

DESCRIPTION

Title of Invention

REFRIGERATOR

Technical Field

5 [0001]

The present invention relates to a refrigerator that includes a dew prevention pipe for preventing dew condensation.

Background Art

[0002]

10 Refrigerators that include a dew prevention pipe for preventing dew condensation (also called cabinet pipe or anti-dew pipe) are thus far known. In the majority of such refrigerators, the dew prevention pipe is located along the periphery of the opening of the main body of the refrigerator. The dew prevention pipe is heated by condensing therein a high-pressure refrigerant
15 discharged from a compressor, so as to prevent dew condensation along the periphery of the opening of the refrigerator main body.

However, the refrigerant in the dew prevention pipe is condensed with the same refrigerant pressure as in a condensation pipe for condensing the refrigerant, arranged on the rear face, top face, or side face of the refrigerator
20 main body, and therefore the dew prevention pipe is heated up to an unnecessary extent and an additional input to the compressor is required.

[0003]

Accordingly, various proposals have been made to control the flow of the refrigerant into the dew prevention pipe to thereby prevent the dew prevention
25 pipe from being excessively heated. For example, a refrigerator has been proposed that includes a refrigerant flow rate distributor (7) interposed between a heat-transfer condenser (2a) and a dew-prevention condenser (2b), the

refrigerant flow rate distributor being configured to distribute the refrigerant to the dew-prevention condenser and a bypass pipe (6) according to a difference between the ambient temperature and the temperature of the dew-prevention condenser, to thereby prevent overheating of the periphery of the opening of the refrigerator main body (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0004]

Patent Literature 1: Japanese Unexamined Patent Application Publication

No. 8-285426 (see, for example, Fig. 1)

Summary of Invention

Technical Problem

[0005]

With the technique according to Patent Literature 1, the flow rate of the refrigerant flowing into the dew prevention pipe varies depending on the refrigerant flow rate into the bypass pipe. In addition, the refrigerant flow rate in the refrigerator is smaller than, for example, in an air-conditioning apparatus. Accordingly, with the technique according to Patent Literature 1, when the refrigerant flow rate into the dew prevention pipe is reduced the flow rate of the refrigerant flowing in the dew prevention pipe is significantly reduced, and therefore it takes longer before the dew prevention pipe is heated to a target temperature, in other words the response time is extended. As a result, the temperature of the dew prevention pipe is unable to be stabilized with the technique according to Patent Literature 1.

[0006]

Further, in the refrigerator according to Patent Literature 1, the dew prevention pipe is located close to the inner space of the refrigerator, yet not

provided with a heat-insulation material for heat insulation from the inner space of the refrigerator. Therefore, the majority of the condensation heat from the dew prevention pipe 13 intrudes in the inner space of the refrigerator thereby increasing the refrigerating load. Consequently, the compressor has to be driven more intensively and power consumption is increased.

[0007]

The present invention has been accomplished in view of the foregoing problem, and provides a refrigerator that enables the temperature of the dew prevention pipe to be stabilized, and power consumption to be reduced.

10 Solution to Problem

[0008]

In an aspect, the present invention provides a refrigerator including a refrigeration cycle including a compressor, a condensation pipe, a pressure reducing device, a dew prevention pipe, a capillary tube, and a cooling device which are sequentially connected. The pressure reducing device is configured to control a flow resistance of a refrigerant in two stages between a first flow resistance and a second flow resistance lower than the first flow resistance.

Advantageous Effects of Invention

[0009]

20 With the refrigerator according to the present invention, the flow resistance of the refrigerant flowing in the pressure reducing device is controlled in two stages between the first flow resistance and the second flow resistance lower than the first flow resistance. Such a configuration allows the temperature of the dew prevention pipe to be stabilized.

25 In the foregoing refrigerator, further, the condensation pipe, the pressure reducing device, and the dew prevention pipe are sequentially connected, and therefore the pressure reducing device can lower the temperature of the

refrigerant in the dew prevention pipe with respect to the refrigerant in the condensation pipe, thereby reducing the difference in temperature between the inner space of the refrigerator and the dew prevention pipe. Therefore, the intrusion of the condensation heat into the inner space from the dew prevention pipe is suppressed, which leads to reduction in compressor input, and consequently the power consumption can be reduced in proportion to the reduction in compressor input.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a diagram for explaining a configuration of a refrigeration cycle of a refrigerator according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a drawing for explaining an arrangement of the dew prevention pipe of the refrigerator according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a graph showing a Mollier diagram of isobutane, a refrigerant generally employed in refrigerators, and transition of status of a refrigerant in the refrigeration cycle of the refrigerator according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a graph showing a relationship between the opening degree and flow resistance of a pressure reducing device according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a diagram for explaining a configuration of a refrigeration cycle of a refrigerator according to Embodiment 2 of the present invention.

[Fig. 6] Fig. 6 is a table showing magnitudes of a total refrigerant flow resistance based on combinations of the pressure reducing device and a three-way valve in the refrigerator according to Embodiment 2 of the present invention.

Description of Embodiments

[0011]

Hereafter, Embodiments of the refrigerator according to the present invention will be described with reference to the drawings. The present invention is in no way limited to Embodiments described here below. In Fig. 1 and other drawings, the relationship in scale between constituents may be different from the actual state.

The refrigerator 100 according to Embodiments is improved in arrangement of a dew prevention pipe buried along the periphery of the opening of the main body of the refrigerator, so that "stabilization of temperature" and "reduction in power consumption" can be realized.

[0012]

Embodiment 1.

Fig. 1 is a diagram for explaining a configuration of a refrigeration cycle of the refrigerator 100 according to Embodiment 1 of the present invention.

Referring to Fig. 1, the configuration of the refrigeration cycle of the refrigerator 100 will be described. The refrigerator 100 is designed to cool the inner space thereof to a target temperature using a steam compression refrigeration cycle.

[0013]

As shown in Fig. 1, the refrigeration cycle of the refrigerator 100 is composed of a compressor 11 that compresses and discharges a refrigerant, a condensation pipe 12 that condenses the refrigerant supplied from the compressor 11, a pressure reducing device 18 that reduces the pressure of the refrigerant flowing out of the condensation pipe 12, a dew prevention pipe 13 buried along the periphery of the opening of the refrigerator main body, a drier 14 connected to the dew prevention pipe 13, a capillary tube 15 that reduces the pressure of the refrigerant flowing out of the drier 14, and a cooling device 16

that generates cooling air to be supplied to the compartments of the refrigerator 100. The mentioned components are sequentially connected via pipes.

In addition, the refrigeration cycle of the refrigerator 100 includes a heat exchange section 17 where heat exchange is performed between the refrigerant flowing in the capillary tube 15 and the refrigerant flowing in a pipe (suction pipe) provided between the cooling device 16 and the compressor 11.

[0014]

(Compressor 11)

The compressor 11 serves to compress the sucked refrigerant, and discharge the compressed refrigerant. The suction side of the compressor 11 is connected to the heat exchange section 17, and the discharge side is connected to the condensation pipe 12. The compressor 11 is located, for example, in a machine room provided in a lower portion of the rear side of the refrigerator 100. The compressor 11 is driven by an inverter so as to compress the refrigerant into high-temperature/high-pressure refrigerant, and controlled according to the conditions of the inner space.

[0015]

(Condensation Pipe 12)

The condensation pipe 12 serves to condense and liquefy the refrigerant discharged from the compressor 11 by causing the refrigerant to transmit the heat. The condensation pipe 12 has an end connected to the discharge side of the compressor 11, and the other end connected to the pressure reducing device 18. The condensation pipe 12 includes a hot pipe for drain evaporation and an air-cooled condenser located in the space where the compressor 11 is installed, and is buried in the side face and the rear face of the refrigerator via a heat-insulation material.

[0016]

(Pressure Reducing Device 18)

The pressure reducing device 18 serves to reduce the pressure of the refrigerant discharged from the condensation pipe 12. The pressure reducing device 18 has an end connected to the condensation pipe 12, and the other end connected to the dew prevention pipe 13. The pressure reducing device 18 according to Embodiment 1 depressurizes the refrigerant so as to expand the same, and will hereafter be assumed to be a device the opening degree of which is variable, for example an electronic expansion valve. The pressure reducing device 18 is configured, as will be subsequently described, to adjust the valve opening degree to thereby set two stages of flow resistance values (see Fig. 4). Details of the pressure reducing device 18 will be described in [Depressurization Amount of Pressure Reducing Device 18] and [Detailed Configuration and Operation of Pressure Reducing Device 18].

[0017]

(Dew Prevention Pipe 13)

The dew prevention pipe 13 serves as a condenser for preventing dew condensation in the front face of the refrigerator main body. To be more detailed, the dew prevention pipe 13 is buried along the periphery of the opening of the refrigerator main body to serve as a condenser for transmitting the heat of the refrigerant flowing out of the pressure reducing device 18 to the periphery of the opening. The dew prevention pipe 13 has an end connected to the pressure reducing device 18, and the other end connected to the drier 14.

The configuration of the dew prevention pipe 13 will be subsequently described in details with reference to Fig. 2.

[0018]

(Drier 14)

The drier 14 includes a filter that prevents wastes and metal powder in the refrigeration cycle of the refrigerator 100 from flowing into the compressor 11, and an adsorbent for adsorbing moisture in the refrigeration cycle. The drier 14 has an end connected to the dew prevention pipe 13, and the other end
5 connected to the capillary tube 15.

[0019]

(Capillary Tube 15)

The capillary tube 15 serves to depressurize the refrigerant flowing out of the drier 14. The capillary tube 15 has an end connected to the drier 14, and
10 the other end connected to the cooling device 16. The refrigerant flowing in the capillary tube 15 is subjected to heat exchange with the refrigerant flowing in the pipe (suction pipe) provided between the cooling device 16 and the compressor 11, in the heat exchange section 17.

[0020]

15 (Cooling Device 16)

The cooling device 16 serves as an evaporator to generate cooling air to be supplied to the compartments (for example, cooling compartment 3 in Fig. 2) of the refrigerator. The cooling device 16 has an end connected to the capillary tube 15 and the other end connected to the heat suction side of the compressor
20 11, via the exchange section 17.

The cooling device 16 is located, for example, in a cooling device chamber on the rear side of the refrigerator 100. A fan is provided, for example, above the cooling device 16, so as to supply air to the cooling device 16 and to supply the air cooled around the cooling device 16 to each of the compartments.

25 [0021]

(Heat Exchange Section 17)

The heat exchange section 17 is a region where heat exchange is performed between the refrigerant flowing in the capillary tube 15 and the refrigerant flowing into the compressor 11.

[0022]

5 In addition, a controller 10 including a microcomputer that controls the operation of the refrigerator 100 is provided, for example, in an upper portion of the rear side of the refrigerator 100.

[0023]

10 Fig. 2 is a drawing for explaining an arrangement of the dew prevention pipe 13 of the refrigerator 100. Referring to Fig. 2, the arrangement of the dew prevention pipe 13 will be described.

[0024]

As shown in Fig. 2, the refrigerator 100 includes a box-shaped cabinet structure 21 having an opening on the front side. The cabinet structure 21 includes an outer box constituting the outer shell of the refrigerator main body, and an inner box constituting the inner wall of the refrigerator main body, with a heat-insulation material such as urethane interposed therebetween. The cabinet structure 21 also includes dividers (partition walls) 22 that divide the inner space of the cabinet structure 21 into a plurality of storage compartments. The storage compartments of the refrigerator 100 include a cooling compartment 3, an ice room 4, a switchable room 5, a freezing compartment 6, and a vegetable compartment 7.

[0025]

25 The cooling compartment 3 is located in the uppermost section of the refrigerator 100, and has the front face openably covered with a double-hinged door having a heat-insulation structure.

The ice room 4 and the switchable room 5 are located side by side under the cooling compartment 3, and each include a drawer-type door having a heat-insulation structure openably covering the front side.

5 The freezing compartment 6 is located under the ice room 4 and the switchable room 5, and has the front face openably covered with a drawer-type door having a heat-insulation structure.

The vegetable compartment 7 is located under the freezing compartment 6 and in the lowermost section of the refrigerator 100, and has the front face openably covered with a drawer-type door having a heat-insulation structure.

10 [0026]

The respective doors of the storage compartments normally include a non-illustrated door position sensor that detects the open and closed position of the door. The controller 10 receives the outputs of the door position sensors thereby detecting the open and closed position of each door and, for example, when one of the door is left open for a long time, the controller 10 outputs a warning to this effect through a non-illustrated operation panel or an audio output device.

[0027]

20 A temperature range (target temperature range) is specified for each of the storage compartments, such that, for example, the cooling compartment 3 is settable to approximately 0 to 4 degrees Celsius, the vegetable compartment 7 is settable to approximately 3 to 10 degrees Celsius, the ice room 4 is settable to approximately -18 degrees Celsius, and the freezing compartment 6 is settable to approximately -16 to -22 degrees Celsius.

25 The switchable room 5 is switchable to different temperature ranges, such as a chilling range (approximately 0 degrees Celsius) and a soft freezing range (approximately -7 degrees Celsius). As a matter of course, the target

temperatures of the respective storage compartments are not limited to the above.

[0028]

5 An operation switch for adjusting the temperature setting of each of the storage compartments, and an operation panel including an LCD indicating the current temperature of each of the storage compartments are provided, for example, on the surface of the door of the cooling compartment 3.

 It is preferable that the operation panel includes an outside air temperature sensor that detects the temperature of ambient air around the refrigerator 100.

10 The controller 10 controls the operation of the refrigeration cycle and the functional components so as to make the values detected by the inner temperature sensors in the respective storage compartments agree with the target temperature set through the operation panel.

[0029]

15 Since the inside of the refrigerator 100 is thus divided into the plurality of storage compartments set to different temperature ranges, dew condensation may take place on the cabinet structure 21 and the divider 22, constituting the boundary between the inner space and the outer space of the refrigerator 100, when surface temperature thereof drops below a dew point of outside air.

20 Accordingly, as shown in Fig. 2, the refrigerator 100 includes the dew prevention pipe 13 that serves to maintain the surface temperature of the cabinet structure 21 and the divider 22 equal to or higher than the outside air dew point utilizing the refrigerant condensation heat.

[0030]

25 The dew prevention pipe 13 is provided inside of the cabinet structure 21 and the divider 22, bent along the periphery of the front opening of the cabinet structure 21 and the front edge of the divider 22. The dew prevention pipe 13 is

attached to the cabinet structure 21 and the divider 22 via an elastic material having a high thermal capacity such as butyl rubber. The dew prevention pipe 13 may be provided along the entire periphery of the front side of the cabinet structure 21 and the divider 22, as shown in Fig. 2.

5 Alternatively, the dew prevention pipe 13 may only be provided along a portion of the periphery of the front side of the cabinet structure 21 and the divider 22 adjacent to the ice room 4, the switchable room 5, and the freezing compartment 6 (region where cold air of the freezing temperature range may leak). The arrangement of the dew prevention pipe 13 is not limited to the
10 example shown in Fig. 2. For example, the dew prevention pipe 13 may be disposed at a desired position effective for preventing dew condensation due to leakage of cold air.

[0031]

15 An increase in surface temperature of the cabinet structure 21 and the divider 22 and the required input to the compressor 11 will be described hereunder.

 For example, to increase the surface temperature of the cabinet structure 21 and the divider 22 with a heater instead of the dew prevention pipe 13, increasing the input to the heater leads to an increase in surface temperature of
20 the cabinet structure 21 and the divider 22. On the assumption that the surface temperature becomes equal to the outside air dew point with a heater input W_h when the surface temperature of the cabinet structure 21 and the divider 22 is to be raised to a level equal to or higher than the outside air dew point to prevent dew condensation, a heater input larger than W_h makes the surface temperature
25 equal to or higher than the outside air dew point, and a heater input I equal to or lower than W_h makes the surface temperature equal to or lower than the outside air dew point. Thus, the heater input and the surface temperature of the cabinet

structure 21 and the divider 22 are correlated with each other, such that an increase in heater input leads to an increase in heater temperature, which results in an increase in surface temperature of the cabinet structure 21 and the divider 22.

5 [0032]

In the refrigerator 100, in contrast, the dew prevention pipe 13 works like the heater, and the compressor input corresponds to the heater input. Accordingly, lowering the surface temperature of the cabinet structure 21 and the divider 22, in other words lowering the temperature of the dew prevention pipe 13 leads to reduction in compressor input.

10 [0033]

Fig. 3 is a graph showing a Mollier diagram of isobutane, a refrigerant generally employed in refrigerators, and transition of refrigerant status in the refrigeration cycle of the refrigerator 100. Referring to Fig. 3, the refrigeration cycle of the refrigerator 100, including the pressure reducing device 18 connected in series between the condensation pipe 12 and the dew prevention pipe 13, will be described. The reference numerals in Fig. 3 correspond to those of Fig. 1. In Fig. 3, the horizontal axis represents enthalpy, and the vertical axis represents pressure. In addition, it is assumed that the outside temperature is 30 (degrees Celsius) and the temperature of air flowing into the cooling device 16 is -15 (degrees Celsius).

15 [0034]

The refrigerant in the refrigerator is compressed by the compressor 11 (A to B in Fig. 3) thereby turning into high-temperature/high-pressure refrigerant, and the refrigerant saturation pressure becomes equal to or higher than the level corresponding to the outside air temperature. The refrigerant under the saturation pressure equal to or higher than the level corresponding to the outside

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25

air temperature flows into the condensation pipe 12 and transmits the condensation heat to the outside air (B to E in Fig. 3).

5 The refrigerant which has flowed out of the condensation pipe 12 flows into the pressure reducing device 18 and is depressurized from the refrigerant pressure in the condensation pipe 12 (E to F in Fig. 3). With the pressure reducing device 18 provided in the refrigerator 100, the refrigerant pressure in the dew prevention pipe 13 is lowered from the refrigerant pressure in the condensation pipe 12.

10 The refrigerant which has entered the dew prevention pipe 13 is condensed under the environment including the inside of the cabinet (F to C in Fig. 3). Here, the expression "condensed under the environment including the inside of the cabinet" refers to the phenomenon that the heat of the dew prevention pipe 13 is transmitted to the outer box and the inner box constituting the outer shell of the refrigerator main body and the air inside of the cabinet, so that the refrigerant in the dew prevention pipe 13 is condensed.

15 [0035]

The refrigerant which has flowed out of the dew prevention pipe 13 flows into the capillary tube 15 thus to be depressurized, and exchanges heat with the refrigerant flowing in the suction pipe of the compressor 11, in the heat exchange section 17 (C to D in Fig. 3). The refrigerant which has flowed out of the capillary tube 15 then flows into the cooling device 16, and exchanges heat with air supplied to the cooling device 16 by the non-illustrated fan. In other words, the refrigerant which has flowed out of the capillary tube 15 removes heat from the air supplied to the cooling device 16 and is evaporated.

25 The refrigerant which has removed heat from the air supplied to the cooling device 16 thus to be evaporated passes through the heat exchange section 17 and returns to the compressor 11 (D to A in Fig. 3).

[0036]

[Depressurizing Amount of Pressure Reducing Device 18]

The method to reduce the power consumption of the refrigerator 100 will now be described. The majority of the power consumption of the refrigerator
5 100 is the input to the compressor, which serves as the driving source of the steam compression refrigeration cycle for maintaining the inner temperature.

When the refrigerator to be cooled has a high heat insulation performance, for example when the refrigerator 100 includes a vacuum heat-insulation material in the side face and the rear face, the load for maintaining the inner temperature
10 is small and hence the requirement of the compressor input is reduced. Now, the internal load of the refrigerator 100 includes "a load originating from the heat insulation performance of the refrigerator 100" and "intrusion of the condensation heat from the condensation pipe 12 and the dew prevention pipe 13 into the refrigerator".

15 [0037]

The condensation pipe 12 is provided in the side face and the rear face of the refrigerator 100 and, as stated above, improving the heat insulation performance of the refrigerator 100 leads to reduction in intrusion of the condensation heat. On the other hand, as shown in Fig. 2 the dew prevention
20 pipe 13 is located close to the inner space and not provided with a heat-insulation material for heat insulation from inner space of the refrigerator, and therefore the majority of the condensation heat from the dew prevention pipe 13 intrudes into the inner space, thus constituting the majority of the internal load.

In the refrigerator 100, as shown in Fig. 3, the pressure reducing device 18
25 serves to reduce the refrigerant temperature of the dew prevention pipe 13 with respect to the condensation pipe 12. The reduction of the temperature in the dew prevention pipe 13 by the pressure reducing device 18 leads to reduction in

difference between the inner temperature and the temperature of the prevention pipe 13, thereby suppressing intrusion of the condensation he dew at into the inner space from the dew prevention pipe 13. Thus, the internal load of the refrigerator 100 is alleviated and the compressor input is reduced, and consequently the power consumption can be reduced.

[0038]

However, the extent of depressurization by the pressure reducing device 18 is limited to the refrigerant saturation temperature corresponding to "a temperature lower than the outside air temperature by 3 to 5 degrees Celsius". A reason of such limitation to the depressurization of the pressure reducing device 18 is as follows.

Normally, when the refrigerant saturation pressure in the dew prevention pipe 13 is below the level corresponding to the outside air temperature, the refrigerant is unable to be condensed. Actually, however, the dew prevention pipe 13 is located close to the inner space as shown in Fig. 2, and resultantly the dew prevention pipe 13 is in contact with the inner space cooler than the outside air temperature. Accordingly, the refrigerant can be condensed despite being depressurized to the saturation pressure corresponding to a temperature lower than the outside air temperature. However, the outside air dew point has also been taken into account, to prevent dew condensation of the outside air.

[0039]

Therefore, it is preferable to set the extent of depressurization by the pressure reducing device 18 during the stable operation of the refrigerator 100 to "refrigerant saturation temperature in the dew prevention pipe 13 equal to or lower than the outside air temperature". To further reduce the compressor input, the pressure reducing device 18 may be set to depressurize to a saturation pressure corresponding to "a temperature lower than the outside air temperature

by 3 to 5 degrees Celsius" or "outside air dew point". It is preferable, however, that when the "temperature lower than the outside air temperature by 3 to 5 degrees Celsius" is adopted the depressurization amount is set kept higher than the "outside air dew point", in order to prevent dew condensation.

5 [0040]

[Detailed Configuration and Operation of Pressure Reducing Device 18]
(Employment of LEV)

It is preferable that the pressure reducing device 18 is constituted of a depressurizing device generally employed in refrigerators, such as an electronic
10 linear expansion valve (LEV). This is because the LEV is adjustable to an appropriate opening degree with a stepping motor or the like, unlike the case of the capillary tube which has a fixed length and inner diameter and hence has a fixed depressurization amount.

In air-conditioning apparatuses and refrigerating/freezing apparatuses in
15 general, the LEV is employed to adjust the flow resistance to a target evaporation temperature (suction temperature) and a target discharge temperature. Therefore, regarding the refrigerator 100 according to Embodiment 1 also, description will be given on the assumption that the LEV is employed as the pressure reducing device 18 to set the temperature of the dew prevention pipe
20 13 to the "outside air dew point" or the "temperature lower than the outside air temperature by 3 to 5 degrees Celsius".

Here, the description of the LEV can be found, for example, in
"Refrigeration and Air Conditioning Handbook Vol. II".

[0041]

25 The refrigerant flow rate of the refrigerator 100 is approximately 1 (kg/h) under the outside temperature of 30 (degrees Celsius). Under a lower outside temperature, the refrigerant flow rate is lower than 1 (kg/h). A response time τ

of the refrigerant with respect to a refrigerant control device such as the LEV may be expressed as follows, on the basis of a refrigerant flow rate Gr and a refrigerant amount M in the apparatus.

[Math. 1]

5 $\tau = M/Gr \cdots (1)$

Explanation of the equation (1) can be found, for example, in "Dynamic Characteristics and Control of Refrigeration Cycle".

[0042]

(Flow Resistance of Pressure Reducing Device 18)

10 Fig. 4 is a graph showing a relationship between the opening degree and flow resistance of the pressure reducing device 18 according to Embodiment 1. Referring to Fig. 4, the configuration of the pressure reducing device 18 will be described in details.

 In generally used refrigerating/freezing apparatuses such as the
15 refrigerator 100, the refrigerant amount M is approximately 80 (g). Accordingly, the response time τ is calculated as 288 (seconds) according to the equation (1). In other words, it takes nearly 5 minutes before the refrigerant flow is stabilized after changing the flow resistance once, with the LEV employed in generally used refrigerating/freezing apparatuses.

20 [0043]

 Now, the "operation time" of the refrigerator 100 is, for example, 30 minutes to one hour. Here, the "operation time" refers to the period of time from turning on to turning off of the compressor 11. In other words, the "operation time" refers to the period corresponding to one of the repeated cycles of the
25 activation, operation for a predetermined time, and stopping of the compressor 11 in the refrigerator 100.

Accordingly, when the adjustment is repeated 3 to 6 times with the LEV employed in used refrigerating/freezing apparatuses, it takes 15 to 30 minutes (5 minutes $\times$ 3 to 6 times) before the refrigerant flow is stabilized after the adjustment of the flow resistance. In other words, more than a half of the operation time is required for the stabilization of the refrigerant flow, and therefore it is only in the remaining half of the operation time that the depressurization effect of the pressure reducing device 18 can be obtained.

[0044]

Therefore, the pressure reducing device 18 is configured so as to exhibit a flow resistance characteristic shown in Fig. 4, in consideration of fluctuation in refrigerant flow rate originating from the flow resistance adjustment performed by the pressure reducing device 18.

More specifically, although conventional pressure reducing devices are configured to gradually increase the flow resistance as the opening degree is made larger, the pressure reducing device 18 according to Embodiment 1 is settable to two ways, namely a higher resistance (first flow resistance) and a lower resistance (second flow resistance) for maximizing the reducing effect of the compressor input caused by the depressurizing effect. In other words, the pressure reducing device 18 is configured to control the flow resistance of a refrigerant in two stages, between the first flow resistance and the second flow resistance lower than the first flow resistance.

In addition, the opening degree of the pressure reducing device 18 is settable to an opening degree A for generating the higher resistance, an opening degree C for generating the lower resistance, and an opening degree B for the transition between the higher resistance and the lower resistance.

[0045]

(Operation of Pressure Reducing Device 18)

The operation of the pressure reducing device 18 will be described hereunder.

5 The pressure reducing device 18 is set to the opening degree for the higher resistance (opening degree A) during the stable operation of the refrigerator 100, so as to obtain the depressurization effect of the pressure reducing device 18 through the entirety of the "operation time". With the opening degree A the opening of the pressure reducing device 18 is narrowed, so as to increase the flow resistance in the pressure reducing device 18 and to reduce the refrigerant flow rate in the pressure reducing device 18.

10 Thus, during the stable operation that does not require abundant circulation of the refrigerant, the pressure reducing device 18 is set to the opening degree A so as to lower the refrigerant temperature in the dew prevention pipe 13 with respect to the condensation pipe 12. Such an arrangement reduces the difference between the inner temperature and the
15 temperature of the dew prevention pipe 13, thereby reducing the condensation heat intruding from the dew prevention pipe 13 into the inner space. Therefore, the internal load of the refrigerator 100 can be alleviated, the compressor input can be reduced, and consequently the power consumption can be reduced.
[0046]

20 In contrast, the pressure reducing device 18 is set to the opening degree for the lower resistance (opening degree C), in a transitional operation such as when the door is opened and closed, the time of activation, or when a defrosting operation is finished. With the opening degree C the opening of the pressure reducing device 18 is expanded, so as to reduce the flow resistance in the
25 pressure reducing device 18 and to increase the refrigerant flow rate in the pressure reducing device 18.

Since the internal load is unable to be clearly defined during the transitional operation (for example, the inner temperature fluctuates with time), it may be presumed that reducing the refrigerant pressure in the dew prevention pipe 13 with respect to the refrigerant pressure in the condensation pipe 12 does not make much sense. Accordingly, it is preferable to reduce the flow resistance in the pressure reducing device 18 as much as possible so as to suppress a refrigerant pressure loss in the overall condenser section including the condensation pipe 12 and the dew prevention pipe 13.

[0047]

Further, whereas the pressure reducing device 18 is settable to the higher resistance and the lower resistance on the respective sides of the opening degree B as shown in Fig. 4, it is preferable to set the opening degree B to approximately half of the fully opened state of the pressure reducing device 18, from the viewpoint of the manufacturing allowance of the pressure reducing device 18, and of securing the controllable range. In other words, it is preferable that the pressure reducing device 18 is set to generate the lower resistance with an opening degree larger than approximately half of the fully opened state of the pressure reducing device 18, and set to generate the higher resistance with an opening degree smaller than approximately half of the fully opened state of the pressure reducing device 18.

Referring further to Fig. 4, the flow resistance may be slightly inclined in the stages of the higher resistance and the lower resistance. In other words, slight fluctuation of the flow resistance value in the stages of the higher resistance and the lower resistance caused by a change in opening degree does not lead to an issue.

Further, it is preferable to reduce the flow resistance value as much as possible as stated above when the pressure reducing device 18 is set to the

lower resistance, and to set the flow resistance value in the higher resistance stage, for example, to a value that allows the refrigerant saturation temperature in the dew prevention pipe 13 to match a target temperature, under the outside temperature of 30 (degrees Celsius).

5 [0048]

Although the pressure reducing device 18 according to Embodiment 1 is assumed to be an LEV settable to two stages of flow resistance, namely the higher resistance and the lower resistance, a different device may be employed. For example, a plurality of capillary tubes may be provided, so as to change the flow resistance with a switching valve. However, it is more preferable to employ the pressure reducing device 18 settable to the higher resistance and the lower resistance as in Embodiment 1, from the viewpoint of the inner volume of the refrigerator 100 and the cost of the necessary materials.

[0049]

15 [Advantageous Effects of Refrigerator 100 of Embodiment 1]

The refrigerator 100 according to Embodiment 1 includes the pressure reducing device 18 which is settable to two stages, namely the higher resistance and the lower resistance. Therefore, the extended response time before reaching the target temperature can be suppressed and the temperature of the dew prevention pipe 13 can be stabilized, even when the refrigerator has a low refrigerant flow rate.

[0050]

In the refrigerator 100 according to Embodiment 1 the pressure reducing device 18 is provided between the condensation pipe 12 and the dew prevention pipe 13, so that the refrigerant temperature in the dew prevention pipe 13 is lowered with respect to the condensation pipe 12, by the pressure reducing device 18. Accordingly, the difference in temperature between the inner space

of the refrigerator and the dew prevention pipe is reduced, and therefore the intrusion of the condensation heat into the inner space from the dew prevention pipe 13 is suppressed. As a result, the compressor input can be reduced, and consequently the power consumption can be reduced.

5 [0051]

Embodiment 2.

Fig. 5 is a diagram for explaining a configuration of a refrigeration cycle of a refrigerator 100A according to Embodiment 2 of the present invention.

Referring to Fig. 5, the configuration of the refrigeration cycle of the refrigerator
10 100A will be described. The refrigerator 100 is designed to cool the inner space thereof to a target temperature using a steam compression refrigeration cycle, like the refrigerator 100 according to Embodiment 1. The description of the Embodiment 2 will be given focusing on the difference from the Embodiment 1, and the same constituents as those of Embodiment 1 will be given the same
15 numeral, and the description thereof will not be repeated.

[0052]

While the refrigeration cycle in the refrigerator 100 according to Embodiment 1 includes a single capillary tube 15, the refrigerator 100A according to Embodiment 2 includes the refrigeration cycle in which a pair of capillary tubes
20 (capillary tube 52, capillary tube 53) are provided as shown in Fig. 5. In addition, a three-way valve 54 serving as a flow switching device for switching the refrigerant flow path is provided upstream of the capillary tube 52 and the capillary tube 53. The remaining portions of the refrigerator 100A are configured in the same way as the refrigerator 100 according to Embodiment 1.

25 [0053]

The pair of capillary tubes is different in flow resistance. It will hereafter be assumed that the capillary tube 52 has a relatively lower flow resistance

(larger inner diameter), and the capillary tube 53 has a relatively higher flow resistance (smaller inner diameter). Here, the magnitude of the flow resistance of the capillary tube 52 and the capillary tube 53 may be reversed.

[0054]

5 The three-way valve 54 is configured not only to switch between the refrigerant flow path for supplying the refrigerant to the capillary tube 52 and the refrigerant flow path for supplying the refrigerant to the capillary tube 53, but also to supply the refrigerant to both of the capillary tube 52 and the capillary tube 53. The three-way valve 54 switches the refrigerant flow path according to the
10 refrigerant flow rate required by the refrigerator 100A. More specifically, the controller 10 determines the required refrigerant flow rate and controls the three-way valve 54 accordingly so as to switch the refrigerant flow path for supplying the refrigerant. Although the flow switching device is herein exemplified by the three-way valve 54, the flow switching device is not limited to the three-way valve
15 54. For example, a combination of two-way valves or a four-way valve may be employed as the flow switching device.

[0055]

The operation of the refrigerator 100A will be described hereunder.

20 In the refrigerator 100A, the refrigerant flow path is determined by controlling the frequency of the compressor 11, the opening degree of the pressure reducing device 18, and the flow switching device according to the required refrigerant flow rate. In other words, the refrigerator 100A is configured to individually control each of the compressor 11, the pressure reducing device 18, and the flow switching device according to the required refrigerant flow rate.

25 [0056]

For example, to increase the refrigerant flow rate, the controller 10 increases the frequency of the compressor 11 and also controls the three-way

valve 54 so as to select either of the refrigerant flow path for supplying the refrigerant to the capillary tube 52 and the refrigerant flow path for supplying the refrigerant to both of the capillary tube 52 and the capillary tube 53.

5 To reduce the refrigerant flow rate, the controller 10 lowers the frequency of the compressor 11 and also controls the three-way valve 54 so as to select the refrigerant flow path for supplying the refrigerant to the capillary tube 53.

[0057]

10 However, malfunction may take place for example in low-pressure introduction, unless the rotation speed of the compressor 11 and the selection of the refrigerant flow path (the refrigerant flow path for supplying the refrigerant to the capillary tube 52, the refrigerant flow path for supplying the refrigerant to the capillary tube 53, and the refrigerant flow path for supplying the refrigerant to both of the capillary tube 52 and the capillary tube 53) are properly matched according to the required refrigerant supply.

15 [0058]

20 In a conventional refrigerator without the pressure reducing device 18, it suffices to match the frequency of the compressor 11 and the selection of the refrigerant flow path, however the refrigerator 100A includes the pressure reducing device 18 upstream of the three-way valve 54 along the flow direction of the refrigerant. As described with reference to Embodiment 1, the pressure reducing device 18 is switched between the opening degree A for generating the higher resistance and the opening degree C for generating the lower resistance, according to the internal load. Therefore, it is preferable to take into account not only the frequency of the compressor 11 but also the opening degree of the pressure reducing device 18, when controlling the selection of the refrigerant flow path. This is because the total refrigerant flow resistance in the refrigerant

circuit is the sum of the resistance of the pressure reducing device 18 and the resistance of the capillary tubes (capillary tube 52, capillary tube 53).

[0059]

Fig. 6 is a table showing magnitudes of the total refrigerant flow resistance based on combinations of the pressure reducing device 18 and the three-way valve 54. In Fig. 6, the order of the refrigerant flow resistance is expressed as "H", "M (M1, M2)", and "L" from the higher side. Referring to Fig. 6, the operation of the refrigerator 100A will be described. The basic operation is the same as above, however the refrigerator 100A is configured to operate as follows because of including the pressure reducing device 18. The difference between "M1" and "M2" will be subsequently described.

[0060]

To increase the refrigerant flow rate, the controller 10 increases the frequency of the compressor 11, and selects the combination of the pressure reducing device 18 and the three-way valve 54 according to "L" in Fig. 6. Specifically, when "L" is selected the pressure reducing device 18 is set to the opening degree C and the three-way valve 54 is controlled so as to select the refrigerant flow path for supplying the refrigerant to both of the capillary tube 52 and the capillary tube 53.

[0061]

To reduce the refrigerant flow rate, the controller 10 reduces the frequency of the compressor 11, and selects the combination of the pressure reducing device 18 and the three-way valve 54 according to "H" in Fig. 6. Specifically, when "H" is selected the pressure reducing device 18 is set to the opening degree A and the three-way valve 54 is controlled so as to select the refrigerant flow path for supplying the refrigerant to the capillary tube 53.

However, when the extent of the reduction of the frequency of the compressor 11 and the total refrigerant flow resistance "H" disagree with each other (for example, when pressure drops on the low-pressure side, or when refrigerant is dried (SH) in the cooling device 16), the combination of the pressure reducing device 18 and the three-way valve 54 is switched from "H" to "M" in Fig. 6.

[0062]

The difference between "M1" and "M2" will now be described.

In the state of "M1" the resistance value of the pressure reducing device 18 is reduced. Accordingly, the saturation pressure in the condensation pipe 12 and the dew prevention pipe 13 are substantially the same, and the refrigerant temperature of the dew prevention pipe 13 is maintained equal to or higher than the outside air temperature, as described with reference to Embodiment 1. For such reason "M1" is selected when the outside humidity is high or when dew condensation is to be prevented (for example, when the inner temperature is set to a lower level than normal). When "M1" is selected, the pressure reducing device 18 is set to the opening degree C, and the three-way valve 54 is controlled so as to select the refrigerant flow path for supplying the refrigerant to the capillary tube 53 or the capillary tube 52.

[0063]

In contrast, in the state of "M2" the pressure reducing device 18 is set to the higher resistance value. Accordingly, the refrigerant saturation temperature in the dew prevention pipe 13 is set to the saturation pressure corresponding to the "temperature lower than the outside air temperature by 3 to 5 degrees Celsius" as described with reference to Embodiment 1, although the saturation pressure may depend on the resistance value of the opening degree A. As described with reference to Embodiment 1, when the dew prevention pipe 13 is

set so as to corresponding to the "temperature lower than the outside air temperature by 3 to 5 degrees Celsius", the internal load of the refrigerator 100A can be alleviated and the compressor input can be reduced, which leads to reduction of the power consumption. For such reason, "M2" is selected when
5 reduction in power consumption is desired. When "M2" is selected, the pressure reducing device 18 is set to the opening degree A, and the three-way valve 54 is controlled so as to select the refrigerant flow path for supplying the refrigerant to the capillary tube 52, or to both of the capillary tube 52 and the capillary tube 53.

10 [0064]

[Advantageous Effects of Refrigerator 100A of Embodiment 2]

The refrigerator 100A according to Embodiment 2 includes the pair of capillary tubes and the flow switching device, and is therefore capable of appropriately setting the flow resistance according to the refrigerant flow rate by
15 controlling the pressure reducing device 18 and the selection of the refrigerant flow path, in addition to the effects provided by the refrigerator 100 according to Embodiment 1.

Reference Signs List

[0065]

20 1: cooling compartment, 3: cooling compartment, 4: ice room, 5: switchable room, 6: freezing compartment, 7: vegetable compartment, 10: controller, 11: compressor, 12: condensation pipe, 13: dew prevention pipe, 14: drier, 15: capillary tube, 16: cooling device, 17: heat exchange section, 18: pressure reducing device, 21: cabinet structure, 22: divider, 52: capillary tube,
25 53: capillary tube, 54: three-way valve, 100: refrigerator, 100A: refrigerator

CLAIMS

[Claim 1]

A refrigerator comprising a refrigeration cycle including a compressor, a condensation pipe, a pressure reducing device, a dew prevention pipe, a capillary
5 tube, and a cooling device each of the components is sequentially connected,

wherein the pressure reducing device is configured to control a flow resistance of a refrigerant in two stages between a first flow resistance and a second flow resistance lower than the first flow resistance, and

wherein the first flow resistance is controlled so as to have a saturation
10 pressure under which a refrigerant saturation temperature in the dew prevention pipe is lower than an external air temperature and equal to or higher than an outside air dew point, when the refrigerator is in a stable operation.

[Claim 2]

The refrigerator of claim 1,

15 wherein the first flow resistance is selected when the refrigerator is in a stable operation, and

the second flow resistance is selected when the refrigerator is in a transitional operation.

[Claim 3]

20 The refrigerator of any one of claim 1 or 2,

wherein the second flow resistance is determined on the basis of a refrigerant pressure loss between the condensation pipe and the dew prevention pipe, when the refrigerator is in the transitional operation.

[Claim 4]

25 The refrigerator of any one of claims 1 to 3,

wherein the first flow resistance is generated by an opening degree narrower than substantially a half of a fully opened state of the pressure reducing device, and

the second flow resistance is generated by an opening degree larger than substantially a half of the fully opened state of the pressure reducing device.

[Claim 5]

The refrigerator of any one of claims 1 to 4,
wherein the pressure reducing device is constituted of an electronic expansion valve.

[Claim 6]

The refrigerator of any one of claims 1 to 5,
wherein the pressure reducing device includes a capillary tube configured to depressurize the refrigerant, and a switching valve configured to switch a flow of the refrigerant.

[Claim 7]

The refrigerator of any one of claims 1 to 6, comprising:
two capillary tubes different in flow resistance from one another; and a flow switching device located upstream of the capillary tubes and configured to select between a refrigerant flow path for supplying the refrigerant to one of the capillary tubes and a refrigerant flow path for supplying the refrigerant to both of the capillary tubes,

wherein the flow switching device is controlled according to the compressor and the pressure reducing device.

[Claim 8]

The refrigerator of claim 7,
wherein, when the refrigerant flow rate is to be increased, a frequency of the compressor is increased and the flow resistance of the pressure reducing

device is reduced, and the flow switching device selects one of the capillary tube having a lower flow resistance and both of the pair of capillary tubes.

[Claim 9]

The refrigerator of claim 7,

5 wherein, when the refrigerant flow rate is to be reduced, a frequency of the compressor is reduced and the flow resistance of the pressure reducing device is increased, and the flow switching device selects the capillary tube having a higher flow resistance.

[Claim 10]

10 The refrigerator of claim 7,

 wherein, when outside humidity is high or when dew condensation is to be avoided, the flow resistance of the pressure reducing device is reduced, and the flow switching device selects the capillary tube having the higher flow resistance.

[Claim 11]

15 The refrigerator of claim 7,

 wherein, when the power consumption is to be reduced, the flow resistance of the pressure reducing device is increased, and the flow switching device selects the capillary tube having the lower flow resistance.