

DESCRIPTION

Title of Invention: COLD STORAGE APPARATUS AND METHOD OF
DISPLAYING STATE OF COLD STORAGE ELEMENT

Technical Field

[0001]

The present disclosure relates to a cold storage apparatus and a method of displaying a state of a cold storage element.

Background Art

[0002]

A conventional cold roll box including a cold storage apparatus is known. The cold roll box is used, for example, such that in a state in which an article such as food is placed in the inside of the cold roll box, the cold roll box is placed on a loading platform of a delivery car and transported.

[0003]

PTL 1 discloses a cold roll box having a cold storage apparatus including a cold storage solution, a memory unit, a temperature detection unit, an amount of stored cold heat calculation unit, and a display. In the cold storage solution, an additive concentration is adjusted so as to obtain a particular characteristic of a temperature gradient between a freezing start temperature and a freezing end temperature. The freezing start temperature of the cold storage solution is, for example, about -7°C, and the freezing end temperature of the cold storage solution is about -22°C. The memory unit stores data associated with the characteristic of temperature gradient. The temperature detection unit detects the temperature of the cold storage solution. The amount of stored cold heat calculation unit determines an amount of stored cold heat based on the detected temperature obtained from the temperature detection unit and the data associated with the characteristic of temperature gradient obtained from the memory unit. The display displays the amount of stored cold heat determined by the amount of stored cold heat calculation unit.

Citation List

Patent Literature

[0004]

PTL 1: Japanese Unexamined Patent Application Publication No. 7-318215

Summary of Invention

[0005]

In the cold storage apparatus described in PTL 1, there is a possibility that, depending on a situation, it is impossible to properly determine an amount of stored cold heat. In view of the above, the present disclosure provides a cold storage apparatus capable of determining a state of a cold storage element more securely and more properly.

Solution to Problem

[0006]

According to a first aspect of the present disclosure, there is provided a cold storage apparatus including a plurality of boxes arranged in a first direction in a cold storage room, each box containing a cold storage element, an air blower that is disposed in a storage room partitioned from the cold storage room such that communication between the storage room and the cold storage room is allowed and that creates a flow of air passing in a second direction through a space defined in the second direction between the plurality of boxes, the second direction crossing the first direction in a plane parallel to a bottom surface of the cold storage room in which the plurality of boxes are arranged, thereby circulating the air cooled by the cold storage element, a temperature sensor that detects, at a plurality of locations in the second direction, a surface temperature of at least one box, a surface temperature of the cold storage element contained in the at least one box, or an internal temperature of the cold storage element contained in the at least one box, a display information generator that receives an input of information indicating the temperature detected by the temperature sensor and generates state information indicating a state of the cold storage element based on the surface temperature of the at least one box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element, and a display that displays the state information, wherein the display information generator estimates a spatial temperature distribution of the cold storage element based on information indicating the surface temperature of the box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element at the plurality of locations, and calculates a remaining amount of stored cold heat as the state information based on the ratio of a part, in the temperature distribution, where the temperature is higher than a predetermined threshold value to the whole temperature distribution.

[0006a]

According to a second aspect of the present disclosure, there is provided a method of displaying information indicating a state of a cold storage element, comprising creating a flow of air by an air blower such that, in a cold storage room in which a plurality of boxes each containing a cold storage element are arranged in a first direction, the flow of air passes in a second direction through a space defined in the second direction between the boxes, the second direction crossing the first direction in a plane parallel to a bottom surface of the cold storage room, thereby circulating the air cooled by the cold storage element; detecting, using a temperature sensor and at a plurality of locations in the second direction, a surface temperature of at least one box, a surface temperature of the cold storage element contained in the at least one box, or an internal temperature of the cold storage element contained in the at least one box; generating state information indicating the state of the cold storage element by acquiring, using a display information generator, an input of information indicating the temperature detected by the temperature sensor and generating the state information based on the information indicating the surface temperature of the at least one box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element; and displaying the state information on a display, wherein the display information generator estimates a spatial temperature distribution of the cold storage element based on information indicating the surface temperature of the box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element at the plurality of locations, and calculates a remaining amount of stored cold heat as the state information based on the ratio of a part, in the temperature distribution, where the temperature is higher than a predetermined threshold value to the whole temperature distribution.

[0007]

The cold storage apparatus described above is capable of more surely and more properly determining the state of the cold storage element.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a schematic diagram schematically illustrating a cold

storage apparatus according to a first embodiment.

[Fig. 2] Fig. 2 is a perspective view illustrating an air flow in a cold storage room.

[Fig. 3] Fig. 3 is a schematic diagram schematically illustrating a part of a cold storage apparatus according to an embodiment.

[Fig. 4] Fig. 4 is a cross-sectional view of a box taken along a line IV-IV of Fig. 3.

[Fig. 5] Fig. 5 is a flow chart illustrating an operation of a cold storage apparatus.

[Fig. 6] Fig. 6 is a graph illustrating an example of a result of a detection performed by a temperature sensor of a cold storage apparatus according to an embodiment.

[Fig. 7] Fig. 7 is a schematic diagram schematically illustrating a part of a cold storage apparatus according to a modification.

[Fig. 8A] Fig. 8A is a schematic diagram illustrating a part of a cold storage apparatus according to another modification.

[Fig. 8B] Fig. 8B is a schematic diagram illustrating a part of a cold storage apparatus according to another modification.

[Fig. 9A] Fig. 9A is a graph schematically illustrating an example of a result of a detection performed by a temperature sensor of the cold storage apparatus shown in Fig. 8A.

[Fig. 9B] Fig. 9B is a graph schematically illustrating an example of a result of a detection performed by a temperature sensor of the cold storage apparatus shown in Fig. 8B.

[Fig. 10A] Fig. 10A is a cross-sectional view of a box of a cold storage apparatus according to a still another modification.

[Fig. 10B] Fig. 10B is a cross-sectional view of a box of a cold storage apparatus according to a still another modification.

[Fig. 11] Fig. 11 is a schematic diagram schematically illustrating a cold storage apparatus according to a second embodiment.

[Fig. 12] Fig. 12 is a cross-sectional view of a box in a cold storage apparatus according to a second embodiment.

[Fig. 13] Fig. 13 is a graph schematically illustrating an example a result of a detection performed by a temperature sensor of a cold storage apparatus

according to a second embodiment.

Description of Embodiments

[0009]

The cold storage apparatus described in reference literature 1 is designed without taking into account a possibility that the cold storage solution can have a spatial temperature variation. Therefore, in the cold storage apparatus described in reference literature 1, there is a possibility that it is difficult to properly determine the amount of stored cold heat in a case where the cold storage solution has a spatial temperature variation. In the cold storage apparatus described in reference literature 1, for example, a cold storage solution having a freezing start temperature of about -7°C and a freezing end temperature T_e equal to about -22°C , and thus the absolute value of the difference between the freezing start temperature T_s and the freezing end temperature T_e is as large as about 15°C . Therefore, in the cold storage apparatus described in reference literature 1, it is easy to determine the amount of stored cold heat using the characteristic of temperature gradient between the freezing start temperature and the freezing end temperature. However, in the cold storage apparatus described in reference literature 1, when the absolute value of the difference between the freezing start temperature and the freezing end temperature becomes small, it becomes difficult to properly determine the amount of stored cold heat.

[0010]

In a first aspect, the present disclosure provides a cold storage apparatus including a plurality of boxes arranged in a first direction in a cold storage room, each box containing a cold storage element, an air blower that is disposed in a storage room partitioned from the cold storage room such that communication between the storage room and the cold storage room is allowed and that creates a flow of air passing in a second direction through a space defined in the second direction between the plurality of boxes, the second direction crossing the first direction in a plane parallel to a bottom surface of the cold storage room in which the plurality of boxes are arranged, thereby circulating the air cooled by the cold storage element, a temperature sensor that detects, at a plurality of locations in the second direction, a surface temperature of at least one box, a surface temperature of the cold storage element contained in the at least one box, or an

internal temperature of the cold storage element contained in the at least one box, a display information generator that receives an input of information indicating the temperature detected by the temperature sensor and generates state information indicating a state of the cold storage element based on the surface temperature of the at least one box, the surface temperature of the cold storage element or the internal temperature of the cold storage element, and a display that displays the state information.

[0011]

In the first aspect, the display information generator generates the state information indicating the state of the cold storage element based on the information indicating the surface temperature of the box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element as detected at a plurality of locations. Thus, it is possible to properly determine the state of the cold storage element even in a case where there is a possibility that the cold storage element has a spatial temperature variation. Furthermore, in the first aspect, it is possible to properly determine the state of the cold storage element regardless of the characteristic of temperature gradient between the freezing start temperature and the freezing end temperature of the cold storage material included in the cold storage element. In addition, to achieve a flow path for circulating air, the plurality of boxes do not necessarily need to be disposed apart from the bottom surface of the cold storage room. Furthermore, since the air blower is disposed in the storage room, a variation does not easily occur in the flow rate of the flow of air in the space defined between the boxes.

[0012]

In a second aspect, in addition to the first aspect, the present disclosure provides a cold storage apparatus in which the plurality of boxes are in contact with the bottom surface of the cold storage room. According to the second aspect, the air can easily flow in the second direction through the space defined between the boxes, which makes it possible for the air to be efficiently cooled by the cold storage element.

[0013]

In a third aspect, in addition to the first aspect or the second aspect, the present disclosure provides a cold storage apparatus in which a longest side of each of the plurality of boxes extends in a direction parallel to the second direction.

According to the third aspect, the fusion state of the cold storage element as a whole tends to vary in the second direction. Furthermore, it is possible to easily achieve a long period for which the air stays in the space defined between the boxes when the air flows in the second direction through the space defined between the boxes, which ensures that the air is cooled when the air flows through the space defined between the boxes. In addition, since a relatively large pressure loss occurs in the air flow passing through the space defined between the boxes, it is possible to easily direct the air flow equally to a plurality of spaces through which the air flows.

[0014]

In a fourth aspect, in addition to one of the first to third aspects, the present disclosure provides a cold storage apparatus in which when two ends of the box as seen in the second direction are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a downstream end, the plurality of locations are distributed relatively densely between the upstream end and a middle location that is between the upstream end and the downstream end in the second direction and that is apart equally from both the upstream end and the downstream end while the plurality of locations are distributed relatively sparsely between the downstream end and the middle location. According to the fourth aspect, it is easy to generate accurate state information indicating the state of the cold storage element, for reasons described below.

[0015]

To keep the temperature of the space for accommodating articles in the cold storage apparatus within a specific temperature range against heat input from the outside of the cold storage apparatus, it is necessary for the air circulating inside the cold storage apparatus to receive cold heat from the cold storage element via heat exchange as much as necessary to cancel out the input heat. In a case where the cold storage element has a heat transfer area sufficiently large for the air circulating in the cold storage apparatus to receive the cold heat quantity, heat exchange occurs effectively between the air and the cold storage element near the upstream end of the box as long as the total cold heat quantity of the cold storage element is large. Thus, the cold heat of the cold storage element is consumed first near the upstream end, and the cold storage element gradually fuses starting from

the upstream end toward the middle location. As a result, the temperature detected by the temperature sensor tends to change in the second direction between the upstream end and the middle location. When the total cold heat quantity of the cold storage element becomes small after the fusion of the cold storage element starting from the upstream end has reached near the middle location, the cold storage element located between a location near the middle location and the downstream end fuses in a manner different from the manner in which the cold storage element fuses near the upstream end when the total cold heat quantity of the cold storage element is large. In this case, the cold storage element located between the location near the middle location and the downstream end fuses substantially uniformly over the region between the location near the middle location and the downstream end.

[0016]

At the point of time when the total cold heat quantity of the cold storage element has become small, the cold storage element between the upstream end and the middle location has fused. However, at last part of the cold storage element between the upstream end and the middle location still has a cold heat quantity in the form of sensible heat sufficient to cool the temperature of the air flowing into the space defined between the boxes. As a result, the air flowing into the space is cooled to a temperature near the melting point of the cold storage element during a period in which the air flows from the upstream end to the location near the middle location. The air can be further cooled to a temperature below the melting point of the cold storage element when the flow flows from the location near the middle location to the downstream end. In this process, only a small quantity of the cold heat is consumed in the cold storage element between the location near the middle location and the downstream end, and thus a variation in fusion state of the cold storage element does not easily occur in the direction of the air flow between the location near the middle location and the downstream end. For the reasons described above, in the region between the location near the middle location and the downstream end, unlike the manner of fusion in the region between the upstream end and the location near the middle location, the cold storage element fuses substantially uniformly over the whole region between the location near the middle location and the downstream end. As a result, in the region between the location near the middle location and the downstream end the

cold storage element does not easily have an unevenness in the fusion state in the direction of the air flow, and the cold storage element does not easily have an unevenness in the temperature in the direction of the air flow. Therefore, the plurality of locations at which the temperature is detected by the temperature sensor are distributed relatively densely between the middle location and the upstream end such that the amount of stored cold heat of the cold storage element can be accurately and easily calculated and thus the state information indicating the state of the cold storage element can be accurately and easily generated.

[0017]

In a fifth aspect, in addition to one of the first to third aspects, the present disclosure provides a cold storage apparatus in which when two ends of the box as seen in the second direction are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a downstream end, the plurality of locations are distributed relatively densely between the downstream end and a middle location that is between the upstream end and the downstream end in the second direction and that is apart equally from both the upstream end and the downstream end while the plurality of locations are distributed relatively sparsely between the upstream end and the middle location. According to the fifth aspect, for example, when the heat transfer area of the cold storage element is relatively small, it is possible to easily generate accurate state information indicating the state of the cold storage element. When the heat transfer area of the cold storage element is relatively small, the cold storage element can easily fuse uniformly over the region between the upstream end and the middle location, and the temperature detected by the temperature sensor does not easily have an unevenness in the second direction between the upstream end and the middle location. On the other hand, in the region between the middle location and the downstream end, the cold storage element fuses gradually starting from the middle location toward the downstream end. Therefore, the temperature detected by the temperature sensor tends to change in the second direction between the middle location and the downstream end. Therefore, the plurality of locations at which the temperature is detected by the temperature sensor are distributed relatively densely between the middle location and the downstream end such that the amount of stored cold heat of the cold storage element can be accurately and

easily calculated and thus the state information indicating the state of the cold storage element can be accurately and easily generated.

[0018]

In a sixth aspect, in addition to one of the first to fifth aspects, the present disclosure provides a cold storage apparatus in which the at least one box contains the plurality of cold storage elements arranged in the second direction. According to the sixth aspect, heat is not easily transferred from a particular cold storage element of the plurality of cold storage elements to another cold storage element adjacent to the particular cold storage element. Therefore, it is easy to properly determine the state of the cold storage element.

[0019]

In a seventh aspect, in addition to one of the first to sixth aspect, the present disclosure provides a cold storage apparatus in which the temperature sensor detects a surface temperature of the at least one box or a surface temperature of the cold storage element contained in the at least one box. According to the seventh aspect, it is not necessary to dispose the temperature sensor inside the cold storage element, and thus a leakage of a cold storage material due to a sealing failure of the cold storage element does not easily occur. Furthermore, even when it is necessary to exchange a cold storage element, it is easy to set the temperature sensor or an operation of setting the temperature sensor is not necessary.

[0020]

In an eighth aspect, in addition to the seventh aspect, the present disclosure provides a cold storage apparatus in which the temperature sensor is disposed on the surface of the cold storage element or on the surface of the box. According to the seventh aspect, it is possible to more surely detect the surface temperature of the cold storage element or the surface temperature of the box.

[0021]

In an example of the eighth aspect (aspect 8A), in addition to the eighth aspect, the present disclosure provides a cold storage apparatus in which a plurality of temperature sensors are provided as the temperature sensor, and in which two ends of the box as seen in the second direction are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a

downstream end, and the plurality of temperature sensors are distributed relatively densely between the upstream end and a middle location that is between the upstream end and the downstream end in the second direction and that is apart equally from both the upstream end and the downstream end while the plurality of temperature sensors are distributed relatively sparsely between the downstream end and the middle location.

[0022]

According to the aspect 8A, for similar reasons to the third aspect, it is easy to accurately generate state information indicating the state of the cold storage element.

[0023]

In an example of the eighth aspect (aspect 8B), in addition to the aspect 8A, the present disclosure provides a cold storage apparatus in which

a longest side of each of the plurality of boxes extends in a direction parallel to the second direction, the temperature sensors include a first temperature sensor, a second temperature sensor, and a third temperature sensor, when the length of the longest side of the box is denoted by L , the first temperature sensor is disposed at a location apart from the upstream end toward the downstream end by a distance greater than $L/2$, the second temperature sensor is disposed at a location apart from the upstream end toward the downstream end by a distance smaller than $L/2$, and the third temperature sensor is disposed at a location between the upstream end and the second temperature sensor in the second direction.

[0024]

According to the aspect 8B, it is possible to efficiently cool the air supplied into the space defined between the boxes and it is also possible to easily generate more accurate state information indicating the state of the cold storage element.

[0025]

In a still another example of the eighth aspect (aspect 8C), in addition to the aspect 8B, the present disclosure provides a cold storage apparatus in which the plurality of temperature sensors further include a fourth temperature sensor, wherein the fourth temperature sensor is disposed at a location between the upstream end and the third temperature sensor in the second direction. According to the aspect 8C, it is easy to more accurately generate the state information

indicating the state of the cold storage element.

[0026]

In a ninth aspect, in addition to one of the first to eighth aspects, the present disclosure provides a cold storage apparatus in which the state information is at least one of the following: a remaining amount of stored cold heat; an allowable cold storage time; and a time needed for solidification to occur for a predetermined amount of cold storage element of the cold storage element included in the cold storage apparatus. According to the tenth aspect, it is possible to notify a user of at least one of the following: the remaining amount of stored cold heat; the allowable cold storage time; and the time needed for solidification to occur for the predetermined amount of cold storage element of the cold storage element included in the cold storage apparatus. This provides a high convenience to a user.

[0027]

In a tenth aspect, in addition to one of the first to ninth aspects, the present disclosure provides a cold storage apparatus in which the display information generator estimates a spatial temperature distribution of the cold storage element based on information indicating the surface temperature of the box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element at the plurality of locations, and calculates a remaining amount of stored cold heat as the state information based on the ratio of a part, in the temperature distribution, where the temperature is higher than a predetermined threshold value to the whole temperature distribution. According to the eleventh aspect, after the spatial temperature distribution of the cold storage element is estimated, it is possible to properly and relatively easily calculate the remaining amount of stored cold heat.

[0028]

In an eleventh aspect, in addition to one of the first to tenth aspects, the present disclosure provides a cold storage apparatus further including an evaporator, a compressor, a condenser, and an expansion valve connected via a pipe in this order in a ring-shape connection, wherein the evaporator is in contact with at least part of the surface of the box. According to the twelfth aspect, since the evaporator is in contact with at least part of the surface of the box, it is possible to cool the air passing through the space defined between boxes while efficiently

cooling the cold storage element in the inside of the box.

[0029]

In a twelfth aspect, the present disclosure provides a method of displaying information indicating a state of a cold storage element, including creating a flow of air by an air blower such that, in a cold storage room in which a plurality of boxes each containing a cold storage element are arranged in a first direction, the flow of air passes in a second direction through a space defined in the second direction between the boxes, the second direction crossing the first direction in a plane parallel to a bottom surface of the cold storage room, thereby circulating the air cooled by the cold storage element, detecting, using a temperature sensor and at a plurality of locations in the second direction, a surface temperature of at least one box, a surface temperature of the cold storage element contained in the at least one box, or an internal temperature of the cold storage element contained in the at least one box, generating state information indicating the state of the cold storage element by acquiring, using a display information generator, an input of information indicating the temperature detected by the temperature sensor and generating the state information based on the information indicating the surface temperature of the at least one box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element, and displaying the state information on a display.

[0030]

According to the twelfth aspect, it is possible to achieve effects similar to those achieved in the first aspect.

[0031]

Embodiments of the present disclosure are described below with reference to drawings. Note that the following description is for illustrating examples of the present invention, and the present invention is not limited to those examples. In the accompanying drawings, directions denoted by an X-axis direction, a Y-axis direction, and a Z-axis direction are the same among different drawings. Note that constituent elements described without being associated with a description of the X-axis direction, the Y-axis direction, or the Z-axis direction are allowed to be disposed at proper locations as necessary.

[0032]

<First Embodiment>

As shown in Fig. 1 to Fig. 3, a cold storage apparatus 100 includes a plurality of boxes 11, an air blower 20, a temperature sensor 12, a display information generator 30, and a display 40. As illustrated in Fig. 2, the plurality of boxes 11 are arranged in a first direction (a Y-axis direction) in the cold storage room 15. For example, the plurality of boxes 11 are disposed at particular intervals in the Y-axis direction. Furthermore, as illustrated in Fig. 3, a cold storage element 10 is disposed in each of the plurality of boxes 11. Arrows in Fig. 1 and Fig. 2 indicate directions of air flows created by an operation of the air blower 20. As shown in Fig. 1, the air blower 20 is disposed in the storage room 50. The storage room 50 is partitioned from the cold storage room 15 such that they are capable of communicating with each other. As shown in Fig. 1 or Fig. 2, the air blower 20 creates air flows passing through spaces defined between adjacent boxes 11 in a second direction (positive X-axis direction) crossing a first direction (the Y-axis direction) in a plane (in an XY plane) parallel to a bottom surface of the cold storage room 15 in which the plurality of boxes 11 are arranged. Thus, the air blower 20 circulates the air cooled by the cold storage element 10. The temperature sensor 12 detects a surface temperature of at least one box 11, a surface temperature of a cold storage element 10 disposed in at least one box 11, or an internal temperature of a cold storage element 10 disposed in at least one box 11. As shown in Fig. 3, the temperature sensor 12 detects the above-described temperature at a plurality of locations in the second direction (the direction in which the air flow passes through the space defined between the adjacent boxes 11: positive X-axis direction). Information indicating the temperatures detected by the temperature sensor 12 is input to the display information generator 30. The display information generator 30 generates state information indicating a state of the cold storage element 10 based on the information indicating the surface temperature of the box 11, the surface temperature of the cold storage element 10, or the internal temperature of the cold storage element 10 as detected at the plurality of locations in the second direction (the direction of the air flow: positive X-axis direction). The display 40 displays the state information generated by the display information generator 30.

[0033]

The display information generator 30 of the cold storage apparatus 100 generates the state information indicating the state of the cold storage element 10

in the manner described above, and thus it is possible to properly determine the state of the cold storage element 10 even in a case where there is a possibility that the temperature of the cold storage element 10 has a spatial change. Besides, the plurality of boxes 11 do not necessarily need to be disposed apart from the bottom surface of the cold storage room 15 to achieve a flow path for circulating the air. Furthermore, because the air blower 20 is disposed in the storage room 50, a variation does not easily occur in the flow rate of the flow of air in the space defined between the boxes 11.

[0034]

As shown in Fig. 1, the plurality of boxes 11 are in contact with the bottom surface of, for example, the cold storage room 15. This makes it possible for the air to easily flow in the second direction in the space defined between the boxes 11, and thus it is possible to efficiently cool the air by the cold storage element 10.

[0035]

As shown in Fig. 4, for example, the cold storage element 10 is defined such that a cold storage material 10a is sealed in a film container 10b. In the cold storage element 10, for example, when the cold storage material 10a in the form of a liquid is cooled and solidified, cold heat is stored in the form of latent heat. The cold storage material 10a is, by way of example but not limitation, a mixture of water and a particular concentration of sodium chloride. The absolute value of the difference between the crystallization start temperature of the cold storage material 10a and the crystallization end temperature of the cold storage material 10b is, by way of example but not limitation, 2°C or lower. A film forming the container 10b is, for example, a laminate film including an aluminum layer and two or more resin layers disposed on both sides of the aluminum layer.

[0036]

Because the display information generator 30 of the cold storage apparatus 100 generates the state information indicating the state of the cold storage element 10 in the manner described above, it is possible to properly determine the state of the cold storage element 10 even in a case where the difference between the crystallization start temperature of the cold storage material 10a and the crystallization end temperature of the cold storage material 10a is relatively small. Note that in the case where the difference between the crystallization start temperature of the cold storage material 10a and the crystallization end

temperature of the cold storage material 10a is relatively small, it is advantageous to use the cold storage element 10, for example, when the allowable range of a storage temperature at which an article is stored is narrow.

[0037]

As shown in Fig. 1 and Fig. 2, for example, a longest side of each of the boxes 11 extends in a direction parallel to the second direction. Therefore, the fusion state of the cold storage element 10 tends to change in the second direction over the whole cold storage element 10. Furthermore, it becomes possible for the air flow to stay for a long time in the space defined between the boxes 11 when the air flow passes through the space in the second direction, which makes it possible to surely cool the air when it flows through the space defined between the boxes 11. In addition, a relatively large pressure loss occurs in the air flow passing through the space defined between the boxes 11, and thus it is possible to easily divide the air equally into the plurality of spaces in which air flows.

[0038]

The box 11 has, by way of example, but not limitation, a rectangular parallelepiped shape in external appearance elongated in the second direction (the direction of the air flow: X-axis direction) as shown in Fig. 1 and Fig. 2. The box 11 may be formed using a plurality of parts combinable in the Y-axis direction taking into account ease of assembling. As for a material forming the box 11, by way of example but not limitation, a metal such as aluminum or an alloy is employed. In this case, the cold heat possessed by the cold storage element 10 can be easily transferred to air flowing near the box 11.

[0039]

The number of boxes 11 arranged in the cold storage room 15 is properly determined, by way of example, but not limitation, based on parameters in terms of the amount of cold heat necessary for the cold storage apparatus 100, the size of the cold storage element 10, the height of the cold storage room 15, or the like. The number of boxes 11 arranged in the cold storage room 15 is preferably determined such that a sufficiently large heat exchange area between the box 11 and the air flowing through the cold storage room 15 is achieved. Furthermore, the number of boxes 11 arranged in the cold storage room 15 is preferably determined such that a pressure loss occurring for the air flow in the air flow path defined between the boxes 11 is maintained at a proper value.

[0040]

The at least one box 11, whose temperature is to be detected by the temperature sensor 12, may contain a single cold storage element 10, or, preferably, as shown in Fig. 3, may contain a plurality of (two in Fig. 3) cold storage elements 10 arranged in the second direction (the direction of the air flow: X-axis direction). For example, a specific amount of gap is defined between a plurality of cold storage elements 10. As described above, a container 10b of the cold storage element 10 may be formed, for example, using a film including an aluminum layer. Therefore, in a case where the box 11 contains a single cold storage element 10, heat possessed by the cold storage element 10 is easily transferred via the container 10b near a particular location in the second direction (the direction of the air flow: X-axis direction) in the cold storage element 10. In contrast, in a case where the box 11 contains a plurality of cold storage elements 10 arranged in the second direction (the direction of the air flow: X-axis direction), a heat transfer to a particular cold storage element 10 of the plurality of cold storage elements 10 from another cold storage element 10 adjacent to the particular cold storage element 10 does not easily occur. Therefore, the temperature of the particular cold storage element 10 is not easily influenced by heat possessed by another cold storage element 10 adjacent to the particular cold storage element 10, which is advantageous in determining the state of the cold storage element 10.

[0041]

The temperature sensor 12 is by way of example, but not limitation, a contact-type temperature sensor including a thermocouple or a thermistor or a noncontact-type temperature sensor including a thermo pile. As shown in Fig. 3, for example, the temperature sensors 12 are respectively disposed at a plurality of locations in the second direction (the direction of the air flow: X-axis direction). For example, two cold storage elements 10 are disposed in each box 11, and six temperature sensors 12 are respectively disposed at three locations of one cold storage element 10 and at three locations of the other cold storage element 10 in the second direction (the direction of the air flow: X-axis direction). The six temperature sensors 12 are arranged, for example, at particular intervals in the X-axis direction. In a case where a noncontact-type temperature sensor having a large measurement view angle or a noncontact-type temperature sensor having a

movable view angle is used as the temperature sensor 12, only one temperature sensor 12 may be used to detect the temperature of a target object at a plurality of locations in the second direction (the direction of the air flow: X-axis direction). In a case where the surface temperature of the cold storage element 10 is measured using a noncontact-type temperature sensor as the temperature sensor 12, it is desirable that the box 11 has an opening for detecting the surface temperature of the cold storage element 10.

[0042]

The temperature sensor 12 preferably detects the surface temperature of at least one box 11 or the surface temperature of the cold storage element 10 disposed in the at least one box 11. In this case, it is not necessary to dispose the temperature sensor 12 inside the cold storage element 10, and thus leakage of the cold storage material 10a does not easily occur, which might otherwise occur due to a sealing failure of the cold storage element 10. When it is necessary to replace the cold storage element 10, it is easy to set the temperature sensor 12 or it is not necessary to set the temperature sensor 12.

[0043]

The temperature sensor 12 is disposed, for example, on the surface of the cold storage element 10 or on the surface of the box 11. In other words, the temperature sensor 12 is in contact with the surface of the cold storage element 10 or the surface of the box 11. In this case, there is substantially no gap between the temperature sensor 12 and the surface of the cold storage element 10 or the surface of the box 11, and thus there is substantially no chance for a foreign object to enter the gap between the temperature sensor 12 and the surface of the cold storage element 10 or the surface of the box 11, which would disturb the temperature detection performed by the temperature sensor 12. Thus, it is possible to more surely detect the surface temperature of the cold storage element 10 or the surface temperature of the box 11. For example, in a manner shown in Fig. 4, the temperature sensor 12 is disposed on the surface of the cold storage element 10.

[0044]

As shown in Fig. 3, the display information generator 30 is connected wirelessly or via a cable to the temperature sensor 12 such that communication between them is allowed. Thus, information indicating the temperature detected

by the temperature sensor 12 is input to the display information generator 30. The display information generator 30 is realized, for example, by a computer including an interface for inputting and outputting information, a processing apparatus such as a CPU, a main storage apparatus such as a memory, and an auxiliary storage device such as a hard disk drive. The display information generator 30 generates the state information indicating the state of the cold storage element 10 in the manner described above. As shown in Fig. 3, the display information generator 30 is connected to the display 40 via a communication cable, and outputs the state information indicating the state of the cold storage element 10 to the display 40. The display 40 is by way of example, but not limitation, a liquid crystal display or an organic EL display. The display 40 is disposed, for example, on a circumferential surface of a housing of the cold storage apparatus 100.

[0045]

As shown in Fig. 1, the cold storage apparatus 100 includes, for example, a cooled air duct 21, a floor board 60, and a refrigeration cycle apparatus 70. An internal space of the cold storage apparatus 100, including the cold storage room 15, is divided by the floor board 60 into the cold storage room 15 and the storage room 50. For example, the cold storage room 15 is defined in a downward direction (in a negative Z-axis direction) below the floor board 60, and the storage room 50 is defined in an upward direction (in a positive Z-axis direction) above the floor board 60. The storage room 50 provides a space for accommodating articles such as foods that need to be cooled in storage. For example, a gap is defined between one end of the floor board 60 and a wall defining the storage room 50 such that the cold storage room 15 and the storage room 50 communicate with each other via this gap.

[0046]

The air blower 20 is disposed, for example, in the inside of the storage room 50. The air blower 20 is disposed on a side wall of the storage room 50 at a location close to a ceiling surface of the storage room 50. The cooled air duct 21 provides a communication between the cold storage room 15 and a space behind the air blower 20. When the air blower 20 operates, the air inside the cold storage room 15 passes through the space defined between the boxes 11. During this process, the air is cooled by the cold storage element 10. The cooled air passes through the inside of the cooled air duct 21 and reaches the space behind the air

blower 20. The cooled air is then blown out into the storage room 50 by the air blower 20. As a result, the articles stored in the storage room 50 are cooled. Part of the air inside the storage room 50 passes through the gap defined between a part of the end of the floor board 60 and the wall defining the storage room 50 and reaches the cold storage room 15.

[0047]

As shown in Fig. 1, the cold storage apparatus 100 further includes, for example, the refrigeration cycle apparatus 70. The refrigeration cycle apparatus 70 includes an evaporator 71, a compressor 72, a condenser 73, and an expansion valve 74. The evaporator 71, the compressor 72, the condenser 73, and the expansion valve 74 are connected in the form of a ring via a pipe such that refrigerant passes through them in this order. The evaporator 71 is disposed in the cold storage room 15. When the refrigeration cycle apparatus 70 is operated, a heat exchange occurs between the refrigerant flowing through the evaporator 71 and the air in the cold storage room 15, and thus the air in the cold storage room 15 is cooled. The temperature of the refrigerant in the evaporator 71 is lower than the crystallization end temperature of the cold storage material 10a. As a result, the cold storage material 10a in the liquid state is solidified and cold heat is stored in the cold storage element 10. The refrigeration cycle apparatus 70 is used to store the cold heat in the cold storage element 10 before an article is cooled in the storage room 50. Therefore, the refrigeration cycle apparatus 70 is usually not operated during a period in which an article is cooled in the storage room 50.

[0048]

The cold storage apparatus 100 may not include the refrigeration cycle apparatus 70. For example, a plurality of boxes 11 each including therein a cold storage element 10 in which cold heat is stored by another refrigeration apparatus may be arranged in the cold storage room 15. In this case, for example, the plurality of boxes 11 are attachable/detachable to/from the cold storage apparatus 100.

[0049]

An example of an operation of displaying the state of the cold storage element 10 by the cold storage apparatus 100 is described below. This operation is performed by way of example, but not limitation, in a situation in which an air flow is created by the air blower 20 such that the air flow passes through the space

defined by the boxes 11 and the air cooled by the cold storage element 10 is circulated. This operation may be performed also when the air blower 20 is not operating but the refrigeration cycle apparatus 70 is operated to store the cold heat in the cold storage element 10. As shown in Fig. 5, when a predetermined condition is satisfied, the cold storage apparatus 100 starts the operation of displaying the state of the cold storage element 10. The predetermined condition is by way of example, but not limitation, that a predetermined time has elapsed since the start of the operation of the air blower 20 or the refrigeration cycle apparatus 70 and information is input to the display information generator 30 to request it to display the state of the cold storage element 10. The cold storage apparatus 100 may perform periodically the operation of displaying the state of the cold storage element 10.

[0050]

First, in step S1, the temperature sensor 12 detects the surface temperature of the box 11, the surface temperature of the cold storage element 10, or the internal temperature of the cold storage element 10 such that the detection is performed at a plurality of locations in the second direction (the direction of the air flow: X-axis direction). Note that the surface temperature of the box 11 is the surface temperature of the at least of one box 11. The surface temperature of the cold storage element 10 is the surface temperature of the cold storage element 10 disposed in the at least one box 11. The internal temperature of the cold storage element 10 is the internal temperature of the cold storage element 10 disposed in the at least one box 11.

[0051]

Next, in step S2, the display information generator 30 acquires information indicating the temperature detected by the temperature sensor 12. This information includes information indicating the surface temperature of the box 11, the surface temperature of the cold storage element 10, or the internal temperature of the cold storage element 10, as detected at a plurality of locations in the second direction (the direction of the air flow: X-axis direction).

[0052]

Next, in step S3, the display information generator 30 generates the state information indicating the state of the cold storage element 10 based on the information indicating the surface temperature of the box 11, the surface

temperature of the cold storage element 10, or the internal temperature of the cold storage element 10, as detected at the plurality of locations in the second direction (the direction of the air flow: X-axis direction). Next, in step S4, the state information generated by the display information generator 30 is output to the display 40, and the display 40 displays the state information, and thus the operation sequence is complete.

[0053]

The state information displayed on the display 40 indicates, for example, one of a remaining amount of stored cold heat, an allowable cold storage time, and a time needed to solidify a particular amount of cold storage element 10 of the cold storage element 10 included in the cold storage apparatus 100.

[0054]

The remaining amount of stored cold heat corresponds, for example, to the ratio of the capacity of the cold storage elements 10 having temperatures lower than or equal to a predetermined threshold value to the total capacity of the cold storage elements 10 disposed in the boxes 11. For example, the display information generator 30 estimates a spatial temperature distribution of the cold storage elements 10 based on the information indicating the surface temperature of the box 11, the surface temperature of the cold storage elements 10, or the internal temperature of the cold storage elements 10, as detected at the plurality of locations in the second direction (the direction of the air flow: X-axis direction). In this case, the display information generator 30 calculates the remaining amount of stored cold heat based on the ratio of a part of the estimated temperature distribution where the temperature is higher than a predetermined threshold value to the whole temperature distribution. For example, let it be assumed that, in the at least one box 11, the temperature is detected by the temperature sensor 12 at ten locations located at equal intervals in the second direction (the direction of the air flow: X-axis direction). Let it be also assumed that the temperature detected by the temperature sensor 12 at each of the 10 locations is a representative value for the temperature of a corresponding one of the cold storage elements 10 which are equal in volume. When the air blower 20 is operating, the cold heat of the cold storage element 10 is consumed first on the upstream side of the air flow, and thus the temperature of the cold storage element 10 exceeds the threshold value sequentially from one location to another in the direction from the upstream side of

the air flow toward the downstream side of the air flow. For example, when the threshold value is exceeded newly at one of the ten locations at which the temperature is detected by the temperature sensor 12, the display information generator 30 reduces the remaining amount of stored cold heat by 10%. However, the algorithm of calculating the remaining amount of stored cold heat based on the ratio of the part where the temperature is higher than the predetermined threshold value to the whole part of the estimated temperature distribution is not limited to that described above. The algorithm of calculating the remaining amount of stored cold heat may be properly determined depending on the number of locations where the temperature is detected by the temperature sensor 12, the locations where the temperature is detected by the temperature sensor 12, and the structure of the cold storage element 10 or the box 11. The predetermined threshold value is determined, for example, based on the melting point of the cold storage material 10a. In a case where there is a difference between the crystallization start temperature of the cold storage material 10a and the crystallization end temperature of the cold storage material 10a, the predetermined threshold value may be given as a temperature range having an upper limit and a lower limit. [0055]

Let it be assumed that a result of detection such as that shown in Fig. 6 is obtained by the six temperature sensors 12 shown in Fig. 3. In a graph shown in Fig. 6, dash-dot lines represent predetermined threshold values defining a particular temperature range having an upper limit and a lower limit. In this case, when the cold storage material 10a is in this specific temperature range, the cold storage material 10a changes into a liquid state. In Fig. 6, plotted points represent temperatures detected by the respective six temperature sensors 12 shown in Fig. 3. As shown in Fig. 6, of temperatures detected by the six temperature sensors 12, temperatures detected by two temperature sensors 12 at upstream locations of the air flow are higher than the predetermined threshold value. More specifically, temperatures detected by two temperature sensors 12 at upstream locations of the air flow are higher than the predetermined threshold value indicating the upper limit. On the other hand, of the temperatures detected by the six temperature sensors 12, temperatures detected by four temperature sensors 12 at downstream locations of the air flow are lower than or equal to the predetermined threshold value indicating the upper limit. As described above, the display information

generator 30 estimates the spatial temperature distribution as shown in Fig. 6 based on the information indicating the temperatures detected by the six temperature sensors 12. The display information generator 30 calculates the remaining amount of stored cold heat based on the ratio of the number of locations where temperatures are higher than the predetermined threshold value indicating the upper limit to the total number of locations included in the estimated temperature distribution.

[0056]

For example, the allowable cold storage time is defined by a time in which the air passing through the cold storage room 15 is cooled by the cold storage element 10 at a temperature lower than or equal to a particular temperature. The allowable cold storage time can be determined, for example, based on the remaining amount of stored cold heat and the amount of cold heat released per unit time from the inside of the cold storage apparatus 100 to the outside of the cold storage apparatus 100. The amount of cold heat released per unit time from the inside of the cold storage apparatus 100 to the outside of the cold storage apparatus 100 is determined based on the difference between the temperature outside the cold storage apparatus 100 and the temperature inside the cold storage apparatus 100. In this case, for example, temperature sensors (not shown in the figure) are disposed in the storage room 50 and in the outside of the cold storage apparatus 100, and information indicating temperatures detected by these temperature sensors is input to the display information generator 30. For example, based on this information, the display information generator 30 calculates the amount of cold heat released per unit time from the inside of the cold storage apparatus 100 to the outside of the cold storage apparatus 100, and the display information generator 30 further calculates the allowable cold storage time. For example, when the remaining amount of stored cold heat is A [J] and the amount of cold heat released per unit time from the inside of the cold storage apparatus 100 to the outside of the cold storage apparatus 100 is B [W], the allowable cold storage time is calculated as A/B [sec]. The display information generator 30 may calculate the allowable cold storage time based on a time needed to consume the cold heat stored in the cold storage element 10 to a particular remaining amount of stored cold heat. For example, in a case where, after the operation of the air blower 20 is started, 1 hour is needed for the remaining amount of stored cold heat

of the cold storage element 10 contained in the box 11 to decrease to one-half, the allowable cold storage time may be calculated as "1 hour".

[0057]

For example, the display information generator 30 calculates, as state information indicating the state of the cold storage element 10, the time needed for a particular amount of cold storage element 10 of the cold storage element 10 contained in the cold storage apparatus 100 to solidify when cold heat is stored, using the refrigeration cycle apparatus 70, in the cold storage element 10 with the cold storage material 10a in the liquid state. The particular amount of cold storage element 10 may be the whole cold storage elements 10 contained in the cold storage apparatus 100 or may be a part of the cold storage elements 10 contained in the cold storage apparatus 100. For example, the display information generator 30 may calculate the time needed for the whole cold storage elements 10 to solidify based on the cooling capacity of the evaporator 71 and the remaining amount of stored cold heat. For example, the cooling capacity of the evaporator 71 is stored in the display information generator 30. For example, in a case where the remaining amount of stored cold heat is C [J], the amount of cold heat stored in the cold storage element 10 is D [j] in the state in which the whole cold storage elements 10 are solidified, and the cooling capacity of the evaporator 71 is E [W], the time for the whole cold storage elements 10 to solidify is calculated as $(D - C)/E$ [sec]. Alternatively, based on the time needed to store cold heat in the cold storage element 10 till the predetermined remaining amount of stored cold heat is achieved, the display information generator 30 may calculate the time needed for the whole cold storage elements 10 to solidify. For example, in a case where, after the operation of the refrigeration cycle apparatus 70 is started, 1 hour is needed for the remaining amount of stored cold heat to decrease to one-half, the time needed for the whole cold storage elements 10 to solidify may be calculated as "1 hour".

[0058]

(Modifications)

The cold storage apparatus 100 described above may be modified from various viewpoints. For example, as shown in Fig. 7, at least one box 11 subjected to the temperature detection performed by the temperature sensors 12 may include four cold storage elements 10 arranged in the second direction (the

direction of the air flow: X-axis direction). In this case, the surface temperature of each cold storage element 10 may be detected by the temperature sensor 12. The number of cold storage elements 10 disposed in the box 11 may be three or five or more. When many cold storage elements 10 are disposed in the box 11, heat transfer between adjacent cold storage elements 10 does not easily occur for many cold storage elements 10. As a result, there are many cold storage elements 10 that are not easily influenced by heat possessed by adjacent cold storage elements 10, which is advantageous in determining the state of the cold storage element 10.

[0059]

Two ends of the box 11 as seen in the second direction (X-axis direction) are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a downstream end. Under this definition, as shown in Fig. 8A, the plurality of locations at which the temperature is detected by the temperature sensor 12 may be distributed, for example, relatively densely between a middle location and the upstream end, while the plurality of locations may be distributed relatively sparsely between the middle location and the downstream end. Herein, the middle location is a location that is at a middle in the second direction between the upstream end of the box 11 and the downstream end of the box 11 and that is apart equally from both the upstream end of the box 11 and the downstream end of the box 11.

[0060]

For example, as shown in Fig. 8A, a plurality of temperature sensors are provided as the temperature sensor 12. The plurality of temperature sensors are distributed relatively densely between the middle location of the box 11 and the upstream end of the box 11, while the plurality of temperature sensors are distributed relatively sparsely between the middle location of the box 11 and the downstream end of the box 11.

[0061]

For example, as shown in Fig. 8A, a longest side of each of the plurality of boxes 11 extends in a direction parallel to the second direction. The temperature sensors 12 include a first temperature sensor 12a, a second temperature sensor 12b, and a third temperature sensor 12c. The length of the longest side of the box

11 is denoted by L . The first temperature sensor 12a is disposed at a location apart from the upstream end toward the downstream end by a distance greater than $L/2$. The second temperature sensor 12b is disposed at a location apart from the upstream end toward the downstream end by a distance smaller than $L/2$. The third temperature sensor 12c is disposed at a location, in the second direction, between the upstream end of the box 11 and the second temperature sensor 12b.

[0062]

For example, as shown in Fig. 8A, the temperature sensors 12 further include a fourth temperature sensor 12d. The fourth temperature sensor 12d is disposed at a location, in the second direction, between the upstream end of the box 11 and the third temperature sensor 12c.

[0063]

To keep the temperature in the storage room 50 within a specific temperature range against heat input from the outside of the cold storage apparatus 100, it is necessary for the air circulating inside the cold storage apparatus 100 to receive a cold heat from the cold storage element 10 via heat exchange as much as necessary to cancel out the input heat. In a case where the cold storage element 10 has a heat transfer area sufficiently large for the air circulating inside the cold storage apparatus 100 to receive the amount of cold heat, heat exchange occurs effectively between the air and the cold storage element 10 near the upstream end of the box 11 where a particularly large temperature difference occurs between the air and the cold storage element 10, as long as the total amount of cold heat possessed by the cold storage element 100 is large. Thus, the cold heat of the cold storage element 10 is consumed first near the upstream end of the box 11, and the cold storage element 10 gradually fuses starting from the upstream end toward the middle location. As a result, the temperature detected by the temperature sensor 12 tends to have a large variation in the second direction between the upstream end and the middle location as shown in Fig. 9A. When the fusion of the cold storage element 10 starting from the upstream end of the box 11 reaches near the middle location, and thus the amount of cold heat possessed by the whole cold storage elements 10 becomes low, the fusing manner of the cold storage element 10 between the middle location and the downstream end is different from the fusing manner of the cold storage element 10 near the upstream end in the state in which the amount of cold heat

possessed by the whole cold storage elements 10 is high. In this situation, the cold storage elements 10 located between a location near the middle location and the downstream end fuse substantially uniformly between the location near the middle location and the downstream end.

[0064]

At a point of time when the amount of cold heat possessed by the whole cold storage elements 10 has become small, the cold storage element 10 between the upstream end of the box 11 and the middle location has fused. However, at last part of the cold storage element 10 between the upstream end and the middle location still has an amount of cold heat in the form of sensible heat sufficient to cool the temperature of the air flowing into the space defined between the boxes 11. Therefore, the air flowing into the space is cooled to a temperature near the melting point of the cold storage element 10 when the air flows from the upstream end to the location near the middle location. The air can be further cooled to a temperature below the melting point of the cold storage element 10 when the flow flows from the location near the middle location to the downstream end. In this process, only a small amount of the cold heat is consumed in the cold storage element 10 between the location near the middle location and the downstream end, and thus a variation in fusion state of the cold storage element 10 does not easily occur in the direction of the air flow between the location near the middle location and the downstream end. For the reasons described above, in the region between the location near the middle location and the downstream end, unlike the manner of fusion in the region between the upstream end and the location near the middle location, the cold storage elements 10 fuse substantially uniformly over the region between the location near the middle location and the downstream end. As a result, a variation in fusion state of the cold storage elements 10 does not easily occur in the direction of the air flow between the location near the middle location and the downstream end, and the cold storage elements 10 do not easily have an unevenness in the temperature in the direction of the air flow. Therefore, the plurality of locations at which the temperature is detected by the temperature sensor 12 are distributed relatively densely between the middle location and the upstream end such that the amount of stored cold heat of the cold storage elements 10 can be accurately and easily calculated and thus the state information indicating the state of the cold storage elements 10 can be accurately and easily

generated.

[0065]

As shown in Fig. 8A, the locations at which the temperature is detected by the temperature sensor 12 may be distributed relatively densely on the upstream side of the air flow and relatively sparsely on the downstream side of the air flow. For example, for the cold storage element 10 located on the upstream side of the air flow, which is one of the two cold storage elements 10 contained in the box 11, the temperature sensor 12 detects the surface temperature of the cold storage element 10 at four locations at equal intervals in the second direction (the direction of the air flow: X-axis direction). For example, for the cold storage element 10 located on the downstream side of the air flow, which is one of the two cold storage elements 10 contained in the box 11, the temperature sensor 12 detects the surface temperature of the cold storage element 10 at two locations at equal intervals in the second direction (the direction of the air flow: X-axis direction). In this case, the temperature is detected by six temperature sensors 12, and a result is obtained, for example, as shown in Fig. 9A. In Fig. 9A, plotted points represent temperatures detected by the respective six temperature sensors 12 shown in Fig. 8A. As described above, in the state in which the air blower 20 is operating, the surface temperature of the cold storage elements 10 is detected at more locations on the upstream side of the air flow where the temperature of the cold storage element 10 increases beyond the predetermined threshold value at an earlier time. This makes it possible to enhance the detection accuracy in detecting the remaining amount of stored cold heat at an early stage when the temperature of the cold storage elements 10 start to get higher than the predetermined threshold value.

[0066]

Two ends of the box 11 as seen in the second direction (X-axis direction) are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a downstream end. Under this definition, as shown in Fig. 8B, the plurality of locations at which the temperature is detected by the temperature sensor 12 may be distributed, for example, relatively densely between the middle location and the downstream end, while the plurality of locations may be distributed relatively sparsely between the middle location and the upstream

end. Herein, the middle location is a location that is at a middle in the second direction between the upstream end of the box 11 and the downstream end of the box 11 and that is apart equally from both the upstream end of the box 11 and the downstream end of the box 11.

[0067]

When the heat transfer area of the cold storage elements 10 is relatively small, the cold storage elements 10 can easily fuse uniformly over the region between the upstream end and the middle location, and the temperature detected by the temperature sensor 12 tends to have no significant variation in the second direction between the upstream end and the middle location. On the other hand, in the region between the middle location and the downstream end, the cold storage elements 10 fuse gradually starting from the middle location toward the downstream end. As a result, the temperature detected by the temperature sensor 12 tends to change in the second direction between the middle location and the downstream end as shown in Fig. 9B. Therefore, the plurality of locations at which the temperature is detected by the temperature sensor 12 are distributed relatively densely between the middle location and the downstream end such that the amount of stored cold heat of the cold storage elements 10 can be accurately and easily calculated and thus the state information indicating the state of the cold storage elements 10 can be accurately and easily generated.

[0068]

Note that the locations at which the temperature is detected by the temperature sensor 12 may be distributed relatively sparsely on the upstream side of the air flow and relatively densely on the downstream side of the air flow. In this case, it is possible to enhance the accuracy in detecting the remaining amount of stored cold heat at a stage where the temperature of the cold storage elements 10 is higher than the predetermined threshold value at many locations. Note that the locations at which the temperature is detected by the temperature sensor 12 may be distributed more sparsely in a particular region in the box 11 than in the other region.

[0069]

As shown in Fig. 10A, temperature sensors 12 may be disposed on the surface of the box 11. In the case where temperature sensors 12 are disposed on the surface of the box 11, it is desirable that there is no significant difference in the

distance between the inner surface of the box 11 and the cold storage elements 10 among a plurality of locations at which the temperature is detected by the temperature sensors 12. In a case where there is a gap between the inner surface of the box 11 and the cold storage elements 10 as shown in Fig. 10A, there is a tendency that large differences occur between the temperatures detected by the temperature sensors 12 and the actual temperatures of the cold storage elements 10. In view of the above, to make it possible to more accurately detect the state of the cold storage elements 10, a recess 13 for disposing a temperature sensor 12 may be defined on the surface of the box 11 and the temperature sensor 12 may be disposed in this recess 13 as shown in Fig. 10B. In this case, the recess 13 causes the inner surface of the box 11 to protrude toward the cold storage element 10, which prevents a gap from easily occurring between the inner surface of the box 11 and the cold storage element 10. Preferably the recess 13 is defined such that the inner surface of the box 11 is brought by the recess 13 into contact with the cold storage element 10. This reduces the variation of the distance between the inner surface of the box 11 and the cold storage elements 10 among a plurality of locations where temperatures are detected by the temperature sensors 12. Furthermore, this reduces the difference between the temperatures detected by the temperature sensors 12 and the actual temperatures of the cold storage elements 10, and thus it is possible to achieve a cold storage apparatus having an advantage in properly determining the state of the cold storage elements 10.

[0070]

<Second Embodiment>

A cold storage apparatus 200 according to a second embodiment is described below. In the second embodiment, a configuration is similar to that according to the first embodiment unless otherwise stated. In the second embodiment, constituent elements similar to those of the first embodiment are denoted by similar symbols, and a further detailed description thereof is omitted. Descriptions of the first embodiment and modifications thereto also apply to the second embodiment unless a technical contradiction occurs.

[0071]

As shown in Fig. 11, the cold storage apparatus 200 includes a refrigeration cycle apparatus 70 as with the cold storage apparatus 100. In the refrigeration cycle apparatus 70, an evaporator 71, a compressor 72, a condenser 73, and an

expansion valve 74 are connected via a pipe in this order in a ring-shape connection. As shown in Fig. 12, the evaporator 71 is in contact with at least part of the surface of the box 11.

[0072]

For example, a pipe determining a flow path of a refrigerant in the evaporator 71 is in contact with the surface of the box 11. To achieve a good thermal conduction between the pipe and the box 11, for example, the pipe is urged by a pressing element made of metal (not illustrated) against the surface of the box 11 such that the pipe is in contact with the surface of the box 11. The pipe determining the flow path of the refrigerant of the evaporator 71 extends from an upstream end of the box 11 in the second direction until reaching a downstream end, and bends at the downstream end. The pipe further extends in the second direction to the upstream end. The pipe determining the flow path of the refrigerant of the evaporator 71 may extend from the downstream end of the box 11 to the upstream end in the second direction, fold back at the upstream end, and further extend to the downstream end in the second direction.

[0073]

As shown in Fig. 11, the cold storage apparatus 200 includes, for example, a storage room temperature sensor 80. The storage room temperature sensor 80 is a temperature sensor for detecting the temperature of the air in the storage room 50.

[0074]

When cold heat is stored in the cold storage element 10 by operating the refrigeration cycle apparatus 70, it is necessary that the refrigerant flowing through the evaporator 71 is kept at a temperature lower than the solidification point of the cold storage element 10, for example, by 10°C or greater. In many cases, when the temperature of the cold storage element 10 is reduced to a level lower than the solidification point of the cold storage element 10, the cold storage element 10 is not likely to be crystallized immediately, and the cold storage element 10 is likely to go to a supercooled state. Therefore, for example, by cooling the cold storage element 10 using a refrigerant at a temperature lower by 10°C or greater than the solidification point of the cold storage element 10, it is possible to make the cold storage element 10 get away from the supercooled state and get crystallized. By increasing the difference between the temperature of the refrigerant flowing

through the evaporator 71 and the solidification point of the cold storage element 10, it is possible to cool the cold storage element 10 more quickly into a solidified state.

[0075]

When cold heat is stored in the cold storage element 10, in some cases, it is necessary to cool the air in the storage room 50 to adjust the temperature of the storage room 50 to a temperature suitable for cooling articles. In such cases, the air blower 20 is operated such that the temperature detected by the storage room temperature sensor 80 becomes equal to a predetermined target temperature higher than the solidification point of the cold storage element 10. In this situation, the air of the storage room 50 is supplied to the cold storage room 15, the air is cooled by the cold storage element 10 or the evaporator 71, and the cooled air is directed to the storage room 50. Thus, the air cooled in the inside of the cold storage apparatus 200 is circulated. As a result, the temperature of the air in the storage room 50 is adjusted to a temperature suitable for cooling articles.

[0076]

In a case where the cold heat of the refrigerant flowing through the evaporator 71 is used only to store cold heat in the cold storage element 10, the box 11 is cooled by the evaporator 71 over the whole box 11. However, in the situation in which the air blower 20 is operated to cool the air in the storage room 50 and the air cooled in the inside of the cold storage apparatus 200 is circulated, a temperature distribution occurs in the box 11 or the cold storage element 10 such that the temperature gradually decreases from the upstream end of the box 11 toward the downstream end as shown in Fig. 13. Note that in Fig. 13, a broken line representing a lowest temperature indicates a temperature T_{EV} of the evaporator 71. When the cold storage element 10 is cooled by the evaporator 71 for a long time, the temperature of the box 11 or the cold storage element 10 at the downstream end of the box 11 decreases to T_{EV} . On the other hand, the temperature of the box 11 or the cold storage element 10 near the upstream end of the box 11 is equilibrated at a temperature at which a balance is achieved with the quantity of heat possessed by the air flowing into the space defined between the boxes 11. Like the case where the cold storage element 10 fuses, it is possible to calculate the amount of stored cold heat of the cold storage element 10 from the temperature distribution that occurs owing to the circulation of the air in

the cold storage room 15. In this calculation, preferably, the amount of cold heat possessed as sensible heat by the cold storage element 10 and the amount of cold heat possessed as latent heat by the cold storage element 10 are both taken into account. For example, the amount of cold heat possessed as latent heat by the cold storage element 10 can be determined by subtracting the amount of cold heat possessed as sensible heat by the cold storage element 10 determined from the temperature of the cold storage element 10 from the amount of stored cold heat determined from the temperature distribution such as that shown in Fig. 13. For example, the amount of cold heat possessed as sensible heat by the cold storage element 10 can be determined from the difference between the solidification point of the cold storage element 10 and the temperature of the cold storage element 10 and the heat capacity of the cold storage element 10 and the box 11. In this calculation, as for the temperature of the cold storage element 10, for example, the arithmetic mean value of temperatures lower than the solidification point of the cold storage element 10 detected at a plurality of locations by the temperature sensors 12 is employed. Furthermore, as for the heat capacity of the cold storage element 10 and the box 11, it is possible to employ the heat capacity corresponding to the sum of the volumes of the box 11 and the cold storage elements 10 represented by the respective locations where temperatures lower than the solidification point of the cold storage element 10 are detected. As for the temperatures of the cold storage elements 10, respective temperatures lower than the solidification point of the cold storage elements 10 detected at a plurality of locations by the temperature sensors 12 may be employed. In this case, the amount of cold heat possessed as sensible heat by the cold storage element 10 can be determined as the sum of the products of the differences between the respective temperatures and the solidification point of the cold storage elements 10 and the heat capacities corresponding to volumes of the box 11 and the cold storage elements 10 represented by the respective locations.

Industrial Applicability

[0077]

The cold storage apparatus according to the present disclosure can be used for purposes of temporarily storing cold heat in cold storage or refrigeration.

Reference Signs List

[0078]

10 cold storage element
11 box
12 temperature sensor
12a first temperature sensor
12b second temperature sensor
12c third temperature sensor
12d fourth temperature sensor
15 cold storage room
20 air blower
30 display information generator
40 display
50 storage room
70 refrigeration cycle apparatus
71 evaporator
72 compressor
73 condenser
74 expansion valve
100 cold storage apparatus

CLAIMS

[Claim 1]

A cold storage apparatus comprising:

a plurality of boxes arranged in a first direction in a cold storage room, each box containing a cold storage element;

an air blower that is disposed in a storage room partitioned from the cold storage room such that communication between the storage room and the cold storage room is allowed and that creates a flow of air passing in a second direction through a space defined in the second direction between the plurality of boxes, the second direction crossing the first direction in a plane parallel to a bottom surface of the cold storage room in which the plurality of boxes are arranged, thereby circulating the air cooled by the cold storage element;

a temperature sensor that detects, at a plurality of locations in the second direction, a surface temperature of at least one box, a surface temperature of the cold storage element contained in the at least one box, or an internal temperature of the cold storage element contained in the at least one box;

a display information generator that receives an input of information indicating the temperature detected by the temperature sensor and generates state information indicating a state of the cold storage element based on the surface temperature of the at least one box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element; and

a display that displays the state information, wherein

the display information generator estimates a spatial temperature distribution of the cold storage element based on information indicating the surface temperature of the box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element at the plurality of locations, and calculates a remaining amount of stored cold heat as the state information based on the ratio of a part, in the temperature distribution, where the temperature is higher than a predetermined threshold value to the whole temperature distribution.

[Claim 2]

The cold storage apparatus according to claim 1, wherein the plurality of boxes are in contact with the bottom surface of the cold storage room.

[Claim 3]

The cold storage apparatus according to claim 1 or 2, wherein a longest side of each of the plurality of boxes extends in a direction parallel to the second direction.

[Claim 4]

The cold storage apparatus according to one of claims 1 to 3, wherein when two ends of the box as seen in the second direction are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a downstream end, the plurality of locations are distributed relatively densely between the upstream end and a middle location that is between the upstream end and the downstream end in the second direction and that is apart equally from both the upstream end and the downstream end while the plurality of locations are distributed relatively sparsely between the downstream end and the middle location.

[Claim 5]

The cold storage apparatus according to one of claims 1 to 3, wherein when two ends of the box as seen in the second direction are defined such that one end located on an upstream side of the air flow is defined as an upstream end while the other end located on a downstream side of the air flow is defined as a downstream end, the plurality of locations are distributed relatively densely between the downstream end and a middle location that is between the upstream end and the downstream end in the second direction and that is apart equally from both the upstream end and the downstream end while the plurality of locations are distributed relatively sparsely between the upstream end and the middle location.

[Claim 6]

The cold storage apparatus according to one of claims 1 to 5, wherein the at least one box contains the plurality of cold storage elements arranged in the second direction.

[Claim 7]

The cold storage apparatus according to one of claims 1 to 6, wherein the temperature sensor detects a surface temperature of the at least one box or a surface temperature of the cold storage element contained in the at least one box.

[Claim 8]

The cold storage apparatus according to claim 7, wherein the temperature

sensor is disposed on the surface of the cold storage element or on the surface of the box.

[Claim 9]

The cold storage apparatus according to one of claims 1 to 8, wherein the state information is at least one of the following: a remaining amount of stored cold heat; an allowable cold storage time; and a time needed for solidification to occur for a predetermined amount of cold storage element of the cold storage element included in the cold storage apparatus.

[Claim 10]

The cold storage apparatus according to one of claims 1 to 10, further comprising an evaporator, a compressor, a condenser, and an expansion valve connected via a pipe in this order into a ring-shape connection, wherein the evaporator is in contact with at least part of the surface of the box.

[Claim 11]

A method of displaying information indicating a state of a cold storage element, comprising:

creating a flow of air by an air blower such that, in a cold storage room in which a plurality of boxes each containing a cold storage element are arranged in a first direction, the flow of air passes in a second direction through a space defined in the second direction between the boxes, the second direction crossing the first direction in a plane parallel to a bottom surface of the cold storage room, thereby circulating the air cooled by the cold storage element;

detecting, using a temperature sensor and at a plurality of locations in the second direction, a surface temperature of at least one box, a surface temperature of the cold storage element contained in the at least one box, or an internal temperature of the cold storage element contained in the at least one box;

generating state information indicating the state of the cold storage element by acquiring, using a display information generator, an input of information indicating the temperature detected by the temperature sensor and generating the state information based on the information indicating the surface temperature of the at least one box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element; and

displaying the state information on a display, wherein

the display information generator estimates a spatial temperature

distribution of the cold storage element based on information indicating the surface temperature of the box, the surface temperature of the cold storage element, or the internal temperature of the cold storage element at the plurality of locations, and calculates a remaining amount of stored cold heat as the state information based on the ratio of a part, in the temperature distribution, where the temperature is higher than a predetermined threshold value to the whole temperature distribution.