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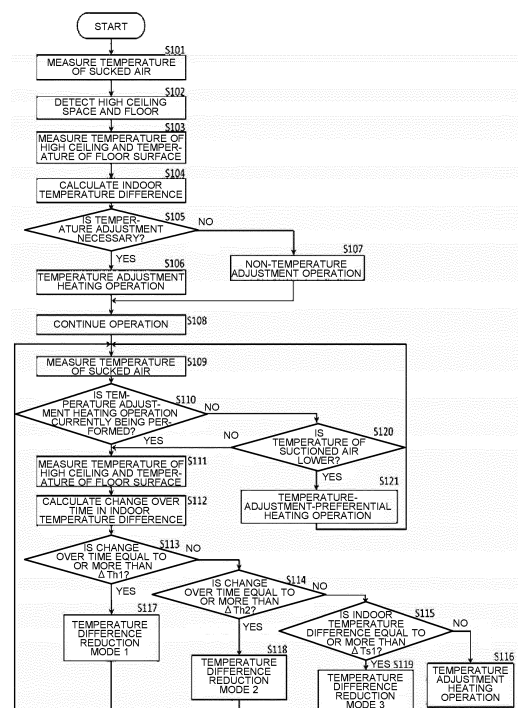
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(54) **AIR-CONDITIONING SYSTEM**

(57) An air-conditioning system according to the present disclosure includes an indoor unit, a distance measurement unit, a high ceiling detection unit, a floor detection unit, a temperature measurement unit, a temperature difference calculation unit configured to calculate a temperature difference between a temperature of a high ceiling space and a surface temperature of a floor, and a controller configured to perform control of generating a first air flow according to a predetermined operating condition in a case where the temperature difference calculated by the temperature difference calculation unit is less than a first threshold, and to perform control of generating a second air flow in a case where the temperature difference is equal to or more than the first threshold, the second air flow satisfying at least either one of a condition that the second air flow has a lower temperature than the first air flow or a condition that the second air flow has a larger velocity component in a vertical direction than the first air flow.

FIG. 8



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Description

Technical Field

[0001] The present disclosure relates to an air-conditioning system.

Background Art

[0002] Patent Literature 1 describes an air-conditioning apparatus that detects the height of a ceiling, the presence of lighting fixtures attached to the ceiling or lintels, and controls an air flow to avoid the lighting fixtures or lintels, thus efficiently performing air-conditioning for the room.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2012-52680

Summary of Invention

Technical Problem

[0004] Recently, to increase a sense of openness in a room or to install a daylighting window, there are an increasing number of cases where a high ceiling is provided by partially increasing the height of a ceiling surface. In such a room, even when a heating operation is performed in winter, warm air concentrates in the vicinity of the high ceiling, so that there may be a case where a space where a person lives is not heated as intended. As a result, a problem occurs, such as a reduction in comfort of a person or waste of energy. To solve the above-mentioned problem, it is necessary to detect the presence or absence and the position of the high ceiling and, in the case where warm air concentrates in the vicinity of the high ceiling, it is necessary to guide the warm air to the space where the person lives. The air-conditioning apparatus described in Patent Literature 1 can detect a lighting fixture attached to a ceiling surface or a lintel and can generate an air flow that avoids these obstacles. However, the air-conditioning apparatus described in Patent Literature 1 fails to take into account a method for performing air-conditioning when a high ceiling is detected and a temperature difference is generated between an area in the vicinity of the high ceiling and a space where a person lives.

[0005] The present disclosure has been made to solve the above-mentioned problem. It is an object of the present disclosure to provide an air-conditioning system that can surely detect the presence of a high ceiling in a room provided with the high ceiling obtained by partially increasing the height of a ceiling, and that can eliminate a temperature difference between the high ceiling space

and a space where a person lives in the case where the above-mentioned temperature difference is generated.

Solution to Problem

[0006] An air-conditioning system according to an embodiment of the present disclosure includes: an indoor unit; a distance measurement unit configured to measure a distance from the indoor unit to a ceiling and a distance from the indoor unit to a floor; a high ceiling detection unit configured to detect, in a case where a room has a plurality of ceilings having different heights, a high ceiling space based on the distance from the indoor unit to the ceiling measured by the distance measurement unit, the high ceiling space being disposed at a position higher than a ceiling having a lowest height of the plurality of ceilings; a floor detection unit configured to detect the floor based on the distance from the indoor unit to the floor measured by the distance measurement unit and a distance from the indoor unit to a wall measured by the distance measurement unit; a temperature measurement unit configured to measure a temperature of the high ceiling space and a surface temperature of the floor; a temperature difference calculation unit configured to calculate a temperature difference between the temperature of the high ceiling space detected by the temperature measurement unit and the surface temperature of the floor detected by the temperature measurement unit; and a controller configured to perform control of generating a first air flow according to a predetermined operating condition in a case where the temperature difference calculated by the temperature difference calculation unit is less than a first threshold, and to perform control of generating a second air flow in a case where the temperature difference is equal to or more than the first threshold, the second air flow satisfying at least either one of a condition that the second air flow has a lower temperature than the first air flow or a condition that the second air flow has a larger velocity component in a vertical direction than the first air flow.

Advantageous Effects of Invention

[0007] In the case where the air-conditioning system of the embodiment of the present disclosure detects the presence of a high ceiling in the room and a difference is generated between the temperature of air in the vicinity of the high ceiling and the temperature of air in the vicinity of floor, the air-conditioning system causes the air in the vicinity of the high ceiling to be mixed with the air in the vicinity of the floor to eliminate the above-mentioned temperature difference. Accordingly, it is possible to achieve an increase in comfort of a person in the room and energy saving.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a diagram showing the configuration

of an air-conditioning system of Embodiment 1.

[Fig. 2] Fig. 2 is a diagram of a room in which an indoor unit in Embodiment 1 is installed.

[Fig. 3] Fig. 3 is a diagram showing the structure of the indoor unit in Embodiment 1.

[Fig. 4] Fig. 4 is a diagram showing the function of a wind direction adjustment unit in Embodiment 1.

[Fig. 5] Fig. 5 is a diagram showing the structure of a distance measurement unit in Embodiment 1.

[Fig. 6] Fig. 6 is a diagram showing the configuration of a controller in Embodiment 1.

[Fig. 7] Fig. 7 is a diagram showing measurement results from the distance measurement unit in Embodiment 1.

[Fig. 8] Fig. 8 is a flowchart showing the example of the action of the air-conditioning system of Embodiment 1.

[Fig. 9] Fig. 9 is a diagram showing conditions for implementing a temperature difference reduction mode in Embodiment 1.

[Fig. 10] Fig. 10 is a diagram showing details of the conditions for implementing the temperature difference reduction mode in Embodiment 1.

[Fig. 11] Fig. 11 is a diagram showing control targets and change values in operation modes in Embodiment 1.

[Fig. 12] Fig. 12 is a diagram showing the function of the temperature difference reduction mode in Embodiment 1.

[Fig. 13] Fig. 13 is a diagram showing another function of the temperature difference reduction mode in Embodiment 1.

[Fig. 14] Fig. 14 is a diagram showing the configuration of a controller in Embodiment 2.

[Fig. 15] Fig. 15 is a flowchart showing the example of the action of an air-conditioning system of Embodiment 2.

[Fig. 16] Fig. 16 is a diagram showing control targets and change values in operation modes in Embodiment 2.

[Fig. 17] Fig. 17 is a diagram showing the configuration of a controller in Embodiment 3.

[Fig. 18] Fig. 18 is a flowchart showing the example of the action of an air-conditioning system of Embodiment 3.

Description of Embodiments

[0009] Hereinafter, modes for carrying out the present disclosure will be described with reference to attached drawings. In the drawings, the same reference symbols denote identical or corresponding components, and the repeated description of such components is simplified or omitted when appropriate. The present disclosure is not limited to the following embodiments, and includes various modifications of the configurations of the following embodiments without departing from the gist of the present disclosure.

Embodiment 1

[0010] Fig. 1 is a diagram showing the configuration of an air-conditioning system 1000 in the present embodiment. The air-conditioning system 1000 is what is called a heat pump type air-conditioning system of a separate type. As shown in Fig. 1, the air-conditioning system 1000 includes an indoor unit 100, an outdoor unit 101, and a terminal 70 that allows a person to operate the air-conditioning system 1000. The indoor unit 100 and the outdoor unit 101 are connected with each other via pipes, such as copper pipes, thus forming a refrigerant circuit. For example, hydrofluorocarbons (HFC refrigerants), such as R32 (difluoromethane), or natural refrigerants, such as R290 (propane), cycle through the refrigerant circuit. In the present embodiment, the kind of refrigerant that flows through the refrigerant circuit is not particularly limited. Hereinafter, the structures and the functions of each constitutional element of the air-conditioning system 1000 will be described mainly for a heating operation that easily generates a difference between the temperature of air in a high ceiling space 300 and the temperature of air in the vicinity of a floor 206.

[0011] The outdoor unit 101 includes a compressor 1, an outdoor heat exchanger 2, an outdoor air sending unit 3, and an expansion valve 4, the compressor 1 compressing refrigerant, the outdoor heat exchanger 2 exchanging heat between outside air and the refrigerant, the outdoor air sending unit 3 sending outside air to the outdoor heat exchanger 2, the opening degree of the expansion valve 4 being variable. The compressor 1 and the outdoor heat exchanger 2 are connected with each other via a copper pipe or the like, and the outdoor heat exchanger 2 and the expansion valve 4 are connected with each other via a copper pipe or the like. The outdoor unit 101 also includes a controller 50. As will be described later, the controller 50 includes a high ceiling detection unit 51, a floor detection unit 52, a temperature difference calculation unit 53, a storage unit 54, and an operation control unit 55.

[0012] The indoor unit 100 includes an indoor heat exchanger 5, an indoor air sending unit 6, and a wind direction adjustment unit 7, the indoor heat exchanger 5 exchanging heat between indoor air and refrigerant, the indoor air sending unit 6 sending indoor air to the indoor heat exchanger 5, the wind direction adjustment unit 7 adjusting the direction of air flow blown out from the indoor unit. The indoor heat exchanger 5 is connected with the compressor 1 and the expansion valve 4 of the outdoor unit 101 via copper pipes or the like. The indoor unit 100 also includes a distance measurement unit 10, a temperature measurement unit 11, and a sucked air temperature measurement unit 12, the distance measurement unit 10 performing distance measurement in a room, the temperature measurement unit 11 measuring temperature distribution in the room, the sucked air temperature measurement unit 12 measuring the temperature of air sucked into the indoor unit 100. The indoor air

sending unit 6, the wind direction adjustment unit 7, the distance measurement unit 10, the temperature measurement unit 11, and the sucked air temperature measurement unit 12 are controlled by the controller 50.

[0013] The compressor 1 may be a scroll compressor, a rotary compressor, or a device that compresses refrigerant by another method, for example. The compressor 1 compresses refrigerant vapor at low pressure that flows into the compressor 1, and the compressor 1 then discharges refrigerant vapor at high temperature and high pressure. The refrigerant vapor discharged by the compressor 1 flows into the indoor heat exchanger 5 of the indoor unit 100.

[0014] The indoor heat exchanger 5 causes heat change to be performed between indoor air and refrigerant. During the heating operation, the indoor heat exchanger 5 serves as a condenser. The refrigerant vapor at high temperature and high pressure that flows into the indoor heat exchanger 5 is condensed, thus being changed into liquid refrigerant at high pressure. The liquid refrigerant that flows out from the indoor heat exchanger 5 flows into the expansion valve 4.

[0015] The expansion valve 4 is a pressure reducing device that can continuously change an opening degree thereof. The expansion valve 4 reduces the pressure of the liquid refrigerant that flows into the expansion valve 4 from the indoor heat exchanger 5, thus changing the liquid refrigerant into two-phase vapor-liquid refrigerant at low pressure and low temperature. The two-phase refrigerant that flows out from the expansion valve 4 flows into the outdoor heat exchanger 2.

[0016] The outdoor heat exchanger 2 exchanges heat between outside air and refrigerant. During the heating operation, the outdoor heat exchanger 2 serves as an evaporator. The two-phase refrigerant at low temperature and low pressure that flows into the outdoor heat exchanger 2 evaporates, thus being changed into refrigerant vapor at low pressure. The refrigerant vapor that flows out from the outdoor heat exchanger 2 flows into the compressor 1.

[0017] The compressor 1 changes the refrigerant vapor at low pressure that flows into the compressor 1 into refrigerant vapor at high temperature and high pressure again, and discharges the refrigerant vapor at high temperature and high pressure to the indoor heat exchanger 5. Refrigerant cycles between the indoor unit 100 and the outdoor unit 101 in this manner. That is, when the air-conditioning system 1000 performs the heating operation, refrigerant passes and cycles through the compressor 1, the indoor heat exchanger 5, the expansion valve 4, and the outdoor heat exchanger 2 in this order.

[0018] The outdoor air sending unit 3 may be a propeller fan, for example. The outdoor air sending unit 3 is disposed in the vicinity of the outdoor heat exchanger 2. When the outdoor air sending unit 2 is activated, outside air is sucked into the outdoor unit 101 and passes through the outdoor heat exchanger 2 and, thereafter, is blown out from the outdoor unit 101.

[0019] The terminal 70 is a remote operation terminal that allows a person to operate the air-conditioning system 1000. The terminal 70 may be a remote control, a smartphone, a wearable terminal, or a smart speaker, for example. The terminal 70 receives information on target temperature, wind direction settings, time reservation and the like inputted by a person, and transmits signals for controlling the air-conditioning system 1000 to an operation control section 55.

[0020] Fig. 2(a) and Fig. 2(b) are diagrams showing examples of an air-conditioned room, the indoor unit 100 being installed in the room. Fig. 2(a) and Fig. 2(b) show rooms having the same shape, and each room is a space surrounded by walls 200, 202, 204 and 205, ceilings 201 and 203, and the floor 206. In Embodiment 1, the ceiling 201 and the ceiling 203 have different heights, and the ceiling 201 is lower than the ceiling 203. A line 207 is an extension obtained by horizontally extending the ceiling 201. In the present embodiment, a space surrounded by the wall 202, the ceiling 203, the wall 204, and the line 207 is defined as the high ceiling space 300. The high ceiling space 300 is not a space where a person actually lives, but is a space provided for increasing a sense of openness in the room or for installing a daylighting window. The high ceiling space 300 is not a space where a person lives and hence, it is not necessary to air-condition the high ceiling space 300. However, in the case where the air-conditioning system 1000 is activated for the heating operation, low density warm air tends to stagnate in the high ceiling space 300. A space surrounded by the wall 200, the ceiling 201, the line 207, the wall 205, and the floor 206 is defined as a living space 301.

[0021] In Fig. 2(a), the indoor unit 100 is installed on the wall 200. Dotted lines L30 and L40 are lines showing arrival routes of an ultrasonic wave when the angle of the distance measurement unit 10, which will be described later, in the vertical direction is set to 30 degrees and 40 degrees in the upward direction. In the same manner, dotted lines L-60, L-30, and L-20 are lines showing arrival routes of an ultrasonic wave when the angle of the distance measurement unit 10, which will be described later, in the vertical direction is set to 60 degrees, 30 degrees, and 20 degrees in the downward direction.

[0022] In the present disclosure, a position where the indoor unit 100 is installed is not particularly limited. The indoor unit 100 is installed on the wall 200 in Fig. 2(a). However, the indoor unit 100 may be installed on the wall 205 as shown in Fig. 2(b). In this case, the example shown in Fig. 2(a) and the example shown in Fig. 2(b) differ from each other in a relative position between the high ceiling space 300 and the indoor unit 100. The indoor unit 100 may be a wall concealed indoor unit that is concealed in a wall surface as shown in Fig. 2(c), or may be a floor-mounted indoor unit that is mounted on the floor 206. In the case of the wall concealed indoor unit or the floor-mounted indoor unit, an air outlet is often formed on the front surface of the housing of the indoor unit, and there may also be a case where an air flow can be blown

out from the air outlet of the indoor unit in the upward direction. Also in such a case, the same structure and action of the air-conditioning system 1000, which will be described below, are adopted.

[0023] In the present disclosure, the use purpose of an indoor space is not particularly limited provided that the high ceiling space 300 as described above is present. A room where the indoor unit 100 is installed may be a residential living room, an office, or a factory, for example. A desired wall or ceiling may have a window, a door, or a ventilating opening, for example.

[0024] Fig. 3 is a diagram showing the structure of the indoor unit 100 in the present embodiment. The indoor unit 100 includes a housing 30. The housing 30 has an air inlet 31 and an air outlet 32. The sucked air temperature measurement unit 12 is attached to the air inlet 31. The sucked air temperature measurement unit 12 may be a thermistor, for example. The wind direction adjustment unit 7 is attached to the air outlet 32. The indoor heat exchanger 5 and the indoor air sending unit 6 are housed in the housing 30. The distance measurement unit 10 and the temperature measurement unit 11 are attached to the right lower portion of the housing 30. A position where the distance measurement unit 10 and the temperature measurement unit 11 are attached is not limited to the above-mentioned right lower portion of the housing. The distance measurement unit 10 and the temperature measurement unit 11 may be attached to a desired position of the housing 30 or may be concealed in the housing 30, for example.

[0025] The indoor air sending unit 6 may be a cross flow fan, for example. The indoor air sending unit 6 is disposed in the vicinity of the indoor heat exchanger 5. When the indoor air sending unit 6 is activated, indoor air is sucked into the indoor unit 100 from the air inlet 31 and passes through the indoor heat exchanger 5 and, thereafter, is blown into the room from the air outlet 32. The indoor air sending unit 6 may be a propeller fan or a sirocco fan, and may be formed by arranging a plurality of propeller fans or a plurality of sirocco fans.

[0026] The wind direction adjustment unit 7 includes plate-like flaps and vanes, for example. In Fig. 3, the wind direction adjustment unit 7 includes flaps 7a, 7b, 7c, and 7d and vanes 7e and 7f. Each of the flaps 7a, 7b, 7c, and 7d has an independent rotating mechanism. When the flaps 7a, 7b, 7c, and 7d rotate to change the angle of the flaps 7a, 7b, 7c, and 7d, the direction of an air flow blown out from the indoor unit 100 changes in the vertical direction. In the same manner, each of the vanes 7e and 7f has an independent rotating mechanism. When the vanes 7e and 7f rotate to change the angle of the vanes 7e and 7f, the direction of an air flow blown out from the indoor unit 100 changes in the lateral direction.

[0027] Fig. 4 is a diagram showing a change in angle of the flaps 7a, 7b, 7c, and 7d. As shown in Fig. 4, the flaps 7a, 7b, 7c, and 7d are controlled to be at any one of five levels including "vertical wind direction 1", which is the horizontal direction, to "vertical wind direction 5",

which is the downward vertical direction. For example, when the level drops from "vertical wind direction 3" by one level, the flaps 7a, 7b, 7c, and 7d are controlled to be in "vertical wind direction 4". With such an operation, the direction of the air flow blown out from the indoor unit 100 changes in the vertical direction. In Fig. 4, a change in angle of the flaps 7a, 7b, 7c, and 7d is shown for five levels. However, a change in angle is not limited to the five levels, and may be greater than or less than the five levels. Although not shown in the drawing, the angle of the vanes 7e and 7f also changes in the lateral direction in the same manner.

[0028] In the indoor unit 100 having the above-mentioned configuration, when the indoor air sending unit 6 is activated, indoor air is sucked from the air inlet 31, and the air is heated by the indoor heat exchanger 5. The heated air is blown out from the air outlet 32, and the wind direction of the air is adjusted by the wind direction adjustment unit 7. With such operations, the temperature of indoor air is adjusted, so that air is conditioned by the heating operation.

[0029] The positions of the air inlet 31 and the positions of the air outlet 32 are not limited to positions in examples shown in Fig. 3. For example, the air inlet 31 may be formed at the lower portion or the side portion of the housing 30. In the same manner, the air outlet 32 may be formed at the upper portion or the side portion of the housing 30. Further, the shape and the number of air inlets 31 and air outlets 32 may be determined as desired. For example, an air inlet having a circular shape may be formed at each of both side portions of the housing 30, or a plurality of air outlets having different sizes may be provided side by side at the lower portion of the housing 30. Note that the shapes and the arrangement of the indoor heat exchanger 5, the indoor air sending unit 6, and the wind direction adjustment unit 7 may be changed as desired according to the positions and the shapes of the air inlet 31 and the air outlet 32.

[0030] The distance measurement unit 10 scans the room to obtain distance data. It is desirable that the distance measurement unit 10 perform distance measurement at an angle as wide as possible in the vertical direction by using the indoor unit 100 as a reference. The distance data measured by the distance measurement unit 10 are transmitted to the high ceiling detection unit 51, the floor detection unit 52, and the storage unit 54. Of the above-mentioned distance data, the high ceiling detection unit 51 particularly analyzes distance data at the time of the distance measurement unit 10 facing in the upward direction relative to the horizontal direction. Based on whether the above-mentioned distance data can be divided into a plurality of groups, the high ceiling detection unit 51 detects the presence or absence of the high ceiling space 300 in the room. When the high ceiling space 300 is present, the high ceiling detection unit 51 further detects the range of the high ceiling space 300. Among the distance data measured by the distance measurement unit 10, the floor detection unit 52 partic-

ularly analyzes distance data at the time of the distance measurement unit 10 facing in the downward direction relative to the horizontal direction. The floor detection unit 52 detects the range of the floor 206 based on a tendency of increase and decrease in distance. Details of a method for analyzing distance data by the high ceiling detection unit 51 and the floor detection unit 52 will be described later.

[0031] The distance measurement unit 10 is formed by an ultrasonic distance sensor (hereinafter referred to as "ultrasonic sensor") and a driving mechanism, for example. The ultrasonic sensor emits an ultrasonic pulse in a specific direction, and receives a reflected wave reflected off a wall, a ceiling, or the like. A period of time from when the ultrasonic sensor transmits an ultrasonic pulse to when the ultrasonic sensor receives a reflected wave is multiplied by a sound speed, and the result is then divided by 2 to acquire information on the distance from the ultrasonic sensor to the wall or the ceiling. The distance measurement unit 10 may be formed by a laser distance sensor or an infrared distance sensor and the driving mechanism.

[0032] The ultrasonic sensor is rotatable at least in the vertical direction by the driving mechanism. The driving mechanism may be a stepping motor, for example, and the motor shaft of the driving mechanism extends in the horizontal direction. The ultrasonic sensor is attached to the motor shaft via a support part. Fig. 5 is a diagram schematically showing one example of the driving mechanism. In Fig. 5, a support part 23 is attached to a motor shaft 22 extending from a motor body 21, and an ultrasonic sensor 24 is attached to the support part 23. Such a driving mechanism allows the ultrasonic sensor 24 to rotate in the vertical direction.

[0033] When another stepping motor is added to the configuration of the distance measurement unit 10 shown in Fig. 5, the ultrasonic sensor can be rotated in the vertical direction and the lateral direction. If the ultrasonic sensor is rotatable in the vertical direction and the lateral direction, it is possible to detect the presence or absence of the high ceiling space 300 in the room more surely. Accordingly, such a configuration is desirable. Hereinafter, a description will be made assuming that the ultrasonic sensor is rotatable in the vertical direction and the lateral direction.

[0034] The temperature measurement unit 11 scans the room to measure the temperature distribution of the floor, the wall, and the ceiling. The temperature measurement unit 11 measures at least the temperature of the floor 206 and the temperature in a range including the ceiling 203 and the wall 204, which form the high ceiling space 300. In the case where the temperature measurement unit 11 measures the temperature of the wall 204, it is desirable that the temperature measurement unit 11 measure the temperature of the wall 204 at a position as high as possible. The reason is to allow the temperature difference calculation unit 53, which will be described later, to calculate a temperature difference in the room in

the vertical direction more surely. At this point of operation, it is considered that the temperature of the ceiling 203 and the temperature of the wall 204 are substantially equal to the temperature of air in the high ceiling space 300, and the temperature of the floor 206 is substantially equal to the temperature of air in the vicinity of the floor 206. The temperature measurement unit 11 transmits information on the measured temperature distribution to the temperature difference calculation unit 53 and the storage unit 54. The temperature difference calculation unit 53 calculates a temperature difference between the high ceiling space 300 and the floor 206.

[0035] The temperature measurement unit 11 is formed by a thermopile, where infrared sensors are arranged in a lattice shape, and a driving mechanism, for example. The thermopile measures a temperature based on infrared rays emitted from the floor, the wall, and the ceiling. The temperature measurement unit 11 may be formed by a non-cooled infrared image sensor or the like and a driving mechanism.

[0036] The driving mechanism of the temperature measurement unit 11 may be a mechanism equivalent to the driving mechanism of the distance measurement unit 10 shown in Fig. 5, and the distance measurement unit 10 and the temperature measurement unit 11 may share one driving mechanism. Fig. 2(a), Fig. 2(b), and Fig. 3 show examples where the distance measurement unit 10 and the temperature measurement unit 11 are driven by one driving mechanism. Hereinafter, the description will be made assuming that the distance measurement unit 10 and the temperature measurement unit 11 share one driving mechanism that can be driven in the vertical direction and the lateral direction.

[0037] The sucked air temperature measurement unit 12 is attached to the indoor unit 100 at a position between the air inlet 31 and the indoor heat exchanger 5. The sucked air temperature measurement unit 12 measures the temperature of indoor air sucked from the air inlet 31. The sucked air temperature measurement unit 12 transmits information on the measured temperature to the storage unit 54 and the operation control unit 55.

[0038] The controller 50 includes, for example, a central processing unit (CPU), a storage medium, such as a read only memory (ROM), which stores a control program, a working memory, such as a random access memory (RAM), and a signal circuit through which a signal is transmitted to and received from the CPU, the ROM, and the RAM.

[0039] The controller 50 may also include a communication unit for communicating with an external cloud server. In this case, the controller 50 can transmit and receive various information to and from the cloud server via the above-mentioned communication unit. Specifically, the controller 50 receives updated data of the control program from the cloud server, and transmits information on the operation history of the air-conditioning system 1000 to the cloud server.

[0040] The controller 50 receives measurement results

from the distance measurement unit 10, the temperature measurement unit 11, and the sucked air temperature measurement unit 12, and the result of inputs performed by a person to the terminal 70. The controller 50 stores a control program by which the function of the air-conditioning system 1000 is exhibited. Based on the above-mentioned received result and the above-mentioned control program, the controller 50 issues an instruction to activate the compressor 1, the outdoor air sending unit 3, the expansion valve 4, the indoor air sending unit 6, and the wind direction adjustment unit 7.

[0041] Fig. 6 is a diagram showing the configuration of the controller 50. The controller 50 includes the high ceiling detection unit 51, the floor detection unit 52, the temperature difference calculation unit 53, the storage unit 54, and the operation control unit 55.

[0042] The high ceiling detection unit 51 detects the presence or absence of the high ceiling space 300 based on distance data measured by the distance measurement unit 10. When the high ceiling space 300 is present, the high ceiling detection unit 51 further detects the range of the high ceiling space 300. The high ceiling detection unit 51 transmits the result of the above-mentioned processing to the temperature difference calculation unit 53, the storage unit 54 and the operation control section 55.

[0043] The high ceiling detection unit 51 detects the presence or absence of the high ceiling space 300 by the following method, for example. First, the high ceiling detection unit 51 extracts, from the distance data measured by the distance measurement unit 10, distance data at the time of the distance measurement unit 10 being at an upward angle in the vertical direction. In Embodiment 1, the phrase "the distance measurement unit 10 being at an upward angle in the vertical direction" refers to the distance measurement unit 10 being at an upward angle relative to the horizontal direction. The high ceiling detection unit 51 detects the presence or absence of the high ceiling space 300 based on whether the extracted data contain data groups that are significantly different from each other.

[0044] Fig. 7(a) and Fig. 7(b) are examples of distance data obtained by extracting, from the distance data measured by the distance measurement unit 10, distance data at the time of the distance measurement unit 10 being at an upward angle in the vertical direction. In Fig. 7(a) and Fig. 7(b), 0 degrees of the angle of the distance measurement unit 10 in the lateral direction refers to the front direction of the indoor unit 100. In the example shown in Fig. 7(a), a distance is large when the angle of the distance measurement unit 10 in the vertical direction is equal to or less than 30 degrees, and a distance is small when the angle of the distance measurement unit 10 in the vertical direction is greater than 30 degrees. The reason is as follows. As shown in Fig. 2(a), when the angle of the distance measurement unit 10 in the vertical direction is 30 degrees, the distance measurement unit 10 measures the distance from the indoor unit 100 to the

wall 204 as shown by the line L30 and, when the angle of the distance measurement unit 10 in the vertical direction is greater than 30 degrees, the distance measurement unit 10 measures the distance to the ceiling 201 as shown by the line L40. In the case where the high ceiling space 300 is present, distance data can be classified into groups that are significantly differ from each other based on a change in angle of the distance measurement unit 10 in the vertical direction as described above. The high ceiling detection unit 51 detects the presence of the high ceiling space 300 in this manner.

[0045] Fig. 7(b) is an example of distance data obtained by partially extracting distance data from the distance data measured by the distance measurement unit 10 in the case where the high ceiling space 300 is present above the indoor unit 100 as shown in Fig. 2(b). In Fig. 7(a) and Fig. 7 (b), each of the angle of the distance measurement unit 10 in the lateral direction and the angle of the distance measurement unit 10 in the vertical direction changes in increments of 10 degrees within a range from 0 degrees to 80 degrees. However, the measurement range and the measurement interval of the distance measurement unit 10 are not limited to the above.

[0046] It is possible to set any criterion for determining whether the distance data measured by the distance measurement unit 10 can be classified into a plurality of significant groups. For example, it may be determined that the distance data measured by the distance measurement unit 10 can be classified into a plurality of significant groups when distance data shown in Fig. 7(a) and Fig. 7(b) are arranged in descending order of values and when there is a decrease of equal to or more than a predetermined value (for example 100 [cm]) between Nth (N being an integer) distance data, counted from the top, and N+1 th distance data.

[0047] Due to erroneous measurement by the distance measurement unit 10, extremely large or small distance data or intermediate distance data between the distance from the indoor unit 100 to the high ceiling space 300 and the distance from the indoor unit 100 to the ceiling 201 may be measured. In this case, there is a possibility of the presence or absence of the high ceiling space 300 being erroneously detected. To reduce an influence of erroneous measurement, the high ceiling detection unit 51 may select distance data by the following method, for example. The high ceiling detection unit 51 selects one distance data from distance data extracted as shown in Fig. 7(a) and Fig. 7(b). When there is no different distance data having a difference of a predetermined value (for example 50 [cm]) or less from such distance data, it is assumed that the selected distance data is caused by erroneous measurement. The distance data that is assumed to be caused by the erroneous measurement is removed, and it is then determined whether the distance data other than the removed distance data can be classified into a plurality of significant groups by the above-mentioned method.

[0048] The method described above is one example

of a method for detecting the presence or absence of the high ceiling space 300 with the high ceiling detection unit 51. The high ceiling detection unit 51 may detect the presence or absence of the high ceiling space 300 by a method other than the method described above. For example, a method for detecting the presence or absence of a stepped portion on a floor surface from distance data is disclosed as a known technique. However, it is also possible to detect the presence or absence of the high ceiling space 300 by applying substantially the same method to the air-conditioning system 1000.

[0049] The high ceiling detection unit 51 also detects the range of the high ceiling space 300 in the lateral direction. Specifically, the high ceiling detection unit 51 detects the range of the high ceiling space 300 based on the distance to the boundary between the ceiling 201 and the high ceiling space 300 when viewed from the indoor unit 100 and the distance from the indoor unit 100 to the wall 205. First, the high ceiling detection unit 51 calculates the distance from the indoor unit 100 to the boundary between the ceiling 201 and the high ceiling space 300 in each of the leftward direction and the rightward direction by the following calculation formula (i).

$$D \times \cos\alpha \dots (i)$$

[0050] In the calculation formula (i), " α " denotes the angle of the distance measurement unit 10 in the vertical direction at a point immediately after the ceiling 201 is switched to the high ceiling space 300, and α is 40 degrees in Fig. 7(a). Further, "D" denotes distance data in such a case. In Fig. 7(a), when the angle of the distance measurement unit 10 in the lateral direction is 0 degrees, the calculation result of the calculation formula (i) is 133 [cm] ($175 \times \cos 40$ degrees). In this case, the high ceiling detection unit 51 calculates that, in the front direction of the indoor unit 100, the distance from the indoor unit 100 to the boundary between the ceiling 201 and the high ceiling space 300 is equal to or more than 133 [cm].

[0051] Also for directions other than the front direction of the indoor unit 100, the distance to the boundary between the ceiling 201 and the high ceiling space 300 is calculated by substantially the same method. In the above-mentioned method, to be more precise, the distance to a point slightly in front of the boundary between the ceiling 201 and the high ceiling space 300 is calculated. Accordingly, a value obtained by adding a predetermined value (for example 30 [cm]) to the above-mentioned calculation result may be used as the distance to the boundary between the ceiling 201 and the high ceiling space 300.

[0052] The high ceiling detection unit 51 further acquires information on the distance from the indoor unit 100 to the wall 205 from distance data at the time of the distance measurement unit 10 being at 0 degrees in the vertical direction. In Fig. 7(a), the distance from the indoor unit 100 to the wall 205 is 525 [cm]. The high ceiling

detection unit 51 detects the range of the high ceiling space 300 by subtracting the above-mentioned distance to the boundary between the ceiling 201 and the high ceiling space 300 from the above-mentioned distance to the wall 205.

[0053] For the method for detecting the range of the high ceiling space 300 with the high ceiling detection unit 51, it is also possible to use a method other than the method described above. For example, as a known technique, a method is disclosed where a recessed portion on a floor surface is detected from distance data and the size of the recessed portion is detected. It is also possible to detect the range of the high ceiling space 300 by applying substantially the same method as the above-mentioned method to the air-conditioning system 1000.

[0054] The floor detection unit 52 identifies the boundary between the floor 206 and the wall 205 based on distance data in the room measured by the distance measurement unit 10, and detects the range of the floor 206 in the lateral direction. Specifically, the floor detection unit 52 extracts, from the distance data measured by the distance measurement unit 10, distance data at the time of the distance measurement unit 10 being at a downward angle in the vertical direction. In Embodiment 1, the phrase "the distance measurement unit 10 being at a downward angle in the vertical direction" refers to the distance measurement unit 10 being at a downward angle relative to the horizontal direction. The floor detection unit 52 detects, when the lateral direction is fixed and the angle of the distance measurement unit 10 is changed toward the upward direction from the downward direction, the range where the distance from the indoor unit 100 continues to increase as the floor 206. The floor detection unit 52 transmits the result of the above-mentioned processing to the temperature difference calculation unit 53, the storage unit 54, and the operation control section 55.

[0055] The above-mentioned method will be described with reference to the example shown in Fig. 2(a). When the angle of the distance measurement unit 10 changes from 60 degrees in the downward direction to 30 degrees in the downward direction, for example, the distance from the indoor unit 100 increases as shown by the line L-60 and the line L-30. In contrast, when the angle of the distance measurement unit 10 reaches 20 degrees in the downward direction, the distance from the indoor unit 100 starts to decrease as shown by the line L-20. Therefore, it is possible to detect that, as viewed from the distance measurement unit 10, the boundary between the floor 206 and the wall 205 is present between 30 degrees in the downward direction and 20 degrees in the downward direction, and a range up to at least 30 degrees in the downward direction is the floor 206.

[0056] In the same manner as the case where the presence or absence of the high ceiling space 300 is detected, a method for detecting the range of a floor by using distance data is disclosed as a known technique. The floor detection unit 52 may detect the range of the floor 206

by using such a known technique.

[0057] The floor detection unit 52 may detect the range of the floor 206 by the following method. The floor detection unit 52 detects the range of the floor 206 based on the temperature data measured by the temperature measurement unit 11. It is known that, in a general building, the temperature distribution of a floor has a pattern different from the pattern of the temperature distribution of a wall. For example, it is known that a floor often has substantially uniform temperature distribution, but a wall is less likely to have uniform temperature distribution. There is a known technique that identifies a floor by making use of such a difference in pattern. Also in the present embodiment, the range of the floor 206 may be detected by using substantially the same method.

[0058] The temperature difference calculation unit 53 acquires information on the temperature of the high ceiling space 300 and the temperature of the floor 206 from the results of processing performed by the high ceiling detection unit 51 and the floor detection unit 52 and temperature data measured by the temperature measurement unit 11. Next, an indoor temperature difference is calculated by subtracting the above-mentioned temperature of the floor 206 from the above-mentioned temperature of the high ceiling space 300. The temperature difference calculation unit 53 transmits information on the calculated indoor temperature difference to the storage unit 54 and the operation control unit 55.

[0059] In the case where the temperature measurement unit 11 measures the temperature of the high ceiling space 300 at a plurality of positions on the ceiling 203 and the wall 204, the temperature difference calculation unit 53 may use the average value or the center value of the plurality of measurement results as the temperature of the high ceiling space 300. Further, processing may be performed where a standard deviation is calculated from the plurality of measurement results, a condition (for example, a difference from the average value is three or more times the standard deviation) is decided based on the standard deviation, values considered, under this condition, to be caused by erroneous measurement are eliminated, and an average value is calculated in such a state. In the case where the temperature of the floor 206 is measured at a plurality of positions, so that a plurality of measurement results are provided, the above-mentioned processing may be applied to the temperatures of the floor 206.

[0060] The storage unit 54 stores a control program that activates the air-conditioning system 1000. More specifically, the storage unit 54 stores a program that activates the compressor 1, the outdoor air sending unit 3, the expansion valve 4, the indoor air sending unit 6, the wind direction setting unit 7, the distance measurement unit 10, the temperature measurement unit 11, and the sucked air temperature measurement unit 12. In addition to the above, the storage unit 54 also stores the measurement results from the distance measurement unit 10, the temperature measurement unit 11, and the

sucked air temperature measurement unit 12, the results of processing performed by the high ceiling detection unit 51, the floor detection unit 52, and the temperature difference calculation unit 53, and the result of inputs performed by a person to the terminal 70.

[0061] To control the operation action of the air-conditioning system 1000 in general, the operation control unit 55 issues instructions to respective elements constituting the air-conditioning system 1000. Specifically, the operation control unit 55 issues an instruction to the compressor 1, the outdoor air sending unit 3, the expansion valve 4, the indoor air sending unit 6, the wind direction adjustment unit 7, the distance measurement unit 10, the temperature measurement unit 11, and the sucked air temperature measurement unit 12. With such an operation, the elements constituting the air-conditioning system 1000 are activated, so that the functions of the air-conditioning system 1000 are exhibited.

[0062] At this point of operation, the contents of the instruction issued by the operation control unit 55 are determined based on at least the results of the processing performed by the high ceiling detection unit 51, the floor detection unit 52, and the temperature difference calculation unit 53, the inputs performed by a person to the terminal 70, and the control program stored in the storage unit 54.

[0063] Subsequently, the action of the air-conditioning system 1000 will be described. Fig. 8 is a flowchart showing an example of the action of the air-conditioning system 1000. The repeated description will be simplified or omitted when appropriate.

[0064] The action of the air-conditioning system 1000 shown in Fig. 8 is started when an instruction to start the heating operation is inputted to the terminal 70 by a person. At this point of operation, at least a target temperature for temperature adjustment of indoor air is specified by the person. The target temperature is stored in the storage unit 54. Immediately after such an operation, S101 is started.

[0065] In S101, the sucked air temperature measurement unit 12 measures the temperature of indoor air sucked into the indoor unit 100. The temperature measured by the sucked air temperature measurement unit 12 is stored in the storage unit 54.

[0066] In S102, the high ceiling detection unit 51 detects the presence or absence of the high ceiling space 300, and detects the range of the high ceiling space 300. Further, the floor detection unit 52 detects the range of the floor 206. First, the distance measurement unit 10 scans the room to obtain distance data. The obtained distance data are transmitted to the high ceiling detection unit 51 and the floor detection unit 52.

[0067] Next, the high ceiling detection unit 51 analyzes the above-mentioned distance data. Specifically, the high ceiling detection unit 51 extracts, from the above-mentioned distance data, data at the time of the distance measurement unit 10 being at an upward angle in the vertical direction, and detects the presence or absence

of the high ceiling space 300 based on whether such extracted data can be classified into a plurality of significant groups. When the high ceiling space 300 is present, the high ceiling detection unit 51 also detects the range of the high ceiling space 300 based on the distance from the indoor unit 100 to the wall 205 and the distance from the indoor unit 100 to the boundary between the ceiling 201 and the high ceiling space 300.

[0068] Also when the high ceiling space 300 is not present in the room in S102 and the ceiling has a single height, the air-conditioning system 1000 continues the action. The case where the high ceiling space 300 is present and the case where the high ceiling space 300 is not present have common action of the air-conditioning system 1000 and hence, only necessary portions will be described hereinafter.

[0069] Then, the floor detection unit 52 detects the range of the floor 206. The floor detection unit 52 identifies the range of the floor 206 from the distance data measured by the distance measurement unit 10. Specifically, the floor detection unit 52 extracts data at the time of the distance measurement unit 10 being at a downward angle in the vertical direction, and detects, when the angle of the distance measurement unit 10 in the vertical direction is changed toward the upward direction, the range where the distance from the indoor unit 100 continues to increase as the floor 206. The results of the processing performed by the high ceiling detection unit 51 and the floor detection unit 52 are transmitted to the temperature difference calculation unit 53, the storage unit 54, and the operation control unit 55.

[0070] In S103, the temperature measurement unit 11 scans the room to measure temperature distribution. The temperature measurement unit 11 measures at least the temperature of the high ceiling space 300 and the temperature of the floor 206. The temperature data measured by the temperature measurement unit 11 are transmitted to the temperature difference calculation unit 53, the storage unit 54, and the operation control unit 55.

[0071] When the high ceiling space 300 is not present, the temperature measurement unit 11 measures the temperature of the ceiling. In the case where the temperature of the high ceiling space 300 is used for the action of the air-conditioning system 1000 in S111, which will be described later, the above-mentioned temperature of the ceiling is used instead.

[0072] In S104, the temperature difference calculation unit 53 calculates an indoor temperature difference being a temperature difference between the high ceiling space 300 and the floor 206. The temperature difference calculation unit 53 extracts the temperature of the high ceiling space 300 and the temperature of the floor 206 from the results of the processing performed by the high ceiling detection unit 51 and the floor detection unit 52 and the measurement result from the temperature measurement unit 11. The temperature difference calculation unit 53 calculates an indoor temperature difference by subtracting the extracted temperature of the floor 206 from the

extracted temperature of the high ceiling space 300. The information on the calculated indoor temperature difference is transmitted to the storage unit 54 and the operation control unit 55.

[0073] When the high ceiling space 300 is not present in the room, an indoor temperature difference is calculated by subtracting the temperature of the floor from the temperature of the ceiling. In S112 and the like, which will be described later, an indoor temperature difference when the high ceiling space 300 is present and an indoor temperature difference when the high ceiling space 300 is not present are not distinguished from each other in terms of the action of the air-conditioning system 1000.

[0074] In S105, the operation control unit 55 determines whether it is necessary to perform temperature adjustment in the room. First, the sucked air temperature measurement unit 12 measures the temperature of indoor air sucked into the indoor unit 100. The information on the measured temperature is transmitted to the storage unit 54 and the operation control unit 55. Next, the operation control unit 55 refers to the storage unit 54 and compares the target temperature that is set at the time of start with the temperature of indoor air measured in S101. When the temperature of indoor air is less than the target temperature, the operation control unit 55 determines that temperature adjustment is necessary, and the process proceeds to S106. In contrast, when the temperature of indoor air is equal to or more than the target temperature, the operation control unit 55 determines that temperature adjustment is not necessary, and the process proceeds to S107.

[0075] In S106, the operation control unit 55 causes the air-conditioning system 1000 to activate for a temperature adjustment heating operation. In the temperature adjustment heating operation, the operation control unit 55 causes the compressor 1, the outdoor air sending unit 3, the expansion valve 4, the indoor air sending unit 6, and the wind direction adjustment unit 7 to activate to supply air into the room, the air being heated to cause the temperature of the room to be equal to the target temperature.

[0076] In S107, the operation control unit 55 causes the air-conditioning system 1000 to activate for a non-temperature adjustment operation. The non-temperature adjustment operation may be an air sending operation, for example. In the air sending operation, the operation control unit 55 causes only the indoor air sending unit 6 and the wind direction adjustment unit 7 to be activated. With such an operation, an air flow with a temperature equal to the temperature of indoor air is blown out from the indoor unit 100.

[0077] In S108, the operation control unit 55 causes the air-conditioning system 1000 to continue the operation performed in S106 or S107 for a predetermined period of time. In Embodiment 1, the predetermined period of time is a desired period of time, and may be 10 seconds, 1 minute, or 10 minutes, for example. After the lapse of the predetermined period of time, the process

proceeds to S109.

[0078] In S109, the sucked air temperature measurement unit 12 again measures the temperature of indoor air sucked into the indoor unit 100. The information on the measured temperature is transmitted to the storage unit 54 and the operation control unit 55. At this point of operation, the storage unit 54 stores both the temperature measured in S101 and the temperature measured in S109.

[0079] In S110, the operation control unit 55 determines whether the air-conditioning system 1000 is in a state activated for the temperature adjustment heating operation. Specifically, the operation control unit 55 determines whether the air-conditioning system 1000 is in a state activated for the temperature adjustment heating operation by referring to the control state of the compressor 1 or the like. When it is determined that the air-conditioning system 1000 is in a state activated for the temperature adjustment heating operation, the process proceeds to S111. In contrast, when it is determined that the air-conditioning system 1000 is not activated for the temperature adjustment heating operation, the process proceeds to S120.

[0080] In S111, the temperature measurement unit 11 again measures the temperature of the high ceiling space 300 and the temperature of the floor 206. At this point of operation, it is desirable that the positions where the temperature of the high ceiling space 300 and the temperature of the floor 206 are measured be equal to the positions where the temperatures are measured in S103. The information on the measured temperature is transmitted to the storage unit 54 and the operation control unit 55.

[0081] In S112, the temperature difference calculation unit 53 calculates a change over time in indoor temperature difference. First, the temperature difference calculation unit 53 subtracts the temperature of the floor 206 measured in S111 from the temperature of the high ceiling space 300 measured in S111 to calculate an indoor temperature difference. The temperature difference calculation unit 53 compares this indoor temperature difference with the indoor temperature difference stored in the storage unit 54 and calculated in S104 to calculate the change over time in indoor temperature difference.

[0082] More specifically, the temperature difference calculation unit 53 calculates the change over time in indoor temperature difference by the following calculation formula (ii) with the indoor temperature difference calculated based on the temperatures measured in S111 being taken as $\Delta T(n+1)$, the indoor temperature difference calculated in S104 being taken as $\Delta T(n)$, the clock time at which $\Delta T(n+1)$ is calculated being taken as $t(n+1)$, and the clock time at which $\Delta T(n)$ is calculated being taken as $t(n)$.

$$(\Delta T(n+1) - \Delta T(n)) / (t(n+1) - t(n)) \dots (ii)$$

[0083] The information on the calculated change over

time in indoor temperature difference is transmitted to the storage unit 54 and the operation control unit 55.

[0084] In S113, the operation control unit 55 determines whether the change over time in indoor temperature difference calculated in S112 is equal to or more than a predetermined first threshold $\Delta Th1$. When the change over time in indoor temperature difference is equal to or more than $\Delta Th1$, the process proceeds to S117. In S117, the air-conditioning system 1000 is activated in a temperature difference reduction mode 1. Details of the temperature difference reduction mode 1 will be described later. In contrast, when the change over time in indoor temperature difference is less than $\Delta Th1$, the process proceeds to S114.

[0085] In S114, the operation control unit 55 determines whether the change over time in indoor temperature difference calculated in S112 is equal to or more than a predetermined second threshold $\Delta Th2$. The second threshold $\Delta Th2$ is smaller than the first threshold $\Delta Th1$. When the change over time in indoor temperature difference is equal to or more than $\Delta Th2$, the process proceeds to S118. In S118, the air-conditioning system 1000 is activated in a temperature difference reduction mode 2. Details of the temperature difference reduction mode 2 will be described later. In contrast, when the change over time in indoor temperature difference is less than $\Delta Th2$, the process proceeds to S115.

[0086] In S115, the operation controller 54 determines whether the indoor temperature difference calculated in S112 is equal to or more than a predetermined third threshold $\Delta Ts1$. When the indoor temperature difference is equal to or more than $\Delta Ts1$, the process proceeds to S119. In S119, the air-conditioning system 1000 is activated in a temperature difference reduction mode 3. Details of the temperature difference reduction mode 3 will be described later. In contrast, when the indoor temperature difference is less than $\Delta Ts1$, the process proceeds to S116.

[0087] S113, S114, and S115 described above are processing performed for detecting whether a temperature difference between the high ceiling space 300 and the floor 206 increases with the lapse of period of time and for detecting a speed of an increase in temperature difference in the case where the temperature difference increases. For example, in S113, it is determined whether the indoor temperature difference increases rapidly. In contrast, in S114, it is determined whether the indoor temperature difference gradually increases and, in S115, it is determined whether the current indoor temperature difference is not increased. The reason is that, as will be described later, such processing is performed to change the action of the air-conditioning system 1000 according to the degree of increase in indoor temperature difference. It is not always necessary to perform processing in S113, S114, and S115 at three levels. However, it is possible to control the air-conditioning system 1000 depending on the state of the room and hence, it is desirable that the processing be performed at a plurality of levels.

[0088] In S116, the operation control unit 55 causes the air-conditioning system 1000 to activate for the temperature adjustment heating operation. The action of the air-conditioning system 1000 in S116 is equal to the action in S106. In S116, processing in S105 may be performed based on the temperature of indoor air measured in S109 and the target temperature determined at the time of start. In this case, the non-temperature adjustment operation may be performed according to the result of the processing.

[0089] After S116, S117, S118, or S119 is performed, the action of the air-conditioning system 1000 returns to S109 after the lapse of a predetermined period of time. After the action of the air-conditioning system 1000 returns to S109, the air-conditioning system 1000 repeats the action described above.

[0090] When the operation control unit 55 determines in S110 that the air-conditioning system 1000 is not activated for the temperature adjustment heating operation, the process proceeds to S120. In S120, it is determined whether the temperature of indoor air measured in S109 in the last cycle is less than the temperature of indoor air measured one cycle earlier. For example, in the case where S109 is performed three times in total, it is determined whether the temperature of indoor air measured in S109 in a third cycle is less than the temperature of indoor air measured in S109 in a second cycle. When the temperature of indoor air measured in S109 in the last cycle is less than the temperature of indoor air measured one cycle earlier, the process proceeds to S121. In contrast, when the temperature of indoor air measured in S109 in the last cycle is not less than the temperature of indoor air measured one cycle earlier, the process proceeds to S111. The action of the air-conditioning system 1000 following after S111 is as described above.

[0091] In S121, the operation control unit 55 causes the air-conditioning system 1000 to activate for a temperature-adjustment-preferential heating operation. In the temperature-adjustment-preferential heating operation, priority is placed on causing the temperature of indoor air to reach the target temperature. Details of the temperature-adjustment-preferential heating operation will be described later. After S121 is performed, the process returns to S109.

[0092] Subsequently, the temperature difference reduction modes 1 to 3 performed in S117, S118, and S119, and the temperature-adjustment-preferential heating operation performed in S121 will be described. The temperature difference reduction modes 1 to 3 are performed in S117, S118, and S119 to reduce the indoor temperature difference. As described above, which of S117, S118, or S119 is performed depends on the determination result in S113, S114, and S115. In the temperature-adjustment-preferential heating operation, causing the temperature of the room to reach the target temperature has priority over a reduction in indoor temperature difference.

[0093] Fig. 9 is a diagram showing determination con-

ditions in S113 in which the temperature difference reduction mode 1 is implemented. Fig. 10 is a diagram showing conditions of the relationship between indoor temperature difference and period of elapsed time, the temperature difference reduction modes 1 to 3 being implemented under the conditions. Fig. 11 is a diagram showing the temperature difference reduction modes 1 to 3, the conditions under which the temperature-adjustment-preferential heating operation is implemented, control targets in respective operations, and control contents. Hereinafter, conditions under which the respective operation modes are implemented will be described in detail and, thereafter, the temperature difference reduction modes 1 to 3, control targets in the temperature-adjustment-preferential heating operation, and control contents will be described.

[0094] Fig. 9 is a diagram showing period of time from when the heating operation is started by a person, temperature of the high ceiling space 300, temperature of the floor 206, and indoor temperature difference. Fig. 9 also shows a change in indoor temperature difference per hour that can be obtained from the above-mentioned values.

[0095] In Fig. 9, an indoor temperature difference is 1.5 degrees C when the heating operation is started. The indoor temperature difference becomes 2.0 degrees C after 15 minutes from the start of the heating operation. The indoor temperature difference becomes 2.5 degrees C after 30 minutes from the start of the heating operation. A change in indoor temperature difference per hour is 2.0 degrees C/h. For example, provided that the first threshold $\Delta Th1$ is 1.5 degrees C/h, the above-mentioned change over time in indoor temperature difference is greater than $\Delta Th1$. When such a condition is satisfied, the temperature difference reduction mode 1 is performed. Values shown in Fig. 9 are merely examples, and conditions under which the temperature difference reduction mode 1 is implemented are not limited to the examples shown in Fig. 9. For example, the above-mentioned determination may be made by comparing the indoor temperature difference at one hour from the start of the heating operation with the indoor temperature difference at two hours from the start of the heating operation. The temperature difference reduction mode 2 is performed when the change over time in indoor temperature difference is equal to or more than the second threshold $\Delta Th2$.

[0096] Fig. 10 is a diagram showing the relationship between period of time from when the heating operation is started by a person and indoor temperature difference. A line S1 in Fig. 10 shows a case where an indoor temperature difference rapidly increases with a period of time, and a line S2 in Fig. 10 shows a case where an indoor temperature difference gradually increases. Further, a line S11 shows a case where a change over time in indoor temperature difference is equal to $\Delta Th1$, and a line S12 shows a case where a change over time in indoor temperature difference is equal to $\Delta Th2$.

[0097] In Fig. 10, an indoor temperature difference rapidly increases in a region A1, shown by light hatching, which is disposed above the line S11. In the case where the indoor temperature difference changes as shown by the line S1, the change over time in indoor temperature difference is greater than $\Delta Th1$ and hence, the temperature difference reduction mode 1 is performed. In contrast, an indoor temperature difference gradually increases in a region A2, shown by dark hatching, which is sandwiched between the line S11 and the line S12. In this case, the change over time in indoor temperature difference is less than $\Delta Th1$ and is greater than $\Delta Th2$. Therefore, when the indoor temperature difference changes as shown by line S2, the temperature difference reduction mode 2 is performed. Further, in the case where the indoor temperature difference changes within a region A3 disposed below the line S12, the temperature difference reduction mode 3 or the temperature adjustment heating operation is implemented.

[0098] The region A3 merely shows a case where a change over time in indoor temperature difference is small, and the region A3 does not intend to show a case where there is no indoor temperature difference. The temperature difference reduction mode 3 is performed when there is a small change over time in indoor temperature difference and the indoor temperature difference itself is equal to or more than the third threshold $\Delta Ts1$. Different from the above-mentioned conditions for implementing the temperature difference reduction modes 1 to 3, the temperature-adjustment-preferential heating operation is performed in the case where the temperature of indoor air drops with a period of time when a change over time in temperature of indoor air, measured by the sucked air temperature measurement unit 12, is referred to.

[0099] Subsequently, control targets and control contents in the temperature difference reduction modes 1 to 3 and the temperature-adjustment-preferential heating operation will be described with reference to Fig. 11. In the temperature difference reduction mode 1 in S117, the operation control unit 55 reduces the frequency of the compressor 1 by F1. With such an operation, the heating capacity of the air-conditioning system 1000 reduces and hence, the temperature of air blown out from the indoor unit 100 drops. One of the reasons that an indoor temperature difference increases with a period of time is that warm air blown out from the indoor unit 100 is blown up due to a density difference between the warm air and indoor air. When the temperature of air blown out from the indoor unit 100 drops, a density difference between the air blown out from the indoor unit 100 and indoor air reduces, thus allowing warm air to arrive at an area in the vicinity of the floor 206. Accordingly, it is possible to achieve a reduction in indoor temperature difference.

[0100] In addition to the above, in S117, the operation control unit 55 increases the rotation speed of the indoor air sending unit 6 by f1. Further, the operation control

unit 55 changes the direction of an air flow, blown out from the indoor unit 100, in the vertical direction toward the downward direction by at least one or more levels by controlling the wind direction adjustment unit 7. With such operations, a stronger air flow in the downward direction than an air flow before the temperature difference reduction mode 1 is performed is generated, thus allowing warm air to easily arrive at the area in the vicinity of the floor 206. Further, the strong air flow is blown out from the indoor unit 100 in the downward direction and hence, the flow of air in the vertical direction is generated in the entire room. Accordingly, air with high temperature in the high ceiling space 300 and air with low temperature in the vicinity of the floor 206 are agitated and hence, it is possible to achieve a further reduction in indoor temperature difference.

[0101] In S117, a change value for the control target may be decided according to a position where the indoor unit 100 is attached or the position of the high ceiling space 300. For example, in Fig. 2(a), the high ceiling space 300 is present at a position away from the indoor unit 100. In Fig. 2(c), the high ceiling space 300 is present at a position above the indoor unit 100. In the case of Fig. 2(a), the direction of an air flow may be changed by one level. In the case of Fig. 2(c), the direction of an air flow may be changed by two or more levels. By performing the above-mentioned control, as will be described later with reference to Fig. 12(a) and Fig. 12(b), it is possible to mix air in the high ceiling space 300 and air in the vicinity of the floor 206 more efficiently.

[0102] In the temperature difference reduction mode 2 in S118, the operation control unit 55 reduces the frequency of the compressor 1 by F2. In this case, F2 is smaller than F1. The reason is as follows. In the case where the temperature difference reduction mode 2 is performed, an indoor temperature difference increases gradually with the lapse of period of time and hence, it is possible to achieve a reduction in indoor temperature difference even when the state of the action of the air-conditioning system 1000 is not significantly changed. By reducing the degree of a reduction in frequency of the compressor 1, there is no possibility of the temperature of an air flow blown out from the indoor unit 100 being dropped more than necessary.

[0103] In S118, the rotation speed of the indoor air sending unit 6 is increased by f2, and the direction of an air flow, blown out from the indoor unit 100, in the vertical direction is changed toward the downward direction by at least one or more levels by controlling the wind direction adjustment unit 7. In this case, f2 is smaller than f1. The reason is to prevent a wind speed from being increased more than necessary since an indoor temperature difference increases gradually with the lapse of period of time.

[0104] In the temperature difference reduction mode 3 in S119, the operation control unit 55 reduces the frequency of the compressor 1 by F3. In this case, F3 is smaller than F2. The reason is as follows. In the case

where the temperature difference reduction mode 3 is performed, it is considered that there is a small change over time in indoor temperature difference and indoor air is in a stable state. Therefore, even when the state of the action of the air-conditioning system 1000 is not significantly changed, it is possible to reduce an indoor temperature difference by breaking a stable state.

[0105] In the same manner, in S119, the operation control unit 55 increases the rotation speed of the indoor air sending unit 6 by f3, and changes the direction of an air flow, blown out from the indoor unit 100, in the vertical direction toward the downward direction by at least one or more levels by controlling the wind direction adjustment unit 7. In this case, f3 is smaller than f2. The reason is that even when agitation of air in the vertical direction is weak, an indoor temperature difference is reduced.

[0106] When each of the above-described temperature difference reduction modes 1 to 3 is performed, it is not always necessary to perform all of a reduction in frequency of the compressor 1, an increase in rotation speed of the indoor air sending unit 6, and a change in direction of the wind direction adjustment unit 7. For example, first, only an increase in rotation speed of the indoor air sending unit 6 and a change in direction of the wind direction adjustment unit 7 may be performed to determine whether an indoor temperature difference is reduced. In this case, when the indoor temperature difference is sufficiently reduced, it is unnecessary to reduce the frequency of the compressor 1. In the case where conditions cannot be changed due to the design of the compressor 1, the indoor air sending unit 6, and the wind direction adjustment unit 7, it is not always necessary to change the conditions.

[0107] When the air-conditioning system 1000 is activated in any one of the temperature difference reduction modes 1 to 3 in S117 to S119, the process returns to S109 after the lapse of a predetermined period of time. When the processing in S112 is performed again, a determination is made again for the change over time in indoor temperature difference described above, and any one of the temperature difference reduction modes 1 to 3 or the temperature adjustment heating operation is performed. By repeating such a process, an optimum operation is suitably performed based on the change over time in indoor temperature difference.

[0108] Fig. 12(a) and Fig. 12(b) are diagrams showing examples of the state of a room when the air-conditioning system 1000 is activated in the temperature difference reduction modes 1 to 3. In the case of Fig. 12(a), in the temperature difference reduction modes 1 to 3, an air flow 400 in the downward direction is blown out from the indoor unit 100. The air flow 400 generates strong agitation of air in the vertical direction in the entire room. With such generation of the agitation, warm air 500 stagnating in the high ceiling space 300 is mixed with air in the living space 301. Accordingly, an indoor temperature difference is reduced.

[0109] In Fig. 12(b), the indoor unit 100 is a wall con-

cealed indoor unit. In this case, change values for control targets in the temperature difference reduction modes 1 to 3 may be decided based on the relative position between the indoor unit 100 and the high ceiling space 300. For example, for the direction of an air flow, the following configuration may be adopted. In the case where the indoor unit 100 is away from the high ceiling space 300 as shown in Fig. 12(a), the direction of the air flow is changed toward the downward direction by one level. In the case where the indoor unit 100 is close to the high ceiling space 300 as shown in Fig. 12(b), the direction of the air flow may be changed toward the upward direction by two or more levels. At this point of operation, in Fig. 12(a), an air flow is formed that can reach the high ceiling space 300, which is at a distance from the indoor unit 100 and, in Fig. 12(b), a particularly strong air flow in the vertical direction is formed in the high ceiling space 300. By deciding the change values for the control targets in the temperature difference reduction modes 1 to 3 based on the relative position between the indoor unit 100 and the high ceiling space 300 as described above, it is possible to efficiently mix warm air in the high ceiling space 300 with air in the vicinity of the floor 206.

[0110] Also in the case where the high ceiling space 300 is not present, the same action is executed in the temperature difference reduction modes 1 to 3. In this case, warm air stagnating in the vicinity of the ceiling is mixed with air in the living space and hence, a temperature difference in the room in the vertical direction is reduced.

[0111] Fig. 11 is referred to again. In the case where the air-conditioning system 1000 is activated for the temperature-adjustment-preferential heating operation in S121, the operation control unit 55 raises the frequency of the compressor 1 by F4. With such an operation, the heating capacity of the air-conditioning system 1000 increases, so that the temperature of an air flow blown out from the indoor unit increases. Such an air flow with high temperature heats indoor air and hence, it is possible to avoid a drop in temperature of the room. In the temperature-adjustment-preferential heating operation, it is not always necessary to change the frequency of an indoor blower 6 and the direction of the wind direction adjustment unit 7.

[0112] As described above, the air-conditioning system 1000 calculates a temperature difference between the high ceiling space 300 and the floor 206 as an indoor temperature difference. Further, when the calculated indoor temperature difference is less than the third threshold $\Delta Ts1$, the air-conditioning system 1000 performs the temperature adjustment heating operation. In contrast, when the indoor temperature difference is equal to or more than the third threshold $\Delta Ts1$, the air-conditioning system 1000 performs the temperature difference reduction mode 3. With such operations, agitation of air is generated in the room in the vertical direction, so that the warm air 500 stagnating in the high ceiling space 300 is mixed with air in the living space 301. As a result, an

indoor temperature difference is reduced, so that it is possible to achieve an increase in comfort of a person and energy saving.

[0113] Further, the air-conditioning system 1000 calculates the change over time in indoor temperature difference. When the change over time in indoor temperature difference is equal to or more than the first threshold $\Delta Th1$, the air-conditioning system 1000 is activated in the temperature difference reduction mode 1. When the change over time in indoor temperature difference is equal to or more than the second threshold $\Delta Th2$, the air-conditioning system 1000 is activated in the temperature difference reduction mode 2. With such a configuration, in the case where an indoor temperature difference increases with a period of time, stronger agitation of air in the vertical direction is provided in the room and hence, it is possible to efficiently reduce the indoor temperature difference. As a result, it is possible to achieve an increase in comfort of a person and energy saving.

[0114] In addition to the above, when the temperature of indoor air drops with a period of time, the air-conditioning system 1000 performs the temperature-adjustment-preferential heating operation. With such an operation, the temperature of indoor air drops, so that it is possible to avoid impairing the comfort of a person.

[0115] The air-conditioning system 1000 described above is merely an example, and various modifications are conceivable without departing from the gist of the present disclosure.

[0116] For example, the present embodiment is also applicable to a case where the indoor unit 100 is a floor-mounted indoor unit.

[0117] Fig. 13 is a diagram showing the function of the air-conditioning system 1000 in the case where the indoor unit 100 is a floor-mounted indoor unit. An upward air flow 401 is blown out from the indoor unit 100 mounted on the floor 206, and warm air 500 stagnating in the high ceiling space 300 is mixed with air in the living space 301 due to the upward air flow 401.

[0118] The air-conditioning system 1000 may also include a notification unit that notifies a current operation state. In this case, the notification unit displays, on the terminal 70, for example, a mode or an operation for which the air-conditioning system 1000 is activated, the mode or the operation being selected from the temperature difference reduction modes 1 to 3, the temperature adjustment heating operation, a non-temperature adjustment heating operation, and the temperature-adjustment-preferential heating operation. With such a configuration, a person can see the state of the action of the air-conditioning system 1000.

[0119] In this case, the terminal 70 may have a function of allowing a person to switch the operation state of the air-conditioning system 1000. The air-conditioning system 1000 is activated for the operation state selected by the person. With such a configuration, the air-conditioning system 1000 can perform an operation more in line with the intention of the person.

Embodiment 2

[0120] Embodiment 2 of the present disclosure will be described with reference to Fig. 14, Fig. 15, and Fig. 16. Hereinafter, the description will be made mainly for a point that makes an air-conditioning system 1000 according to the present embodiment different from the air-conditioning system according to Embodiment 1. Components, the description of which is omitted, are substantially equal to the corresponding components in Embodiment 1.

[0121] Fig. 14 is a diagram showing the configuration of a controller 50 in the present embodiment. The controller 50 in the present embodiment includes, in addition to the components of the controller 50 in Embodiment 1 shown in Fig. 6, a person detection unit 56 configured to detect a person present in the room.

[0122] Further, in the present embodiment, in addition to the temperature of the floor 206 and the temperature of a range including the ceiling 203 and the wall 204 forming the high ceiling space 300, the temperature measurement unit 11 also measures the temperature of the living space 301 disposed between the floor 206 and the high ceiling space 300 to detect a person. Specifically, the temperature measurement unit 11 also measures the temperature of an area ranging from the boundary between the wall 204 and the wall 205 to the boundary between the wall 205 and the floor 206. The information on the measured temperature is transmitted to the temperature difference calculation unit 53, the operation controller 54, the storage unit 55, and the person detection unit 56.

[0123] The person detection unit 56 detects a person based on the above-mentioned temperature measured by the temperature measurement unit 11. Note that a technique of detecting a person from temperature distribution in the room is disclosed as a known technique. For example, the head of a person is often exposed in a room, and the temperature of the head of the person is less affected by age and sex and is approximately 36 degrees C. A technique of detecting a person by making use of such a fact is disclosed. Also in the present embodiment, a person may be detected by substantially the same method.

[0124] In the case where the person detection unit 56 detects the presence of a person in the room, the person detection unit 56 also detects the person in a direction in which the above-mentioned person is present as viewed from the indoor unit 100. The reason is, as will be described later, to prevent a reduction in comfort due to an air flow directly impinging on the person in implementing the temperature difference reduction modes 1 to 3. The detection result from the person detection unit 56 is transmitted to the operation controller 54 and the storage unit 55.

[0125] Subsequently, the action of the air-conditioning system 1000 in the present embodiment will be described. Fig. 15 is a flowchart showing the action of the

air-conditioning system 1000 in the present embodiment. Compared with the flowchart shown in Fig. 8, S111 is replaced with S201 and, in addition to the above, S202 is added after S211 in Fig. 15.

[0126] In S201, the temperature measurement unit 11 also measures the temperature of the high ceiling space 300, the temperature of the floor 206, and the temperature of the living space 300. The information on the measured temperature is transmitted to the temperature difference calculation unit 53, the operation controller 54, the storage unit 55, and the person detection unit 56.

[0127] In S202, the person detection unit 56 detects a person based on the temperature of the living space 300 measured in S201. The person detection unit 56 detects a person based on, for example, whether a part considered to be the head of a person based on the above-mentioned measured temperature is present in the room. At this point of operation, the person detection unit 56 also detects the direction in which the person is present as viewed from the indoor unit 100. The detection result from the person detection unit 56 is transmitted to the operation controller 54 and the storage unit 55.

[0128] In the same manner as Embodiment 1, the temperature difference reduction modes 1 to 3 are performed in S117, S118, and S119. However, control targets and change values in the temperature difference reduction modes 1 to 3 in the present embodiment are different from the control targets and the change values in Embodiment 1.

[0129] Fig. 16 is a diagram showing the control targets and the change values in the temperature difference reduction modes 1 to 3 in the present embodiment. In the present embodiment, when a person is detected in S202, the direction of an air flow in the lateral direction is also changed in the temperature difference reduction modes 1 to 3 in addition to the direction of the air flow in the vertical direction. Specifically, in the temperature difference reduction modes 1 to 3, by controlling the wind direction adjustment unit 7, the operation control unit 55 changes the direction of the air flow, blown out from the indoor unit 100, in the lateral direction to a direction in which a person is not present. At this point of operation, other control targets and change values may be substantially equal to the corresponding other control targets and change values in Embodiment 1.

[0130] As described above, the air-conditioning system 1000 of the present embodiment detects the presence of a person in the room, and adjusts the direction of the air flow in the lateral direction to the direction in which the person is not present in the temperature difference reduction modes 1 to 3. With such an operation, when each of the temperature difference reduction modes 1 to 3 is performed, there is no possibility of a high speed air flow directly impinging on the person, so that the comfort of the person is increased.

[0131] In the present embodiment, the air-conditioning system 1000 may perform the following action. In the flowchart shown in Fig. 15, when the person detection

unit 56 detects a person in S202, the process proceeds to S116, and when the person detection unit 56 does not detect a person, the process proceeds to S112. In this case, in the case where a person is present in the room, the temperature difference elimination modes 1 to 3 are not performed. With such a configuration, it is possible to more surely eliminate a possibility of a high speed air flow directly impinging on the person when each of the temperature difference reduction modes 1 to 3 is performed, so that the comfort of the person is increased.

Embodiment 3

[0132] Embodiment 3 of the present disclosure will be described with reference to Fig. 17 and Fig. 18. Hereinafter, the description will be made mainly for a point that makes an air-conditioning system 1000 according to the present embodiment different from the air-conditioning system according to Embodiment 1. Components, the description of which is omitted, are substantially equal to the corresponding components in Embodiment 1.

[0133] Fig. 17 is a diagram showing the configuration of a controller 50 in the present embodiment. The controller 50 in the present embodiment includes, in addition to the components of the controller 50 in Embodiment 1, a room entry prediction unit 57 that predicts the entry of a person into a room.

[0134] The room entry prediction unit 57 can communicate with a smartphone or a wearable terminal that is owned by a person, for example, and utilizes a GPS (registered trademark) or the like to detect the position of the person not in the room in which at least the indoor unit 100 is installed. Further, the room entry prediction unit 57 predicts the entry of the person into the room, in which the indoor unit 100 is installed, from a change over time in detected position of the person.

[0135] Specifically, the room entry prediction unit 57 detects the position of a person at predetermined period of time intervals (5 minutes, for example). In such a case, when the person is within a predetermined distance (5 [km], for example) from the room, in which the indoor unit 100 is installed, and the person approaches the room, the room entry prediction unit 57 predicts that the person is to enter into the room. The predicted result is transmitted to the operation controller 54 and the storage unit 55.

[0136] Subsequently, the action of the air-conditioning system 1000 of the present embodiment will be described. Fig. 18 is a flowchart showing the action of the air-conditioning system 1000 in the present embodiment.

[0137] In S301, the room entry prediction unit 57 predicts the entry of a person into the room. Specifically, the room entry prediction unit 57 detects the position of the person at least at two different clock times. When the person is present within a predetermined distance from the room and the person approaches the room with the lapse of period of time, the room entry prediction unit 57 predicts that the person is to enter into the room. When the room entry prediction unit 57 predicts the entry of the

person into the room, the process proceeds to S102. In contrast, when the room entry prediction unit 57 does not predict the entry of the person into the room, the processing in S301 is repeated at predetermined period of time intervals (10 minutes, for example).

[0138] When the indoor temperature difference calculated by the temperature difference calculation unit 53 in S104 is equal to or more than the third threshold ΔT_s1 in S302, the process proceeds to S304. In contrast, when the above-mentioned indoor temperature difference is less than the third threshold ΔT_s1 , the process proceeds to S303. In S302, it is not always necessary to perform the determination based on the third threshold ΔT_s1 and the indoor temperature difference. The determination may be performed based on a predetermined fourth threshold ΔT_s2 , which is different from the third threshold ΔT_s1 , and the indoor temperature difference.

[0139] In S303, the operation controller 54 stops the action of the air-conditioning system 1000. At this point of operation, the operation controller 54 stops the action of the compressor 1, the outdoor air sending unit 3, the expansion valve 4, the indoor air sending unit 6, and the wind direction adjustment unit 7. However, the operation controller 54 continues the action of at least the temperature measurement unit 11 and the temperature difference calculation unit 53. After the action of the air-conditioning system 1000 is stopped, the process returns to S103.

[0140] In S304, the air-conditioning system 1000 is activated in a temperature difference reduction mode 4. In the temperature difference reduction mode 4, the operation controller 54 causes the indoor air sending unit 6 and the wind direction adjustment unit 7 to be activated. At this point of operation, the rotation speed of the indoor fan of the indoor air sending unit 6 is not particularly limited and may be a predetermined constant value, for example, or may be decided according to the distance from the indoor unit 100 to the high ceiling space 300. Further, the wind direction adjustment unit 7 is at least controlled such that an air flow is blown out in a direction other than the horizontal direction. In the example shown in Fig. 4, the wind direction adjustment unit 7 is controlled to be in any one of states including vertical wind directions 2 to 5. In the same manner as the temperature difference reduction modes 1 to 3 in Embodiment 1, the direction of the wind direction adjustment unit 7 may be decided according to the distance between the indoor unit 100 and the high ceiling space 300.

[0141] With such operations, in the temperature difference reduction mode 4, an air flow in the downward direction is blown out from the indoor unit 100 and, further, the flow of air in the vertical direction is generated in the entire room. Accordingly, warm air in the high ceiling space 300 is mixed with air in the living space 301 and hence, an indoor temperature difference can be eliminated.

[0142] In S305, the room entry prediction unit 57 determines whether a person has entered into the room.

Specifically, the room entry prediction unit 57 determines that the person has entered into the room when the person is present in front of the indoor unit 100 and within a predetermined distance (for example, 5 [m]) or less from the indoor unit 100. When the person has entered into the room, in S306, the action of the air-conditioning system 1000 is switched to the action in Embodiment 1 shown in Fig. 8. At this point of operation, a target temperature for the air-conditioning system 1000 may be a target temperature or the like at the time of the air-conditioning system 1000 being activated for the action in Embodiment 1 in a previous cycle, for example. In contrast, when the person has not entered into the room, the process returns to S103.

[0143] As described above, the air-conditioning system 1000 of the present embodiment predicts the entry of a person into a room. When the entry of the person into the room is predicted and an indoor temperature difference is equal to or more than the third threshold ΔT_s1 , the air-conditioning system 1000 performs the temperature difference reduction mode 3. With such operations, for example, when the person returns to the room from the outside, the air-conditioning system 1000 causes warm air stagnating in the high ceiling space 300 to be mixed in advance with air in the living space 300. Accordingly, the temperature of air in the living space 300 is already raised when the person arrives home and hence, the comfort of the person is increased.

[0144] The action of the air-conditioning system 1000 in the present embodiment may be combined with the action of the air-conditioning system 1000 in Embodiment 2. In this case, in S306, the action of the air-conditioning system 1000 is switched to the action in Embodiment 2 shown in Fig. 15. In this case, the person detection unit 56 may determine whether the person has entered into the room in S305.

Reference Signs List

[0145] 1: compressor, 2: outdoor heat exchanger, 3: outdoor air sending unit, 4: expansion valve, 5: indoor heat exchanger, 6: indoor air sending unit, 7: wind direction adjustment unit, 10: distance measurement unit, 11: temperature measurement unit, 12: sucked air temperature measurement unit, 21: motor body, 22: motor shaft, 23: support part, 24: ultrasonic distance sensor, 30: housing, 31: air inlet, 32: air outlet, 50: controller, 51: high ceiling detection unit, 52: floor detection unit, 53: temperature difference calculation unit, 54: storage unit, 55: operation controller, 56: person detection unit, 70: terminal, 100: indoor unit, 101: outdoor unit, 200, 202, 204, 205: wall, 201, 203: ceiling, 206: floor, 207: horizontal extension of ceiling 201, 300: high ceiling space, 301: living space, 400: air flow, 401: upward air flow, 500: warm air, 1000: air-conditioning system

Claims

1. An air-conditioning system comprising:

an indoor unit; 5
 a distance measurement unit configured to measure a distance from the indoor unit to a ceiling and a distance from the indoor unit to a floor;
 a high ceiling detection unit configured to detect, 10
 in a case where a room has a plurality of ceilings having different heights, a high ceiling space based on the distance from the indoor unit to the ceiling measured by the distance measurement unit, the high ceiling space being disposed at a position higher than a ceiling having a lowest height of the plurality of ceilings;
 a floor detection unit configured to detect the floor based on the distance from the indoor unit to the floor measured by the distance measurement unit and a distance from the indoor unit to a wall measured by the distance measurement unit;
 a temperature measurement unit configured to measure a temperature of the high ceiling space and a surface temperature of the floor;
 a temperature difference calculation unit configured to calculate a temperature difference between the temperature of the high ceiling space detected by the temperature measurement unit and the surface temperature of the floor detected by the temperature measurement unit; and
 a controller configured to perform control of generating a first air flow according to a predetermined operating condition in a case where the temperature difference calculated by the temperature difference calculation unit is less than a first threshold, and to perform control of generating a second air flow in a case where the temperature difference is equal to or more than the first threshold, the second air flow satisfying at least either one of a condition that the second air flow has a lower temperature than the first air flow or a condition that the second air flow has a larger velocity component in a vertical direction than the first air flow. 45

2. The air-conditioning system of claim 1, wherein

the temperature difference calculation unit is configured to measure the temperature difference at least at two or more different clock times, and to calculate a change over time in the temperature difference from the temperature difference measured at least at the two or more different clock times, and 50
 the controller is configured to perform control of generating a third air flow in a case where the 55

change over time in the temperature difference is equal to or more than a second threshold different from the first threshold, the third air flow satisfying at least either one of a condition that the third air flow has a lower temperature than the second air flow or a condition that the third air flow has a larger velocity component in the vertical direction than the second air flow.

3. The air-conditioning system of claim 2, wherein the controller is configured to perform control of generating the second air flow in a case where the change over time in the temperature difference is less than the second threshold and, of the temperature difference measured at least at the two or more different clock times, the temperature difference measured last is equal to or more than the first threshold.

4. The air-conditioning system of claim 2 or claim 3, comprising:

a target temperature acquisition unit configured to acquire information on a target temperature set by a user; and
 a sucked air temperature measurement unit configured to measure a temperature of indoor air sucked into the indoor unit, wherein the controller is configured to perform control of generating a fourth air flow having a higher temperature than the first air flow in a case where either one of the second air flow or the third air flow is generated and the temperature of the indoor air measured by the sucked air temperature measurement unit is lower than the target temperature acquired by the target temperature acquisition unit.

5. The air-conditioning system of any one of claims 2 to 4, wherein the controller is configured to perform control of changing a direction of the second air flow and a direction of the third air flow in the vertical direction according to a distance between the indoor unit and the high ceiling.

6. The air-conditioning system of any one of claims 2 to 5, wherein

the temperature measurement unit is configured to measure a surface temperature of an object present in a space between the floor and the high ceiling,
 the air-conditioning system includes a person detection unit configured to detect presence of a person in a room from the surface temperature of the object measured by the temperature measurement unit, and to further detect a direc-

tion in which the person is present as viewed from the indoor unit, and the controller is configured to, in a case where the person is present in the room, control the direction of the second air flow or the direction of the third air flow in a lateral direction to a direction other than the direction in which the person is present, the person being detected by the person detection unit.

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7. The air-conditioning system of any one of claims 1 to 6, comprising a room entry prediction unit configured to detect a position of a person outside the room, and to predict entry of the person into the room from a change over time in the position of the person outside the room, wherein the controller is configured to perform control of generating a fifth air flow in a case where the room entry prediction unit predicts entry of the person into the room and the temperature difference calculated by the temperature difference calculation unit is greater than the first threshold, the fifth air flow performing only sending of air without performing temperature adjustment.

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FIG. 1

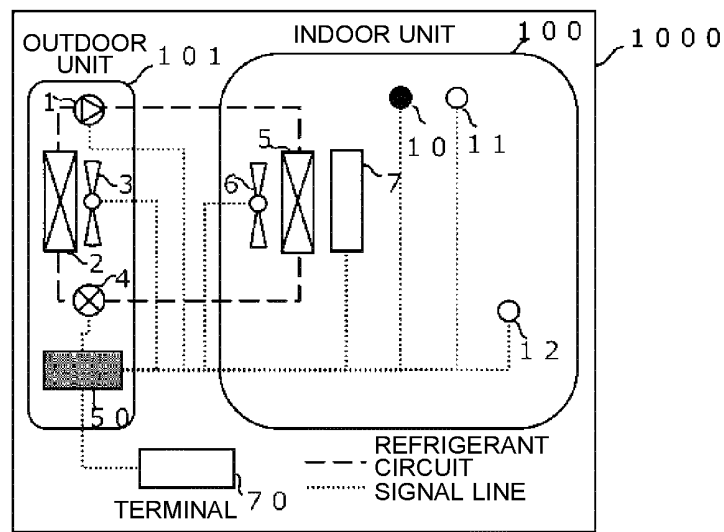


FIG. 2

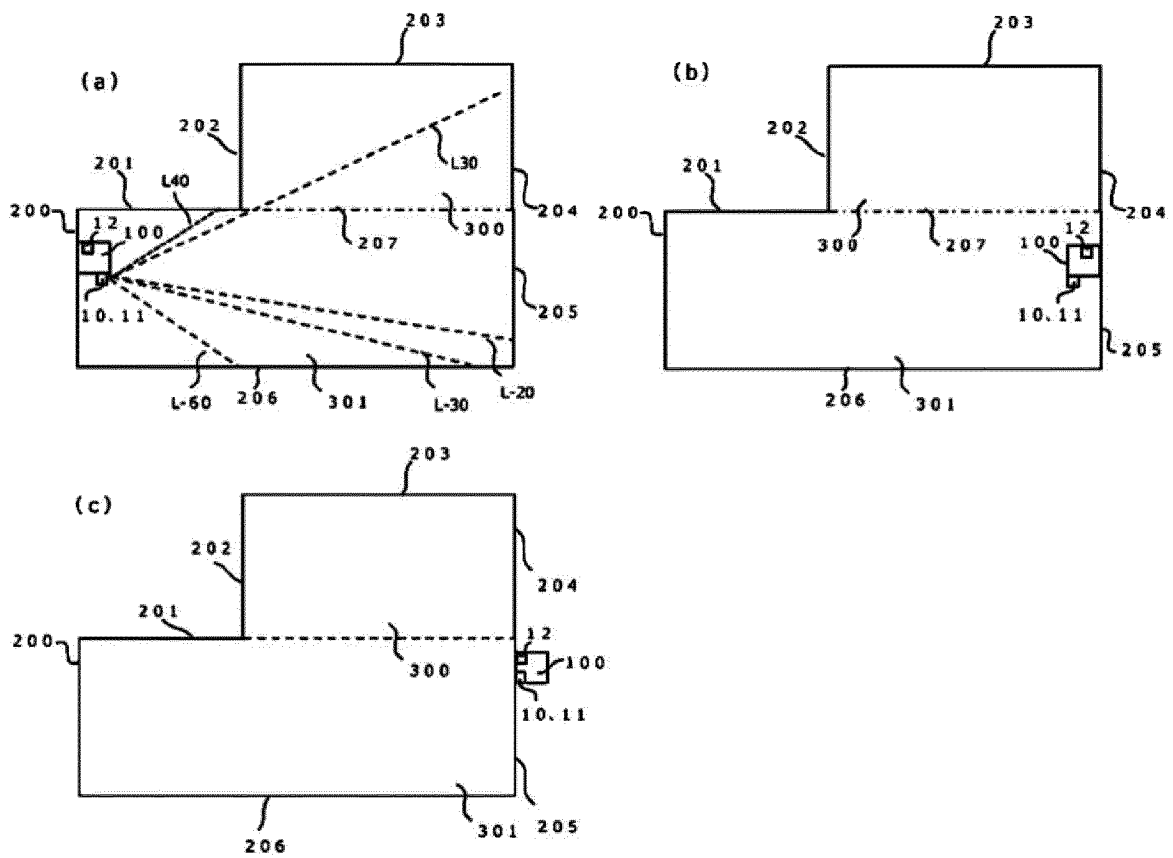


FIG. 3

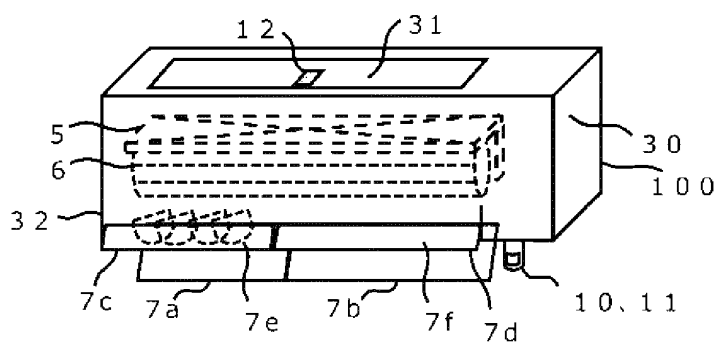


FIG. 4

	UPWARD DIRECTION ← → DOWNWARD DIRECTION				
	VERTICAL WIND DI-RECTION 1	VERTICAL WIND DI-RECTION 2	VERTICAL WIND DI-RECTION 3	VERTICAL WIND DI-RECTION 4	VERTICAL WIND DI-RECTION 5
ANGLE OF FLAP					

FIG. 5

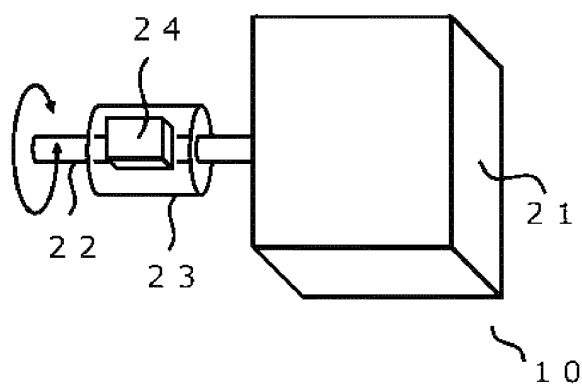


FIG. 6

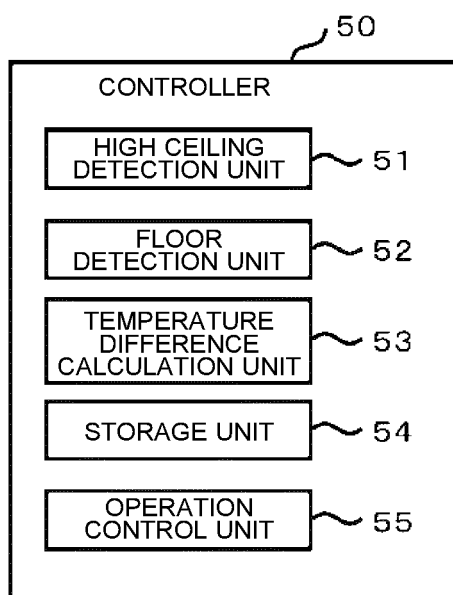


FIG. 7

(a)		DISTANCE DATA [cm]									
ANGLE OF DISTANCE MEASUREMENT UNIT 10 IN VERTICAL DIRECTION		ANGLE OF DISTANCE MEASUREMENT UNIT 10 IN LATERAL DIRECTION									
			0	10	20	30	40	50	60	70	80
		0	525	555	565	575	580	595	605	610	620
		10	535	565	575	585	590	605	615	620	630
		20	540	570	580	590	595	610	620	625	635
		30	550	580	590	600	605	620	630	635	645
		40	175	185	185	190	195	210	220	225	235
		50	160	170	170	175	180	195	205	210	220
		60	150	160	160	165	170	185	195	200	210
		70	145	155	155	160	165	180	190	195	205
		80	140	150	150	155	160	175	185	190	200

(b)		DISTANCE DATA [cm]									
ANGLE OF DISTANCE MEASUREMENT UNIT 10 IN VERTICAL DIRECTION		ANGLE OF DISTANCE MEASUREMENT UNIT 10 IN LATERAL DIRECTION									
			0	10	20	30	40	50	60	70	80
		0	310	320	320	325	335	340	355	360	370
		10	325	335	335	340	350	355	370	375	385
		20	310	320	320	325	335	340	355	360	370
		30	300	310	310	315	325	330	345	350	360
		40	295	305	305	310	320	325	340	345	355
		50	290	300	300	305	315	320	335	340	350
		60	535	565	575	585	595	600	615	620	630
		70	540	570	580	590	600	605	620	625	635
		80	550	580	590	600	610	615	630	635	645

FIG. 8

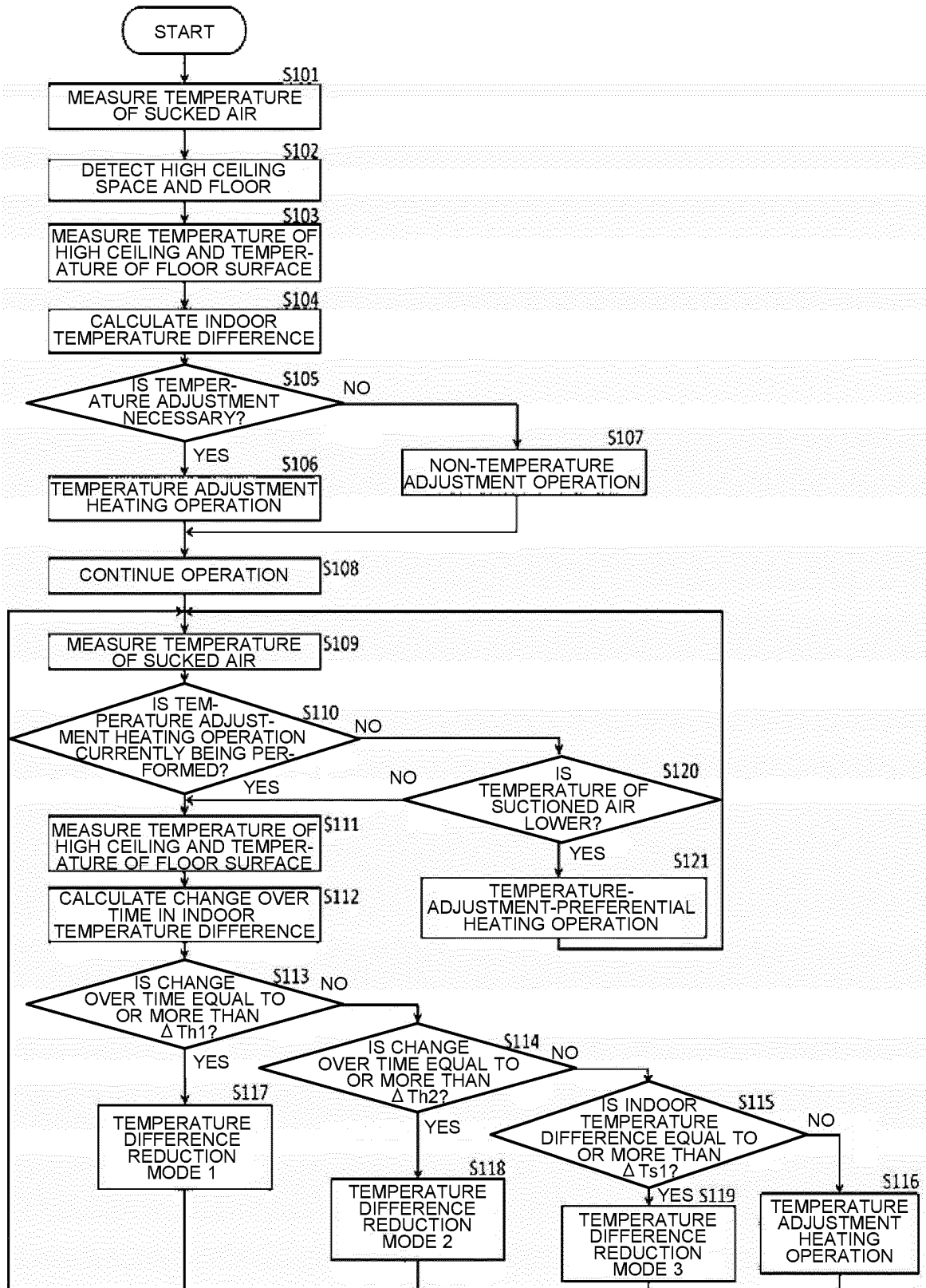


FIG. 9

	AT TIME OF START	AFTER 15 MINUTES	AFTER 30 MINUTES	CHANGE IN INDOOR TEMPERATURE DIFFERENCE PER HOUR [$^{\circ}$ C/h]
TEMPERATURE [$^{\circ}$ C] OF HIGH CEILING SPACE 300	20.5	21.5	22.5	2.0
TEMPERATURE [$^{\circ}$ C] OF FLOOR 206	19.0	19.5	20.0	
INDOOR TEMPERATURE DIFFERENCE [$^{\circ}$ C]	1.5	2.0	2.5	

FIG. 10

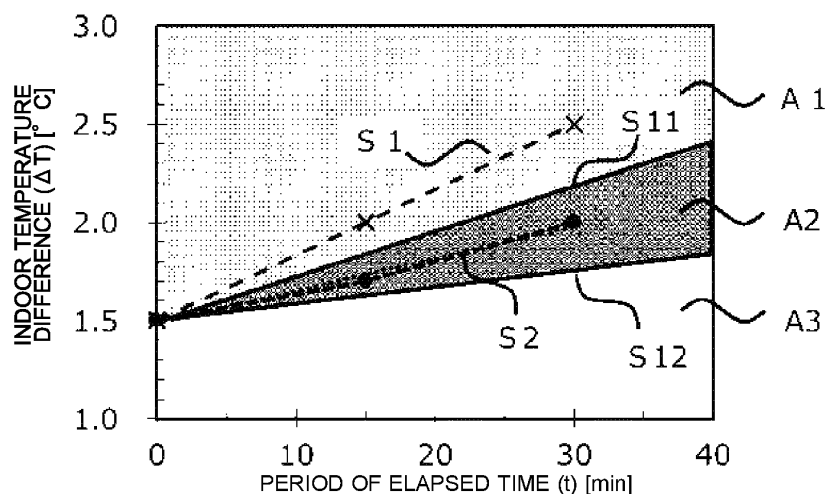


FIG. 11

		TEMPERATURE DIFFERENCE REDUCTION MODE 1 (S117)	TEMPERATURE DIFFERENCE REDUCTION MODE 2 (S118)	TEMPERATURE DIFFERENCE REDUCTION MODE 3 (S119)	TEMPERATURE-ADJUSTMENT-PREFERENTIAL HEATING OPERATION (S121)
	CONDITION FOR IMPLEMENTATION	CHANGE OVER TIME IN INDOOR TEMPERATURE DIFFERENCE IS EQUAL TO OR MORE THAN THRESHOLD $\Delta TH1$	CHANGE OVER TIME IN INDOOR TEMPERATURE DIFFERENCE IS LESS THAN THRESHOLD $\Delta TH1$ AND EQUAL TO OR MORE THAN $\Delta TH2$	(A) CHANGE OVER TIME IN INDOOR TEMPERATURE DIFFERENCE IS LESS THAN THRESHOLD $\Delta TH2$ AND (B) INDOOR TEMPERATURE DIFFERENCE IS EQUAL TO OR MORE THAN $\Delta TS1$	TEMPERATURE OF SUCTIONED AIR IS LESS THAN TEMPERATURE OF SUCTIONED AIR MEASURED ONE CYCLE EARLIER
		CHANGE VALUE			
CONTROL TARGET	FREQUENCY [Hz] OF COMPRESSOR	REDUCED BY F1	REDUCED BY F2 ($F2 < F1$)	REDUCED BY F3 ($F3 < F2$)	INCREASED BY F4
	ROTATION SPEED [rpm] OF INDOOR FAN	INCREASED BY f1	INCREASED BY f2 ($f2 < f1$)	INCREASED BY f3 ($f3 < f2$)	NO CHANGE
	DIRECTION OF AIR FLOW IN VERTICAL DIRECTION	CHANGED TOWARD DOWNWARD DIRECTION BY ONE OR MORE LEVELS	CHANGED TOWARD DOWNWARD DIRECTION BY ONE OR MORE LEVELS	CHANGED TOWARD DOWNWARD DIRECTION BY ONE OR MORE LEVELS	NO CHANGE

FIG. 12

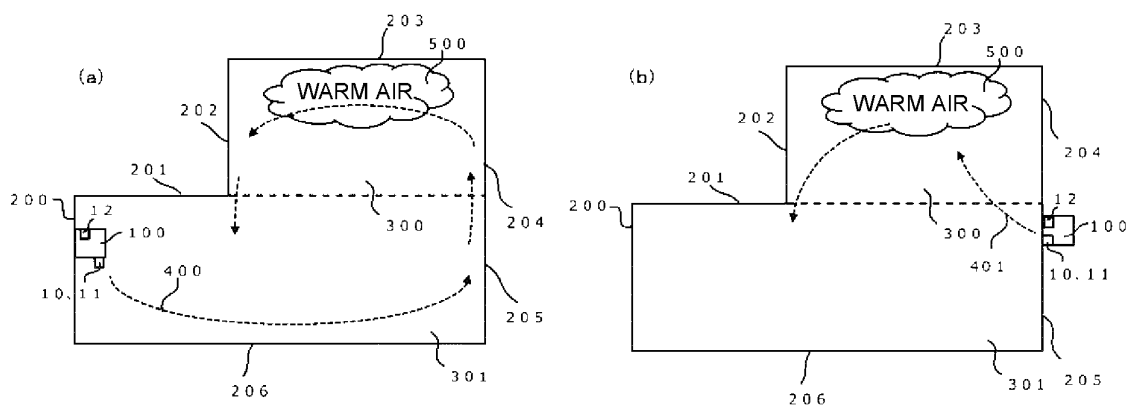


FIG. 13

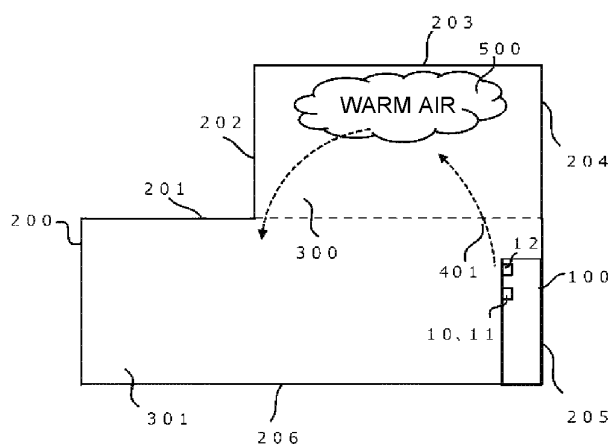


FIG. 14

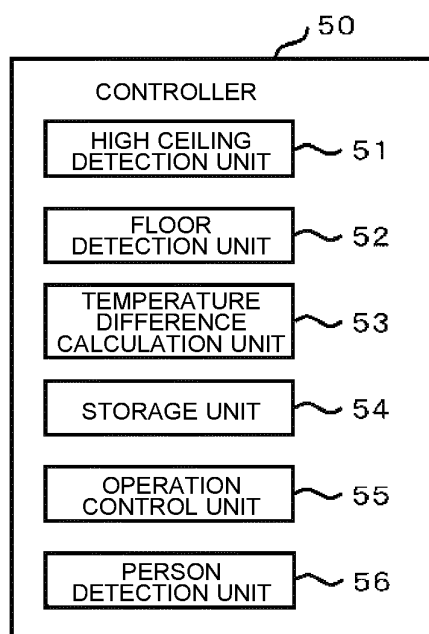


FIG. 15

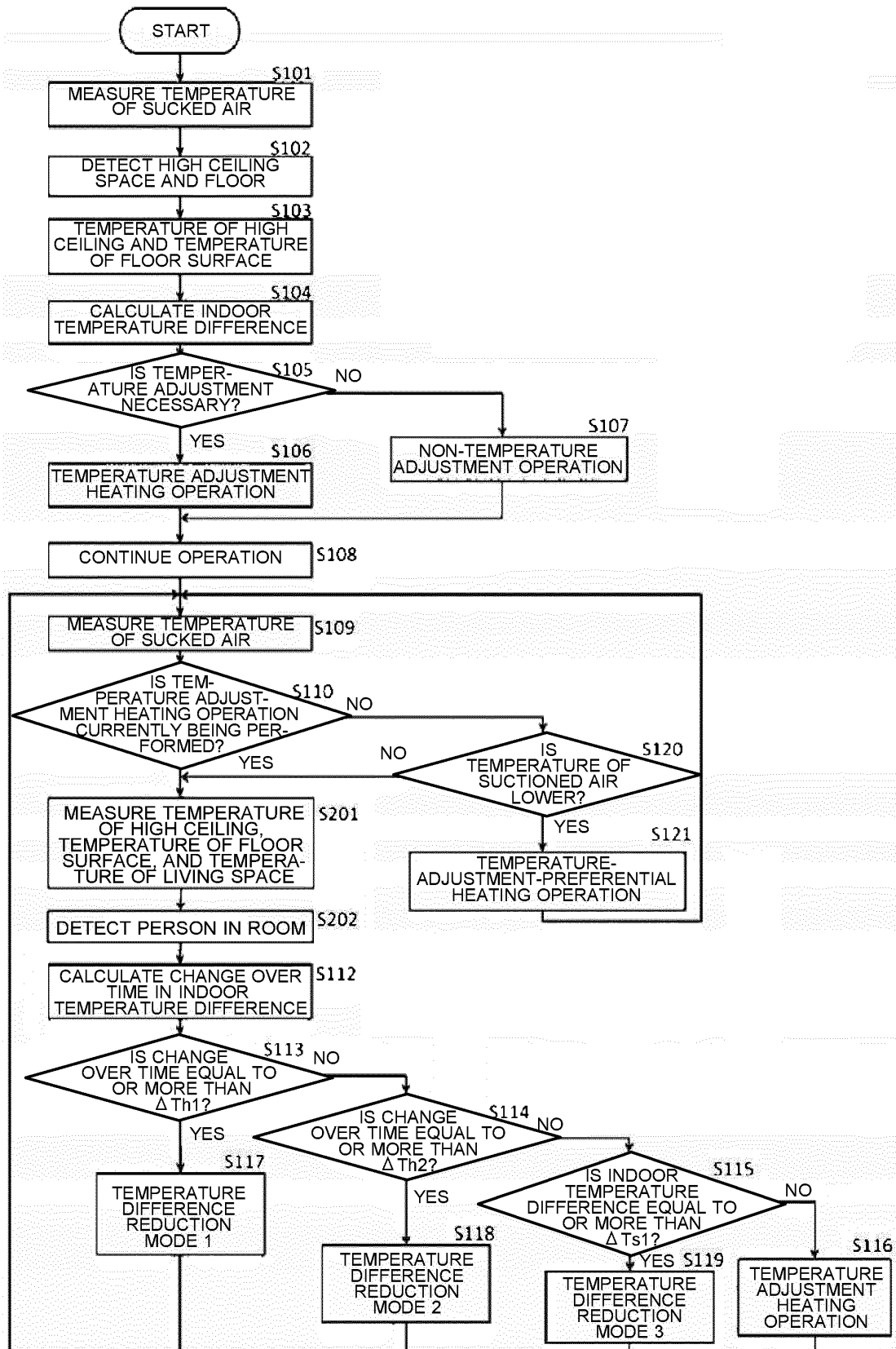


FIG. 16

		TEMPERATURE DIFFERENCE REDUCTION MODE 1 (S117)	TEMPERATURE DIFFERENCE REDUCTION MODE 2 (S118)	TEMPERATURE DIFFERENCE REDUCTION MODE 3 (S119)	TEMPERATURE- ADJUSTMENT- PREFERENTIAL HEATING OPERATION (S121)
	CONDITION FOR IMPLEMENTATION	CHANGE OVER TIME IN INDOOR TEMPERATURE DIFFERENCE IS EQUAL TO OR MORE THAN THRESHOLD $\Delta TH1$	CHANGE OVER TIME IN INDOOR TEMPERATURE DIFFERENCE IS LESS THAN THRESHOLD $\Delta TH1$ AND EQUAL TO OR MORE THAN $\Delta TH2$	(A) CHANGE OVER TIME IN INDOOR TEMPERATURE DIFFERENCE IS LESS THAN THRESHOLD $\Delta TH2$ AND (B) INDOOR TEMPERATURE DIFFERENCE IS EQUAL TO OR MORE THAN $\Delta TS1$	TEMPERATURE OF SUCTIONED AIR IS LESS THAN TEM- PERATURE OF SUCTIONED AIR MEASURED ONE CYCLE EARLIER
		CHANGE VALUE			
CONTROL TARGET	FREQUENCY [HZ] OF COMPRESSOR	REDUCED BY F1	REDUCED BY F2 ($F2 < F1$)	REDUCED BY F3 ($F3 < F2$)	INCREASED BY F4
	ROTATION SPEED [rpm] OF INDOOR FAN	INCREASED BY f1	INCREASED BY f2 ($f2 < f1$)	INCREASED BY f3 ($f3 < f2$)	NO CHANGE
	DIRECTION OF AIR FLOW IN VERTICAL DIRECTION	CHANGED TOWARD DOWNWARD DIRECTION BY ONE OR MORE LEVELS	CHANGED TOWARD DOWNWARD DIRECTION BY ONE OR MORE LEVELS	CHANGED TOWARD DOWNWARD DIRECTION BY ONE OR MORE LEVELS	NO CHANGE
	DIRECTION OF AIR FLOW IN LATERAL DIRECTION	CHANGED TOWARD DIRECTION IN WHICH PERSON IS NOT PRESENT	CHANGED TOWARD DIRECTION IN WHICH PERSON IS NOT PRESENT	CHANGED TOWARD DIRECTION IN WHICH PERSON IS NOT PRESENT	NO CHANGE

FIG. 17

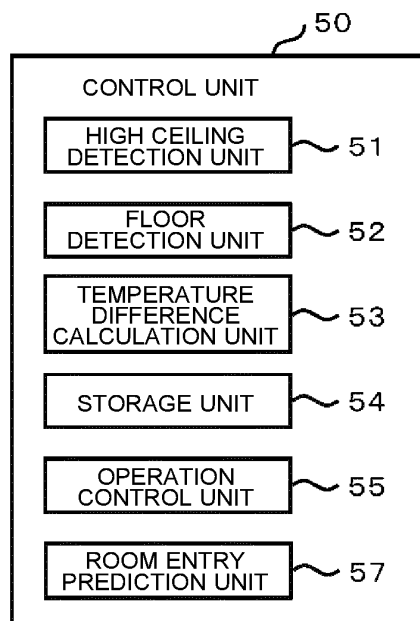
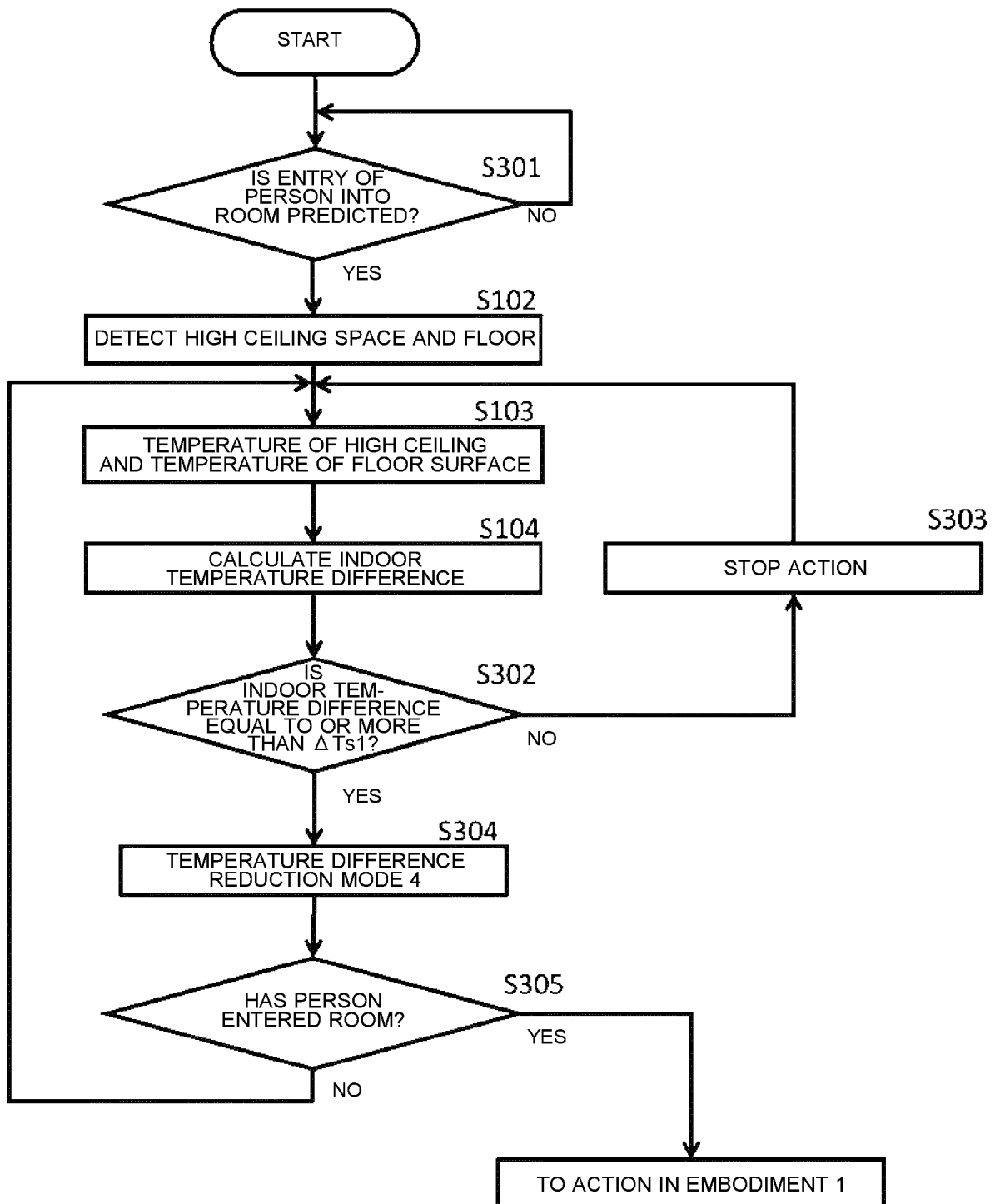


FIG. 18



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/033926

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A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F24F11/74 (2018.01) i, F24F11/79 (2018.01) i, F24F1/0317 (2019.01) i
 FI: F24F11/74, F24F11/79, F24F1/0317

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

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. F24F11/74, F24F11/79, F24F1/0317

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2020
 Registered utility model specifications of Japan 1996-2020
 Published registered utility model applications of Japan 1994-2020

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-322062 A (DAIKIN INDUSTRIES, LTD.) 13 December 2007	1-7
A	JP 2012-21735 A (MITSUBISHI ELECTRIC CORP.) 02 February 2012	1-7
A	JP 2019-45057 A (ASAHI KASEI HOMES CO.) 22 March 2019	1-7
A	JP 2017-101871 A (FUJITSU GENERAL LTD.) 08 June 2017	1-7

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☐	Further documents are listed in the continuation of Box C.	☒	See patent family annex.
* Special categories of cited documents:			
"A"	document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

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Date of the actual completion of the international search
09.11.2020

Date of mailing of the international search report
24.11.2020

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INTERNATIONAL SEARCH REPORT
Information on patent family membersInternational application No.
PCT/JP2020/033926

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JP 2012-21735 A	02.02.2012	US 2012/0012297 A1 EP 2407728 A2 CN 102338446 A	
JP 2019-45057 A	22.03.2019	(Family: none)	
JP 2017-101871 A	08.06.2017	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2012052680 A [0003]