

DESCRIPTION

Title of Invention

THERMALLY INSULATED BOX, REFRIGERATOR INCLUDING THERMALLY
INSULATED BOX, AND HOT WATER STORAGE APPARATUS INCLUDING
5 THERMALLY INSULATED BOX

Technical Field

[0001]

The present invention relates to a thermally insulated box including rigid
polyurethane foam and a vacuum thermal insulator, a refrigerator including the
10 thermally insulated box, and a hot water storage apparatus including the thermally
insulated box.

Background Art

[0002]

Various efforts to achieve resource saving, energy saving, and in particular,
15 power saving have been made in view of the protection of global environment and the
safety of nuclear power plants.

[0003]

Techniques have been developed of disposing a vacuum thermal insulator as
well as rigid polyurethane foam inside a thermally insulated box including a shell
20 composed of an outer casing and an inner casing, in view of energy saving and
power saving. An example of such techniques is a "thermally insulated box which
includes rigid polyurethane foam having a flexural modulus of 8.0 MPa or higher and
a density of 60 kg/m³ or lower to provide rigidity or strength and thermal insulation
performance and a vacuum thermal insulator and in which the rate of coverage with
25 the vacuum thermal insulator exceeds 50% of the surface area of an outer casing"
(refer to Patent Literature 1).

Citation List

Patent Literature

[0004]

30 Patent Literature 1: Japanese Patent No. 3478810

Summary of Invention

Technical Problem

[0005]

A vacuum thermal insulator has, for example, thermal insulation performance which is six times or more that of conventional-art rigid polyurethane foam. In terms of energy saving, for example, the use of a vacuum thermal insulator, as well as rigid polyurethane foam, in a space defined between an outer casing and an inner casing has been increasing. In recent years, as requests for energy saving have increased, the amount of vacuum thermal insulator disposed in a thermally insulated box has also increased as in the thermally insulated box disclosed in Patent Literature 1.

[0006]

The space defined between the outer and inner casings in the thermally insulated box, that is, the reduction in thickness of a wall of the thermally insulated box has also been requested in order to reduce the footprint and increase the internal volume of the box. A typical conventional-art thermally insulated box has been made on the basis of a technical idea of allowing rigid polyurethane foam to serve as a principal member to provide thermal insulation and allowing a vacuum thermal insulator to assist the rigid polyurethane foam in providing thermal insulation. In other words, the strength of a wall surface of the conventional-art thermally insulated box has been ensured by the rigid polyurethane foam. If the wall thickness of the thermally insulated box is reduced, the amount of rigid polyurethane foam used would be accordingly reduced by a reduction in wall thickness. Unfortunately, this would result in poor thermal insulation performance or insufficient strength of the thermally insulated box. Disadvantageously, it has been difficult to reduce the wall thickness of the conventional-art thermally insulated box.

[0007]

In the thermally insulated box disclosed in Patent Literature 1, the wall thickness could be increased to some extent because the amount of (or rate of coverage with) vacuum thermal insulator used is increased to enhance the flexural modulus of the rigid polyurethane foam (i.e., the rigidity of the rigid polyurethane

foam). The thermally insulated box disclosed in Patent Literature 1, however, has been made on the basis of the conventional-art technical idea and the rigid polyurethane foam serves as a principal member to provide thermal insulation and the vacuum thermal insulator assists the rigid polyurethane foam in providing thermal insulation. In other words, the strength of the wall surface of the thermally insulated box disclosed in Patent Literature 1 is ensured by the rigid polyurethane foam. To suppress a reduction in thermal insulation performance of the rigid polyurethane foam, accordingly, the flexural modulus of the rigid polyurethane foam cannot be increased to 10.0 MPa or more. Thus, a certain amount of rigid polyurethane foam with which the space between the outer and inner casings is filled is needed to ensure the strength of the wall surface of the thermally insulated box disclosed in Patent Literature 1. Disadvantageously, reducing the wall thickness remains difficult. [0008]

In other words, the conventional-art thermally insulated boxes have disadvantages in that it is difficult to further increase the internal volume of the thermally insulated box while ensuring thermal insulation performance of the box. [0009]

The present invention has been made to overcome the above-described disadvantages and provides a thermally insulated box having a larger internal volume than in the related art while ensuring thermal insulation performance, a refrigerator including the thermally insulated box, and a hot water storage apparatus including the thermally insulated box.

Solution to Problem

[0010]

The present invention provides a thermally insulated box including an outer casing, an inner casing, at least one vacuum thermal insulator, and rigid polyurethane foam such that a first space defined between the outer casing and the inner casing is filled with the vacuum thermal insulator and the rigid polyurethane foam. The vacuum thermal insulator is disposed at least in right and left side portions and a rear portion of the box. The first space is filled with the vacuum thermal insulator at a

filling rate ranging from 40% to 80%. The ratio of the area of the vacuum thermal insulator to the surface area of the outer casing is greater than or equal to 60%. The rigid polyurethane foam has a flexural modulus greater than or equal to 15.0 MPa.

[0011]

5 The present invention further provides a refrigerator including the thermally insulated box according to the present invention and a cooling device to cool air to be supplied to a storage compartment disposed in the thermally insulated box.

[0012]

10 The present invention further provides a hot water storage apparatus including the thermally insulated box according to the present invention, a heating device to heat water, and a tank, disposed in the thermally insulated box, to store the water heated by the heating device.

Advantageous Effects of Invention

[0013]

15 The thermally insulated box according to the present invention has been made on the basis of a novel technical idea of allowing the vacuum thermal insulator to serve as a principal member to provide thermal insulation and this technical idea is entirely different from the relate-art technical idea. In the thermally insulated box according to the present invention, the first space defined between the outer casing
20 and the inner casing is filled with the vacuum thermal insulator at a filling rate ranging from 40% to 80% and the ratio of the area of the vacuum thermal insulator to the surface area of the outer casing is greater than or equal to 60%. The filling rate and the area ratio of the vacuum thermal insulator are higher than those in the related art. Specifically, the vacuum thermal insulator has, for example, thermal insulation
25 performance which is six times or more that of rigid polyurethane foam in the conventional-art thermally insulated boxes. Consequently, the thermally insulated box according to the present invention can achieve sufficient thermal insulation if the box has a reduced wall thickness.

[0014]

Although rigid polyurethane foam included in the conventional-art thermally insulated boxes has a flexural modulus of, for example, approximately 6 MPa to approximately 12 MPa, the vacuum thermal insulator has a flexural modulus of approximately 20 MPa to approximately 40 MPa. In other words, the vacuum thermal insulator has a higher flexural modulus than rigid polyurethane foam included in the conventional-art thermally insulated boxes. Thus, the thermally insulated box according to the present invention in which the filling rate of the vacuum thermal insulator is higher than that in the related art can ensure sufficient strength. Note that according to the conventional-art technical idea of allowing rigid polyurethane foam to ensure the strength of a wall surface of a thermally insulated box, just increasing the rate of coverage with the vacuum thermal insulator in the thermally insulated box does not increase the filling rate of the vacuum thermal insulator in the first space to 40% and the wall thickness of the thermally insulated box, accordingly, cannot be reduced. Specifically, to reduce the wall thickness of the thermally insulated box, it is important that the filling rate of the vacuum thermal insulator having a higher flexural modulus than rigid polyurethane foam be greater than or equal to 40% and the vacuum thermal insulator be allowed to provide the strength of the thermally insulated box.

[0015]

Since the increase of the filling rate of the vacuum thermal insulator leads to a reduction in filling rate of the rigid polyurethane foam, it may be feared that the adhesiveness between the outer casing and the inner casing may become insufficient, resulting in a reduction in strength of the thermally insulated box. As described above, however, the thermally insulated box according to the present invention has been made on the basis of the technical idea of allowing the vacuum thermal insulator to serve as a principal member to provide thermal insulation. Accordingly, the thermally insulated box according to the present invention is little affected by the reduction in thermal insulation performance of the rigid polyurethane foam caused by an increase in flexural modulus of the rigid polyurethane foam (i.e., rigidity of the rigid polyurethane foam). Thus, the thermally insulated box according

to the present invention permits the flexural modulus of the rigid polyurethane foam to be greater than or equal to 15.0 MPa which is higher than that of rigid polyurethane foam included in the conventional-art thermally insulated boxes. Consequently, the thermally insulated box according to the present invention can prevent a reduction in strength caused by a reduction in filling rate of the rigid polyurethane foam.

[0016]

The present invention, therefore, can provide a thermally insulated box having a larger internal volume than in the related art while ensuring thermal insulation performance, a refrigerator including the thermally insulated box, and a hot water storage apparatus including the thermally insulated box.

Brief Description of Drawings

[0017]

[Fig. 1] Fig. 1 is a front cross-sectional view of a thermally insulated box according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a rear view of the thermally insulated box according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a perspective view of the thermally insulated box according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a diagram (perspective view) for explaining a process of making the thermally insulated box according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a perspective view of another example of the thermally insulated box according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a perspective view of further another example of the thermally insulated box according to Embodiment 1 of the present invention.

[Fig. 7] Fig. 7 is a front cross-sectional view of a thermally insulated box according to Embodiment 2 of the present invention.

[Fig. 8] Fig. 8 is a front cross-sectional view of a thermally insulated box according to Embodiment 3 of the present invention.

[Fig. 9] Fig. 9 is a side cross-sectional view of a thermally insulated box according to Embodiment 4 of the present invention.

[Fig. 10] Fig. 10 is a side cross-sectional view of another example of the thermally insulated box according to Embodiment 4 of the present invention.

5 [Fig. 11] Fig. 11 is a perspective view of an exemplary mechanism for attaching a door to the thermally insulated box according to Embodiment 4 of the present invention when the door is opened.

[Fig. 12] Fig. 12 is a side cross-sectional view of a refrigerator according to Embodiment 5 of the present invention.

10 [Fig. 13] Fig. 13 is a graph illustrating the relationship between the density of polyurethane and the flexural modulus thereof determined by actual measurement in Embodiment 1 of the present invention.

[Fig. 14] Fig. 14 is a graph illustrating results of calculation of the filling rate of vacuum thermal insulators and a deformation of the box in Embodiment 1 of the present invention.

15 [Fig. 15] Fig. 15 is a graph illustrating results of calculation of the ratio of the area of the vacuum thermal insulators to the area of each of side and rear portions of the box and a deformation of the box in Embodiment 5 of the present invention.

Description of Embodiments

20 [0018]

Embodiments of a thermally insulated box according to the present invention and a refrigerator including the thermally insulated box will be described below with reference to the drawings.

[0019]

25 Embodiment 1

Fig. 1 is a front cross-sectional view of a thermally insulated box according to Embodiment 1 of the present invention. Fig. 2 is a rear view of the thermally insulated box. Fig. 3 is a perspective view of the thermally insulated box. Actually, at least one vacuum thermal insulator 6 is disposed in a space 4 (corresponding to a first space in the present invention) defined between an outer casing 2 and an inner

30

casing 3 as will be described later. In Fig. 2, a rear surface of the outer casing 2 is illustrated as transparent and the vacuum thermal insulators 6 disposed adjacent to a rear surface of a thermally insulated box 1 are illustrated (i.e., the vacuum thermal insulators 6 are visible by solid lines) for the sake of easy understanding of the shape of the vacuum thermal insulator 6. In Fig. 3, rails 16 are not illustrated.

The thermally insulated box 1 according to Embodiment 1 will be described below with reference to these figures.

[0020]

The thermally insulated box 1 includes the outer casing 2 made of, for example, metal and the inner casing 3 made of, for example, resin. The space 4 defined between the outer casing 2 and the inner casing 3, specifically, a top portion, right and left side portions, a rear portion, and a bottom portion of the thermally insulated box 1 accommodate (or are filled with) rigid polyurethane foam 5 and the vacuum thermal insulators 6.

[0021]

The thermally insulated box 1 according to Embodiment 1 is intended to be used as a thermally insulated box included in a refrigerator. Accordingly, the thermally insulated box 1 according to Embodiment 1 has a closed top and a closed bottom and is square columnar (or substantially rectangular-parallelepiped) and has an open front. The interior of the thermally insulated box 1 is divided into three storage compartments 7 by, for example, two partitions 24. In Fig. 3, these storage compartments are indicated at 7, 7', and 7" to distinguish from one another. A sheet metal cover 34 (having a thickness of 1 mm or more, for example) is attached to a front surface of each of the partitions 24 by screws or the like. Fastening of the sheet metal covers 34 to the thermally insulated box 1 by screws or the like results in attachment of the partitions 24 to the thermally insulated box 1. The above-described attachment of the partitions 24 to the thermally insulated box 1 by the sheet metal covers 34 allows an increase in strength of the thermally insulated box 1.

The thermally insulated box 1 according to Embodiment 1 further includes the rails 16 to support a shelf plate disposed in the storage compartment 7 such that the rails 16 are arranged inside the thermally insulated box 1 (i.e., the inner casing 3).

[0022]

5 The thermally insulated box 1 with the above-described structure is made in the following manner, for example. First, the vacuum thermal insulators 6 are bonded and fixed to the outer casing 2. Subsequently, the outer casing 2 and the inner casing 3 are fixed to each other by bonding, for example. After that, as illustrated in Fig. 4, the rear surface of the thermally insulated box 1 is turned up, a liquid raw material of the rigid polyurethane foam 5 is injected into the space 4 through inlet ports 32 arranged in the rear surface, and integral foaming is performed, so that the space 4 is filled with the rigid polyurethane foam 5.

[0023]

15 Accordingly, the vacuum thermal insulators 6 cannot be positioned so as to face the inlet ports 32 in the rear surface of the thermally insulated box 1. According to Embodiment 1, the vacuum thermal insulators 6 are arranged opposite the rear surface of the thermally insulated box 1 as illustrated in Fig. 2. Specifically, the vacuum thermal insulator 6 in one piece is not used for the rear surface of the thermally insulated box 1 and a plurality of (for example, two or three) vacuum thermal insulators 6 are arranged. The inlet ports 32 are arranged so as to face corners of some of the vacuum thermal insulators 6. Since some of the vacuum thermal insulators 6 have a cutaway portion 33 at each corner facing the inlet port 32, the vacuum thermal insulators 6 can be arranged so as to increase the area of the vacuum thermal insulators 6 and avoid the inlet ports 32 (i.e., the liquid raw material of the rigid polyurethane foam 5 can be injected). The above-described arrangement of the vacuum thermal insulators 6 allows the thermally insulated box 1 to have enhanced thermal insulation performance.

25 The shape and position of the inlet port 32 are intended only to be illustrative. The inlet ports 32 may be appropriately formed depending on the shape of the thermally insulated box 1, that is, the shape of the space 4 defined between the outer

casing 2 and the inner casing 3. For the positions of the inlet ports 32, the inlet ports 32 may be arranged in any surface (e.g., a left side surface, a right side surface, a front surface, the rear surface, a top surface, or a bottom surface) depending on the shape of the thermally insulated box 1.

[0024]

The thermally insulated box 1 according to Embodiment 1 is made on the basis of the novel technical idea entirely different from the conventional-art technical idea of allowing rigid polyurethane foam inside a thermally insulated box to serve as a principal member to provide thermal insulation. The thermally insulated box 1 according to Embodiment 1 is configured such that the vacuum thermal insulators 6 serve as a principal member to provide thermal insulation. In the thermally insulated box 1 according to Embodiment 1, accordingly, the space 4 is filled with the vacuum thermal insulators 6 at a filling rate greater than or equal to 40% such that the vacuum thermal insulators 6 account for 40% or more of the space 4. Increasing the filling rate of the vacuum thermal insulators 6 in the space 4 to be higher than that in the related art enables the thermal insulation performance to be higher than that in the related art. Consequently, if the wall thickness of the thermally insulated box 1 is thinner than that in the related art, thermal insulation performance at the same level or higher than that in the related art can be ensured. Fig. 14 illustrates the amount of deformation of the thermally insulated box 1 upon load application plotted against the filling rate at which the vacuum thermal insulators 6 occupies the space 4. The vacuum thermal insulator 6 has a higher flexural modulus than the rigid polyurethane foam 5. Accordingly, increasing the ratio in amount of the vacuum thermal insulators 6 can reduce the deformation of the thermally insulated box 1, or significantly increase the strength of the thermally insulated box 1. Although the same advantages can be obtained by increasing the thickness, increasing the area facilitates reduction of the wall thickness of the thermally insulated box 1. Thus, the thermally insulated box 1 according to Embodiment 1 is configured such that the vacuum thermal insulators 6 are arranged at least on side and rear portions of the outer casing 2, the filling rate of the vacuum thermal insulators 6 in the space 4 is

greater than or equal to 40%, and the ratio of the area of the vacuum thermal insulators 6 to the surface area of the outer casing 2 is greater than or equal to 60%, so that the vacuum thermal insulators 6 having a higher flexural modulus than rigid polyurethane foam included in conventional-art thermally insulated boxes are allowed to serve as a principal member to provide the strength of each wall surface of the thermally insulated box 1. Consequently, the thermally insulated box 1 according to Embodiment 1 can be reduced in wall thickness. Thus, each storage compartment 7 can be increased in size without changing outer dimensions of the box, so that the thermally insulated box 1 can carry more objects. If the strength of each wall surface decreases, the thermally insulated box 1 would deform, resulting in a defect, such as causing a shelf plate in the box to fall or causing the slidability of a drawer container or a door to degrade.

[0025]

In the thermally insulated box 1 according to Embodiment 1, the filling rate of the vacuum thermal insulators 6 in the space 4 should not exceed 80% for the following reason. According to the technical idea in Embodiment 1 as described above, ideally, the space 4 is filled only with the vacuum thermal insulators 6. As illustrated in Fig. 1, however, the rails 16 arranged on the inner casing 3 protrude inwardly in the space 4. If the thermally insulated box 1 is included in, for example, a refrigerator, a harness for connection of, for example, a compressor and a control panel (for control of a rotation speed or the like of the compressor) arranged in the thermally insulated box 1 is disposed in the space 4. Additionally, if the thermally insulated box 1 is included in, for example, a refrigerator, a refrigerant pipe or the like is disposed in the space 4. To completely fill the space 4 only with the vacuum thermal insulators 6, the shape of each vacuum thermal insulator 6 would become complicated. It would be accordingly difficult to form the vacuum thermal insulators 6. Furthermore, the outer casing 2 has to be bonded to the inner casing 3 in order to suppress a reduction in strength of the thermally insulated box 1 and prevent deformation of the thermally insulated box 1. The rails 16 for supporting the shelf plates arranged in the storage compartments 7 and other members are often

attached to the inner casing 3. Accordingly, although it is easy to bond the vacuum thermal insulators 6 to the outer casing 2, it is difficult to bond the vacuum thermal insulators 6 to the inner casing 3. Filling the space 4 with the rigid polyurethane foam 5, however, enables the outer casing 2 to be bonded to the inner casing 3

without any difficulty if the rails 16 and other members are arranged in the space 4.

In this case, if the thermally insulated box 1 has therein an area (i.e., a gap) which is not filled with the rigid polyurethane foam 5, the thermal insulation performance of the thermally insulated box 1 would degrade. In the thermally insulated box 1 according to Embodiment 1, therefore, the space 4 is filled with the vacuum thermal insulators 6 at a filling rate of 80% or less in order to provide a certain expanse (for example, approximately 6 mm) of gap that has to be filled with rigid polyurethane foam.

[0026]

Increasing the filling rate of the vacuum thermal insulators 6 in the space 4 reduces the filling rate of the rigid polyurethane foam 5 in the space 4. It may be feared that the adhesiveness between the outer casing 2 and the inner casing 3 may become insufficient, resulting in a reduction in strength of the thermally insulated box 1. As described above, however, the thermally insulated box 1 according to Embodiment 1 has been made on the basis of the technical idea of allowing the vacuum thermal insulator 6 to serve as a principal member to provide thermal insulation. Accordingly, the thermally insulated box 1 according to Embodiment 1 is little affected by the reduction in thermal insulation performance of the rigid polyurethane foam 5 caused by an increase in flexural modulus of the rigid polyurethane foam 5 (i.e., rigidity of the rigid polyurethane foam 5). Thus, the thermally insulated box 1 according to Embodiment 1 permits the density of the rigid polyurethane foam 5 to be higher than that in the related art (for example, greater than or equal to 60 kg/m³) and permits the flexural modulus of the rigid polyurethane foam 5 to be greater than or equal to 15.0 MPa which is higher than that of rigid polyurethane foam included in the conventional-art thermally insulated boxes, as illustrated in Fig. 13. Consequently, the thermally insulated box 1 according to Embodiment 1 can prevent a reduction in strength caused by a reduction in filling rate

of the rigid polyurethane foam 5 and eliminate a problem, such as deformation of the thermally insulated box 1 under the weight of objects it receives. In other words, the thermally insulated box 1 exhibits good quality if including a large amount of vacuum thermal insulators 6 and thus exhibits enhanced thermal insulation performance, thereby achieving energy saving.

[0027]

Note that the density of the rigid polyurethane foam 5 can be increased by, for example, injecting a larger amount of the liquid raw material of the rigid polyurethane foam 5 than in the related art into the space 4.

In Embodiment 1, an upper limit of the flexural modulus of the rigid polyurethane foam 5 is less than or equal to 150.0 MPa. If the flexural modulus of the rigid polyurethane foam 5 exceeds 150.0 MPa, the density of the rigid polyurethane foam 5 would increase too much such that the foam hardens without having sponge-like holes, which would lead to a steep reduction in thermal insulation performance of the rigid polyurethane foam 5.

[0028]

Although any well-known thermal insulator may be used as the vacuum thermal insulator 6 for the thermally insulated box 1 according to Embodiment 1, for example, the following vacuum thermal insulator 6 is used in Embodiment 1. Specifically, the thermally insulated box 1 according to Embodiment 1 is intended to be included in a refrigerator with the following specifications.

(1) The thermally insulated box 1 is used in which the total thickness of the outer casing 2 and the inner casing 3 is 2 mm and an average wall thickness of the thermally insulated box 1 is 30 mm, that is, an average dimension of the space 4 in a wall thickness direction is 28 mm.

(2) The thickness of the vacuum thermal insulator 6 is 20 mm and an average passage length for the rigid polyurethane foam 5 in the wall thickness direction in the space 4 is 8 mm.

(3) The rigid polyurethane foam 5 has a thermal conductivity ranging from 0.018 W/mk to 0.025 W/mK.

(4) The refrigerator has an internal volume on the order of 500 L and has a power consumption of 40 W or less.

When the thermal conductivity of the vacuum thermal insulator 6 exceeded 0.0030 W/mK under the above-described conditions, the reduction of the wall thickness significantly affected the thermal insulation performance, so that the thermal insulation performance was lower than specified (that is, the power consumption was more than 40 W). According to Embodiment 1, the vacuum thermal insulator 6 is allowed to have a thermal conductivity of 0.0030 W/mK or less, thus preventing the thermal insulation performance from being affected by the reduction of the wall thickness. As the thermal conductivity of the vacuum thermal insulator 6 is reduced, the cost per reduction of 0.001 W/mK dramatically increases. In addition, a thermal conductivity of 0.0012 W/mK ensures sufficient thermal insulation performance. Accordingly, the vacuum thermal insulator 6 having a thermal conductivity ranging from 0.0030 to 0.0012 W/mK is used. Table 1 illustrates the wall thickness, the filling rate of the vacuum thermal insulator, the flexural modulus of polyurethane foam, and the deformation of the box in Embodiment 1 of the present invention. For example, a comparison between Case 1 and Case 4 in Table 1 demonstrates that the thermally insulated box 1 having a wall thickness of 30 mm is allowed to have a strength equal to or higher than that in a conventional-art product having a wall thickness of 40 mm by including the vacuum thermal insulators 6 at a filling rate of 40% or more and polyurethane having a flexural modulus of 15 Mpa or more.

[Table 1]

Case	Wall Thickness (mm)	Filling rate (%)	Polyurethane Flexural Modulus (Mpa)	Box Deformation
1	40	20	9	1
2	30	20	9	1.53
3	30	40	9	1.08
4	30	40	15	0.93

[0029]

As regards the vacuum thermal insulator 6 in the thermally insulated box 1 according to Embodiment 1, a vacuum thermal insulator including an aluminum-evaporated film as an exterior film is preferably used for the following reason. In the

thermally insulated box 1 according to Embodiment 1 in which the vacuum thermal insulators 6 serve as a principal member to provide thermal insulation, a heat bridge phenomenon (transmission of heat from a front surface of the vacuum thermal insulator to a rear surface thereof through an exterior film of the vacuum thermal insulator) is more likely to occur than in the related art. Thus, the thermally insulated box 1 according to Embodiment 1 preferably includes, as the vacuum thermal insulator 6, a vacuum thermal insulator including an aluminum-evaporated film, serving as an exterior film, which does not tend to cause a heat bridge phenomenon as compared with a vacuum thermal insulator including an aluminum foil film as an exterior film.

[0030]

The flexural modulus and density of the rigid polyurethane foam 5 in Embodiment 1 may be measured as follows. The rigid polyurethane foam 5 having a size of $100 \times 100 \times 5$ mm or larger is cut from central part of the rigid polyurethane foam 5 on each of five surfaces including the right and left side surfaces, the rear surface, the top surface, and the bottom surface and an average flexural modulus and density thereof is calculated for the measurement. If it is difficult to cut the rigid polyurethane foam 5 because a refrigerant pipe or a lead wire is disposed in the central part, the rigid polyurethane foam 5 having a size of $100 \times 100 \times 5$ mm or larger may be cut from part closest to the central part.

[0031]

As described above, since the thermally insulated box 1 according to Embodiment 1 can be allowed to have a thinner wall thickness than in the related art, the thermally insulated box 1 can achieve energy saving and exhibit higher internal volume efficiency than in the related art. In other words, each storage compartment 7 can be increased in size as compared with that in the related art without changing the outer dimensions of the thermally insulated box 1, so that the thermally insulated box 1 can receive more objects than in the related art.

[0032]

The shape of the thermally insulated box 1 illustrated in Embodiment 1 is intended only to be illustrative. For example, as illustrated in Fig. 5, the interior of the thermally insulated box 1 may be divided into four storage compartments 7 by three partitions 24. Additionally, for example, as illustrated in Fig. 6, the interior of the thermally insulated box 1 may be divided into five storage compartments 7 by four partitions 24. The strength of the thermally insulated box 1 can be enhanced by increasing the partitions 24 and the sheet metal covers 34. In other words, as the number of storage compartments 7 increases, the sheet metal covers 34 enhance the strength of the box. Thus, if the average thickness of the rigid polyurethane foam 5 in a portion covered with the vacuum thermal insulator 6 is reduced (to 5 mm or less, for example), the box can be allowed to have sufficient strength. Accordingly, each storage compartment 7 can be increased in size without changing the outer dimensions of the thermally insulated box 1, such that the thermally insulated box 1 can receive more objects.

[0033]

Although not particularly mentioned in Embodiment 1, the partition 24 may have the same inner structure as that of the thermally insulated box 1. Specifically, an internal space of the partition 24 may be filled with the rigid polyurethane foam 5 and the vacuum thermal insulator 6 such that the filling rate of the vacuum thermal insulator 6 ranges from 40% to 80% and the flexural modulus of the rigid polyurethane foam 5 is greater than or equal to 15.0 MPa. The partitions 24 having such a structure further enhance the thermal insulation performance of the thermally insulated box 1.

[0034]

Embodiment 2

In Embodiment 1, the vacuum thermal insulators 6 are arranged in the space 4 defined between the outer casing 2 and the inner casing 3 such that the vacuum thermal insulators 6 are bonded to the outer casing 2. The arrangement should not be construed as limiting. The vacuum thermal insulators 6 may be arranged in the space 4 in the following manner, for example. In the following description, the same

functions and components as those in Embodiment 1 are designated by the same reference numerals and any item which is not particularly mentioned in Embodiment 2 is the same as that in Embodiment 1.

[0035]

5 Fig. 7 is a front cross-sectional view of a thermally insulated box according to Embodiment 2 of the present invention.

As illustrated in Fig. 7, the thermally insulated box 1 according to Embodiment 2 includes condensing pipes 9 arranged on an inner surface of the outer casing 2. Each condensing pipe 9 is a refrigerant pipe through which a high-temperature high-
10 pressure refrigerant discharged from a compressor flows and which allows the refrigerant flowing through the pipe is cooled (or condensed) by outdoor air through the pipe wall of the condensing pipe 9 or the outer casing 2. The thermally insulated box 1 according to Embodiment 2 further includes spacers 8 having a thickness greater than or equal to the diameter of the condensing pipe 9 such that the spacers
15 8 are attached to the inner surface of the outer casing 2 so as not to overlap the condensing pipes 9. The vacuum thermal insulators 6 are bonded to the spacers 8. Specifically, the thermally insulated box 1 according to Embodiment 2 is configured such that the vacuum thermal insulators 6 are arranged at a predetermined distance from each of the outer casing 2 and the inner casing 3 and the vacuum thermal
20 insulators 6 are embedded in the rigid polyurethane foam 5.

[0036]

Since the vacuum thermal insulators 6 are embedded in the rigid polyurethane foam 5 in the thermally insulated box 1 according to Embodiment 2 as mentioned above, the vacuum thermal insulators 6 can be arranged if the condensing pipes 9
25 are arranged on the outer casing 2.

[0037]

The vacuum thermal insulator 6 has the following characteristics. The vacuum thermal insulator 6 absorbs more ambient gas with increasing temperature, so that the degree of vacuum inside the vacuum thermal insulator 6 is reduced and
30 the thermal conductivity thereof is accordingly reduced. Arranging the vacuum

thermal insulators 6 at a distance from the outer casing 2 having a higher temperature and the condensing pipes 9 reduces the temperature of the vacuum thermal insulators 6, thus suppressing the deterioration of the vacuum thermal insulators 6. Thus, the thermally insulated box 1 can be allowed to exhibit high reliability for a long term.

[0038]

Although the vacuum thermal insulators 6 have such characteristics that when the insulator absorbs an ambient gas, the degree of vacuum inside the insulator is reduced and the thermal conductivity of the insulator is accordingly reduced, the amount of gas surrounding the vacuum thermal insulators 6 can be reduced because the vacuum thermal insulators 6 are embedded in the rigid polyurethane foam 5. Thus, the deterioration of the vacuum thermal insulators 6 can be suppressed, so that the thermally insulated box 1 can be allowed to exhibit high reliability for a long term. In particular, the density of the rigid polyurethane foam 5 in the thermally insulated box 1 according to Embodiment 2 is higher than that of rigid polyurethane foam included in the conventional-art thermally insulated boxes. Consequently, the amount of gas surrounding the vacuum thermal insulators 6 can be further reduced. Thus, the deterioration of the vacuum thermal insulators 6 can be further suppressed, so that the thermally insulated box 1 can be allowed to exhibit high reliability for a longer term.

[0039]

Although the thermally insulated box 1 including the condensing pipes 9 arranged in the space 4 has been described as an example in Embodiment 2, the vacuum thermal insulators 6 may be embedded in the rigid polyurethane foam 5 in the thermally insulated box 1 in which the condensing pipes 9 are not arranged in the space 4. Since the amount of gas surrounding the vacuum thermal insulators 6 can be reduced, the deterioration of the vacuum thermal insulators 6 can be suppressed. The thermally insulated box 1 can be allowed to exhibit high reliability for a long term.

[0040]

Embodiment 3

The arrangement of the vacuum thermal insulators 6 in the space 4 is not limited to that described in Embodiment 1 or Embodiment 2. The vacuum thermal insulators 6 may be arranged in the space 4 depending on the shape or the like of the inner casing 3 in the following manner, for example. In the following description, the same functions and components as those in Embodiment 1 or Embodiment 2 are designated by the same reference numerals and any item which is not particularly mentioned in Embodiment 3 is the same as that in Embodiment 1 or Embodiment 2.

[0041]

Fig. 8 is a front cross-sectional view of a thermally insulated box according to Embodiment 3 of the present invention.

As illustrated in Fig. 8, the thermally insulated box 1 according to Embodiment 3 has no rails 16 (refer to Figs. 1 and 7) on the inner casing 3. If the inner casing 3 has such a shape that facilitates bonding of the vacuum thermal insulators 6 to the inner casing 3, all or some of the vacuum thermal insulators 6 may be arranged on the inner casing 3.

[0042]

The thermally insulated box 1 with the above-described structure according to Embodiment 3 can achieve energy saving and exhibit higher internal volume efficiency than in the related art with a less amount of vacuum thermal insulators 6. Specifically, if the vacuum thermal insulators 6 having the same size as that in Embodiment 3 are bonded to, for example, the outer casing 2, a gap defined between the vacuum thermal insulators 6 at a corner or the like of the outer casing 2 is larger than that between the vacuum thermal insulators 6 arranged on the inner casing 3 because the surface area of the outer casing 2 is larger than that of the inner casing 3. In other words, the arrangement of the vacuum thermal insulators 6 on the inner casing 3 reduces the gap between the vacuum thermal insulators 6 and loss is accordingly smaller than that in the arrangement in which the vacuum thermal insulators 6 having the same size as that of the vacuum thermal insulators 6 arranged on the inner casing 3 are arranged on the outer casing 2. Thus, the thermally insulated box 1 can be allowed to exhibit higher efficiency.

[0043]

Embodiment 4

If the thermally insulated box 1 described in each of Embodiments 1 to 3 is provided with a door, the thermally insulated box 1 may have the following structure.

5 In the following description, the same functions and components as those in Embodiments 1 to 3 are designated by the same reference numerals and any item which is not particularly mentioned in Embodiment 4 is the same as that in Embodiments 1 to 3.

[0044]

10 Fig. 9 is a side cross-sectional view of a thermally insulated box according to Embodiment 4 of the present invention.

As illustrated in Fig. 9, the thermally insulated box 1 according to Embodiment 4 includes doors 10 to close openings of the storage compartments 7 arranged inside the box. Each door 10 includes a face member 12 (corresponding to an outer plate in the present invention) made of, for example, metal and an inner plate 13 made of, 15 for example, resin. A space 10a (corresponding to a second space in the present invention) defined between the face member 12 and the inner plate 13 accommodates (or is filled with) the rigid polyurethane foam 5 and the vacuum thermal insulator 6. Each door 10 is made on the basis of the technical idea (of 20 allowing the vacuum thermal insulator 6 to serve as a principal member to provide thermal insulation) described in Embodiments 1 to 3 and is accordingly configured such that the filling rate of the vacuum thermal insulator 6 in the space 10a ranges from 40% to 80%.

[0045]

25 As regards a method of making the door 10, the vacuum thermal insulator 6 is bonded and fixed to the face member 12, a liquid raw material of the rigid polyurethane foam 5 is injected into the space 10a, and integral foaming is performed, so that the space 10a can be filled with the rigid polyurethane foam 5.

[0046]

The structure of each door 10 illustrated in Fig. 9 is intended only to be illustrative. For example, a frame or the like to support a storage container received in the storage compartment 7 may be attached to the door 10 (or the inner plate 13) so as to be adjacent to the storage compartment 7. In this case, as illustrated in Fig. 9, the rigid polyurethane foam 5 is preferably disposed adjacent to the storage compartment 7 (or the inner plate 13) in the space 10a in order to fasten the frame to the door 10 by screws (or provide nuts in the door 10). If any part is not attached to the door 10 (or the inner plate 13) so as to be adjacent to the storage compartment 7, the door 10 may be configured as illustrated in Fig. 10, for example.

[0047]

Fig. 10 is a side cross-sectional view of another example of the thermally insulated box according to Embodiment 4 of the present invention.

Specifically, as illustrated in Fig. 10, all or some of the vacuum thermal insulators 6 may be arranged on the inner plates 13. In this case, areas (refer to part A in Fig. 9) which are arranged in upper and lower doors 10 and which are not covered with the vacuum thermal insulators 6 are smaller than those in the arrangement of the vacuum thermal insulators 6 on the face members 12 if the vacuum thermal insulators 6 used have the same size. Thus, the thermally insulated box 1 exhibits higher efficiency.

[0048]

Furthermore, all of the doors 10 do not have to include the vacuum thermal insulator 6. For example, assuming that the difference in temperature between outdoor air and the inside (i.e., the storage compartment 7) of the thermally insulated box 1 is small, disposing the vacuum thermal insulator 6 in the door 10 is not so effective in improving the thermal insulation performance. In such a case, if the vacuum thermal insulator 6 is not disposed in the door 10, sufficient thermal insulation performance can be ensured.

[0049]

The door 10 in Embodiment 4 may be attached to a body (housing composed of the outer casing 2 and the inner casing 3) of the thermally insulated box 1 in any

manner. For example, the door 10 may be attached to the body of the thermally insulated box 1 by a slide-out attachment mechanism with rails. Furthermore, the door 10 may be attached to the body of the thermally insulated box 1 by, for example, a rotatable attachment mechanism as illustrated in Fig. 11.

5 [0050]

Fig. 11 is a perspective view of an exemplary mechanism for attaching the door to the thermally insulated box in Embodiment 4 of the present invention when the door is opened.

10 In the case where the door 10 is attached to the body of the thermally insulated box 1 by the rotatable attachment mechanism, hinges 14 are fixed to either of right and left sides of the body of the thermally insulated box 1. A pin of each hinge 14 is inserted into the door 10, so that the door 10 is rotatable about the pin of the hinge 14 so as to be opened or closed.

[0051]

15 Furthermore, preferably, a gasket 11 is attached to the door 10 so as to be adjacent to the storage compartment 7 as illustrated in Fig. 11. The gasket 11 is made of, for example, polyvinyl chloride. While the door 10 is closed, the gasket 11 is in tight contact with a front flange surface 15 of the body of the thermally insulated box 1. This prevents air in the storage compartment 7 from flowing out of the box.

20 [0052]

25 In the thermally insulated box 1 configured as described above in Embodiment 4, the filling rate of the vacuum thermal insulators ranges 40% to 80% in the sum of the space 4 defined between the outer casing 2 and the inner casing 3 and the spaces 10a as the internal spaces of the doors 10. Consequently, the wall thickness (i.e., the distance between the outer casing 2 and the inner casing 3 and the thickness of each door 10) of the thermally insulated box 1 can be thinner than that in the related art. Thus, the thermally insulated box 1 can achieve energy saving and exhibit higher internal volume efficiency than in the related art. Accordingly, each storage compartment 7 can be increased in size without changing the outer
30 dimensions of the thermally insulated box 1, so that the thermally insulated box 1 can

receive more objects than in the related art. Thus, the thermally insulated box 1 can be allowed to have a higher commercial value than in the related art.

[0053]

Increasing the filling rate of the vacuum thermal insulators 6 in the space 4 reduces the filling rate of the rigid polyurethane foam 5 in the space 4. The thermally insulated box 1 according to Embodiment 4, however, permits the density of the rigid polyurethane foam 5 to be higher than that in the related art (for example, greater than or equal to 60 kg/m^3) and permits the flexural modulus of the rigid polyurethane foam 5 to be greater than or equal to 15.0 MPa which is higher than that of rigid polyurethane foam included in the conventional-art thermally insulated boxes. Consequently, the thermally insulated box 1 according to Embodiment 4 can prevent a reduction in strength caused by a reduction in filling rate of the rigid polyurethane foam 5 and eliminate a problem, such as deformation of the thermally insulated box 1 under the weight of objects received and the weight of the doors 10.

[0054]

This suppresses tilting of the doors 10 caused by the deformation of the thermally insulated box 1, thus preventing deterioration in appearance. In addition, the gasket 11 and the front flange surface 15 can be prevented from being deviated from each other to produce a clearance therebetween which causes air in the storage compartment 7 to flow out of the box. Thus, the thermally insulated box 1 exhibits good quality while including a large amount of vacuum thermal insulators 6 and thus exhibits enhanced thermal insulation performance, thereby achieving energy saving.

[0055]

Embodiment 5

For the deformation due to the reduction of the strength of the thermally insulated box 1 described in each of Embodiments 1 to 4, the strengths of the side and rear portions of the box extending perpendicular to gravity more significantly affect the deformation than those of the bottom and top portions extending horizontally relative to gravity. Accordingly, the strength of the thermally insulated box 1 can be enhanced by arranging the vacuum thermal insulators 6 in the following

manner. In the following description, the same functions and components as those in Embodiments 1 to 4 are designated by the same reference numerals and any item which is not particularly mentioned in Embodiment 5 is the same as that in Embodiments 1 to 4.

[0056]

Fig. 15 illustrates results of calculation of the ratio of the area of the vacuum thermal insulators 6 to the surface area of each of the side and rear portions of the thermally insulated box 1 illustrated in Fig. 1 and the deformation of the box. Note that the filling rate of the vacuum thermal insulators 6 is 40% and the deformation is 1 when the area ratio is 50%. The flexural modulus of the vacuum thermal insulator 6 ranges from 20 MPa to 40 Mpa, that is, the flexural modulus of the vacuum thermal insulator 6 is higher than that of the rigid polyurethane foam 5. Accordingly, as the ratio of the area of the vacuum thermal insulators 6 to the surface area of each of the side and rear portions is larger, the deformation of the thermally insulated box 1 is smaller, that is, the strength of the thermally insulated box 1 is greater.

[0057]

Fig. 15 demonstrates that when the area ratio of the vacuum thermal insulators 6 exceeds 70%, the influence on the strength of the thermally insulated box 1 is reduced. The reason is as follows: since the calculation was based on a filling rate of 40%, the influence of a reduction in thickness of the vacuum thermal insulators 6 was enhanced by an increase in area of the vacuum thermal insulators 6. If the area of the vacuum thermal insulators 6 is increased and the filling rate thereof is increased while the thickness thereof is kept constant, such a situation will not occur. Disadvantageously, increasing the filling rate of the vacuum thermal insulators 6 increases the cost. To efficiently increase the strength of the thermally insulated box 1 without changing the filling rate of the vacuum thermal insulators 6, the area ratio of the vacuum thermal insulators 6 should be increased in the above-described manner. So long as the area ratio is greater than or equal to 70%, the strength can be ensured. The volume of the storage compartment 7 can be increased while the reduction of the wall thickness of the thermally insulated box 1 is achieved.

[0058]

As described above, since the thermally insulated box 1 according to Embodiment 5 is allowed to have a thinner wall thickness than in the related art, the thermally insulated box 1 can achieve energy saving and exhibit higher internal volume efficiency than in the related art. In other words, each storage compartment 7 can be increased in size as compared with that in the related art without changing the outer dimensions of the thermally insulated box 1, so that the thermally insulated box 1 can receive more objects than in the related art.

[0059]

Embodiment 6

A thermally insulated box 1 having more stable strength, improved appearance, and high quality can be provided by increasing a free foam density of the rigid polyurethane foam 5 in the thermally insulated box 1 described in each of Embodiments 1 to 5. In the following description, the same functions and components as those in Embodiments 1 to 5 are designated by the same reference numerals and any item which is not particularly mentioned in Embodiment 6 is the same as that in Embodiments 1 to 5.

[0060]

As described above, increasing the density of the rigid polyurethane foam 5 increases the flexural modulus, thus enhancing the strength of the thermally insulated box 1. If a large amount of liquid polyurethane raw material is injected to increase the density, unevenness in density of polyurethane having a high expansion ratio as in the related art would tend to occur near the inlet ports 32 and end parts of the thermally insulated box 1. It would be difficult to obtain stable strength.

[0061]

Increasing the free foam density facilitates evenness in density of the rigid polyurethane foam 5. The term "free foam density" as used herein refers to the density of the rigid polyurethane foam 5 obtained by foaming polyurethane not in an enclosed space of a box or the like but in an open space. Typically, the density of

polyurethane foamed and expanded in a small space is higher than its free foam density.

[0062]

In general, as more bubbles are contained, that is, the density is lower, foam, such as the rigid polyurethane foam 5, provides higher thermal insulation. For the density of the rigid polyurethane foam 5 typically included in the thermally insulated box 1, the rigid polyurethane foam 5 with a low density ranging from approximately 25 kg/m³ to approximately 30 kg/m³ is often used. To ensure the strength of the thermally insulated box 1 using this polyurethane foam with a flexural modulus of 15 MPa or more, the amount of polyurethane foam for, for example, the above-described thermally insulated box having a polyurethane thickness of 8 mm has to exceed a just pack amount (with which a target box is just filled with the rigid polyurethane foam 5). Unfortunately, this tends to cause an uneven density. Furthermore, since the amount of polyurethane packed is larger than the just pack amount, polyurethane overflows from gaps of the thermally insulated box 1 and the doors 10 (for example, a junction between the outer casing 2 and the inner casing 3). Unfortunately, an intended density of rigid polyurethane foam cannot be achieved. In addition, other problems tend to occur, for example, an operation to remove overflowing polyurethane is needed.

[0063]

Reducing the amount of foaming agent contained in the liquid polyurethane raw material can increase the free foam density. For the above-described thermally insulated box 1 having a polyurethane thickness of 8 mm, for example, when the free foam density is 35 kg/m³, the density with the just pack amount is greater than or equal to 60 kg/m³. Advantageously, this allows the rigid polyurethane foam 5 to have a flexural modulus of 15 MPa and eliminates the problems, such as the unevenness in density and the leakage of polyurethane. In this case, it may be feared that the increase of the free foam density of polyurethane may affect the thermal insulation performance. As described above, however, since the filling rate of the vacuum thermal insulators 6 ranges from 40% to 80%, the deterioration of the

thermal insulation performance of the rigid polyurethane foam 5 affects little the thermal insulation performance of the thermally insulated box 1 and the doors 10. If the above-described polyurethane thickness is less than 8 mm, the just pack amount can be controlled by setting the free foam density to be greater than or equal to 35 kg/m³.

[0064]

As described above, the thermally insulated box 1 according to Embodiment 6 can be allowed to have a thinner wall thickness than in the related art, ensure stable strength and quality while suppressing the leakage of polyurethane, achieve energy saving, and have higher internal volume efficiency than in the related art. In other words, each storage compartment 7 can be increased in size as compared with in the related art without changing the outer dimensions of the thermally insulated box 1, so that the thermally insulated box 1 can receive more objects than in the related art.

[0065]

Embodiment 7

An exemplary refrigerator including the thermally insulated box 1 described in any of Embodiments 1 to 6 will be described in Embodiment 7. In the following description, the same functions and components as those in Embodiments 1 to 6 are designated by the same reference numerals and any item which is not particularly mentioned in Embodiment 7 is the same as that in Embodiments 1 to 6.

[0066]

Fig. 12 is a side cross-sectional view of a refrigerator according to Embodiment 5 of the present invention. Fig. 12 illustrates a refrigerator 100 including the thermally insulated box 1 according to Embodiment 4 illustrated in Fig. 9.

In the refrigerator 100 according to Embodiment 7, the storage compartments 7 arranged in the thermally insulated box 1 are used as a refrigerator compartment 21, a freezer compartment 22, and a crisper compartment 23 in that order from the top.

[0067]

The refrigerator 100 according to Embodiment 7 further includes a cooling device disposed in the thermally insulated box 1 and the cooling device is configured

to cool air to be supplied to the refrigerator compartment 21, the freezer compartment 22, and the crisper compartment 23. The cooling device includes a compressor 30, the condensing pipes 9 (refer to Fig. 7), a pressure reducing device (not illustrated), such as an expansion valve or a capillary tube, and a cooler 27. Specifically, the refrigerator 100 according to Embodiment 5 includes a refrigeration cycle, serving as the cooling device. For the above-described components of the cooling device, the compressor 30 and the pressure reducing device are arranged in a machine room 29 disposed in rear lower part of the thermally insulated box 1. The condensing pipes 9 are arranged on, for example, the side portions of the thermally insulated box 1. The cooler 27 is disposed in a cooling room 25 defined by the inner casing 3 and a fan grille 26. The cooling room 25 further accommodates a cooler fan 28 to send air cooled by the cooler 27 to the refrigerator compartment 21, the freezer compartment 22, and the crisper compartment 23. A control panel room 31 is disposed in rear upper part of the thermally insulated box 1. The control panel room 31 accommodates a control panel for control of a rotation speed or the like of each of the compressor 30 and the cooler fan 28.

[0068]

In the refrigerator 100 with the above-described configuration, a high-temperature high-pressure gas refrigerant discharged by the compressor 30 in the machine room 29 is condensed into a low-temperature high-pressure liquid refrigerant while passing through the condensing pipes 9 (refer to Fig. 7). This low-temperature high-pressure liquid refrigerant is pressure-reduced by the pressure reducing device such that the refrigerant turns into a low-temperature, low-pressure two-phase gas-liquid refrigerant. When the refrigerant reaches the cooler 27, the temperature of the refrigerant is -20°C or less. This low-temperature, low-pressure two-phase gas-liquid refrigerant cools air in the cooling room 25. The cooled air is supplied to the refrigerator compartment 21, the freezer compartment 22, and the crisper compartment 23 by the cooler fan 28, thus cooling the refrigerator compartment 21, the freezer compartment 22, and the crisper compartment 23 (more specifically, objects received in these storage compartments). On the other hand, the low-

temperature, low-pressure two-phase gas-liquid refrigerant, which has cooled the air in the cooling room 25, is heated by the air in the cooling room 25 such that the refrigerant evaporates into a low-pressure gas refrigerant. The refrigerant is again sucked into the compressor 30 and is compressed by the compressor 30.

5 [0069]

In the refrigerator 100 according to Embodiment 7 with the above-described configuration, the filling rate of the vacuum thermal insulators ranges from 40% to 80% in the sum of the space 4 defined between the outer casing 2 and the inner casing 3 and the spaces 10a, serving as internal spaces of the doors 10.

10 Accordingly, if the wall thickness (i.e., the distance between the outer casing 2 and the inner casing 3 and the thickness of each door 10) of the thermally insulated box 1 is thinner than those in the related art, the thermal insulation performance of the thermally insulated box 1 can be ensured. Thus, each storage compartment 7 is made resistant to warming. Advantageously, the amount of air flow necessary for
15 cooling can be reduced, so that the rotation speed of the compressor 30 can be reduced or non-operation (OFF) time can be extended. Consequently, the refrigerator 100 can achieve energy saving. Furthermore, each storage compartment of the refrigerator 100 with the above-described configuration according to Embodiment 7 can be increased in size as compared with in the related art without
20 changing outer dimensions of the refrigerator, so that the storage compartment can receive more objects than in the related art.

[0070]

Furthermore, since the freezer compartment 22 whose temperature is the most different from that of outdoor air is disposed in the middle of the refrigerator, the
25 number of surfaces through which heat from the outdoor air penetrates into the freezer compartment 22 can be reduced to four (the door 10, serving as a front surface, the right and left side surfaces, and the rear surface). Thus, energy saving can be further enhanced in the refrigerator 100.

[0071]

In addition, since the flexural modulus of the rigid polyurethane foam 5 disposed in the space 4 and the spaces 10a is greater than or equal to 15.0 MPa in Embodiment 7, the strength of the thermally insulated box 1 can be ensured, thus suppressing deformation of the thermally insulated box 1 under the weight of objects received. This suppresses tilting of the doors 10 caused by the deformation of the thermally insulated box 1, thus preventing deterioration in appearance. In addition, the gasket 11 and the front flange surface 15 for each of the refrigerator compartment 21, the freezer compartment 22, and the crisper compartment 23 can be prevented from being deviated from each other to produce a clearance therebetween which causes air in the compartment to flow out of the thermally insulated box 1. Thus, energy saving can be further enhanced in the refrigerator 100.

[0072]

Although the distribution of filling rate of the vacuum thermal insulators 6 in the space 4 and the spaces 10a has not particularly been mentioned in Embodiment 7, the filling rate of the vacuum thermal insulators 6 may be changed for each given position in the space 4 and the spaces 10a depending on the temperature difference between the outside air and each storage compartment.

[0073]

For example, the difference between the temperature inside the freezer compartment 22 and that of the outdoor air is the largest. The filling rate of the vacuum thermal insulators 6 in each of the right and left side portions, the rear portion, and the front portion (the door 10) of the thermally insulated box 1 in a region corresponding to the freezer compartment 22 may be higher than that in the other region (for example, may be greater than or equal to 60%). Such a structure can suppress heat penetration into the freezer compartment 22 with the lowest temperature, thus further enhancing energy saving in the refrigerator 100.

[0074]

For example, if the outdoor air temperature is 30°C, a temperature in the machine room 29 may rise to, for example, 35°C or higher and a temperature in the control panel room 31 may rise to, for example, 40°C or higher. In other words, the

temperature difference between each of the machine room 29 and the control panel room 31 and the storage compartments is larger than that between the other portions and the storage compartments. The storage compartments near the machine room 29 and the control panel room 31 are susceptible to heat penetration. Accordingly, the filling rate of the vacuum thermal insulators 6 in an area between the storage compartment and each of the machine room 29 and the control panel room 31 may be higher than that in the other area (for example, may be greater than or equal to 60%). Such a structure can suppress heat penetration from the machine room 29 and the control panel room 31 with high temperature into the storage compartments near these rooms, thus further enhancing energy saving in the refrigerator 100.

[0075]

Although the refrigerator 100 including the three storage compartments (the refrigerator compartment 21, the freezer compartment 22, and the crisper compartment 23) has been described in Embodiment 7, the interior of the thermally insulated box 1 may be divided as illustrated in Fig. 5 or 6, for example, such that the refrigerator 100 includes four or more storage compartments. The refrigerator 100 with such a configuration can offer the same advantages as those described above.

Industrial Applicability

[0076]

The thermally insulated box 1 according to the present invention can be included in, for example, a hot water storage apparatus that includes a heating device to heat water and a tank to store the water heated by the heating device. The tank is disposed in the thermally insulated box 1. Since the tank can be insulated from heat by the thermally insulated box 1 having smaller outer dimensions than in the related art, the hot water storage apparatus can be reduced in footprint.

Reference Signs List

[0077]

1 thermally insulated box 2 outer casing 3 inner casing 4 space 5 rigid polyurethane foam 6 vacuum thermal insulator 7 storage compartment 8 spacer 9 condensing pipe 10 door 10a space 11 gasket 12 face

member 13 inner plate 14 hinge 15 front flange surface 16 rail 21
refrigerator compartment 22 freezer compartment 23 crisper compartment 24
partition 25 cooling room 26 fan grille 27 cooler 28 cooler fan 29
machine room 30 compressor 31 control panel room 32 inlet port 33
5 cutaway portion 34 sheet metal cover 100 refrigerator

CLAIMS

[Claim 1]

A thermally insulated box comprising:

an outer casing;

an inner casing;

at least one vacuum thermal insulator; and

rigid polyurethane foam,

wherein a first space defined between the outer casing and the inner casing is filled with the vacuum thermal insulator and the rigid polyurethane foam,

wherein the at least one vacuum thermal insulator is disposed at least in right and left side portions and a rear portion of the box,

wherein the first space is filled with the at least one vacuum thermal insulator at a filling rate ranging from 40% to 80%,

wherein a ratio of an area of the at least one vacuum thermal insulator to a surface area of the outer casing is greater than or equal to 60%, and

wherein the rigid polyurethane foam has a flexural modulus greater than or equal to 15.0 MPa.

[Claim 2]

The thermally insulated box of claim 1, further comprising:

a door that includes

an outer plate,

an inner plate,

the vacuum thermal insulator, and

the rigid polyurethane foam,

wherein a second space defined between the outer plate and the inner casing is filled with the at least one vacuum thermal insulator and the rigid polyurethane foam, and

wherein a filling rate of the at least one vacuum thermal insulator in a sum of the first space and the second space ranges from 40% to 80%.

[Claim 3]

The thermally insulated box of claim 1 or 2,
wherein the rigid polyurethane foam has an average thermal conductivity
ranging from 0.018 W/mK to 0.025 W/mK, and
wherein the at least one vacuum thermal insulator has a thermal conductivity
5 ranging from 0.0030 W/mK to 0.0012 W/mK.

[Claim 4]

The thermally insulated box of any one of claims 1 to 3,
wherein the at least one vacuum thermal insulator is disposed at a
predetermined distance from each of the outer casing and the inner casing, and
10 wherein the at least one vacuum thermal insulator is embedded in the rigid
polyurethane foam.

[Claim 5]

The thermally insulated box of any one of claims 1 to 4,
wherein one surface of the outer casing has at least one inlet port through
15 which a liquid raw material of the rigid polyurethane foam is injected into the first
space,

wherein the at least one vacuum thermal insulator includes a plurality of
vacuum thermal insulators arranged opposite the one surface of the outer casing
having the inlet port,

20 wherein at least one of the vacuum thermal insulators has a cutaway portion at
least one corner of the vacuum thermal insulator, and

wherein the inlet port is disposed so as to face the cutaway portion.

[Claim 6]

The thermally insulated box of any one of claims 1 to 5, wherein the ratio of the
25 area of the at least one vacuum thermal insulator to the area of each of the right and
left side surfaces and the rear surface of the outer casing exceeds 70%.

[Claim 7]

The thermally insulated box of any one of claims 1 to 6, wherein the rigid
polyurethane foam has a free foam density greater than or equal to 35 kg/m³ and a

just pack amount of the rigid polyurethane foam relative to the thermally insulated box is greater than or equal to 60 kg/m^3 .

[Claim 8]

A refrigerator comprising:

- 5 the thermally insulated box of any one of claims 1 to 7; and
 a cooling device to cool air to be supplied to a storage compartment disposed in the thermally insulated box.

[Claim 9]

A hot water storage apparatus comprising:

- 10 the thermally insulated box of any one of claims 1 to 7;
 a heating device to heat water; and
 a tank disposed in the thermally insulated box, the tank being configured to store the water heated by the heating device.