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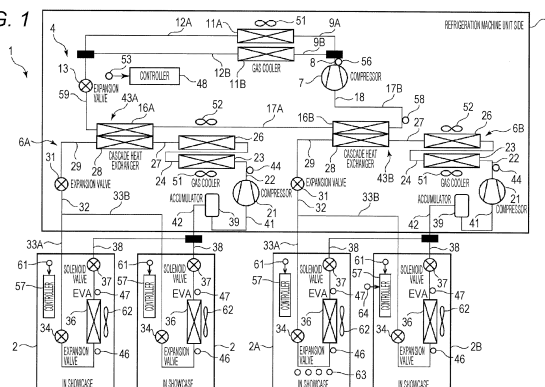
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(54) REFRIGERATION DEVICE

(57) The present invention provides a refrigeration apparatus that can prevent supercooling of the inside of a showcase, excessive formation of frost on an evaporator, and liquid floodback to a compressor, and reduce the number of times of the activation and stop of the compressor with relatively simple control over an expansion valve. The refrigeration apparatus includes low stage-side refrigerant circuits each having a low stage-side compressor, a low stage-side gas cooler, a low stage-side expansion valve, and a low stage-side evaporator. The refrigeration apparatus includes a controller that controls the low stage-side expansion valve. The controller calculates refrigerant superheat in the low stage-side evaporator from the refrigerant outlet temperature and refrigerant inlet temperature of the low stage-side evaporator. The controller selectively controls the degree of opening of the low stage-side expansion valve on the basis of the refrigerant superheat or an internal temperature of the showcase.

FIG. 1



Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus configured to cool an inside of a display chamber of a showcase with an evaporator of a refrigerant circuit including a compressor, a radiator, an expansion valve, and the evaporator.

BACKGROUND ART

[0002] Stores such as convenience stores and supermarkets are conventionally equipped with a plurality of showcases for displaying and selling goods in a display chamber while cooling them. Each showcase is equipped with an evaporator for cooling the display chamber. The evaporator is configured such that a refrigerant is distributed and supplied via an expansion valve from a compressor of a refrigeration machine unit placed outside the store or the like.

[0003] In this case, the compressor is controlled on the basis of the pressure on the low pressure side. The degree of opening of the expansion valve on the evaporator inlet side of the showcase is controlled on the basis of refrigerant superheat in the evaporator. The control of the expansion valve based on the refrigerant superheat is performed such that liquid refrigerant is not sucked into the compressor (what is called the prevention of liquid floodback). Furthermore, a tank called an accumulator is provided on a suction side of the compressor to prevent the liquid floodback.

[0004] Moreover, a solenoid valve (on/off valve) is provided on the evaporator outlet side of each showcase. Control is performed as follows: When an internal temperature of the showcase drops to a target internal temperature, the solenoid valve is closed; and when all the solenoid valves have been closed to reduce the pressure on the low pressure side, the compressor is stopped.

[0005] Moreover, carbon dioxide has started being used as a refrigerant also in this type of showcase due to recent years' global environmental issues. In order to compress carbon dioxide, a relatively large compressor is required. Hence, such a refrigeration apparatus as described below has also been developed (for example, refer to Patent Literatures 1 and 2). In this refrigeration apparatus, a high stage-side refrigerant circuit and a low stage-side refrigerant circuit, each of which configures an independent refrigerant closed circuit, are cascaded. The refrigerant of the high stage-side refrigerant circuit is evaporated to supercool the high pressure-side refrigerant of the low stage-side refrigerant circuit; accordingly, required refrigeration capacity is obtained by the evaporator of the low stage-side refrigerant circuit.

CITATION LIST

PATENT LITERATURE

[0006]

Patent Literature 1: JP-A-2001-91074
Patent Literature 2: JP-A-2000-205672
Patent Literature 3: JP-A-11-281222

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0007] If a solenoid valve is closed on the basis of the internal temperature as before, the pressure of the refrigerant changes greatly. Especially if carbon dioxide is used as the refrigerant, the change is remarkable. Hence, there is a problem that unless an accumulator is upsized, a safety device such as a high-pressure cut-out operates to result in forcing the compressor to stop. On the other hand, if the solenoid valve is not used, it is necessary to control the internal temperature with an expansion valve. However, the expansion valve is conventionally controlled on the basis of the refrigerant superheat in the evaporator. Hence, even if the internal temperature drops to and below a target internal temperature, cooling is continued.

[0008] Hence, if, for example, a plurality of showcases is connected to the compressor when the degree of opening of the expansion valve is controlled on the basis of the internal temperature, the flow of refrigerant may become unbalanced. This becomes a cause of the liquid floodback to the compressor. Moreover, if frost forms on the evaporator, heat exchange efficiency is reduced. Hence, if the expansion valve is controlled on the basis of the internal temperature, the expansion valve is controlled so as to flow more refrigerant into the evaporator. Consequently, the frost that has formed on the evaporator tends to grow further. Hence, this has a risk to cause excessive frost on the evaporator.

[0009] On the other hand, as in Patent Literature 3, if the expansion valve is controlled on the basis of both the internal temperature and the refrigerant superheat in the evaporator, the control is very complicated. Furthermore, it is very difficult in reality to achieve control that solves problems such as supercooling of the inside of the showcase, liquid floodback to the compressor, and excessive formation of frost on the evaporator.

[0010] The present invention has been made to solve such known technical problems. The present invention provides a refrigeration apparatus that can, for example, prevent supercooling of the inside of a showcase, excessive formation of frost on an evaporator, and liquid floodback to a compressor, and reduce the number of times of activation and stop of the compressor.

SOLUTIONS TO THE PROBLEMS

[0011] In order to solve the above problems, a refrigeration apparatus of the present invention is a refrigeration apparatus, including a refrigerant circuit having a compressor, a radiator, an expansion valve, and an evaporator, for cooling an inside of a display chamber of a showcase with the evaporator, the refrigeration apparatus including: internal temperature detection means for detecting an internal temperature being a temperature in the display chamber; refrigerant inlet temperature detection means for detecting a refrigerant inlet temperature of the evaporator; refrigerant outlet temperature detection means for detecting a refrigerant outlet temperature of the evaporator; and a controller for controlling the expansion valve on the basis of outputs of each of the temperature detection means, wherein the controller calculates refrigerant superheat in the evaporator from the refrigerant outlet temperature and refrigerant inlet temperature of the evaporator, and selectively controls the degree of opening of the expansion valve on the basis of the refrigerant superheat or the internal temperature.

[0012] According to the refrigeration apparatus of the invention of claim 2, in the above invention, the controller, upon the internal temperature being equal to or greater than a predetermined first temperature, controls the expansion valve such that the refrigerant superheat in the evaporator reaches predetermined target superheat on the basis of the refrigerant superheat, and upon the internal temperature dropping below the first temperature, controls the expansion valve such that the internal temperature reaches a predetermined target internal temperature on the basis of the internal temperature.

[0013] According to the refrigeration apparatus of the invention of claim 3, in the above invention, upon the internal temperature increasing to or above a predetermined second temperature higher than the first temperature in a state of controlling the expansion valve on the basis of the internal temperature, the controller returns to the control of the expansion valve based on the refrigerant superheat in the evaporator.

[0014] According to the refrigeration apparatus of the invention of claim 4, in the above invention, the second temperature is the target internal temperature.

[0015] According to the refrigeration apparatus of the invention of claim 5, in the invention of claim 1, the controller controls the expansion valve such that the internal temperature reaches a predetermined target internal temperature on the basis of the internal temperature, and upon the internal temperature increasing to or above a predetermined third temperature higher than the target internal temperature, and the refrigerant superheat in the evaporator dropping to or below predetermined first refrigerant superheat, controls the expansion valve such that the refrigerant superheat in the evaporator reaches predetermined target superheat on the basis of the refrigerant superheat.

[0016] According to the refrigeration apparatus of the

invention of claim 6, in the above invention, the controller returns to the control of the expansion valve based on the internal temperature after the end of defrost operation of the evaporator.

[0017] According to the refrigeration apparatus of the invention of claim 7, in the above each invention, the refrigerant circuit includes an accumulator connected to a refrigerant suction side of the compressor.

[0018] According to the refrigeration apparatus of the invention of claim 8, in the above each invention, the refrigerant circuit includes a plurality of series circuits of the expansion valve and the evaporator, the plurality of series circuits being connected in parallel to each other, the series circuits are provided respectively to a plurality of the showcases, and the compressor supplies a refrigerant to the evaporators via the expansion valves.

[0019] According to the refrigeration apparatus of the invention of claim 9, in the above invention, an on/off valve is provided to an outlet side of each of the evaporators, and upon the internal temperature dropping to or below a predetermined fourth temperature lower than the first temperature, the controller closes the on/off valve.

[0020] The refrigeration apparatus of the invention of claim 10, in the above each invention, includes a low stage-side refrigerant circuit being the refrigerant circuit, and a high stage-side refrigerant circuit independent of the low stage-side refrigerant circuit, and an evaporator of the high stage-side refrigerant circuit cools a high pressure-side refrigerant of the low stage-side refrigerant circuit.

[0021] According to the refrigeration apparatus of the invention of claim 11, in the above each invention, the refrigerant circuit uses carbon dioxide as the refrigerant.

EFFECTS OF THE INVENTION

[0022] According to the present invention, a refrigeration apparatus, including a refrigerant circuit having a compressor, a radiator, an expansion valve, and an evaporator, for cooling an inside of a display chamber of a showcase with the evaporator, includes: internal temperature detection means for detecting an internal temperature being a temperature in the display chamber; refrigerant inlet temperature detection means for detecting a refrigerant inlet temperature of the evaporator; refrigerant outlet temperature detection means for detecting a refrigerant outlet temperature of the evaporator; and a controller for controlling the expansion valve on the basis of outputs of the temperature detection means. The controller calculates refrigerant superheat in the evaporator from the refrigerant outlet temperature and refrigerant inlet temperature of the evaporator, and selectively controls the degree of opening of the expansion valve on the basis of the refrigerant superheat or the internal temperature. Hence, as in, for example, the invention of claim 2, upon the internal temperature being equal to or greater than a predetermined first temperature, the controller controls the expansion valve such that the refrigerant su-

perheat in the evaporator reaches predetermined target superheat on the basis of the refrigerant superheat; accordingly, it is possible to prevent liquid floodback to the compressor and excessive formation of frost on the evaporator. On the other hand, upon the internal temperature dropping below the first temperature, the controller controls the expansion valve such that the internal temperature reaches a predetermined target internal temperature on the basis of the internal temperature; accordingly, it is possible to prevent the display chamber from being supercooled.

[0023] In other words, according to the present invention, with such simple control switching, all of the liquid floodback to the compressor, the excessive formation of frost on the evaporator, and the supercooling of the inside of the display chamber can be smoothly resolved. Moreover, the expansion valve resolves the supercooling of the inside of the display chamber. Hence, as before, it is possible to avoid variations in the pressure of the refrigerant circuit due to the opening and closing of a solenoid valve that interrupts the supply of the refrigerant to the evaporator. Consequently, also if, for example, the capacity of an accumulator provided as in the invention of claim 7 is small and carbon dioxide is used as the refrigerant as claim 11, the number of times of the activation and stop of the compressor is reduced; accordingly, the inside of the display chamber can be stably cooled.

[0024] In this case, upon the internal temperature increasing to or above a predetermined second temperature higher than the first temperature in a state of controlling the expansion valve on the basis of the internal temperature, the controller may return to the control of the expansion valve based on the refrigerant superheat in the evaporator as in the invention of claim 3. Consequently, it is possible to smoothly return to the control based on the refrigerant superheat in the evaporator at a stage where the risk of the supercooling of the inside of the display chamber is resolved. It becomes possible to smoothly control the inside of the display chamber to a target internal temperature, especially by setting the second temperature as the target internal temperature as in the invention of claim 4.

[0025] On the other hand, according to the invention of claim 1, the controller controls the expansion valve such that the internal temperature reaches a predetermined target internal temperature on the basis of the internal temperature as in the invention of claim 5; accordingly, it is similarly possible to encourage the prevention of the supercooling of the inside of the display chamber and a reduction in the number of times of the activation and stop of the compressor. Upon, in this state, the internal temperature increasing to or above a predetermined third temperature higher than the target internal temperature, and the refrigerant superheat in the evaporator dropping to or below predetermined first refrigerant superheat, the controller may control the expansion valve such that the refrigerant superheat in the evaporator reaches predetermined target superheat on the basis of

the refrigerant superheat. Consequently, the controller can accurately determine that frost has formed on the evaporator since the refrigerant superheat in the evaporator has dropped although frost has formed on the evaporator, heat exchange efficiency has been reduced, and the internal temperature has increased, under the control of the expansion valve based on the internal temperature. The controller can subsequently shift to the control of the expansion valve based on the refrigerant superheat in the evaporator.

[0026] Consequently, relatively easy control switching makes it possible to suppress excessive formation of frost on the evaporator and a further increase in the internal temperature. In this case, as in the invention of claim 6, the controller may return to the control of the expansion valve based on the internal temperature after the end of defrost operation of the evaporator. Consequently, the controller can smoothly return to the state where the expansion valve is controlled on the basis of the internal temperature after defrosting the evaporator.

[0027] The above points are especially effective in the refrigeration apparatus of the invention of claim 8. In this refrigeration apparatus, the refrigerant circuit includes a plurality of series circuits of the expansion valve and the evaporator, the plurality of series circuits being connected in parallel to each other, the series circuits are provided respectively to a plurality of the showcases, and the compressor supplies a refrigerant to the evaporators via the expansion valves. As in the invention of claim 9, an on/off valve is provided to an outlet side of each of the evaporators, and upon the internal temperature dropping to or below a predetermined fourth temperature lower than the first temperature, the controller closes the on/off valve. Accordingly, it is possible to further suppress variations in pressure in the refrigerant circuit.

[0028] According to the present invention, especially the switching of the control of the expansion valve makes it possible to prevent or suppress the liquid floodback to the compressor, the excessive formation of frost on the evaporator, the supercooling of the inside of the display chamber, and a variation in the pressure of the refrigerant circuit. Hence, it is also possible to obsolete such a solenoid valve as the invention of claim 9.

[0029] Moreover, especially if carbon dioxide is used as the refrigerant as in the invention of claim 11, it is very effective to provide the present invention to a low stage-side refrigerant circuit of such what is called a two-stage refrigeration apparatus as the invention of claim 10.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

Fig. 1 is a refrigerant circuit diagram of a refrigeration apparatus of one example to which the present invention has been applied.

Fig. 2 is a diagram illustrating the pressure distribution of each unit of a high stage-side refrigerant circuit

of the refrigeration apparatus of Fig. 1.

Fig. 3 is a flowchart of a controller related to the control of a high stage-side compressor of the high stage-side refrigerant circuit of the refrigeration apparatus of Fig. 1.

Fig. 4 is a diagram for explaining the operation of calculating a target value of low pressure-side pressure of the high stage-side refrigerant circuit by the controller of the refrigeration apparatus of Fig. 1.

Fig. 5 is a control flowchart of a pressure control expansion valve of a low stage-side refrigerant circuit by the controller of the refrigeration apparatus of Fig. 1.

Fig. 6 is a diagram for explaining the operation of calculating a target value of high pressure-side pressure of the low stage-side refrigerant circuit by the controller of the refrigeration apparatus of Fig. 1.

Fig. 7 is a timing chart explaining control over the degree of opening of a low stage-side expansion valve by the controller of the refrigeration apparatus of Fig. 1 (First Example).

Fig. 8 is a diagram explaining control at the time of switching to all hot of a known hot and cold showcase.

Fig. 9 is a diagram explaining an example of control at the time of switching to all hot of a hot and cold showcase of the refrigeration apparatus of Fig. 1.

Fig. 10 is a diagram explaining another example of the control at the time of switching to all hot of the hot and cold showcase of the refrigeration apparatus of Fig. 1.

Fig. 11 is a diagram explaining still another example of the control at the time of switching to all hot of the hot and cold showcase of the refrigeration apparatus of Fig. 1.

Fig. 12 is a diagram explaining control at the time of switching to all hot of another known hot and cold showcase.

Fig. 13 is a diagram explaining still another example of the control at the time of switching to all hot of the hot and cold showcase of the refrigeration apparatus of Fig. 1.

Fig. 14 is a diagram explaining still another example of the control at the time of switching to all hot of the hot and cold showcase of the refrigeration apparatus of Fig. 1.

Fig. 15 is a timing chart explaining another example of control of a low stage-side compressor of the refrigeration apparatus of Fig. 1.

DESCRIPTION OF EMBODIMENTS

[0031] An embodiment of the present invention is described in detail hereinafter. Fig. 1 is a refrigerant circuit diagram of a refrigeration apparatus 1 of one example to which the present invention has been applied.

First Example

[0032] In the refrigeration apparatus 1 of the example, a refrigerant is supplied from a refrigeration machine unit 3 placed outside a store such as a convenience store or supermarket to a plurality of showcases 2 (2A and 2B. Four in total in the example) placed in the store. The refrigeration apparatus 1 is configured including one high stage-side refrigerant circuit 4, and a plurality of (two systems in the example) low stage-side refrigerant circuits (refrigerant circuits of the present invention) 6A and 6B independent of the high stage-side refrigerant circuit 4.

[0033] The high stage-side refrigerant circuit 4 of the example includes a high stage-side compressor 7 including a scroll compressor, (a plurality of) first and second high stage-side gas coolers (radiators) 11A and 11B, a high stage-side expansion valve 13, a first high stage-side evaporator (an evaporator of the present invention) 16A, and a second high stage-side evaporator (an evaporator of the present invention) 16B. The first and second high stage-side gas coolers 11A and 11B are respectively connected in parallel to branch pipes 9A and 9B branching from a discharge pipe 8 of the high stage-side compressor 7. The high stage-side expansion valve 13 is connected downstream of a junction of an outlet pipe 12A of the first high stage-side gas cooler 11A and an outlet pipe 12B of the second high stage-side gas cooler 11B. The first high stage-side evaporator 16A is connected to an outlet pipe 59 of the high stage-side expansion valve 13. The second high stage-side evaporator 16B is connected to an outlet pipe 17A of the first high stage-side evaporator 16A. An outlet pipe 17B of the second high stage-side evaporator 16B is connected to a suction pipe 18 of the high stage-side compressor 7. The above configuration forms a refrigeration cycle. A predetermined amount of carbon dioxide as a refrigerant is sealed in the high stage-side refrigerant circuit 4. A reference numeral 58 denotes a temperature sensor that is attached to the outlet pipe 17B to detect the temperature of the refrigerant that has left the second high stage-side evaporator 16B.

[0034] On the other hand, the low stage-side refrigerant circuits 6A and 6B have the same configuration. In other words, the low stage-side refrigerant circuit 6A (and the low stage-side refrigerant circuit 6B alike) of the example includes a low stage-side compressor (a compressor of the present invention) 21 also including a scroll compressor, a first low stage-side gas cooler (a radiator of the present invention) 23, a second low stage-side gas cooler (a radiator of the present invention) 26, a supercooling heat exchanger 28, a pressure control expansion valve 31, low stage-side expansion valves (expansion valves of the present invention) 34 and 34, and low stage-side evaporators (evaporators of the present invention) 36 and 36. The first low stage-side gas cooler 23 is connected to a discharge pipe 22 of the low stage-side compressor 21. The second low stage-side gas cooler 26 is connected to an outlet pipe 24 of the first low stage-side

gas cooler 23, and is downstream of the first low stage-side gas cooler 23 in terms of the refrigerant. The supercooling heat exchanger 28 is connected to an outlet pipe 27 of the second low stage-side gas cooler 26. The pressure control expansion valve 31 is connected to an outlet pipe 29 of the supercooling heat exchanger 28. The low stage-side expansion valves 34 and 34 are connected respectively to branch pipes 33A and 33B branching from an outlet pipe 32 of the pressure control expansion valve 31. The low stage-side evaporators 36 and 36 are connected respectively to outlets of the low stage-side expansion valves 34 and 34.

[0035] Two series circuits each including the low stage-side expansion valve 34 and the low stage-side evaporator 36 are connected in parallel to each other in the example. The series circuits are placed respectively in two (a plurality of) showcases 2 (2A and 2B). An outlet of the low stage-side evaporator 36 in each of the showcases 2 (2A and 2B) is connected to a solenoid valve (an on/off valve of the present invention) 37. Outlet pipes 38 of the solenoid valves 37 are joined to be connected to an accumulator 39 via an inlet pipe 42. An outlet of the accumulator 39 is connected to a suction pipe 41 of the low stage-side compressor 21. The above configuration forms a refrigeration cycle. The accumulator 39 is a tank with a predetermined capacity. Moreover, a predetermined amount of carbon dioxide as the refrigerant is also sealed in each of the low stage-side refrigerant circuits 6A and 6B.

[0036] The first high stage-side evaporator 16A of the high stage-side refrigerant circuit 4 and the supercooling heat exchanger 28 of the low stage-side refrigerant circuit 6A are provided to have a heat exchange relation to configure a first cascade heat exchanger 43A. The second high stage-side evaporator 16B of the high stage-side refrigerant circuit 4 and the supercooling heat exchanger 28 of the low stage-side refrigerant circuit 6B are provided to have a heat exchange relation to configure a second cascade heat exchanger 43B. Consequently, the first high stage-side evaporator 16A and the second high stage-side evaporator 16B of the high stage-side refrigerant circuit 4 cool the high pressure-side refrigerants that flow through the supercooling heat exchangers 28 of the low stage-side refrigerant circuits 6A and 6B. Moreover, the branch pipes 33A and 33B and the outlet pipe 38 are pipes reaching each showcase 2 (2A, 2B) from the refrigeration machine unit 3.

[0037] In Fig. 1, a reference numeral 44 denotes a pressure sensor that is attached to the discharge pipe 22 of the low stage-side compressor 21 of each of the low stage-side refrigerant circuits 6A and 6B. The pressure sensor detects the pressure of the high pressure-side refrigerant discharged from the low stage-side compressor 21. In Fig. 1, a reference numeral 56 denotes a pressure sensor that is attached to the discharge pipe 8 of the high stage-side compressor 7 to detect the discharge pressure of the high stage-side compressor 7 (the high pressure-side pressure of the high stage-side refrigerant circuit 4).

A reference numeral 58 denotes a pressure sensor that is attached to the outlet pipe 17B to detect the suction pressure of the high stage-side compressor 7 (the low pressure-side pressure of the high stage-side refrigerant circuit 4).

[0038] In Fig. 1, reference numerals 51 and 52 denote first and second gas cooler-specific air blowers. The first gas cooler-specific air blower 51 sends air to the high stage-side gas coolers 11A and 11B and the first low stage-side gas cooler 23 to air-cool them. The second gas cooler-specific air blower 52 sends air to the second low stage-side gas cooler 26 to air-cool it. Moreover, in Fig. 1, a reference numeral 53 denotes a temperature sensor that detects an ambient temperature.

[0039] Furthermore, in Fig. 1, a reference numeral 48 is a controller on the refrigeration machine unit 3 side. The controller controls the operating frequency of the high stage-side compressor 7 of the high stage-side refrigerant circuit 4, the degree of opening of the high stage-side expansion valve 13, the operating frequency of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A, 6B, the degree of opening of the pressure control expansion valve 31, and the operation of the gas cooler-specific air blower 51, 52, on the basis of outputs of the sensors 44, 53, 56, 58, and the like.

[0040] Moreover, each showcase 2 (2A, 2B) is also provided with a controller (a controller of the present invention) 57 on the showcase side. Furthermore, a refrigerant inlet temperature sensor (refrigerant inlet temperature detection means) 46 that detects the refrigerant inlet temperature of the low stage-side evaporator 36 is attached to a refrigerant inlet of the low stage-side evaporator 36 of the showcase 2 (2A, 2B). A refrigerant outlet temperature sensor (refrigerant outlet temperature detection means) 47 that detects the refrigerant outlet temperature of the low stage-side evaporator 36 is attached to a refrigerant outlet of the low stage-side evaporator 36.

[0041] In Fig. 1, a reference numeral 61 denotes an internal temperature sensor (internal temperature detection means) that detects an internal temperature being a temperature in a display chamber of the showcase 2 (2A, 2B). In Fig. 1, a reference numeral 62 is a cold air circulation purpose air blower for circulating cold air that has exchanged heat with the low stage-side evaporator 36 in the display chamber of the showcase 2 (2A, 2B). The controller 57 controls the degree of opening of the low stage-side expansion valve 34, the opening and closing of the solenoid valve 37, and the operation of the cold air circulation purpose air blower 62 on the basis of outputs of the sensors 46, 47, 61, and the like.

[0042] The showcase indicated by 2A in Fig. 1 is what is called a hot and cold showcase in the example. In other words, this showcase can switch between a state of being used to cool the inside of the display chamber and a state of being used to heat the inside of the display chamber. An electric heater 63 that heats the inside of the display chamber is provided to, for example, shelves placed in the display chamber.

Furthermore, the showcase indicated by 2B is what is called a week-in showcase. In other words, a worker enters a stock room behind the display chamber of this showcase to conduct work upon carrying in/out goods. A switch 64 for controlling a walk-in timer is provided to the showcase 2B. The electric heaters 63 are controlled by the controller 57 of the showcase 2A. The switch 64 is connected to the controller 57 of the showcase 2B.

[0043] The controller 57 on the showcase 2 side and the controller 48 of the refrigeration machine unit 3 are centrally controlled by an integrated controller SM (illustrated in Fig. 10) equipped in the store to operate in coordination with each other.

(1) Operation of the High Stage-side Refrigerant Circuit 4

[0044] With the above configuration, when the controller 48 causes the high stage-side compressor 7 of the high stage-side refrigerant circuit 4, the low stage-side compressors 21 of the low stage-side refrigerant circuits 6A and 6B, and the gas cooler-specific air blowers 51 and 52 to operate, a high temperature and high pressure refrigerant (carbon dioxide) that has been compressed by the high stage-side compressor 7 is discharged into the discharge pipe 8. The refrigerant is split into branch pipes 9A and 9B and then flow into the high stage-side gas coolers 11A and 11B. The refrigerants that have flowed into the high stage-side gas coolers 11A and 11B are cooled by the gas cooler-specific air blower 51 in a supercritical state to reduce their temperatures to low.

[0045] The refrigerants cooled by the first high stage-side gas cooler 11A and the second high stage-side gas cooler 11B pass through the outlet pipes 12A and 12B to be merged, and then flow into the high stage-side expansion valve 13. The refrigerant is throttled (reduced in pressure) by the high stage-side expansion valve 13 and then flows into the first high stage-side evaporator 16A configuring the first cascade heat exchanger 43A. The refrigerant evaporates to cool (supercool) the refrigerant flowing through the supercooling heat exchanger 28 of the first low stage-side refrigerant circuit 6A.

[0046] The refrigerant that has left the first high stage-side evaporator 16A passes through the outlet pipe 17A and then flows into the second high stage-side evaporator 16B configuring the second cascade heat exchanger 43B. The refrigerant evaporates to cool (supercool) the refrigerant flowing through the supercooling heat exchanger 28 of the second low stage-side refrigerant circuit 6B. The refrigerant that has left the second high stage-side evaporator 16B then passes through the outlet pipe 17B to be sucked into the high stage-side compressor 7 from the suction pipe 18. The above circulation is repeated.

[0047] Fig. 2 illustrates the pressure distribution of each unit of the high stage-side refrigerant circuit 4. Rhombuses in Fig. 2 indicate target values of suction pressure P_s of the high stage-side compressor 7 (the low pressure-side pressure) detected by the pressure sensor

58. Squares indicate target values of discharge pressure P_d of the high stage-side compressor 7 (the high pressure-side pressure) detected by the pressure sensor 56. Triangles indicate the compression ratio of the high stage-side compressor 7. Circles indicate the amount of refrigerant sealed in the high stage-side refrigerant circuit 4.

[0048] The target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 (the suction pressure P_s of the high stage-side compressor 7) is conventionally fixed at, for example, 4 MPa. The operating frequency of the high stage-side compressor 7 is controlled to reach the target value. Hence, there is the influence of an optimum amount of sealed refrigerant that changes with ambient temperature variations. Especially, the high stage-side refrigerant circuit 4 of the example is not provided on the refrigerant suction side of the high stage-side compressor 7 with an accumulator. Hence, the above influence is remarkable. The high stage-side compressor 7 becomes unable to operate under optimum compression ratio conditions; accordingly, the efficiency is reduced.

[0049] On the other hand, it can be seen that as in Fig. 2, a compressor of the high stage-side compressor 7 can be maintained at an optimum ratio (2.1 to 2.2) by appropriately setting the target value of the suction pressure P_s of the high stage-side compressor 7 (the low pressure-side pressure) according to the ambient temperature. Hence, the controller 48 appropriately sets the target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 (the target value of the suction pressure P_s of the high stage-side compressor 7) according to an ambient temperature T_a detected by the temperature sensor 53 to control the high stage-side compressor 7. The specific control method is described below.

(1-1) Control of the High Stage-side Compressor 7

[0050] Fig. 3 illustrates a flowchart of the controller 48 related to the control of the high stage-side compressor 7 of the high stage-side refrigerant circuit 4. In step S1 of Fig. 3, the controller 48 judges whether or not the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A or 6B is being operated, and its operating frequency is equal to or greater than a predetermined value (for example, 40 Hz) and also the ambient temperature T_a detected by the temperature sensor 53 is equal to or greater than a predetermined temperature (for example, +15°C). If the operating frequency of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A or 6B is equal to or greater than the predetermined value (40 Hz) and also the ambient temperature T_a detected by the temperature sensor 53 is equal to or greater than +15°C, the controller 48 sets the high stage-side expansion valve 13 at a degree of opening at the time of activation in step S2.

[0051] Next, in step S3, the first gas cooler-specific air

blower 51 is activated. Wait a predetermined time (for example, two minutes). After the passage of two minutes, the temperature sensor 53 detects the ambient temperature T_a in step S4. The operating frequency at the activation of the high stage-side compressor 7 is computed on the basis of the ambient temperature T_a at this point. In this case, for example, the controller 48 sets the operating frequency at the activation of the high stage-side compressor 7 at 75 Hz if the ambient temperature T_a is equal to or greater than 35°C. The controller 48 sets the operating frequency at 65 Hz if 35°C > T_a ≥ 30°C, sets the operating frequency at 55 Hz if 30°C > T_a ≥ 25°C, sets the operating frequency at 45 Hz if 25°C > T_a ≥ 20°C, and sets the operating frequency at 35 Hz if 20°C > T_a ≥ 15°C. In this manner, the controller 48 calculates the operating frequency at the activation of the high stage-side compressor 7 in such a manner as to increase with the increasing ambient temperature T_a .

[0052] In step S5, the controller 48 then activates the high stage-side compressor 7. The controller 48 increases the operating frequency up to the operating frequency at the time of activation computed in step S4. The controller 48 then waits a predetermined time (for example, five minutes) in step S6, and sets the target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 (the target value of the suction pressure P_s of the high stage-side compressor 7) in step S7.

[0053] In this case, the controller 48 holds in advance information indicating a relationship between the ambient temperature T_a that was detected by the temperature sensor 53 in step S4 and the optimum low pressure-side pressure of the high stage-side refrigerant circuit 4 at this point. The optimum value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 of the present invention indicates the low pressure-side pressure of the high stage-side refrigerant circuit 4 that the compression ratio of the high stage-side compressor 7 is the optimum value (2.1 to 2.2) in Fig. 2 described above. An approximate expression ($y = 0.0525x + 2.6155$, R^2 (the coefficient of determination) = 0.9994) of Fig. 4 is information indicating the relationship between the optimum low pressure-side pressure of the high stage-side refrigerant circuit 4 and the ambient temperature. The horizontal axis (x) of Fig. 4 indicates the ambient temperature, and the vertical axis (y) indicates the optimum value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 (the suction pressure of the high stage-side compressor 7). The approximate expression is obtained in advance from an experiment. For example, it can be seen that the optimum value (y) of the low pressure-side pressure = approximately 4.2 MPa in an environment where the ambient temperature (x) = +30°C.

[0054] The controller 48 uses the approximate expression in step S7 to calculate the optimum low pressure-side pressure (the optimum value of the low pressure-side pressure) of the high stage-side refrigerant circuit 4 at this point from the ambient temperature T_a . The con-

troller 48 sets the calculated low pressure-side pressure as the target value. For example, the target value (the optimum low pressure-side pressure) of when the ambient temperature T_a is +20°C is approximately 3.7 MPa.

5 The target value at +30°C is approximately 4.2 MPa as described above. However, the controller 48 fixes the target value at 3.5 MPa when the ambient temperature T_a is equal to or less than +15°C, and at 4.7 MPa equal to or greater than +35°C. The control over the low pressure-side pressure of the high stage-side refrigerant circuit 4 is then started.

[0055] In this case, firstly, the controller 48 determines whether or not to stop the high stage-side compressor 7 in step S8. The procedure for stop determination is as follows: in other words, if any of the following conditions 1 to 3 holds, the controller 48 stops the high stage-side compressor 7. (Condition 1) A state where the high stage-side compressor 7 is at a minimum operating frequency continues for a predetermined time (for example, 10 minutes), and also the temperatures of the first and second high stage-side gas coolers 11A and 11B (which are separately detected by temperature sensors, and can be substituted by the ambient temperature) are equal to or less than a predetermined temperature (for example, +10°C). (Condition 2) Both of the low stage-side compressors 21 are being stopped. (Condition 3) It is the time to defrost the low stage-side evaporator 36 of each show-case 2 (2A, 2B).

[0056] If having determined in step S8 to stop the high stage-side compressor 7, the controller 48 proceeds to step S9 to enter a predetermined stop process. The controller 48 then waits a predetermined time (for example, 10 minutes) in step S10, and then returns to START. If, again in step S1, the ambient temperature T_a is equal to or greater than the predetermined temperature (for example, +15°C), and also the low stage-side compressor 21 of the low stage-side refrigerant circuit 6 or 6A is being operated, and its operating frequency is equal to or greater than the predetermined value (for example, 40 Hz), the controller 48 proceeds to step S2 and later to reactivate the high stage-side compressor 7.

[0057] On the other hand, if the determination condition to stop the high stage-side compressor 7 does not hold in step S8, the controller 48 proceeds to step S11, and detects the low pressure-side pressure of the high stage-side refrigerant circuit 4 with the pressure sensor 58. In step S12, the controller 48 then compares the target value of the low pressure-side pressure set in step S7 and the current low pressure-side pressure detected in step S11. The controller 48 judges whether or not an absolute value of a difference between them (the target value - the current value) is within a predetermined small value (for example, 0.1 MPa). The controller 48 then proceeds to step S13 if the difference is within 0.1, and does not give an instruction to change the operating frequency of the high stage-side compressor 7 (does not change the operating frequency).

[0058] On the other hand, if the absolute value of the

difference between the target value of the low pressure-side pressure and the current low pressure-side pressure is greater than 0.1, the controller 48 proceeds from step S12 to step S14. In step S14, the controller 48 judges whether or not the current low pressure-side pressure (the current value) is less than the target value. If the current low pressure-side pressure (the current value) is less than the target value set in step S7, the controller 48 proceeds to step S15 to reduce the operating frequency of the high stage-side compressor 7 by predetermined steps. Conversely, if the current low pressure-side pressure (the current value) is equal to or greater than the target value in step S14, the controller 48 proceeds to step S16 to increase the operating frequency of the high stage-side compressor 7 by predetermined steps.

[0059] The processing from steps S12 to S16 is conducted by PID control based on the deviation of the current value of the low pressure-side pressure from its target value. In this manner, the controller 48 controls the low pressure-side pressure of the high stage-side refrigerant circuit 4 to the target value set in step S7.

[0060] Next, the controller 48 proceeds to step S17 to wait a predetermined time (for example, 30 sec). In step S18, the controller 48 subsequently detects the ambient temperature T_a with the temperature sensor 53. The controller 48 judges in step S19 whether or not an absolute value of a difference between the ambient temperature T_a of when the target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 was set in step S7, and the ambient temperature detected in step S18 (the current ambient temperature) (the set ambient temperature - the current ambient temperature) is within a predetermined small value (for example, 2K). If the absolute value of the difference is within 2K, the controller 48 proceeds to step S20, maintains the target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 at the current value (maintenance of the status quo), and returns to step S8.

[0061] If the absolute value of the difference is greater than 2K in step S19, the controller 48 proceeds to step S21 to update the target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4. Also in this case, the controller 48 uses the approximate expression of Fig. 4 to calculate an optimum low pressure-side pressure (an optimum value of the low pressure-side pressure) of the high stage-side refrigerant circuit 4 at this point from the ambient temperature T_a detected in step S18. The controller 48 sets (updates) the calculated low pressure-side pressure as the target value and returns to step S8.

[0062] In this manner, the operating frequency of the high stage-side compressor 7 is controlled so as to appropriately set the target value of the low pressure-side pressure of the high stage-side refrigerant circuit 4 (the suction pressure P_s of the high stage-side compressor 7) according to the ambient temperature T_a and reach the target value. Hence, the influence of the optimum

amount of sealed refrigerant that changes with ambient temperature variations is removed. Even if an accumulator is not provided as in the example, the operation of the high stage-side compressor 7 of the high stage-side refrigerant circuit 4 can be highly efficiently controlled.

(2) Operation of the Low Stage-side Refrigerant Circuits 6A and 6B

[0063] On the other hand, a high temperature and high pressure refrigerant (carbon dioxide) compressed by the low stage-side compressor 21 of the first low stage-side refrigerant circuit 6A (and the second low stage-side refrigerant circuit 6B alike) is discharged into the discharge pipe 22 to flow into the first low stage-side gas cooler 23. The refrigerant that has flowed into the first low stage-side gas cooler 23 is cooled by the gas cooler-specific air blower 51 in a supercritical state to reduce its temperature to low. Next, the refrigerant subsequently passes through the outlet pipe 24 to flow into the second low stage-side gas cooler 26. The refrigerant that has flowed into the second low stage-side gas cooler 26 is cooled by the gas cooler-specific air blower 52 in a supercritical state to be further reduced in temperature. The refrigerant subsequently passes through the outlet pipe 27 to flow into the supercooling heat exchanger 28 configuring the first cascade heat exchanger 43A (the second cascade heat exchanger 43B in the case of the second low stage-side refrigerant circuit 6B).

[0064] The refrigerant that has flowed into the supercooling heat exchanger 28 is cooled (supercooled) by the refrigerant of the high stage-side refrigerant circuit 4 that evaporates in the first high stage-side evaporator 16A (the second high stage-side evaporator 16B in the case of the second low stage-side refrigerant circuit 6B) to be further reduced in temperature. The refrigerant subsequently passes through the outlet pipe 29 to reach the pressure control expansion valve 31.

[0065] The high pressure-side refrigerant of the low stage-side refrigerant circuit 6A (6B) is throttled by the pressure control expansion valve 31. The refrigerant then passes through the outlet pipe 32 to be split into the branch pipes 33A and 33B. Furthermore, the refrigerants leave the refrigeration machine unit 3 and enter the showcases 2 (2A and 2B). The refrigerants flowing through the branch pipes 33A and 33B reach the low stage-side expansion valves 34 of the showcases 2 (2A and 2B) to be throttled therein. The refrigerants flow into the low stage-side evaporators 36 to evaporate. The inside of the display chamber of each showcase (2A, 2B) is cooled to a predetermined temperature by an endothermic reaction at this point.

[0066] The refrigerants that have left the low stage-side evaporators 36 of the showcases 2 (2A and 2B) pass through the solenoid valves 37 (the solenoid valves 37 are assumed to be open when the showcases 2 (2A and 2B) are cooled) and the outlet pipes 38 to be merged. The refrigerant flows into the accumulator 39 from the

inlet pipe 42. The refrigerant that has flowed into the accumulator 39 is separated into gas and liquid. The gas refrigerant is sucked into the low stage-side compressor 21 through the suction pipe 41. The above circulation is repeated.

[0067] The controller 48 controls the degree of opening of the expansion valve 13 on the basis of the high pressure-side pressure of the high stage-side refrigerant circuit 4 detected by the pressure sensor 56 as in the control of the pressure control expansion valve 31 of the low stage-side refrigerant circuit 6A, 6B described below. Consequently, the controller 48 controls the high pressure-side pressure of the high stage-side refrigerant circuit 4 to an appropriate value (a target value of the high pressure-side pressure of the high stage-side refrigerant circuit 4).

[0068] In this manner, the refrigerant of the high stage-side refrigerant circuit 4 evaporates in the high stage-side evaporators 16A and 16B of the cascade heat exchangers 43A and 43B to supercool the high pressure-side refrigerants of the low stage-side refrigerant circuits 6A and 6B that flow through the supercooling heat exchangers 28. Consequently, also if carbon dioxide is used as the refrigerant, the low stage-side evaporators 36 of the showcases 2 (2A and 2B) can obtain required cooling capacity without using relatively large (large capacity) compressors as the compressors 7 and 21 of the refrigerant circuits 4, 6A, and 6B.

[0069] Moreover, the refrigerants that have left the low stage-side evaporators 36 of the low stage-side refrigerant circuits 6A and 6B are sucked into the low stage-side compressors 21 of the low stage-side refrigerant circuits 6A and 6B without exchanging heat with the high pressure-side refrigerants of the low stage-side refrigerant circuits 6A and 6B. Hence, especially in, for example, the summer when the ambient temperature increases, the high pressure-side pressure of the low stage-side refrigerant circuits 6A and 6B is prevented from increasing abnormally. Furthermore, dense refrigerants can be sucked into the low stage-side compressors 21; accordingly, the efficiency is also increased.

[0070] In this case, the liquid floodback to the low stage-side compressor 21 is prevented since the accumulator 39 is provided on the suction side of the low stage-side compressor 21. Moreover, the accumulator 39 functions as a reservoir. Accordingly, it becomes possible to seal a sufficient amount of carbon dioxide refrigerant in the low stage-side refrigerant circuit 6A, 6B.

[0071] Moreover, the cascade heat exchangers 43A and 43B supercool the refrigerants that have left the low stage-side gas coolers 26. Hence, the carbon dioxide refrigerants of the low stage-side refrigerant circuits 6A and 6B cooled by the low stage-side gas coolers 24 and 26 are further supercooled by the cascade heat exchangers 43A and 43B. Consequently, the improvement of the cooling capacity can be further encouraged.

[0072] Furthermore, in the example, the low stage-side refrigerant circuits 6A and 6B of two systems and the two

cascade heat exchangers 43A and 43B provided respectively to the low stage-side refrigerant circuits 6A and 6B are provided. Hence, the high pressure-side refrigerants of the low stage-side refrigerant circuits 6A and 6B of two (a plurality of) systems can be supercooled by one high stage-side refrigerant circuit 4.

[0073] Moreover, the refrigerants that have left the high stage-side evaporators 16A and 16B of the high stage-side refrigerant circuit 4 are sucked into the high stage-side compressor 7 of the high stage-side refrigerant circuit 4 without exchanging heat with the high pressure-side refrigerant of the high stage-side refrigerant circuit 4. Hence, especially in, for example, the summer when the ambient temperature increases, the high pressure-side pressure of the high stage-side refrigerant circuit 4 can be prevented from increasing abnormally. Moreover, a dense refrigerant can be sucked into the high stage-side compressor 7; accordingly, the efficiency is also increased.

(2-1) Control of the Pressure Control Expansion Valve 31

[0074] Next, the controller 48's control over the degree of opening of the pressure control expansion valve 31 of each of the low stage-side refrigerant circuits 6A and 6B is described with reference to Figs. 5 and 6. As described above, the controller 48 of the high stage-side refrigerant circuit 4 also controls the degree of opening of the expansion valve 13 on the basis of the high pressure-side pressure of the high stage-side refrigerant circuit 4 detected by the pressure sensor 56 as in the control of the pressure control expansion valve 31 of the low stage-side refrigerant circuit 6A, 6B described here. Consequently, the controller 48 of the high stage-side refrigerant circuit 4 controls the high pressure-side pressure of the high stage-side refrigerant circuit 4 to an appropriate value (the target value of the high pressure-side pressure of the high stage-side refrigerant circuit 4). In the example, the controller 48 calculates optimum high pressure-side pressure of the low stage-side refrigerant circuit 6A, 6B on the basis of the ambient temperature, and controls the degree of opening of each pressure control expansion valve 31 with the optimum high pressure-side pressure as the target value. In other words, the controller 48 sets the degree of opening of the pressure control expansion valve 31 at a predetermined opening at the time of activation in step S22 of the flowchart of Fig. 5. Next, the controller 48 activates the low stage-side compressor 21 in step S23, and waits a predetermined time (for example, 10 minutes) in step S24. Next, in step S25, the controller 48 detects the ambient temperature T_a detected by the temperature sensor 53. In step S26, the controller 48 sets the target value of the high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) on the basis of the ambient temperature T_a .

[0075] In this case, the controller 48 holds in advance information indicating a relationship between the ambient temperature T_a and the optimum high pressure-side

pressure of the low stage-side refrigerant circuit 6A (6B) at this point. The optimum value of the high pressure-side pressure in the present invention indicates the high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) at maximum efficiency COP or a value close to it. An approximate expression ($y = 0.1347x + 5.4132$, R^2 (the coefficient of determination) = 0.9846) of Fig. 6 is information indicating the relationship between the optimum high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) and the ambient temperature. The horizontal axis (x) of Fig. 6 indicates the ambient temperature, and the vertical axis (y) indicates the optimum value of the high pressure-side pressure (the pressure of the high pressure-side refrigerant discharged by the low stage-side compressor 21) of the low stage-side refrigerant circuit 6A (6B) of the refrigeration apparatus 1. The approximate expression is obtained in advance from an experiment. For example, it can be seen that the optimum value (y) of the high pressure-side pressure = 10.5 MPa in an environment where the ambient temperature (x) = +38°C.

[0076] The controller 48 uses the approximate expression in step S26 to calculate optimum high pressure-side pressure (an optimum value of the high pressure-side pressure) at this point from the ambient temperature Ta. The controller 48 sets the calculated high pressure-side pressure as the target value. For example, the target value (the optimum high pressure-side pressure) of when the ambient temperature is +20 °C is approximately 8.1 MPa. The target value at +30°C is approximately 9.5 MPa. However, the controller 48 fixes the target value at 6.5 MPa (to prevent the turn-over of the scroll) when the ambient temperature Ta is equal to or less than +8°C, and fixes the target value at 10.8 MPa when the ambient temperature Ta is equal to or greater than +40°C. Moreover, if the discharge temperature of the low stage-side compressor 21 (detected separately by a temperature sensor) increases to or above a predetermined high value (for example, 118°C) and, if this state continues for a predetermined time (for example, three minutes), the controller 48 reduces the target value of the high pressure-side pressure by 0.1 MPa.

[0077] Next, in step S27, the controller 48 detects the current high pressure-side pressure detected by the pressure sensor 44. Next, the controller 48 judges in step S28 whether or not an absolute value (abs) of a difference between the target value (the optimum high pressure-side pressure) and the current high pressure-side pressure (the current value) (the target value - the current value) is equal to or less than a predetermined value (for example, 0.1 MPa). If the difference is equal to or less than the predetermined value (there is no difference, or the difference is small), the controller 48 proceeds to step S29 and does not give an instruction to change the degree of opening of the pressure control expansion valve 31 (the degree of opening of the pressure control expansion valve 31 is maintained).

[0078] Next, the controller 48 waits a predetermined

time (for example, 30 seconds) in step S30, and then, in step S31, detects the ambient temperature Ta detected again by the temperature sensor 53. The controller 48 then judges in step S32 whether or not a difference between the ambient temperature whose target value was set (the ambient temperature in step S25. The set ambient temperature) and the current ambient temperature Ta (the current ambient temperature detected in step S31) (the set ambient temperature - the current ambient temperature) is within a range of predetermined values (for example, plus/minus 2K). If the difference is within the predetermined values (plus/minus 2K), the controller 48 maintains the target value of the high pressure-side pressure in step S33 to return to step S27.

[0079] If the difference (the set ambient temperature - the current ambient temperature) is not within the predetermined values in step S32, the controller 48 proceeds to step S34, and uses the approximate expression of Fig. 6 to calculate an optimum high pressure-side pressure at the ambient temperature Ta at this point (the current ambient temperature). The controller 48 sets (updates) the calculated high pressure-side pressure as the target value. The controller 48 then returns to step S27. In this manner, the controller 48 keeps updating the target value of the high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B), following changes in the ambient temperature Ta.

[0080] On the other hand, if the absolute value of the difference between the target value and the current high pressure-side pressure (the current value) (the target value - the current value) is not equal to or less than the predetermined value (0.1 MPa) (the difference is large) in step S28, the controller 48 proceeds to step S35 to judge whether or not the difference (the target value - the current value) is greater than the predetermined value (for example, 0.1 MPa).

[0081] If the current high pressure-side pressure (the current value) is low and the difference (the target value - the current value) is greater than the predetermined value (0.1 MPa), the controller 48 proceeds to step S36 to close the degree of opening of the pressure control expansion valve 31 by predetermined pulses (xppls). Consequently, more high pressure-side refrigerant of the low stage-side refrigerant circuit 6A (6B) is held back immediately after leaving the supercooling heat exchanger 28 of the cascade heat exchanger 43A (43B). Hence, the high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) increases.

[0082] On the other hand, if the current high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) (the current value) is high, and the difference (the target value - the current value) is equal to or less than the predetermined value (0.1 MPa), the controller 48 proceeds to step S37 to open the degree of opening of the pressure control expansion valve 31 by predetermined pulses (xppls), which facilitates the flow of the high pressure-side refrigerant of the low stage-side refrigerant circuit 6A (6B) that has left the supercooling heat exchanger

28 of the cascade heat exchanger 43A (43B). Hence, the high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) is reduced.

[0083] The above processing is repeated to allow the controller 48 to control the high pressure-side pressure of the low stage-side refrigerant circuit 6A (6B) to an optimum value, using the pressure control expansion valve 31. In other words, the pressure control expansion valve 31 for adjusting the high pressure-side pressure of the low stage-side refrigerant circuit 6A, 6B is provided. The controller 48 controls the pressure control expansion valve 31 with the optimum high pressure-side pressure as the target value on the basis of the high pressure-side pressure of the low stage-side refrigerant circuit 6A, 6B. Consequently, the difference in specific enthalpy of the high pressure-side refrigerant of the low stage-side refrigerant circuit 6A, 6B is secured; accordingly, the increase of the cooling capacity, and the improvement of efficiency can be encouraged.

[0084] Especially, the controller 48 holds in advance the information (approximate expression) indicating the relationship between the ambient temperature T_a and the optimum high pressure-side pressure at this point. Furthermore, the controller 48 calculates the target value of the high pressure-side pressure on the basis of the ambient temperature. Consequently, the high pressure-side pressure of the low stage-side refrigerant circuit 6A, 6B can be smoothly controlled by the pressure control expansion valve 31 to an optimum value.

(2-2) Control of the Low Stage-side Expansion Valve 34

[0085] Next, the controller 57's control over the degree of opening of the low stage-side expansion valve 34 of each showcase 2 (2A, 2B) is described with reference to Fig. 7. Fig. 7 is a timing chart illustrating the state of the controller 57's control of the low stage-side expansion valve 34. The top row illustrates a current internal temperature PT being the temperature of the inside of the display chamber detected by the internal temperature sensor 61 of the showcase 2 (and the showcases 2A and 2B alike). The second row from the top illustrates refrigerant superheat PSH in the low stage-side evaporator 36. The third row from the top illustrates the degree of opening of the low stage-side expansion valve 34. The bottom row illustrates the open and closed states of the solenoid valve 37.

[0086] The controller 57 calculates the current refrigerant superheat PSH being a difference between the refrigerant outlet temperature of the low stage-side evaporator 36 detected by the refrigerant outlet temperature sensor 47 and the refrigerant inlet temperature of the low stage-side evaporator 36 detected by the refrigerant inlet temperature sensor 46 (the refrigerant outlet temperature - the refrigerant inlet temperature), from the refrigerant outlet temperature and the refrigerant inlet temperature. Moreover, a target internal temperature ST (for example, $+5^{\circ}\text{C}$. A second temperature in the present in-

vention), which is a target value of the internal temperature of each showcase 2 (2A, 2B) is set for the controller 57. Furthermore, in the example, a temperature lower by 1K than the target internal temperature ST (a differential) is set as a first temperature $T1$. A temperature lower by 4K is set as a thermostat-off temperature $TOFF$ (a fourth temperature). Moreover, it is assumed that target superheat SSH (for example, 5K) being a target value of the refrigerant superheat in the low stage-side evaporator 36 is also set.

[0087] Assume that now it is in a state where the internal temperature PT detected by the internal temperature sensor 61 is higher than the target internal temperature ST . In this case, the controller 57 controls the degree of opening of the low stage-side expansion valve 34 on the basis of the current refrigerant superheat PSH in the low stage-side evaporator 36 calculated as described above, and the target superheat SSH . In this case, the controller 57 controls the degree of opening (the amount of control) of the low stage-side expansion valve 34 by PID control based on a deviation e of the refrigerant superheat PSH from the target superheat SSH such that the refrigerant superheat PSH reaches the target superheat SSH . Consequently, liquid floodback to the low stage-side compressor 21 is prevented.

[0088] If the internal temperature PT starts dropping in this state and then drops below the above-mentioned first temperature $T1$, the controller 57 switches to a state where the degree of opening of the low stage-side expansion valve 34 is controlled on the basis of the internal temperature PT detected by the internal temperature sensor 61. In this case, the controller 57 controls the degree of opening (the amount of control) of the low stage-side expansion valve 34 by PID control based on the deviation e of the current internal temperature PT from the target internal temperature ST such that the internal temperature PT reaches the target internal temperature ST .

[0089] Consequently, the internal temperature PT turns to an increase. If the internal temperature PT drops to the above-mentioned thermostat-off temperature $TOFF$, the controller 57 closes the solenoid valve 37 to prevent goods in the display chamber from becoming frozen. The controller 57 switches to the control of the low stage-side expansion valve 34 based on the internal temperature PT and the target internal temperature ST at the time when the internal temperature PT drops below the first temperature $T1$. Hence, the inconvenience that the inside of the display chamber is unintendedly supercooled is prevented and also a situation where the solenoid valve 37 is closed is also suppressed (it is not closed in the example).

[0090] Under the control based on the internal temperature PT and the target internal temperature ST , the degree of opening of the low stage-side expansion valve 34 is gradually reduced (throttled). Consequently, the amount of the refrigerant flowing into the low stage-side evaporator 36 is reduced. Hence, the internal tempera-

ture PT increases to the target internal temperature ST in the end. At the point when the internal temperature PT has increased to or above the target internal temperature ST, the controller 57 returns to a state where the degree of opening of the low stage-side expansion valve 34 is controlled on the basis of the refrigerant superheat in the low stage-side evaporator 36.

[0091] In this manner, the controller 57 of each showcase 2 (2A, 2B) controls the low stage-side expansion valve 34 such that the refrigerant superheat PSH in the low stage-side evaporator 36 reaches the target superheat SSH on the basis of the refrigerant superheat PSH if the internal temperature PT is equal to or greater than the first temperature T1. Hence, it is possible to prevent liquid floodback to the low stage-side compressor 21 and excessive formation of frost on the low stage-side evaporator 36. On the other hand, the controller 57 controls the low stage-side expansion valve 34 on the basis of the internal temperature PT such that the internal temperature PT reaches the target internal temperature ST if the internal temperature PT drops below the first temperature T1. Hence, it is possible to prevent the display chamber from being supercooled.

[0092] In other words, the simple control switching enables all of the liquid floodback to the low stage-side compressor 21, the excessive formation of frost on the low stage-side evaporator 36, and supercooling of the inside of the display chamber to be smoothly resolved. Moreover, the supercooling of the inside of the display chamber is resolved by the low stage-side expansion valve 34. Hence, it is possible to avoid variations in the pressure of the low stage-side refrigerant circuit 6A, 6B due to the opening and closing of the solenoid valve 37. Consequently, even if the capacity of the accumulator 39 is small and carbon dioxide is used as the refrigerant, the inconvenience of forcing the low stage-side compressor 21 to stop by a safety device (not illustrated) such as a high-pressure cut-out is suppressed. Consequently, the number of times of the activation and stop of the low stage-side compressor 21 is reduced; accordingly, the inside of the display chamber can be stably cooled.

[0093] In this case, the controller 57 returns to the control of the low stage-side expansion valve 34 based on the refrigerant superheat PSH in the low stage-side evaporator 36 if the internal temperature PT increases to or above the target internal temperature ST (a predetermined second temperature higher than the first temperature T1) in a state of controlling the low stage-side expansion valve 34 on the basis of the internal temperature PT. Hence, the controller 57 can smoothly return to the control based on the refrigerant superheat PSH in the low stage-side evaporator 36 at a stage where the risk of supercooling the inside of the display chamber is resolved. Especially, the return temperature (second temperature) is set at the target internal temperature ST. Hence, it becomes possible to smoothly control the temperature of the inside of the display chamber to the target internal temperature ST.

(3) Control of the Showcase 2A

[0094] As described above, the showcase 2A is the hot and cold showcase including the electric heater 63. If the showcase 2A is switched by the operation of a changeover switch 66 (Fig. 8 and the like) to a state where the inside of the display chamber is heated for use (all hot), the controller 57 of the showcase 2A closes the low stage-side expansion valve 34 and the solenoid valve 37 to stop the supply of refrigerant to the low stage-side evaporator 36. Furthermore, the controller 57 causes the electric heater 63 to produce heat to heat (warm) the inside of the display chamber.

[0095] However, conventionally, the degree of opening of the low stage-side expansion valve 34 is reduced to close the solenoid valve 37 at the time when the changeover switch 66 is switched to all hot as in Fig. 8. Hence, the variation in the low pressure-side pressure in the low stage-side refrigerant circuit 6B increases. Hence, if the capacity of the accumulator 39 is small, the high pressure-side pressure increases sharply and it is too late for the speed reduction control of the low stage-side compressor 34. Consequently, a safety device such as a high-pressure cut-out forces the low stage-side compressor 21 to stop. When the low stage-side compressor 21 is forced to stop, there is the risk of the occurrence of an overcurrent anomaly or the like.

(3-1) High-pressure Cut-out Prevention Control 1

[0096] Hence, in the example, if the showcase 2A has been switched to the state where all hot is used by the operation of the changeover switch 66, the controller 57 of the showcase 2A starts reducing the degree of opening of the low stage-side expansion valve 34 at this point as illustrated in Fig. 9. The controller 57 fully closes the low stage-side expansion valve 34 after fixing its degree of opening at a predetermined opening (for example, a minimum opening in terms of the control). Moreover, the controller 57 does not close the solenoid valve 37 immediately, either, and closes the solenoid valve 37 after delaying the closure until a timing when the low stage-side expansion valve 34 is fully closed.

[0097] Consequently, variations in the pressure of the refrigerant in the low stage-side refrigerant circuit 6B are suppressed. Hence, as long as the solenoid valve 37 of the showcase 2B is open, the low stage-side compressor 21 continues operation within a normal operating range (the speed is reduced in reality).

(3-2) High-pressure Cut-out Prevention Control 2

[0098] In this case, the controller 57 of the showcase 2A may transmit information to the integrated controller SM at the point when the changeover switch 66 is switched to the state where all hot is used, as illustrated in Fig. 10. The integrated controller SM may transmit information on switching related to the controller 48 of the

refrigeration machine unit 3. The controller 48 starts reducing the speed of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B at the point when receiving the switching information; accordingly, it is possible to reduce the speed from an earlier point in time. Hence, variations in the pressure of the refrigerant in the low stage-side refrigerant circuit 6B can be further suppressed.

(3-3) High-pressure Cut-out Prevention Control 3

[0099] Next, Fig. 11 illustrates still another example of the high-pressure cut-out prevention control of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B. In this example, if the showcase 2A is switched by the operation of the changeover switch 66 to the state where all hot is used, the controller 57 of the showcase 2A fixes the degree of opening of the low stage-side expansion valve 34 at a predetermined opening from that point onward. Moreover, the controller 57 waits without closing the solenoid valve 37 either.

[0100] On the other hand, the controller 57 of the showcase 2A transmits the information to the integrated controller SM at the point when the changeover switch 66 switches to the state where all hot is used, as in the above description. The integrated controller SM transmits the switching information related to the controller 48 of the refrigeration machine unit 3. The controller 48 gradually reduces the speed of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B from the point in time when receiving the switching information, and then stops the low stage-side compressor 21.

[0101] The controller 48 transmits the stop information of the low stage-side compressor 21 to the controller 57 of the showcase 2A via the integrated controller SM. After receiving the stop information, the controller 57 fully closes the low stage-side expansion valve 34 of the showcase 2A and also closes the solenoid valve 37. In other words, the controller 57 delays the closure of the solenoid valve 37 until the low stage-side compressor 21 stops.

[0102] The controller 48 subsequently reactivates the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B. This control ensures the resolution of the forced stop of the low stage-side compressor 21 due to a variation in the pressure of the refrigerant in the low stage-side refrigerant circuit 6B at the time when the showcase 2A is switched to the state where all hot is used.

(3-4) High-pressure Cut-out Prevention Control 4

[0103] Next, an example of the high-pressure cut-out prevention control of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B of when three showcases 2A, 2B, and 2C (not illustrated) are connected to the low stage-side refrigerant circuit 6B is described using Figs. 12 and 13. In Figs. 12 and 13, reference numerals 34A and 37A denote a low stage-side expansion

valve and a solenoid valve of the hot and cold showcase 2A. A reference numeral 34B denotes a low stage-side expansion valve of the second showcase 2B. A reference numeral 37C denotes a solenoid valve 37C of the third showcase 2C.

[0104] Assume that now the showcases 2A and 2B are in operation, and the showcase 2C is being stopped (therefore, the solenoid valve 37C is closed), and in this state the changeover switch 66 is switched to all hot, the degree of opening of the low stage-side expansion valve 34 is reduced at that point in time to close the solenoid valve 37. In this case, the showcase 2B has excess capacity, and the evaporation temperature of the low stage-side evaporator 36 is reduced. Hence, the degree of opening of the low stage-side expansion valve 34B is in a throttle direction. Hence, the low pressure-side pressure in the low stage-side refrigerant circuit 6B is reduced to sharply increase the high pressure-side pressure. Consequently, as described above, it is too late for the speed reduction control of the low stage-side compressor 34. Consequently, a safety device such as a high-pressure cut-out forces the low stage-side compressor 21 to stop; accordingly, there is the risk of the occurrence of an overcurrent anomaly in the low stage-side compressor 21.

[0105] Hence, as illustrated in Fig. 13, the solenoid valve 37C of the showcase 2C, which is being stopped, is forced to be opened at the point when the changeover switch 66 of the showcase 2A switches to the state where all hot is used. Moreover, the degree of opening of the low stage-side expansion valve 34B of the showcase 2B is also fixed at a predetermined high degree of opening. In this case, the controller 57 of the showcase 2A transmits the switching information to the controllers 57 of the showcases 2B and 2C via the integrated controller SM.

[0106] Furthermore, as in the above description, the integrated controller SM transmits the switching information also to the controller 48 of the refrigeration machine unit 3 at the point when the changeover switch 66 switches to the state where all hot is used. The controller 48 starts reducing the speed of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B at the point when receiving the switching information; accordingly, variations in the pressure of the refrigerant in the low stage-side refrigerant circuit 6B can be suppressed more efficiently from an early point in time.

(3-5) High-pressure Cut-out Prevention Control 5

[0107] In this case, as illustrated in Fig. 14, the controller 57 may gradually reduce the degree of opening of the low stage-side expansion valve 34A of the showcase 2A at the point when the changeover switch 66 of the showcase 2A switches to the state where all hot is used. In this case, the solenoid valve 37A is closed after the low stage-side expansion valve 34A is fully closed. Moreover, in terms of the showcase 2C that is being stopped, the solenoid valve 37C is similarly opened.

[0108] Consequently, the speed of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6B is also slowly reduced. Hence, the high-pressure cut-out due to a variation in pressure is more efficiently resolved.

(4) Control of the Low Stage-side Compressor 21

[0109] Next, another example of the control of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A, 6B is described with reference to Fig. 15. In the example of Fig. 15, a temperature lower by 2K than the target internal temperature ST is set as the thermostat-off temperature TOFF. If the internal temperature PT detected by the internal temperature sensor 61 drops to the thermostat-off temperature TOFF, the solenoid valve 37 of the showcase 2 (2A, 2B) is conventionally closed (the status quo on the left side in Fig. 15). However, especially if the capacity of the accumulator 39 is relatively small, a variation in pressure caused by closing the solenoid valve 37 is large. If carbon dioxide is used, there is a problem that, as in the above description, the high-pressure cut-out works, which leads to the forced stop of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A, 6B.

[0110] Hence, in this control example, the controller 57 of the showcase 2 (2A, 2B) sets the internal temperature PT detected by the internal temperature sensor 61 at a predetermined lower limit TL higher than the thermostat-off temperature TOFF (for example, a value higher by 1K than the thermostat-off temperature TOFF). If the internal temperature PT drops to the lower limit TL, the controller 57 reduces the operating frequency of the low stage-side compressor 21 that supplies the refrigerant to the showcase 2 (2A, 2B).

[0111] The state of the control is illustrated on the right side (the present plan) of Fig. 15. The low stage-side compressor 21 of the low stage-side refrigerant circuit 6A, 6B is normally operated at a predetermined operating frequency. Assume, for example, that the internal temperature PT of one of the showcases 2 of the low stage-side refrigerant circuit 6A drops below the target internal temperature ST, and then to the lower limit TL lower by 1K than the target internal temperature ST (higher by 1K than the thermostat-off temperature TOFF). In this case, the controller 57 gradually reduces the operating frequency of the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A in predetermined steps to, for example, a control lower limit. Consequently, the internal temperature PT turns to an increase.

[0112] The controller 57 subsequently increases the operating frequency of the low stage-side compressor 21 again at the point when the internal temperature PT increases to the target internal temperature ST to return to the initial value. In this manner, the operating frequency of the low stage-side compressor 21 is reduced before the internal temperature PT drops to the thermostat-off temperature TOFF (the temperature at which the sole-

noid valve 37 is closed). Consequently, the solenoid valve 37 will not be closed. Consequently, it becomes possible to avoid in advance the occurrence of the forced stop of the low stage-side compressor 21 that is accompanied by the closure of the solenoid valve 37.

(5) Control of the Low Stage-side Expansion Valve 34 at the Time of Stop/Activation of the Low Stage-side Compressor 21

[0113] Next, a description is given of a control example of the low stage-side expansion valve 34 at the time of stopping and activating the low stage-side compressor 21 of the low stage-side refrigerant circuit 6A, 6B. Assume, for example, that at the point when the low stage-side compressor 21 is stopped, the degree of opening of the low stage-side expansion valve 34 is a minimum opening in terms of the control. In this case, the degree of opening of the low stage-side expansion valve 34 is conventionally maintained at the minimum opening during the stop of the low stage-side compressor 21. Hence, when the low stage-side compressor 21 is activated, the high pressure-side pressure in the low stage-side refrigerant circuit 6A, 6B may increase quickly to cause the high-pressure cut-out to force the low stage-side compressor 21 to stop. This is remarkable when the capacity of the accumulator 39 is relatively small.

[0114] Hence, the controller 57 of the showcase 2 (2A, 2B) receives information on the activation/stop of the low stage-side compressor 21 from the controller 48 of the refrigeration machine unit 3 via the above-mentioned integrated controller SM. If the degree of opening of the low stage-side expansion valve 34 at the point when the low stage-side compressor 21 stops is a predetermined small value (the minimum opening or a value close to it), the controller 57 increases the degree of opening of the low stage-side expansion valve 34 to, for example, a medium value (a medium opening: a standby opening) larger than the minimum opening during standby when the low stage-side compressor 21 is at rest. Alternatively, when the low stage-side expansion valve 34 is reactivated, the controller 57 increases the degree of opening of the low stage-side expansion valve 34 to the medium opening (an opening at the time of activation).

[0115] Consequently, the inconvenience that at the time of the reactivation of the low stage-side compressor 21, the high pressure-side pressure of the low stage-side refrigerant circuit 6A, 6B increases abnormally to force the low stage-side compressor 21 to stop can be avoided in advance.

(6) Control of the Showcase 2B

[0116] Next, the control of the showcase 2B is described. As described above, the showcase 2B is what is called a week-in showcase. A worker enters a stock room behind the display chamber of the showcase 2B to conduct work upon carrying in/out goods. To do so, the

showcase 2B is provided with the switch 64 for controlling a walk-in timer. The worker presses the switch 64 (operation) when entering the stock room.

[0117] When the switch 64 is pressed, the controller 57 of a known showcase 2B closes the solenoid valve 37 of the showcase 2B to stop the cold air circulation purpose air blower 62. If the switch 64 is pressed again, then the controller 57 opens the solenoid valve 37 to activate the cold air circulation purpose air blower 62.

[0118] At this point in time, assume that after the first press of the switch 64, the switch 64 is pressed again in a short time. In this case, the solenoid valve 37 is closed and opened within the short time; accordingly, the low pressure-side pressure of the low stage-side refrigerant circuit 6B is sharply reduced. Hence, there is a problem that a protection device that is what is called a low-pressure cut-out is activated to force the low stage-side compressor 21 to stop or cause the loss of synchronization of the low stage-side compressor 21.

[0119] Hence, the controller 57 of this example closes the solenoid valve 37 and stops the cold air circulation purpose air blower 62, as before, after the first press of the switch 64. However, the controller 57 maintains the closed state without opening the solenoid valve 37 even if the switch 64 is pressed again within a predetermined time (for example, five minutes) from this point in time. The controller 57 then opens the solenoid valve 37 after the passage of the predetermined time. Consequently, the forced stop and loss of synchronization of the low stage-side compressor 21 can be avoided in advance.

[0120] However, if the switch 64 is pressed again within the predetermined time, the controller 57 starts operating the cold air circulation purpose air blower 62 at that point in time. Consequently, the problem that the worker misunderstands that the showcase 2B is broken no longer exists.

Second Example

(7) Another Example of the Control of the Low Stage-side Expansion Valve 34

[0121] Next, a description is given of another example related to the control over the degree of opening of the low stage-side expansion valve 34 of the low stage-side refrigerant circuit 6A, 6B. In the example, the controller 57 of each showcase 2 (2A, 2B) normally controls the degree of opening of the low stage-side expansion valve 34 such that the internal temperature PT detected by the internal temperature sensor 61 reaches the target internal temperature ST of Fig. 7 on the basis of the internal temperature PT. The control over the degree of opening of this case is also executed by PID control based on the deviation e of the current internal temperature PT from the target internal temperature ST. Such control can encourage the prevention of the supercooling of the inside of the display chamber and the reduction of the number of times of the activation and stop of the low stage-side

compressor 21.

[0122] Assume that in such a state, the internal temperature PT increases to or above a third temperature T3 (Fig. 7) higher by a predetermined value (for example, 1K) than the target internal temperature ST, and also the refrigerant superheat PSH in the low stage-side evaporator 36 at this point drops to or below first refrigerant superheat SH1 (Fig. 7) lower by a predetermined value (for example, 1K) than the target superheat SSH (Fig. 7). In this case, the controller 57 shifts to the control over the degree of opening of the low stage-side expansion valve 34 based on the refrigerant superheat PSH in the low stage-side evaporator 36.

[0123] The control over the degree of opening in this case is also executed by PID control based on the deviation e of the current refrigerant superheat PSH from the target superheat SSH. The controller 57 controls the degree of opening of the low stage-side expansion valve 34 such that the refrigerant superheat PSH reaches the target superheat SSH.

[0124] Assume here that the degree of opening of the low stage-side expansion valve 34 is controlled on the basis of the internal temperature PT and also a plurality of the showcases 2 (2A and 2B) is connected to the low stage-side compressor 21 as in the example. In this case, there is the risk that the flow of refrigerant to the low stage-side evaporator 36 of each showcase 2 (2A, 2B) becomes unbalanced and the liquid floodback to the low stage-side compressor 21 from the low stage-side evaporator 36 where the amount of flow becomes excessive occurs (especially if the capacity of the accumulator 39 is relatively small).

[0125] Moreover, if frost forms on the low stage-side evaporator 36, the heat exchange efficiency is reduced. Hence, if the degree of opening of the low stage-side expansion valve 34 is controlled on the basis of the internal temperature PT, the controller 57 results in controlling such that the low stage-side expansion valve 34 causes more refrigerant to flow into the low stage-side evaporator 36. Hence, the frost that has formed on the low stage-side evaporator 36 tends to grow further. Hence, excessive frost forms on the low stage-side evaporator 36 to degrade the capacity of cooling the inside of the display chamber.

[0126] On the other hand, if, for example, the internal temperature PT increases to or above the third temperature T3 that is higher than the target internal temperature ST, and also the refrigerant superheat PSH in the low stage-side evaporator 36 at this point drops to or below the first refrigerant superheat SH1 that is lower than the target superheat SSH as described above, it can be judged that frost has formed on the low stage-side evaporator 36.

[0127] In the example, if such a condition holds, the controller 57 shifts to the control over the degree of opening of the low stage-side expansion valve 34 based on the refrigerant superheat PSH in the low stage-side evaporator 36. Hence, the controller 57 can accurately deter-

mine that frost has formed on the low stage-side evaporator 36 since the refrigerant superheat PSH in the low stage-side evaporator 36 has dropped although frost has formed on the low stage-side evaporator 36, heat exchange efficiency has been reduced, and the internal temperature PT has increased, under the control over the degree of opening of the low stage-side expansion valve 34 based on the internal temperature PT. The controller 57 can subsequently shift to the control of the low stage-side expansion valve 34 based on the refrigerant superheat PSH and the target superheat SSH in the low stage-side evaporator 36. Consequently, relatively simple control switching makes it possible to suppress the excessive formation of frost on the low stage-side evaporator 36 and a further increase in the internal temperature PT.

[0128] The controller 57 of the showcase 2 (2A, 2B) periodically closes the solenoid valve 37 and/or fully closes the low stage-side expansion valve 34 to run the defrost operation for the low stage-side evaporator 36. In the case of the example, the controller 57 returns to the control over the degree of opening of the low stage-side expansion valve 34 based on the internal temperature PT after the end of the defrost operation of the low stage-side evaporator 36. Consequently, the controller 57 can smoothly return to the state where the degree of opening of the low stage-side expansion valve 34 is controlled on the basis of the internal temperature PT after the low stage-side evaporator 36 is defrosted.

[0129] Moreover, in the example, the present invention is described using a refrigeration apparatus where the high stage-side refrigerant circuit 4 and the low stage-side refrigerant circuits 6A and 6B are cascaded. However, the invention excluding the claim 10 is not limited to this, and is also effective for a refrigeration apparatus including what is called a single-stage refrigerant circuit including only the low stage-side refrigerant circuit 6A (6B) of the example. Furthermore, in the example, the refrigerant circuits (such as the low stage-side refrigerant circuit 6A) that supply refrigerant to the plurality of showcases 2 from one low stage-side compressor 21 is described. However, the invention excluding the claims 8 and 9 is also effective for a refrigeration apparatus including a refrigerant circuit that includes a compressor and an evaporator in a showcase and cools what is called a built-in case to supply the refrigerant from the compressor to the evaporator.

DESCRIPTION OF REFERENCE SIGNS

[0130]

1	Refrigeration apparatus	
2, 2A, 2B	Showcase	
3	Refrigeration machine unit	
4	High stage-side refrigerant circuit	
6A, 6B	Low stage-side refrigerant circuit (refrigerant circuit)	

7	High stage-side compressor	
11A, 11B	High stage-side gas cooler	
13	High stage-side expansion valve	
16A, 16B	High stage-side evaporator	
5 21	Low stage-side compressor (compressor)	
23, 26	Low stage-side gas cooler (radiator)	
28	Supercooling heat exchanger	
31	Pressure control expansion valve	
34	Low stage-side expansion valve (expansion valve)	
10 36	Low stage-side evaporator (evaporator)	
37	Solenoid valve	
39	Accumulator	
48, 57	Controller	

Claims

1. A refrigeration apparatus, including a refrigerant circuit having a compressor, a radiator, an expansion valve, and an evaporator, for cooling an inside of a display chamber of a showcase with the evaporator, the refrigeration apparatus comprising:

internal temperature detection means for detecting an internal temperature being a temperature in the display chamber;

refrigerant inlet temperature detection means for detecting a refrigerant inlet temperature of the evaporator;

refrigerant outlet temperature detection means for detecting a refrigerant outlet temperature of the evaporator; and

a controller for controlling the expansion valve on the basis of outputs of each of the temperature detection means, wherein

the controller calculates refrigerant superheat in the evaporator from the refrigerant outlet temperature and refrigerant inlet temperature of the evaporator, and selectively controls the degree of opening of the expansion valve on the basis of the refrigerant superheat or the internal temperature.

2. The refrigeration apparatus according to claim 1, wherein the controller

upon the internal temperature being equal to or greater than a predetermined first temperature, controls the expansion valve such that the refrigerant superheat in the evaporator reaches predetermined target superheat on the basis of the refrigerant superheat, and

upon the internal temperature dropping below the first temperature, controls the expansion valve such that the internal temperature reaches a predetermined target internal temperature on the basis of the internal temperature.

3. The refrigeration apparatus according to claim 2,
wherein upon the internal temperature increasing to
or above a predetermined second temperature high-
er than the first temperature in a state of controlling
the expansion valve on the basis of the internal tem-
perature, the controller returns to the control of the
expansion valve based on the refrigerant superheat
in the evaporator. 5
4. The refrigeration apparatus according to claim 3, 10
wherein the second temperature is the target internal
temperature.
5. The refrigeration apparatus according to claim 1,
wherein the controller 15
controls the expansion valve such that the internal
temperature reaches a predetermined target internal
temperature on the basis of the internal temperature,
and
upon the internal temperature increasing to or above 20
a predetermined third temperature higher than the
target internal temperature, and the refrigerant su-
perheat in the evaporator dropping to or below pre-
determined first refrigerant superheat, controls the
expansion valve such that the refrigerant superheat 25
in the evaporator reaches predetermined target su-
perheat on the basis of the refrigerant superheat.
6. The refrigeration apparatus according to claim 5,
wherein the controller returns to the control of the 30
expansion valve based on the internal temperature
after the end of defrost operation of the evaporator.
7. The refrigeration apparatus according to any of
claims 1 to 6, wherein the refrigerant circuit includes 35
an accumulator connected to a refrigerant suction
side of the compressor.
8. The refrigeration apparatus according to any of
claims 1 to 7, wherein 40
the refrigerant circuit includes a plurality of series
circuits of the expansion valve and the evaporator,
the plurality of series circuits being connected in par-
allel to each other,
the series circuits are provided respectively to a plu- 45
rality of the showcases, and the compressor supplies
a refrigerant to the evaporators via the expansion
valves, respectively.
9. The refrigeration apparatus according to claim 8, 50
wherein
an on/off valve is provided to an outlet side of each
of the evaporators, and upon the internal tempera-
ture dropping to or below a predetermined fourth
temperature lower than the first temperature, the 55
controller closes the on/off valve.
10. The refrigeration apparatus according to any of

claims 1 to 9, comprising:

a low stage-side refrigerant circuit being the re-
frigerant circuit; and
a high stage-side refrigerant circuit independent
of the low stage-side refrigerant circuit, wherein
an evaporator of the high stage-side refrigerant
circuit cools a high pressure-side refrigerant of
the low stage-side refrigerant circuit.

11. The refrigeration apparatus according to any of
claims 1 to 10, wherein the refrigerant circuit uses
carbon dioxide as the refrigerant.

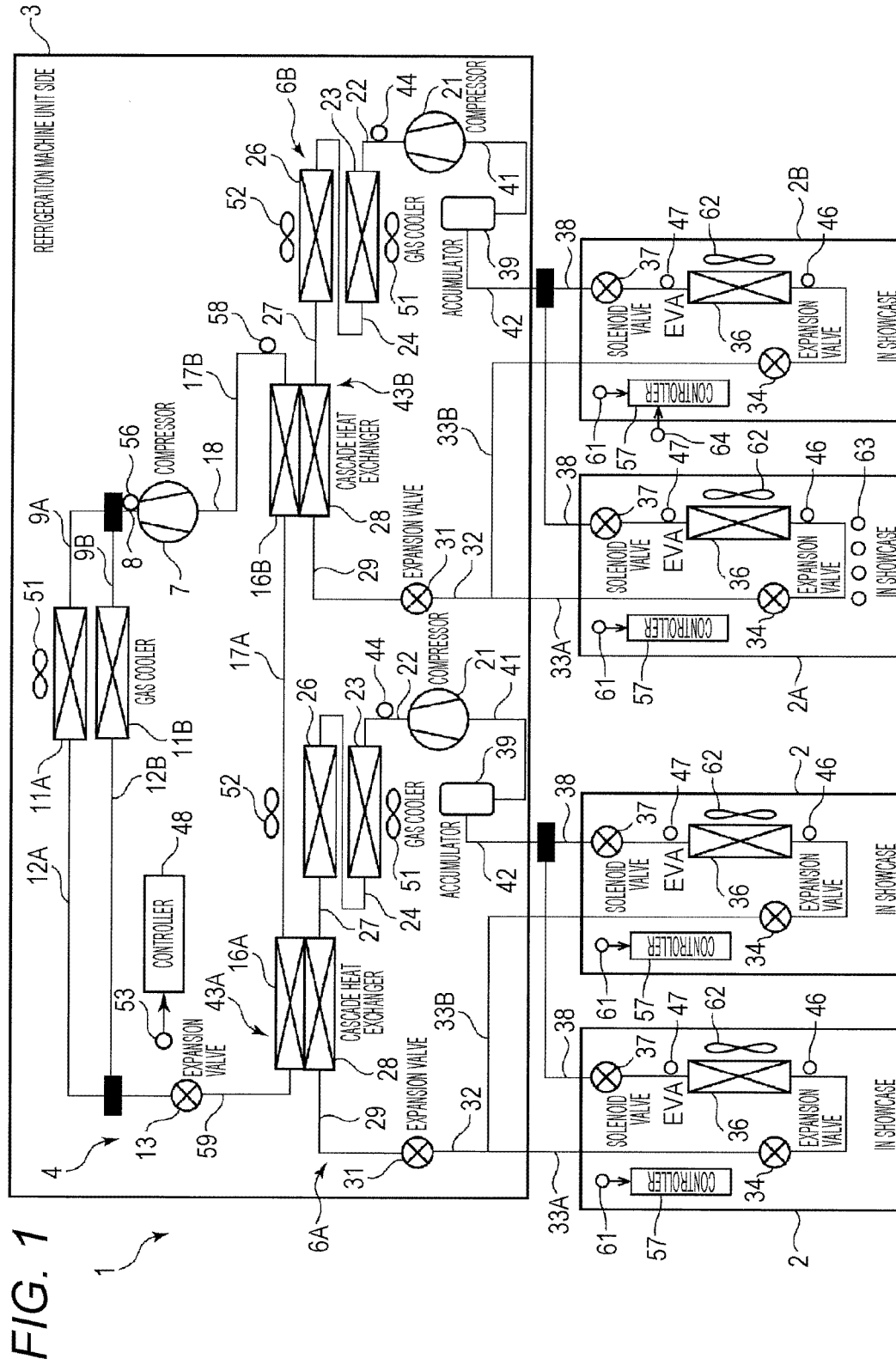


FIG. 2

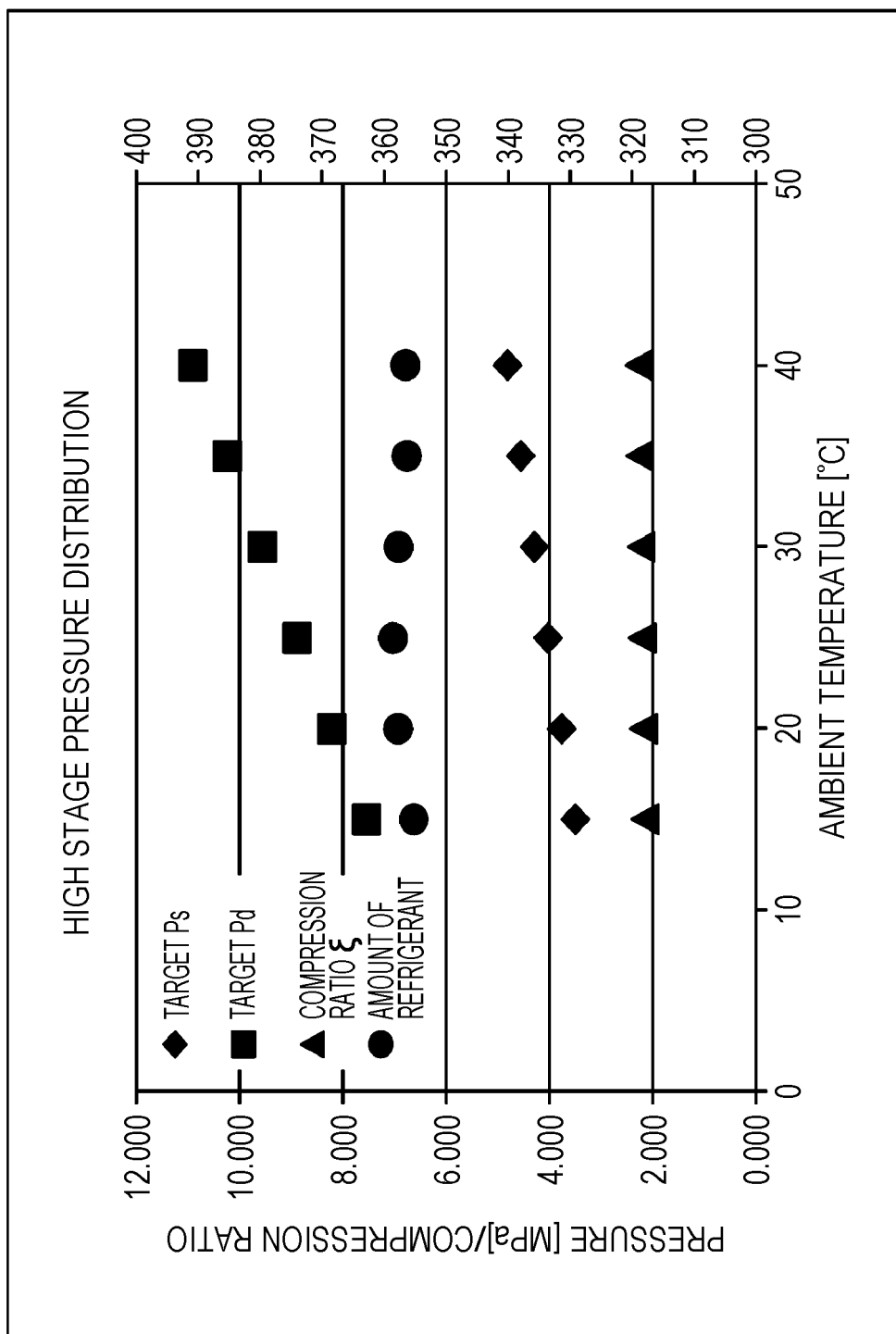


FIG. 3

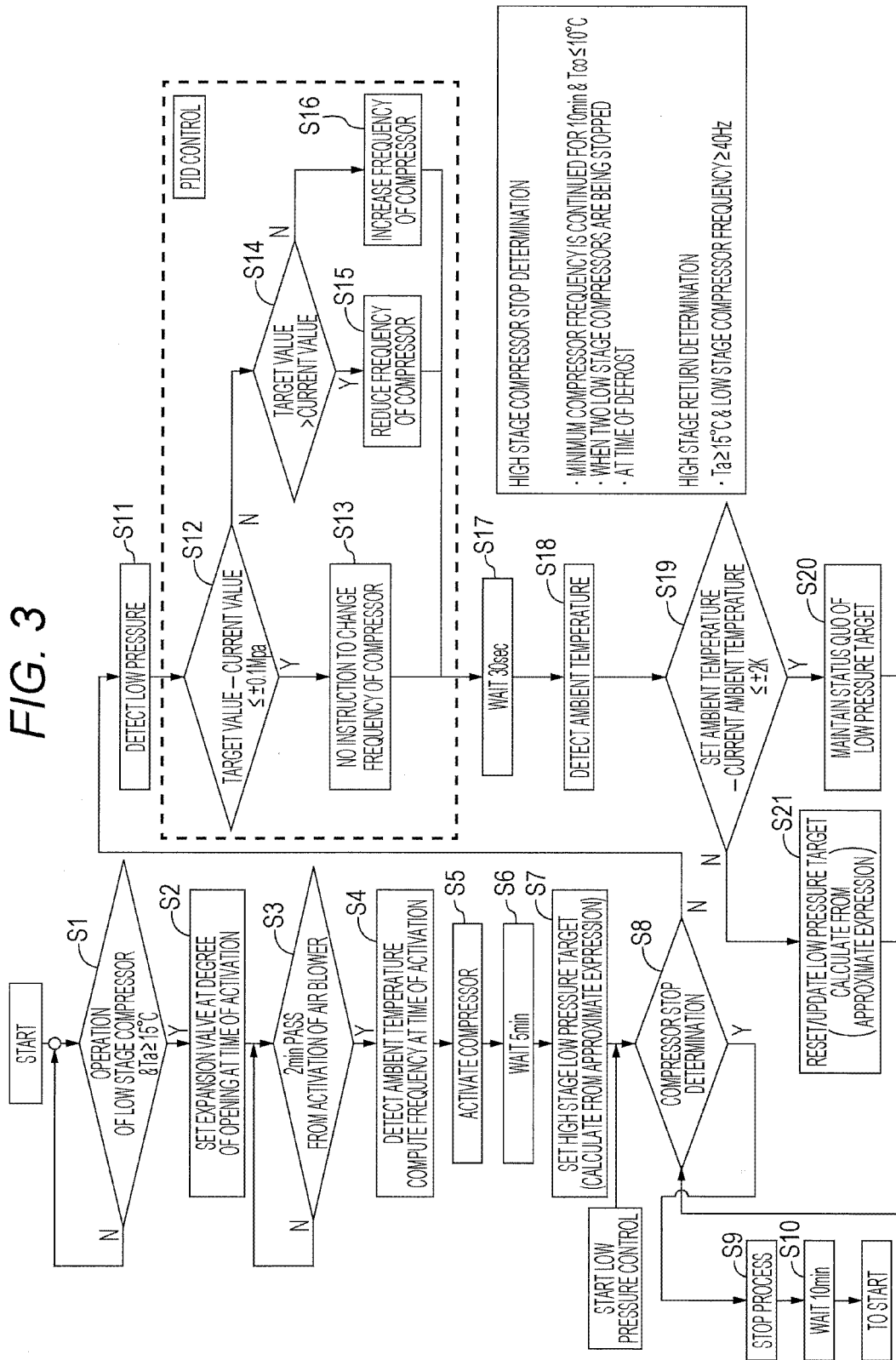


FIG. 4

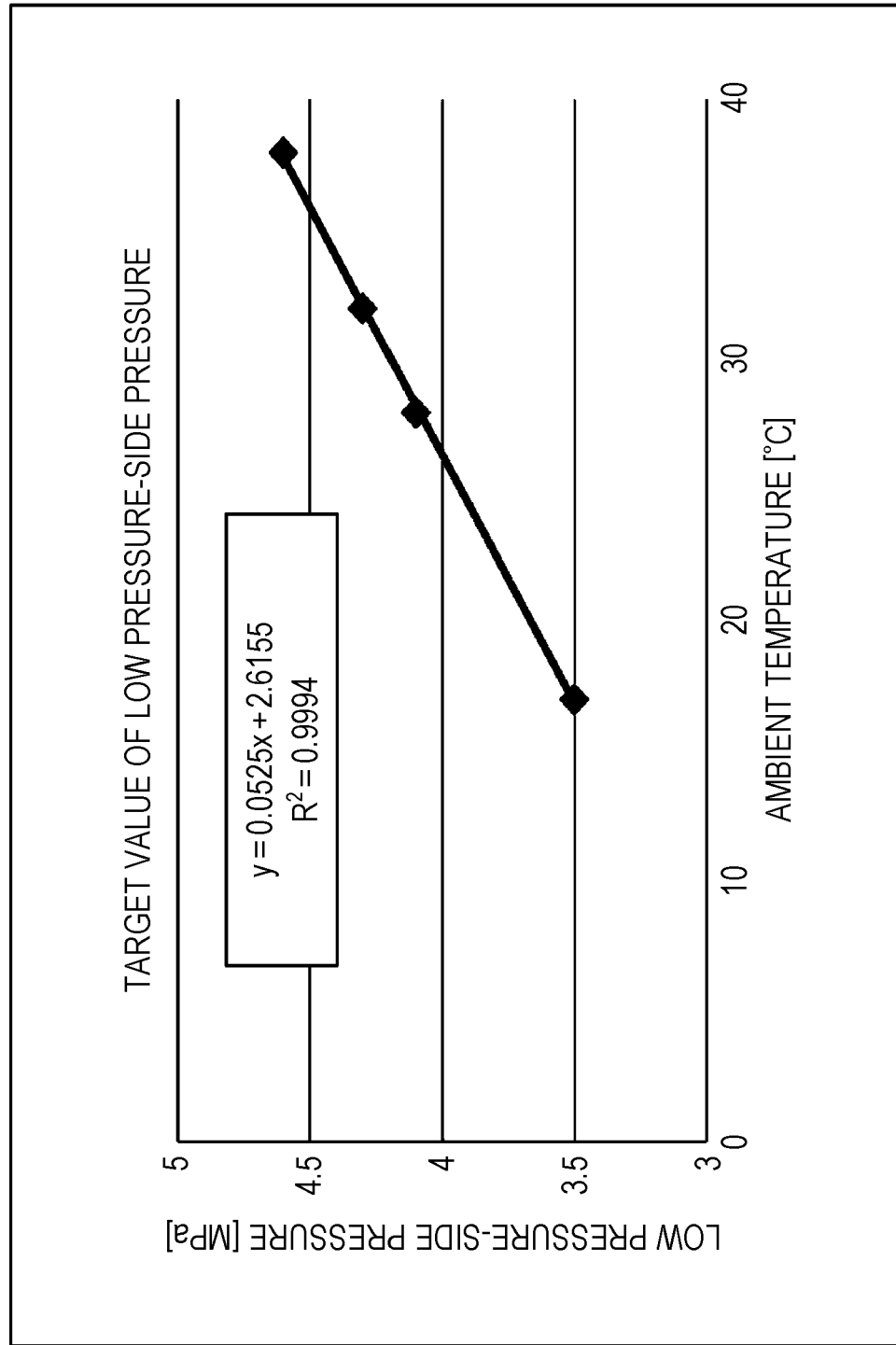


FIG. 5

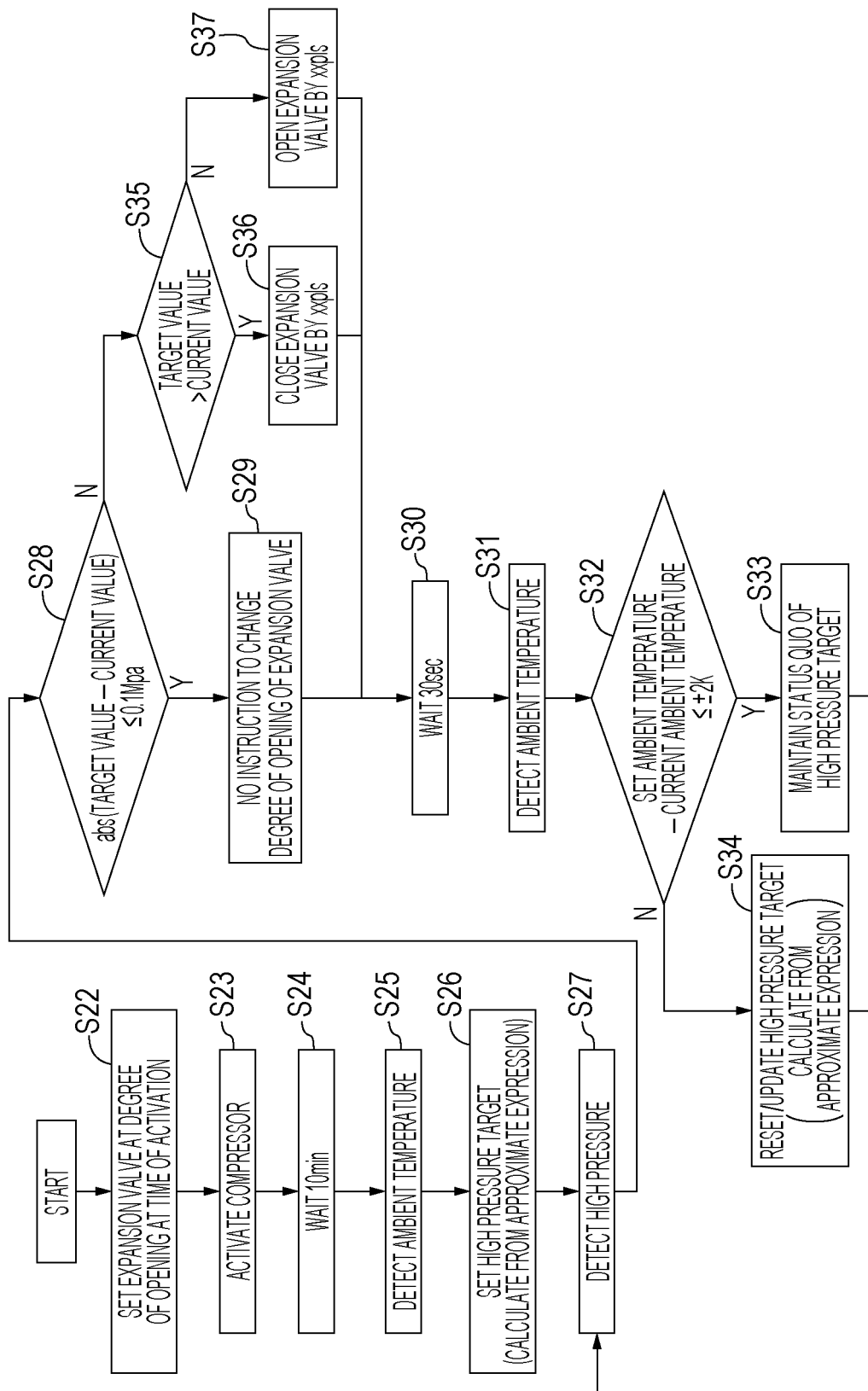


FIG. 6

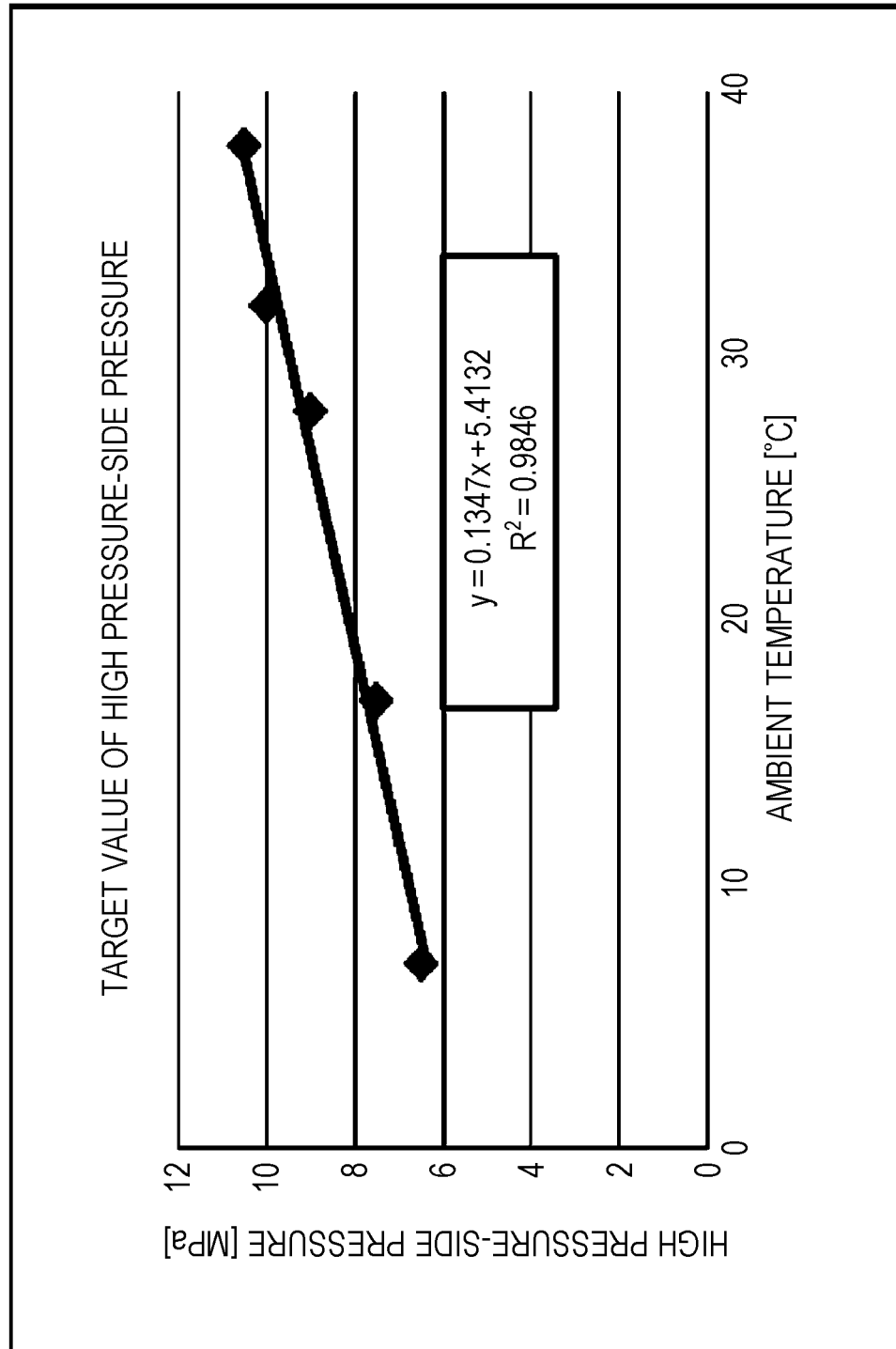


FIG. 7

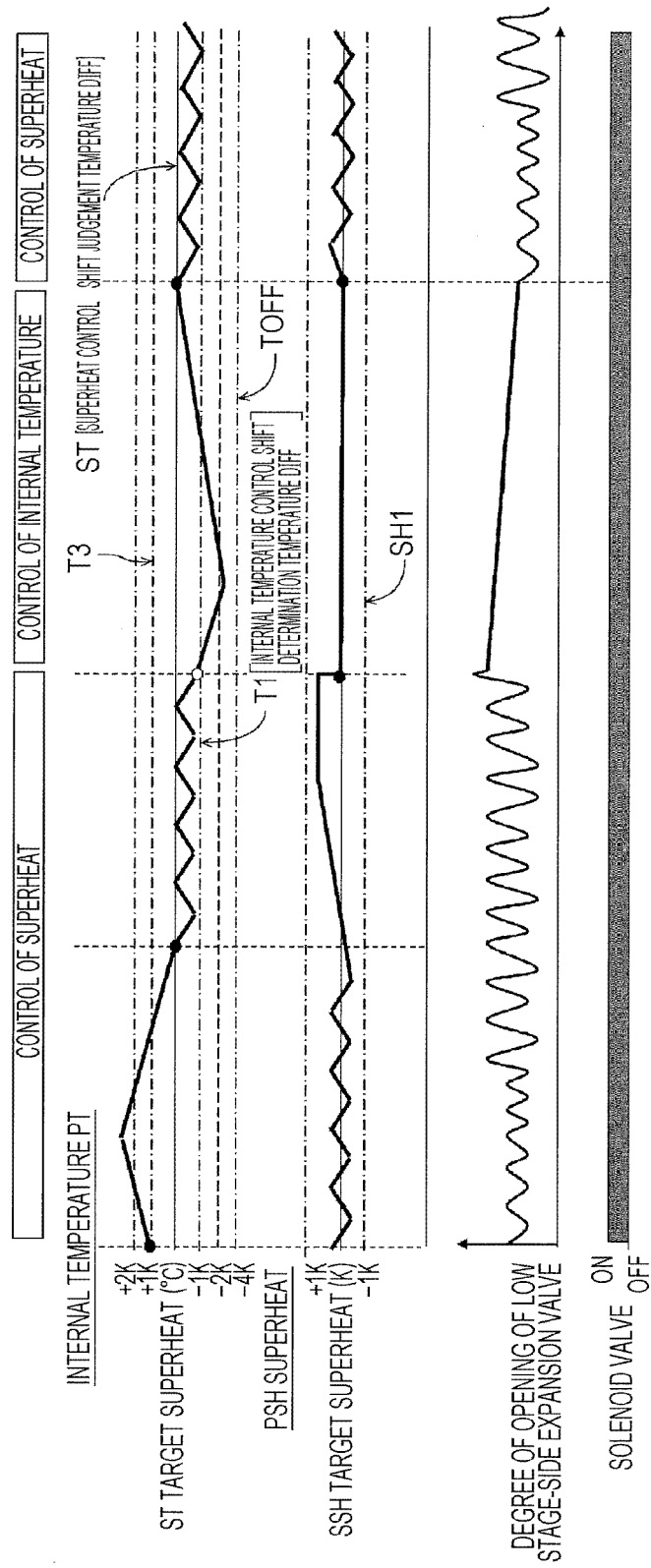


FIG. 8

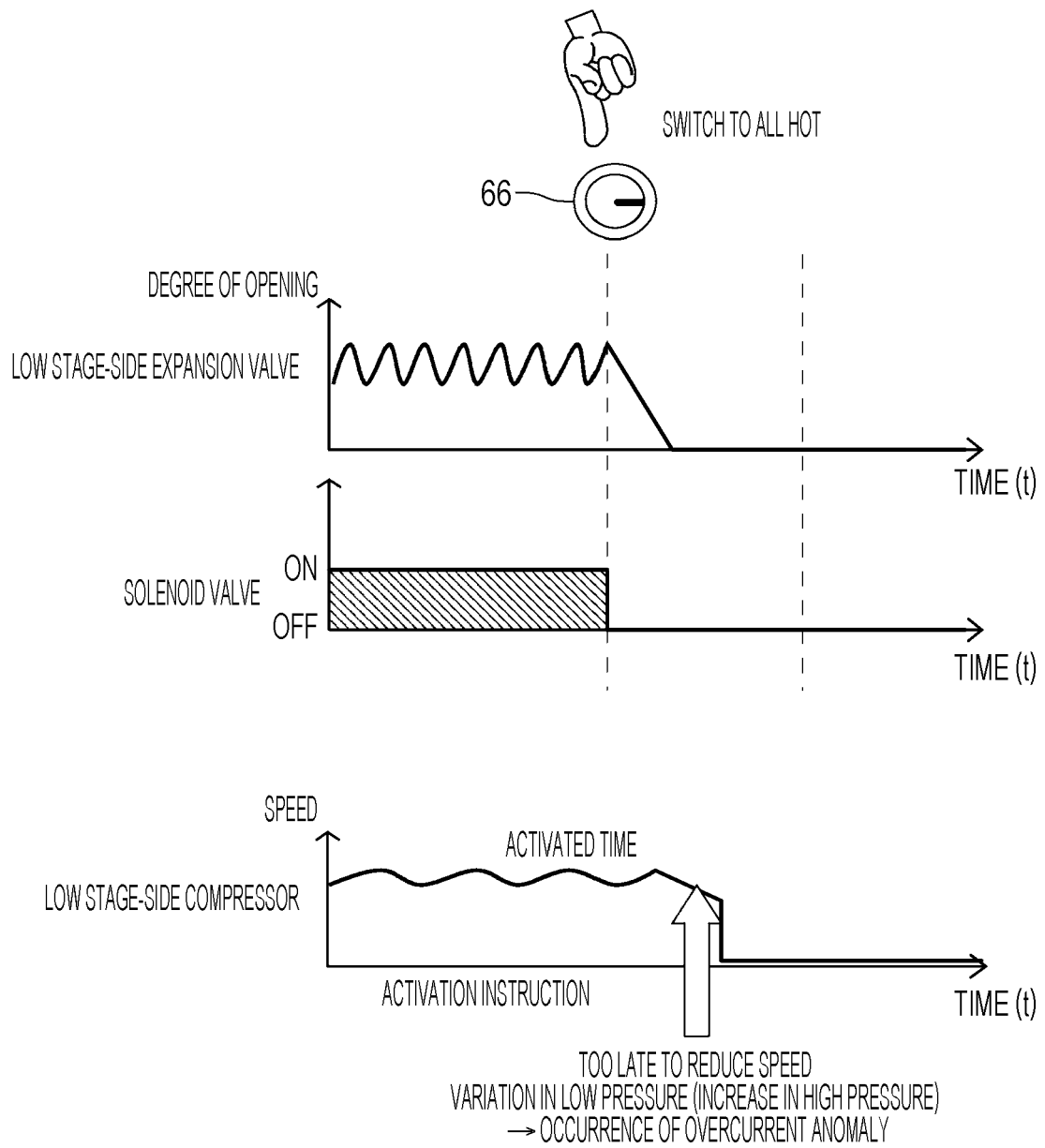


FIG. 9

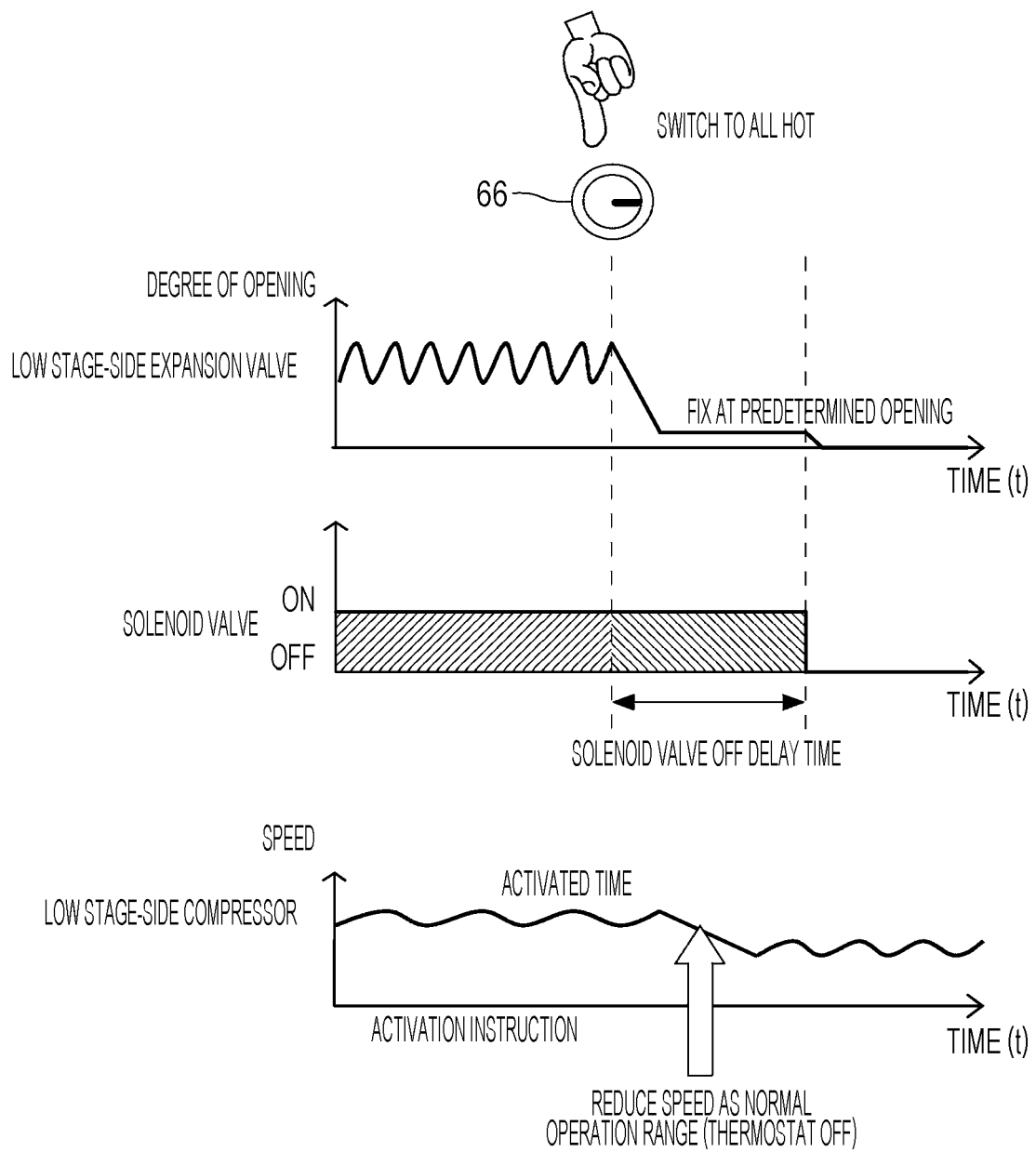


FIG. 10

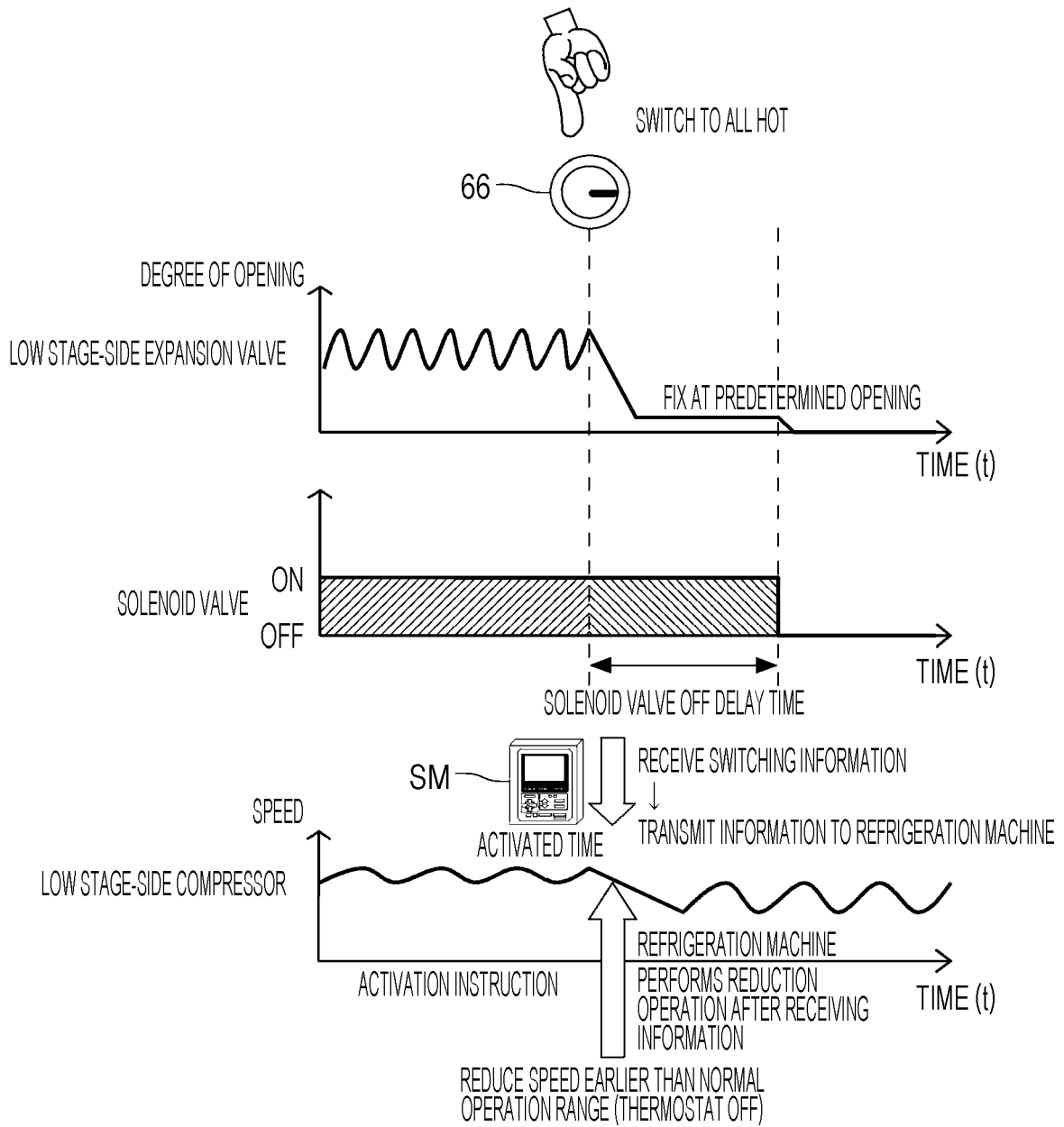


FIG. 11

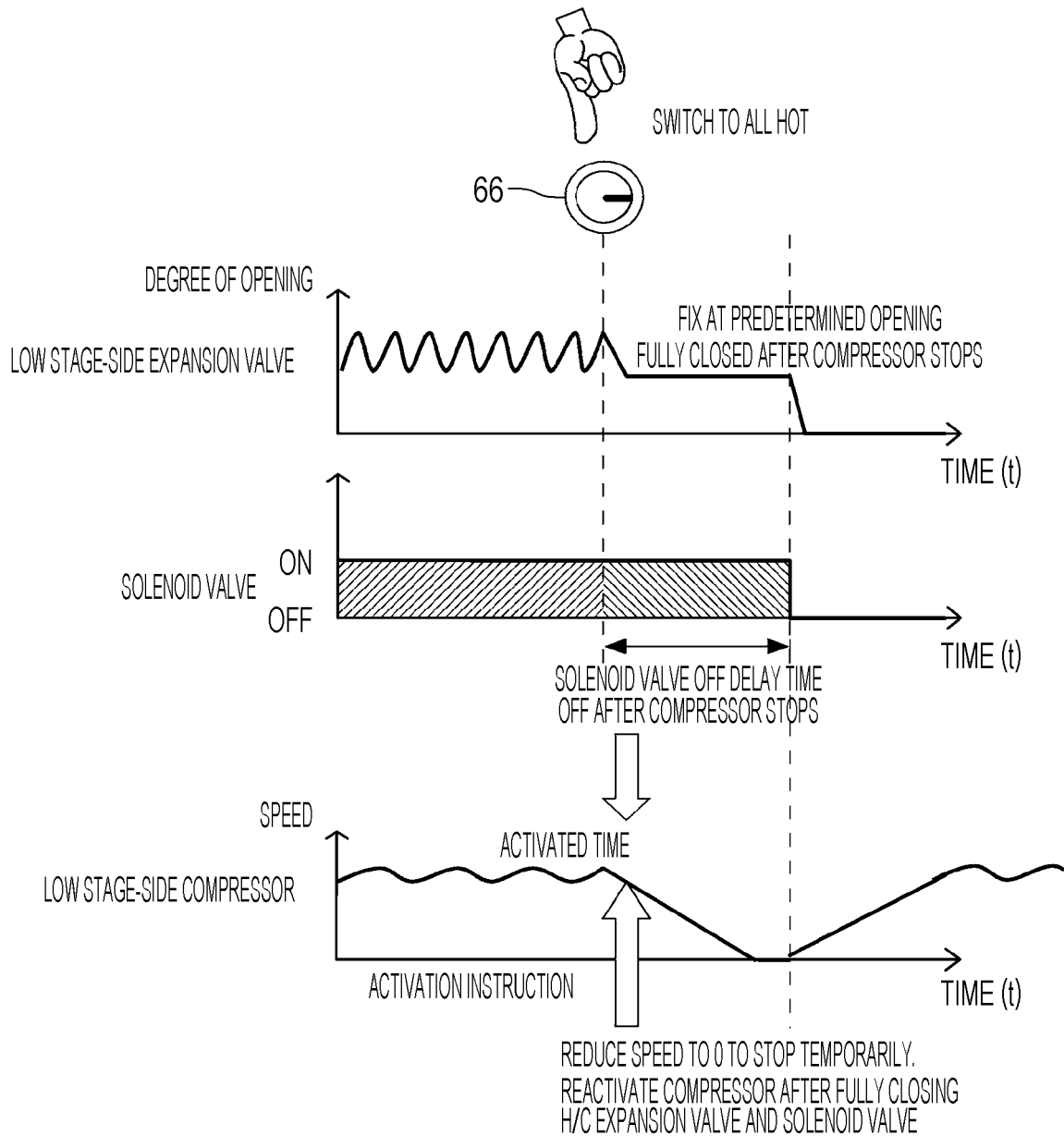


FIG. 12

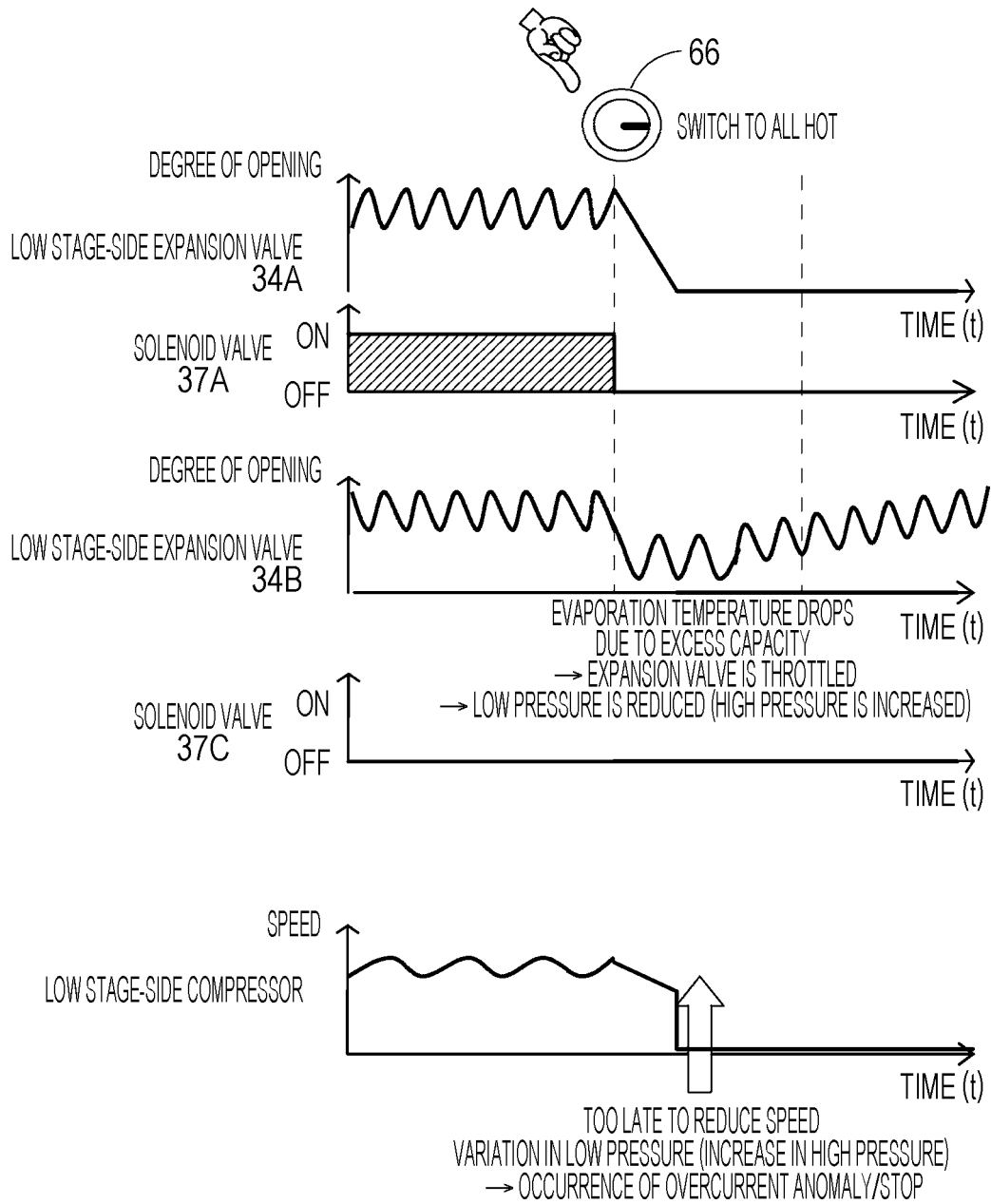


FIG. 13

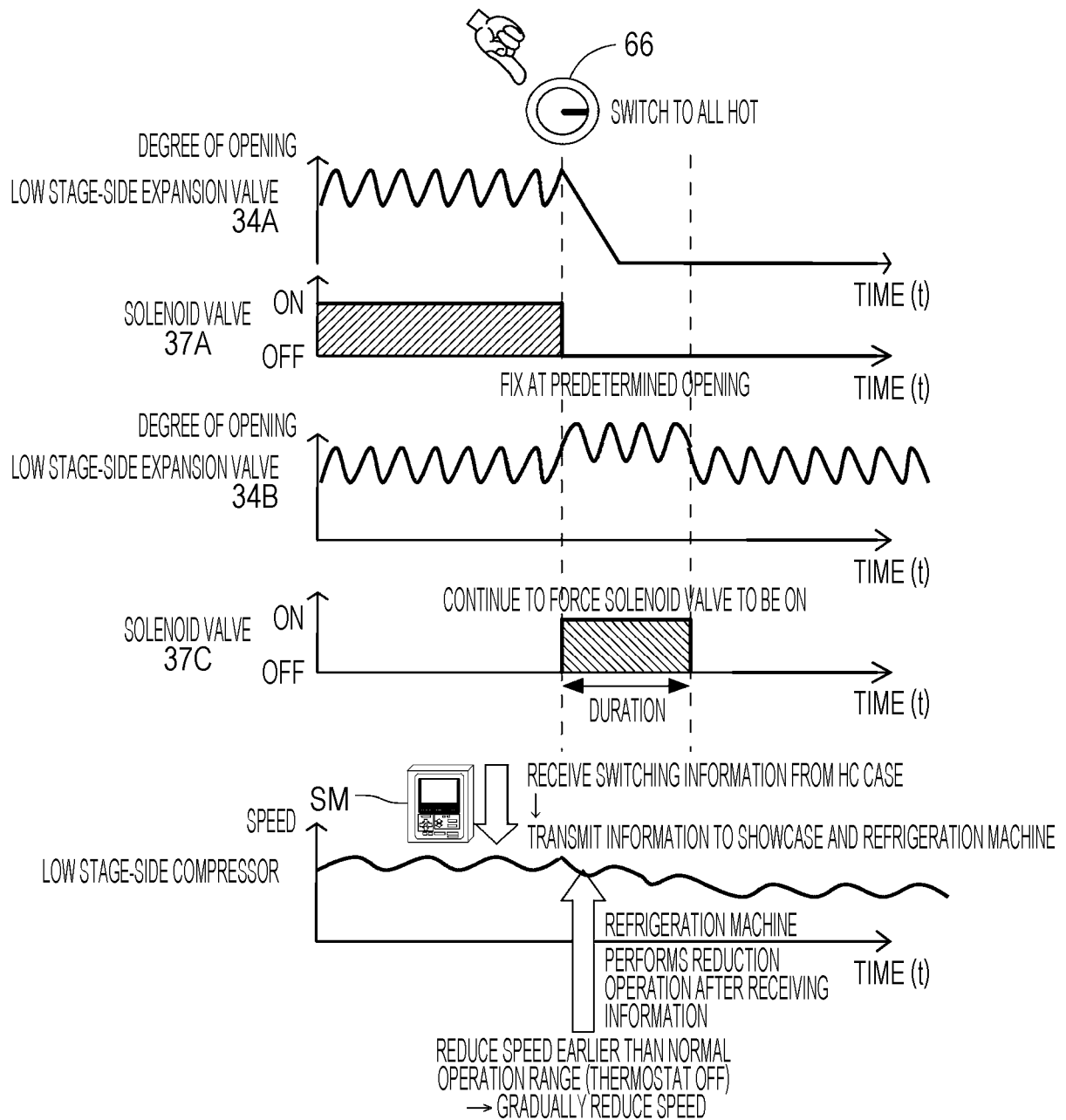


FIG. 14

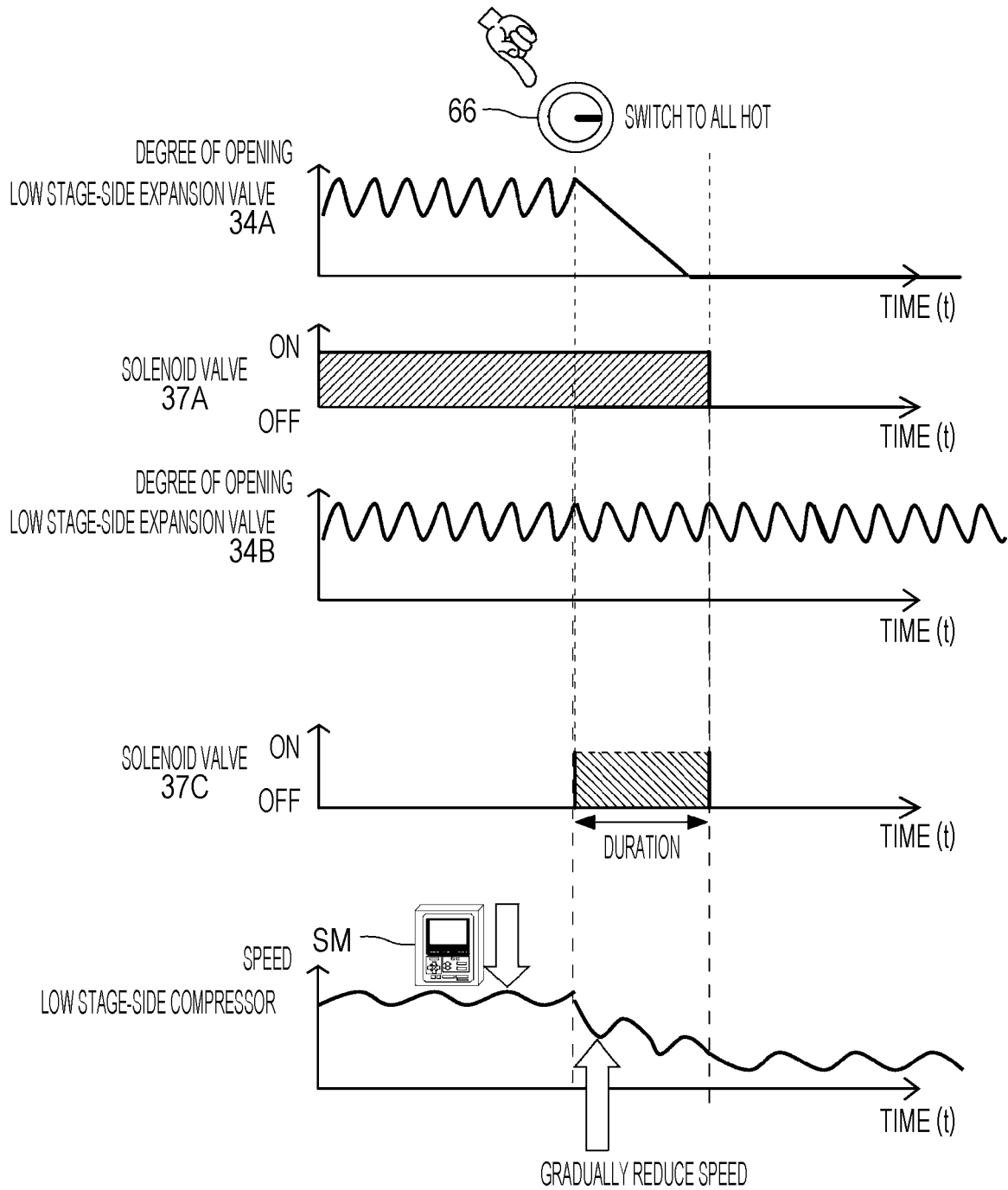
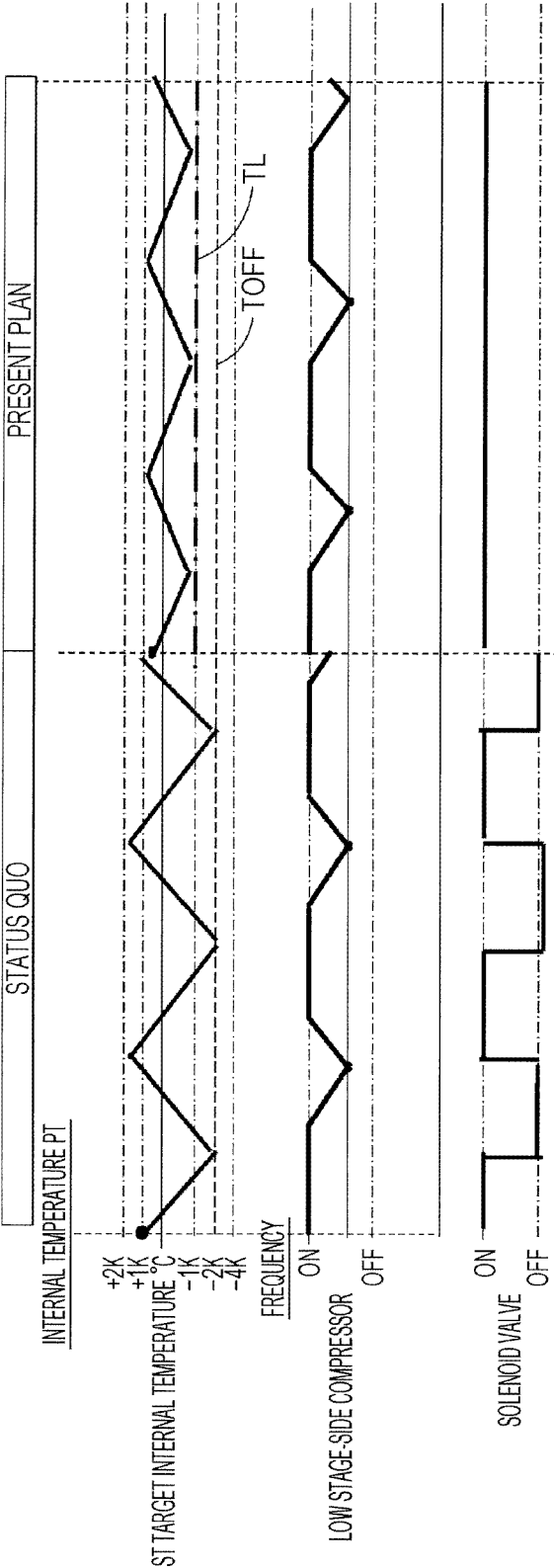


FIG. 15



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/081840

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/00(2006.01)i, A47F3/04(2006.01)i, F25B5/02(2006.01)i, F25B7/00(2006.01)i, F25D11/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00, A47F3/04, F25B5/02, F25B7/00, F25D11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-281221 A (Nihon Kentetsu Co., Ltd.),	1-4
Y	15 October 1999 (15.10.1999),	7-11
A	paragraphs [0014] to [0024]; fig. 1 (Family: none)	5-6
Y	JP 2005-030679 A (Mitsubishi Electric Corp.),	7-11
A	03 February 2005 (03.02.2005),	5-6
	paragraphs [0007] to [0018]; fig. 1 to 4 (Family: none)	
Y	JP 10-205958 A (Toshiba Corp.),	9-11
A	04 August 1998 (04.08.1998),	5-6
	paragraph [0072]; fig. 5 (Family: none)	

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search
26 January 2016 (26.01.16)

Date of mailing of the international search report
09 February 2016 (09.02.16)

Name and mailing address of the ISA/
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3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2010-255993 A (Okamura Corp.), 11 November 2010 (11.11.2010), paragraphs [0012] to [0017]; fig. 1 to 2 (Family: none)	10-11 5-6

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Patent documents cited in the description

- JP 2001091074 A [0006]
- JP 2000205672 A [0006]
- JP 11281222 A [0006]