid adjustment of the compressing performance. As the result of this adjustment, a further improved cooling efficiency can be achieved. An amount

of reduction in the compressing performance is determined on the basis of the difference e_{Ru} or e_{Fu} between the temperature t_R or t_F in the refrigerating or freezing compartment for which the cooling operation is not being performed and the respective upper
5 limit temperature t_{Ru} or t_{Fu} , and the difference e_{Fl} or e_{Rl} between the temperature t_F or t_R in the compartment for which the cooling operation is being performed and the respective lower limit temperature t_{Fl} or t_{Rl} . Consequently, the compressor 46 can be set at a more proper compressing performance.

10 The resonance points of vibration and noise produced by the overall refrigerator are avoided when the running speeds of the compressor 46 and the blowers 54 and 56 are varied. Consequently, a high level of noise reduction can be achieved in the refrigerator. Further, the compressing performance sometimes
15 becomes excessive even when the compressor is driven with the minimum compressing performance under a low load condition where an atmospheric temperature is at or below 15°C and the doors are not opened and closed. In the foregoing embodiment, however, the compressor 46 is controlled to be stopped under such a low
20 load condition as mentioned above. Consequently, a wasteful cooling operation can reliably be prevented. Further, the re-start of the compressor is prohibited for the predetermined time when the operation of the compressor is stopped. Accordingly, the compressor is re-started after the refrigerant
25 pressure is uniformed between the suction side and the discharge side of the compressor 46. This results in a further noise reduction.

When the compressor 46 is re-started after the stop, the

cooling operation is first performed for either compartment in which the temperature t_R or t_F has reached the respective upper limit temperature t_{Ru} or t_{Fu} faster than in the other. Consequently, the temperatures t_R and t_F can reliably be set at
5 the respective proper low temperatures. Further, in a case where a high-temperature load (food etc.) is accommodated in the refrigerating or freezing compartment 14 or 22 such that the temperatures t_R and t_F in both compartments exceed the respective
10 performed first for either compartment in which the temperature t_R or t_F has exceeded the upper limit temperature t_{Ru} or t_{Fu} to a larger degree than in the other compartment. Consequently, the temperatures t_R and t_F in the refrigerating and freezing compartments can more reliably be maintained at the respective
15 proper low temperatures.

In the foregoing embodiment, the defrosting operation is carried out for each of the refrigerating and freezing evaporators 50 and 52. Consequently, the cooling efficiency can be prevented from being reduced by frost formation.
20 Particularly with respect to the refrigerating evaporator 50, the defrosting operation is carried out during the freezing compartment cooling operation. Consequently, the defrosting operation does not interrupt the cooling operation. Since heat exchange with air in the refrigerating compartment 14 is utilized
25 in this defrosting operation and the defrosting heater 96 is not used, energy loss can be restrained.

There is a case where an excessively high temperature load (food etc.) is accommodated into one compartment for which the

cooling operation is in progress. Further, there is a case where the door is half-opened or one or both of the temperature sensors are wrong. In each of these cases, the control section 121 cannot sometimes determine fulfillment of the cooling operation
5 switching condition. In the foregoing embodiment, however, the control circuit 123 switches the cooling operation upon lapse of a predetermined time (one hour, for example). This can reliably prevent the interior of each compartment from remaining uncooled for a long time. Further, the temperature in a
10 compartment sometimes rises to a large extent when an excessively large-sized load is accommodated in the compartment, when the door is half-open, or when the three-way valve 68 or one or both of the capillary tubes 70 and 72 have failed. In the foregoing embodiment, when the temperature t_R or t_F in the refrigerating
15 or freezing compartment exceeds the respective predetermined forced cooling temperature, the compressor 46 is controlled so as to be driven with the maximum compressing performance so that the temperature t_R or t_F drops to the respective upper limit temperature t_{Ru} or t_{Fu} . Consequently, the temperatures t_R and
20 t_F can rapidly be reduced to the respective proper low temperatures in the above-described conditions.

The control circuit 123 actuates the alarm and returns the compressing performance to the normal one in a case where the temperature t_R or t_F in the refrigerating or freezing compartment
25 does not rise to the respective upper limit temperature t_{Ru} or t_{Fu} even when the compressor 46 has been continuously driven with the maximum compressing performance for the predetermined time. Consequently, the compressor 46 can be prevented from being

excessively loaded and accordingly, the reliability of the compressor can be improved. The aforesaid predetermined time is set at 20 minutes in the refrigerating compartment cooling operation and at 30 minutes in the freezing compartment cooling
5 operation, for example. Although the alarm is actuated to inform the user of the abnormal condition in the foregoing embodiment, an indication indicative of the abnormal condition may be displayed on a display section of a panel.

The foregoing description and drawings are merely
10 illustrative of the principles of the present invention and are not to be construed in a limiting sense. Various changes and modifications will become apparent to those of ordinary skill in the art. All such changes and modifications are seen to fall within the scope of the invention as defined by the appended
15 claims.



WE CLAIM:

1. A refrigerator comprising:
 - a compressor;
 - 5 a condenser;
 - refrigerating throttling means;
 - a refrigerating evaporator;
 - a refrigerating blower supplying a cold air produced by the refrigerating evaporator into a refrigerating compartment;
 - 10 a freezing evaporator;
 - a freezing blower supplying a cold air produced by the freezing evaporator into a freezing compartment;
 - a refrigerant circuit serially connecting the compressor, the condenser, the refrigerating throttling means, the
 - 15 refrigerating evaporator and the freezing evaporator sequentially;
 - a refrigerant branch pipe diverged between the condenser and the refrigerating throttling means and connected at a downstream between the refrigerating evaporator and the freezing
 - 20 evaporator;
 - freezing throttling means provided on the refrigerant branch pipe;
 - passage switching means for switching a flow direction of the refrigerant from the condenser between the refrigerating
 - 25 evaporator side and the refrigerant branch pipe side; and
 - control means for switching a cooling operation between a refrigerating compartment cooling mode in which the passage switching means is switched to the refrigerating evaporator side



and the refrigerating blower is driven with the freezing blower being stopped and a freezing compartment cooling mode in which the passage switching means is switched to the refrigerant branch pipe side and the freezing blower is driven with the refrigerating
5 blower being stopped, the control means switching the cooling operation from the refrigerating compartment cooling mode to the freezing compartment cooling mode when a temperature in the freezing compartment has reached a predetermined freezing compartment upper limit temperature, the control means switching
10 the cooling operation from the freezing compartment cooling mode to the refrigerating compartment cooling mode when a temperature in the refrigerating compartment has reached a predetermined refrigerating compartment upper limit temperature.

15 2. A refrigerator according to claim 1, wherein the control means switches the cooling operation from the refrigerating compartment cooling mode to the freezing compartment cooling mode when the temperature in the refrigerating compartment has reached a predetermined refrigerating compartment lower limit
20 temperature and the control means switches the cooling operation from the freezing compartment cooling mode to the refrigerating compartment cooling mode when the temperature in the freezing compartment has reached a predetermined freezing compartment lower limit temperature.

25

3. A refrigerator according to claim 1, wherein the control means adjusts a compressing performance of the compressor based on a difference between the temperature of either the freezing



or the refrigerating compartment and a predetermined reference temperature.

4. A refrigerator according to claim 3, the control means
5 adjusts the compressing performance of the compressor when switching the passage switching means.

5. A refrigerator according to claim 3, wherein the control means adjusts a rotational speed of either the freezing or
10 refrigerating blower.

6. A refrigerator according to claim 4, wherein the control means stops the compressor when the compressor is in operation with a minimum compressing performance in a case where the control
15 means reduces the compressing performance of the compressor.

7. A refrigerator according to claim 6, wherein after the compressor has been stopped, the control means determines which of the temperatures in the freezing and refrigerating
20 compartments has reached the respective upper limit temperature faster, so that the control means re-starts the cooling operation for either compartment in which the temperature has reached the upper limit temperature faster.

25 8. A refrigerator according to claim 1, wherein the control means obtains a difference between the temperature in the freezing compartment and the freezing compartment upper limit temperature and a difference between the temperature in the



refrigerating compartment and the refrigerating compartment upper limit temperature when the temperatures in the freezing and refrigerating compartments have exceeded the respective upper limit temperatures, so that the control means performs the cooling operation first for either one of the compartments in which the difference is larger than in the other.

9. A refrigerator according to claim 1, wherein the control means drives the refrigerating blower with delay after having switched the passage switching means to finish the cooling operation in the refrigerating compartment cooling mode.

10. A refrigerator according to claim 9, wherein the control means obtains an accumulated time of the freezing compartment cooling mode and starts a defrosting operation of the freezing evaporator when the accumulated time has exceeded a predetermined set time.

11. A refrigerator according to claim 1, wherein when the freezing compartment or refrigerating compartment cooling mode has been carried out continuously for a respective predetermined time, the control means switches the passage switching means so that the cooling operation is switched from the freezing compartment cooling mode to the refrigerating compartment cooling mode or from the refrigerating compartment cooling mode to the freezing compartment cooling mode.

12. A refrigerator according to claim 1, wherein the control



means drives the compressor with a maximum compressing performance when the temperature in either freezing or refrigerating compartment has reached a respective freezing or refrigerating compartment forced cooling temperature.

5

13. A refrigerator according to claim 12, wherein the cooling operation is executed with the maximum compressing performance being maintained until the temperature in the freezing or refrigerating compartment reaches the respective
10 upper limit temperature.

14. A refrigerator according to claim 13, wherein the control means carries out an alarming operation and returns the compressor to a normal compressing performance when the
15 temperature in the freezing or refrigerating compartment does not reach the respective upper limit temperature upon lapse of a predetermined time from start of drive of the compressor with the maximum compressing performance.

20 15. A refrigerator substantially as herein described with reference to the accompanying drawings.