

**PHASE CHANGE MATERIAL ELEMENTS FOR USE IN A THERMALLY
INSULATED TRANSPORTATION CONTAINER**

The invention relates to phase change material (PCM) elements for use in a thermally insulated transportation container, a set of PCM elements, a thermally insulated
5 transportation container having such PCM elements, and a method for loading PCM elements into a thermally insulated transportation container.

Thermally insulated containers are used to transport items that are sensitive to temperature and must therefore be maintained within predetermined temperature ranges, such as +2°C to +8°C and +15°C to +25°C, or close to a particular temperature such as -
10 20°C. Such items include goods such as vaccines and drugs, biological samples, tissue cultures, chilled and frozen foods and many other products, some of which have extremely high financial value and are very sensitive to temperature changes. It is essential that such products are maintained within the appropriate temperature ranges during transportation.

15 It is known to transport such goods in reusable thermally insulated transportation containers, which include an arrangement of PCM elements that are used to maintain the temperature within the predetermined temperature range selected, hopefully for the duration of the journey. While in transit, heat energy flows into or out of the container, according to the difference between the ambient temperature and the internal temperature
20 of the container. The temporal ambient temperature profile that will be experienced by the container cannot be predicted a priori, since containers may be moved from relatively cold countries to relatively hot countries and may be left standing for a significant period of time outside, or within a warehouse.

If the container is exposed to excessively high or low temperatures for extended periods,
25 the internal temperature may go outside the required range, causing damage to the contents. The requirement to open a container on its journey increases the risk of payload theft. In current containers, the number and type of PCM packs employed is calculated according to the anticipated delivery time and the ambient temperature ranges likely to be

experienced during transportation. However, as delivery can take longer than anticipated and the ambient temperatures may be much higher or lower than expected, the payload temperature may go outside the required range. During transportation, shocks, collisions or vibrations can cause the goods to move within the container, particularly those located
5 at the side walls; these might then fall to a lower part of the container, increasing the risk of being heated/cooled to a temperature outside the predetermined safe range.

Anecdotal evidence suggests that large numbers of pharmaceutical/medicinal products are rendered unusable each year because they are not transported in the correct temperature range. For the pharmaceutical industry this presents significant waste, and
10 hence cost, and there is an environmental impact as new goods will have to be produced and transported. For recipients of the goods there are significant health risks, because it may not be evident at the endpoint of the transport that the product has been rendered unsafe. For products such as vaccines this may result in loss of efficacy.

Certain vaccines degrade at a rate that depends on ambient temperature. As the loss of
15 efficacy increases with temperature, it is desirable to maintain the temperature within the acceptable range (e.g. 2°C to 8°C).

The transportation container and PCM elements disclosed in WO2010/055295 addresses the some of the above-mentioned problems by providing an arrangement of PCM elements that provides a structure around the goods being transported. The arrangement
20 helps to provide temperature equilibration within the payload volume during transit and the container provides good thermal insulation, and a robust structure to protect the goods. However, the inventors have identified certain aspects of the container of WO2010/055295 that can be changed to produce an even more efficient and effective container. For example, the inventors have identified that certain parts of the container
25 structure allow more heat into the container payload because of the arrangement of the thermal insulation in the walls of the container. In particular, the edges of the container typically have less insulation than say central portions of the container side walls. The inventors have also identified that the PCM unit structure within the transportation container, which houses the goods being transported and which comprises a number of

rectangular plates formed into a generally hollow cuboid structure, is arranged such that some gaps between adjacent PCM elements are generally aligned with the edges of the container, particularly vertical edges, where there is less thermal insulation than central portions of the side walls of the container. This can lead to heat leaking into the storage volume faster than desired. The PCM unit structure, comprising the PCM rectangular plates, is also relatively heavy and uses a significant amount of plastic material to form the structure, particularly where double layers are required in order to provide the cooling effect required. This is undesirable with today's environmental concerns. These containers are often transported by aeroplane, and given the negative effects of jet fuel on the atmosphere, it is desirable to minimise the weight of the transportation container so that less jet fuel is required to transport the container. Also, the rectangular plate PCM elements have a limited distribution for phase change material within the PCM unit container, which can contribute to having to increase the number of plates in a particular part of the transportation container to obtain the desired cooling effect. The inventors have also determined that it is possible to improve upon the temperature profile within the payload volume so that the temperature is more homogeneous within the payload volume.

Accordingly, the invention seeks to address one of the above-mentioned problems or to at least provide an alternative PCM element, set of PCM elements, and thermally insulated transportation container compared with known PCM elements and containers. The invention also seeks to provide a method for inserting PCM elements into a thermally insulated transportation container that mitigates at least one of the above-mentioned problems, or at least provides an alternative to known methods.

According to one aspect, there is provided a set of PCM elements according to claim 1. The invention provides a set of PCM elements that requires a fewer number of PCM elements than the prior art flat plates to construct the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element receptacles when compared with the traditional flat plate PCM elements, thus leading to a reduction in

weight of the overall container. This is important since thermally insulated transportation containers are flown by aeroplane over long distances and therefore a reduction in overall weight reduces the amount of fuel required to transport the container over the life of the container, thereby benefiting the environment. It has been found that the invention
5 prolongs the time that goods remain within the specified temperature range, given the same operating conditions, when compared to the prior art flat plates, and also provides better temperature homogeneity within the hollow cuboid structure.

According to another aspect of the invention there is provided a set of phase change material (PCM) elements for use in a thermally insulated transportation container that
10 transports temperature sensitive goods. The set of PCM elements can be arranged to fit together to form a hollow cuboid structure. The hollow cuboid structure can have first, second, third, fourth, fifth and sixth sides defining an enclosed payload volume that is arranged to receive the temperature sensitive goods.

At least one, and preferably each, of the PCM elements in the set of PCM elements
15 comprises a sealed or sealable receptacle. The receptacle can have at least a first side. The receptacle can have a second side. The receptacle can have a third side. The receptacle can have an internal cavity. The internal cavity can extend into the first side. The internal cavity can extend into the second side. The internal cavity can extend into the third side. PCM can be stored within the cavity in the first side. PCM can be stored
20 within the cavity in the second side. PCM can be stored within the cavity in the third side. For embodiments wherein the cavity extends into the first side, second side and third side, and PCM is stored in each of the first side, second side and third side, better thermal outcomes can be achieved for the PCM element. For example, fluid PCM is able to move between the first side, second side and third sides since the cavity is continuous
25 through the first side, second side and third sides.

For at least one, and preferably each of the PCM elements, the first side, second side, third side can define a structure having an open side and a recess. In the condition wherein the set of PCM elements are fitted together to form the hollow cuboid structure, the recesses and open sides are arranged to face inwards and define the payload volume.

For at least one, and preferably each of the PCM elements, one of the first side, second side and third side of can have a different thickness from the other two of the first side, second side and third side. The thickness of the side of the PCM element is the perpendicular distance measured from the outer surface of the outer wall to the inner surface of the inner wall. This enables more PCM material to be stored in a thicker side of the PCM element. For example, the side of the PCM element that is used for the top side of the hollow cuboid structure can be thicker than the sides of the PCM element that are used for the vertical side walls of the hollow cuboid structure. This can be desirable because the lid of the thermally insulated transportation can allow more heat to enter the container than other, better insulated, parts of the container, and also heat rises once in the container thereby creating greater heat stress at the upper part of the hollow cuboid structure. Accordingly, having more PCM material at the top of the hollow cuboid structure can help to increase the time to failure. Thus the thickness of each side of the PCM element can be tuned to its position within the hollow cuboid structure to position more PCM where most needed, and less PCM where thermal insulation is better, to maximise the time to failure without increasing the weight of the thermally insulated transportation container, i.e. without simply increasing the total amount of PCM used. In some embodiments, the PCM element can be arranged to have the side of the PCM element that is used for the base side of the hollow cuboid structure to be thicker than the sides of the PCM element that are used for the vertical side walls of the hollow cuboid structure. This can further improve the homogeneity of temperature with the hollow cuboid structure.

Each PCM element in the set of PCM elements can be identical. This only requires one tooling setup to provide all of the PCM elements in the set, which can save on cost and time.

In some embodiments the PCM elements can be stackable. For example, one of the first PCM element and the second PCM element can nest within the recess of the other one of the first PCM element and the second PCM element. Each PCM element in the set of

PCM elements can nest within the recess of an adjacent PCM element when being stacked for example for storage or thermal conditioning in a freezer.

For at least one, and preferably each, of the PCM elements, the first side can be orthogonal to the second side. The first side can be orthogonal to the third side. The
5 second side can be orthogonal to the third side.

For at least one, and preferably each, of the PCM elements the first side, second side and third side can meet at a common corner.

For at least one, and preferably each, of the PCM elements the receptacle can include a plastics material, such as polyethylene. Typically, a main body of the receptacle
10 comprises the plastics material.

The receptacle for at least one, and preferably each, of the PCM elements can be moulded, and is preferably blow moulded.

For at least one, and preferably each, of the PCM elements, the receptacle can comprise a thin walled structure. The first side can have an inner wall and an outer wall. The second
15 side can have an inner wall and an outer wall. The third side can comprise an inner wall and an outer wall. The cavity can be located between the inner and outer walls for the first side. The cavity can be located between the inner and outer walls for the second side. The cavity can be located between the inner and outer walls for the third side. PCM material can be stored in the cavity between the inner and outer walls for the first
20 side. PCM material can be stored in the cavity between the inner and outer walls for the second side. PCM material can be stored in the cavity between the inner and outer walls for the third side. By “thin walled”, it is meant inner and outer walls of the receptacle have a thickness typically in the range 0.5mm to 3mm. The thin walls are typically formed by the moulding process. The inner walls of the receptacle define the PCM
25 element recess.

The outer wall of each side of the PCM element can be planar. The inner wall of each side of the PCM element can be planar.

The receptacle can be rigid. That can be, the receptacle can be arranged to substantially maintain its shape when the PCM is in a non-frozen condition.

For at least one, and preferably each, of the PCM elements at least one the first side, second side, and third side can be triangular in plan. In some embodiments, the first,
5 second and third sides can be triangular in plan.

The set of PCM elements can comprise, or consist of, a first PCM element, a second PCM element, a third PCM element and a fourth PCM element. In some embodiments, each of the first, second, third and fourth PCM elements can comprise one quarter of the hollow cuboid structure. Thus the set of PCM elements can consist of four PCM
10 elements, and the hollow cuboid structure can be made up of the four PCM elements. This is a fewer number of PCM elements than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element
15 receptacles.

For at least one, and preferably each, of the PCM elements, a first edge of the first side can be contiguous with a first edge of the second side. A second edge of the second side can be contiguous with a first edge of the third side. A second edge of the first side can be contiguous with a second edge of the third side. The first, second and third sides can
20 define the recess. Each PCM element can have an open side. The open side can have a triangular shape.

At least one, and preferably each, of the PCM elements can comprise a recessed pyramidal shape. The recessed pyramidal shape can be open at one side. The advantage of using recessed pyramidal PCM elements helps to ensure that the joints between PCM
25 elements overlie parts of the walls of the thermally insulated transportation container that are heavily insulated and are kept away from parts that are not as well insulated, such as vertical edges of the transportation container and where a lid/door abuts a main body of the thermally insulated container. That is, the joints are not aligned with the parts that are

less insulated. In the condition wherein the PCM elements are fitted together to form the hollow cuboid structure the recesses and open sides face inwards and define the payload volume.

- The PCM elements can be fitted together to form the hollow cuboid structure. In some
- 5 embodiments the first side of the first PCM element forms part of a first side, such as a top side, of the hollow cuboid structure, the second side of the first PCM element forms part of a second side, such as a left side, of the hollow cuboid structure, and the third side of the first PCM element forms part of a third side, such as a rear side, of the hollow cuboid structure.
- 10 In some embodiments the first side of the second PCM element forms part of the fourth side, such as a base side, of the hollow cuboid structure, the second side of the second PCM element forms part of a third side, such as a rear side, of the hollow cuboid structure, and the third side of the second PCM element forms part of a fifth side, such as a right side, of the hollow cuboid structure.
- 15 In some embodiments the first side of the third PCM element forms part of the fourth side, such as a base side, of the hollow cuboid structure, the second side of the third PCM element forms at of the second side, such as a left side, of the hollow cuboid structure, and the third side of the third PCM element forms part of a sixth side, such as a front side, of the hollow cuboid structure.
- 20 In some embodiments the first side of the fourth PCM element forms part of the first side, such as the top side, of the hollow cuboid structure, the second side of the fourth PCM element forms part of the sixth side, such as the front side, of the hollow cuboid structure, and the third side of the fourth PCM element forms part of a fifth side, such as the right side, of the hollow cuboid structure.
- 25 Thus the first side of the hollow cuboid structure can be split diagonally into first and second parts, that can be a tapering edge of the first PCM element abuts a tapering edge of the fourth PCM element along a diagonal line. The second side of the hollow cuboid

structure can be split diagonally into first and second parts, that is a tapering edge of the first PCM element abuts a tapering edge of the third PCM element along a diagonal line. The third side of the hollow cuboid structure can be split diagonally into first and second parts, that is a tapering edge of the first PCM element abuts a tapering edge of the second PCM element along a diagonal line. The fourth side of the hollow cuboid structure can be split diagonally into first and second parts, that is a tapering edge of the second PCM element abuts a tapering edge of the third PCM element along a diagonal line. The fifth side of the hollow cuboid structure can be split diagonally into first and second parts, that is a tapering edge of the second PCM element abuts a tapering edge of the fourth PCM element along a diagonal line. The sixth side of the hollow cuboid structure can be split diagonally into first and second parts, that is a tapering edge of the third PCM element abuts a tapering edge of the fourth PCM element along a diagonal line. An advantage of each of these options is that the joints between PCM elements overlie parts of the walls of the thermally insulated transportation container that are heavily insulated and are kept away from parts that are not as well insulated, such as vertical edges of the transportation container and where a lid/door abuts a main body of the thermally insulated container. That is, the joints are not aligned with the parts that are less insulated.

The set of PCM elements can comprise, or consist of, a first PCM element and a second PCM element. Each of the first and second PCM elements can comprise one half of the hollow cuboid structure. Thus the set of PCM elements can consist of two PCM elements, and the cuboid structure can be made up of the two PCM elements. This is a fewer number of PCM elements than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element receptacles.

For at least one, and preferably each, of the PCM elements, each of the first, second and third sides can be rectangular in plan. A first edge of the first side can be contiguous with a first edge of the second side. A second edge of the first side can be contiguous with a first edge of the third side. A second edge of the second side can be contiguous

with a second edge of the third side. The first side can be perpendicular to each of the second and third sides. The second side can be perpendicular to the third side. The recess defined by the first, second and third sides.

5 In some embodiments, in a condition wherein the PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms the first side, such as a top side, of the hollow cuboid structure, the second side of the first PCM element forms the second side, such as a left side, of the hollow cuboid structure, and the third side of the first PCM element forms the third side, such as a rear side, of the hollow cuboid structure.

10 In some embodiments the first side of the second PCM element forms the fourth side, such as a base side, of the hollow cuboid structure, the second side of the second PCM element forms the fifth side, such as a right side, of the hollow cuboid structure, and the third side of the second PCM element forms the sixth side, such as a front side, of the hollow cuboid structure. The first and second PCM elements can be mounted together in
15 a manner such that the top side of the first PCM element rests on upper edges of the front and right sides of the second PCM element, and lower edges of the left side and the rear side of the first PCM element rests on the base side of the second PCM element.

In some embodiments, for at least one, and preferably each, of the PCM elements, the second and third sides can be parallel with one another and the first side can be
20 perpendicular to each of the second and third sides.

In some embodiments at least one, and preferably each, of the PCM elements has a substantially U-shaped structure.

In some embodiments, in a condition wherein the PCM elements can be fitted together to form the hollow cuboid structure, the first side of the first PCM element forms the first
25 side, such as a top side, of the hollow cuboid structure, the second side of the first PCM element forms the second side, such as a rear side, of the hollow cuboid structure, and the

third side of the first PCM element forms the third side, such as a front side, of the hollow cuboid structure.

In some embodiments the first side of the second PCM element forms the fourth side, such as a base side, of the hollow cuboid structure, the second side of the second PCM
5 element forms the fifth side, such as a right side, of the hollow cuboid structure, and the third side of the second PCM element forms the sixth side, such as a left side, of the hollow cuboid structure.

In some embodiments, for at least one, and preferably each, of the PCM elements the receptacle can include a fourth side. The internal cavity can extend into the fourth side.
10 PCM can be stored within the cavity in the fourth side.

In some embodiments, at least one, and preferably each, of the PCM elements can comprise a recessed wedge shape. The shape can be recessed on its tapered side, such that the tapered side is open. In a condition, wherein the first and second PCM elements are fitted together to form the hollow cuboid structure, the recesses and open sides face
15 inwards.

In some embodiments, for at least one, and preferably each PCM, the first and second sides can be rectangular in plan and the third and fourth sides can be triangular in plan. The recess can be defined by the first, second, third and fourth sides of the PCM element.

In some embodiments, for at least one, and preferably each, of the first and second PCM
20 elements, the first side can be perpendicular to the second side, the third side can be perpendicular to the first and second sides, the fourth side can be perpendicular to the first and second sides, and the third and fourth sides can be parallel to one another.

In some embodiments, for at least one, and preferably each, of the PCM elements, a first edge of the first side can be contiguous with a first edge of the second side, a first edge of
25 the third side can be contiguous with a second edge of the first side, a second edge of the third side can be contiguous with a second edge of the second side, a third edge of the third side can be located at an open side of the PCM element, a first edge of the fourth

side can be contiguous with a third edge of the first side, a second edge of the fourth side can be contiguous with a third edge of the second side, a third edge of the fourth side can be located at the open side of the PCM element, a recess can be defined by the first, second, third and fourth sides of the PCM element. The openside can be rectangular in
5 plan.

In some embodiments, in a condition wherein the PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms the first side, such as a top side, of the hollow cuboid structure, the second side of the first PCM element forms the second side, such as a right side, of the hollow cuboid structure, the
10 third side of the first PCM element forms part of the third side, such as a front side, of the hollow cuboid structure, and the fourth side of the first PCM element forms part of the fourth side, such as a rear side, of the hollow cuboid structure.

In some embodiments, the first side of the second PCM element forms the fifth side, such as a base side, of the hollow cuboid structure, the second side of the second PCM element forms the sixth side, such as a left side, of the hollow cuboid structure, the third
15 side of the second PCM element forms part of the third side, such as a front side, of the hollow cuboid structure, and the fourth side of the second PCM element forms part of the fourth side, such as a rear side, of the hollow cuboid structure.

Thus the third side of the hollow cuboid structure can be split diagonally into first and second parts, that can be a tapering edge of the first PCM element abuts a tapering edge
20 of the second PCM element along a diagonal line; and/or the fourth side of the hollow cuboid structure can be split diagonally into first and second parts, that is a tapering edge of the second PCM element abuts a tapering edge of the third PCM element along a diagonal line. The advantage of each of these options is that the joints between PCM
25 elements overlie parts of the walls of the thermally insulated transportation container that are heavily insulated and are kept away from parts that are not as well insulated, such as vertical edges of the transportation container and where a lid/door abuts a main body of the thermally insulated container. That is, the joints are not aligned with the parts that are less insulated.

The receptacle for at least one, and preferably each, of the PCM elements can include a fifth side. The internal cavity can extend into the fifth side. PCM can be stored within the cavity in the fifth side.

5 In some embodiments, at least one, and preferably each, of the PCM elements can comprise a recessed cuboid structure, which is open at one side. Thus the first PCM element and/or the second PCM element can comprise an open sided box. The two open sided boxes can be fitted together to form the hollow cuboid structure.

10 In some embodiments, for at least one, and preferably each, of the PCM elements the first, second, third, fourth and fifth sides can be rectangular in plan, the first side can be arranged perpendicularly to the second, third, fourth and fifth sides, the second side can be parallel to the fourth side, the third side can be parallel to the fifth side, the second side can be perpendicular to the third side and the fifth side, and the fourth side can be perpendicular to the third side and the fifth side.

15 In some embodiments, in a condition wherein the first and second PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms a first (Top) side of the hollow cuboid structure, the second side of the first PCM element forms part of a second (Right) side of the hollow cuboid structure, the third side of the first PCM element forms part of a third (Rear) side of the hollow cuboid structure, the fourth side of the first PCM element forms part of a fourth (Left) side of the hollow cuboid structure, and the fifth side of the first PCM element forms part of a fifth (Front) side of the hollow cuboid structure; the first side of the second PCM element forms a sixth (Base) side of the hollow cuboid structure, the second side of the second PCM element forms part of the second (Right) side of the hollow cuboid structure, the third side of the second PCM element forms part of the third (Rear) side of the hollow cuboid structure, the fourth side of the second PCM element forms part of the fourth (Left) side of the hollow cuboid structure, and the fifth side of the second PCM element forms part of the fifth (Front) side of the hollow cuboid structure. The join line between the first and second PCM elements is preferably horizontal when the first and second PCM elements

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and are located in the storage volume, and typically is located around halfway up the vertical sides of the container.

The set of PCM elements of any one of the preceding claims, wherein the PCM can be arranged to maintain the temperature sensitive goods at a temperature in a predetermined temperature range. For example, the PCM units can be arranged to maintain the temperature of the goods in one of the following ranges: +2°C to +8°C; -25°C to -15°C; +15°C to +25°C. Any suitable temperature range can be used. In some embodiments, the PCM can be selected to change phase at a temperature in the range -30°C to +30°C. Preferably the PCM is selected to have a melting point at a temperature in the range -20°C to +5°C. Preferably the PCM is water-based with a melting point around 0°C, and may include additives such as acticides and nucleating agents.

According to another aspect there is provided a thermally insulated transportation container arranged to transport temperature sensitive goods, said container can include: a rigid body having thermally insulated walls that define a storage volume; means for accessing the storage volume; and a set of PCM elements according to any configuration described herein. The PCM elements are arranged to fit within the storage volume in a condition wherein the PCM elements are fitted together to form of the hollow cuboid structure.

At least one thermally insulated container wall can comprise at least one part having a higher thermal insulation zone and at least one part having a lower thermal insulation zone. The higher thermal insulation parts can be for example adjacent central parts of the vertical walls of the container and/or central parts of the vacuum insulation panels. The lower thermal insulation zones can be located adjacent edges of the vacuum insulation panels. It has been found that the polymer located at the edges of some vacuum insulation panels can provide a thermally conductive pathway for heat to travel into / out of the container storage volume. For a hollow cuboid structure formed from 6 prior art rectangular plate PCM elements, the hollow cuboid structure has 12 joints/gaps/lines where the plates abut one another. Each of the joints/gaps/lines is generally aligned with an edge of vacuum insulation panel and therefore presents the worst case scenario.

The invention provides PCM elements that are arranged to reduce, or eliminate entirely, the number of joints/gaps/lines between adjacent PCMs that are aligned with low insulation zones. This helps to ensure that the heat is conducted in the PCM material rather than around the PCM material. The lower thermal insulation zones can be located adjacent vertical edges of the vertical walls of the container and/or vertical edges of the vacuum insulation panels. The lower thermal insulation zones can be located adjacent horizontal edges of the vertical walls of the container and/or horizontal edges of the vacuum insulation panels. The lower thermal insulation zones can be located adjacent the opening member. The lower thermal insulation zones can be arranged in an elongate rectilinear manner. The PCM elements can be located within the storage volume such that rectilinear joints between the PCM elements each have a different orientation from the elongate rectilinear lower thermal insulation zone. This ensures that heat entering the container via the zones of low insulation does not immediately encounter joints / gaps between PCM elements that are aligned/parallel with the low insulation zone. This helps to lengthen the time to failure. The time to failure is the length of time it takes for the temperature within the container to reach a limit of the desired temperature range. For example, for a container seeking to maintain the temperature with the payload volume at between +2°C and +8°C, the time to failure can be the time it takes for the temperature to rise to 8°C in a condition where external ambient is greater than or equal to 8°C, or the time it takes for the temperature to drop to 2°C in a condition where the external ambient is greater than or equal to 2°C.

The container can include a plurality of rectilinear lower thermal insulation zones, and the PCM elements can be located within the storage volume such that rectilinear joints between the PCM elements each have a different orientation from the elongate rectilinear lower thermal insulation zones. The rectilinear lower thermal insulation zones can include top edges of thermally insulated vertical walls of the container, for example adjacent a lid of the container.

The insulation for the walls of the container can comprise vacuum insulation panels.

The container can comprise an outer shell. The outer shell can be roto-moulded.

The container comprise an inner liner.

Each container wall can include a vacuum insulation panel. is the vacuum insulation panel can be located between the inner liner and the outer shell. In some embodiments, there can be at least one vacuum insulation panel for the base and at least one vacuum
5 insulation panel for each vertical wall. In some embodiments, the lid can include at least one vacuum insulation panel.

According to another aspect there is provided a method for loading a set of PCM elements into a thermally insulated transportation container. The method can include: providing a thermally insulated transportation container having a rigid body having
10 thermally insulated walls that define a storage volume; means for accessing the storage volume; and a set of PCM elements according to any configuration described herein.

The method can include mounting the set of PCM elements within the storage volume to form a hollow cuboid structure.

At least one thermally insulated container wall can comprise at least one part having a
15 higher thermal insulation zone, such as a central part of container side walls, and at least one part having a lower thermal insulation zone, which can be arranged in an elongate rectilinear manner, and locating the set of PCM elements within the storage volume such that rectilinear joints between the PCM elements each have a different orientation from the elongate rectilinear lower thermal insulation zones. According to another aspect there
20 is provided a PCM element for use in a thermally insulated transportation container to help maintain temperature sensitive goods within a selected temperature range, the PCM element can comprise: a sealed or sealable moulded plastics receptacle. The receptacle can have at least a first triangular side, a second triangular side and a third triangular side. The first, second and third triangular sides can form a recessed pyramid shape having an
25 open side. The receptacle can have an internal cavity that extends into each of the first side, second side and third triangular sides. PCM can be stored within the cavity in each of the first, second and third triangular sides.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container to help maintain temperature sensitive goods within a selected temperature range, wherein the PCM element comprises a recessed pyramid shape having an open side. First, second, third and fourth PCM elements can be fitted
5 together to form a hollow cuboid shape.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container to help maintain temperature sensitive goods within a selected temperature range, wherein the PCM element comprises one half of a hollow cuboid shape. For clarity, the PCM element itself does not have to be cuboid shaped,
10 however when first and second PCM elements are fitted together they form a hollow cuboid shape.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container to maintain temperature sensitive goods within a selected temperature range. The PCM element can comprise a sealed or sealable moulded
15 plastics receptacle. The PCM element can have at least a first rectangular side, a second rectangular side and a third rectangular side. The first, second and third rectangular sides can form one half of a hollow cuboid shape. The first rectangular side can be arranged perpendicularly to the second and third rectangular sides. The second rectangular side can be arranged perpendicularly to the third rectangular side. A first edge of the first
20 rectangular side can be contiguous with a first edge of the second rectangular side. A second edge of the first rectangular side can be contiguous with a first edge of the third rectangular side. A second edge of the second rectangular side can be contiguous with a second edge of the third rectangular side. The receptacle can an internal cavity that extends into each of the first, second and third rectangular sides. PCM can be stored
25 within the cavity in each of the first, second and third rectangular sides. The first edge of the first side can be perpendicular to the second edge of the second side and the first edge of the third side. The second edge of the first side can be perpendicular to the first edge of the first side. In some embodiments, the PCM element has no further sides other than the first, second and third rectangular sides.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container to maintain temperature sensitive goods within a selected temperature range. The PCM element can comprise a sealed or sealable moulded plastics receptacle. The PCM element can have at least a first rectangular side, a second rectangular side and a third rectangular side. The first, second and third rectangular sides can form one half of a hollow cuboid shape. The first rectangular side can be arranged perpendicularly to the second and third rectangular sides. The second rectangular side can be arranged parallel to the third rectangular side. A first edge of the first rectangular side can be contiguous with a first edge of the second rectangular side. A second edge of the first rectangular side can be contiguous with a first edge of the third rectangular side to provide a substantially U-shaped structure. The receptacle can have an internal cavity that extends into each of the first, second and third rectangular sides. PCM can be stored within the cavity in each of the first, second and third rectangular sides. The first edge of the first side can be parallel to the second edge of the first side. The first side spaces apart the second and third sides. In some embodiments, the PCM element has no further sides other than the first, second and third rectangular sides.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container to maintain temperature sensitive goods within a selected temperature range. The PCM element can comprise a sealed or sealable moulded plastics receptacle. The PCM element can have at least a first rectangular side, a second rectangular side, a first triangular side and a second triangular side. The first rectangular side, second rectangular side, first triangular side and second triangular side can form one half of a hollow cuboid shape. The first rectangular side can be arranged perpendicularly to the second rectangular side. The first triangular side can be arranged perpendicular to the first and second rectangular sides. The second triangular side can be arranged perpendicular to the first and second rectangular sides. The first triangular side can be arranged parallel to the second triangular side. A first edge of the first rectangular side can be contiguous with a first edge of the second rectangular side. A first edge of the first triangular side can be contiguous with a second edge of the first rectangular side. A second edge of the first triangular side can be contiguous with a second edge of the

second rectangular side. A first edge of the second triangular side can be contiguous with a third edge of the first rectangular side. A second edge of the second triangular side can be contiguous with a third edge of the second rectangular side. The receptacle can have an open side. The receptacle can be the form of a wedge-shaped structure having a recess. The receptacle can have an internal cavity that extends into each of the first rectangular side, second rectangular side, first triangular side and second triangular side. PCM can be stored within the cavity in each of the first rectangular side, second rectangular side, first triangular side and second triangular side.

In some embodiments, the PCM element has no further sides other than the first, second, third and fourth sides.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container to maintain temperature sensitive goods within a selected temperature range. The PCM element can comprise a sealed or sealable moulded plastics receptacle. The PCM element can have least a first rectangular side, a second rectangular side, a third rectangular side, a fourth rectangular side and fifth rectangular side. The first rectangular side can be arranged perpendicularly to the second, third, fourth and fifth rectangular sides. The second rectangular side can be arranged parallel to the fourth rectangular side. The third rectangular side can be arranged parallel to the fifth rectangular side. The second rectangular side can be arranged perpendicular to the third rectangular side and the fifth rectangular side. The fourth rectangular side can be arranged perpendicular to the third rectangular side and the fifth rectangular side. The arrangement can be such that the first, second, third, fourth and fifth rectangular sides form an open sided box having a recess. The first, second, third, fourth and fifth sides can form one half of a hollow cuboid shape. The receptacle can have an internal cavity that extends into each of the first, second, third, fourth and fifth rectangular sides. PCM can be stored within the cavity in each of the first, second, third, fourth and fifth rectangular sides. In some embodiments, the PCM element has no further sides other than the first, second, third, fourth and fifth sides.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first side, a second side and a third side, wherein the receptacle has an internal cavity that extends into each of the first side,
5 second side and third side, and PCM is stored within the cavity in each of the first side, second side and third side. PCM is stored in each of the first side, second side and third side, which provides better thermal outcomes for the PCM element. The PCM element according to this aspect of the invention can be arranged according to any configuration of the PCM elements described herein.

10 In some embodiments the first side is triangular in plan, the second side is triangular in plan and the third triangular side is triangular in plan, wherein the first side, second side and third side form a recessed pyramid shape having an open side.

In some embodiments the first side is rectangular in plan, the second side is rectangular in plan and the third side is rectangular in plan, wherein the first rectangular side, second
15 rectangular side and third rectangular side form one half a hollow cuboid shape, wherein the first rectangular side is arranged perpendicularly to the second rectangular side and third rectangular side, and the second rectangular side is arranged perpendicularly to the third rectangular side, a first edge of the first rectangular side is contiguous with a first edge of the second rectangular side, a second edge of the first rectangular side is
20 contiguous with a first edge of the third rectangular side, a second edge of the second rectangular side is contiguous with a second edge of the third rectangular side.

In some embodiments the first side is rectangular in plan, the second side is rectangular in plan and the third side is rectangular in plan, the first rectangular side, second rectangular side and third rectangular side form one half of a hollow cuboid shape,
25 wherein the first rectangular side is arranged perpendicularly to the second rectangular side and third rectangular side, and the second rectangular side is arranged parallel to the third rectangular side, a first edge of the first rectangular side is contiguous with a first edge of the second rectangular side and a second edge of the first rectangular side is

contiguous with a first edge of the third rectangular side to provide a substantially U-shaped structure.

In some embodiments the first side is rectangular in plan, the second side is rectangular in plan, the third side is triangular in plan, and including at least a fourth side, which is triangular in plan, wherein the first side, second side, third side and fourth side form one half of a hollow cuboid shape, the first side is arranged perpendicularly to the second side, the third side is arranged perpendicular to the first and second sides, the fourth side is arranged perpendicular to the first and second sides, the third side is arranged parallel to the fourth side, a first edge of the first side is contiguous with a first edge of the second side, a first edge of the third side is contiguous with a second edge of the first side, a second edge of the third side is contiguous with a second edge of the second side, a first edge of the fourth side is contiguous with a third edge of the first side, a second edge of the fourth side is contiguous with a third edge of the second side, thereby providing an open sided wedge-shaped structure having a recess, and the receptacle has an internal cavity that extends into each of the first side, second side, third side and fourth side, and PCM is stored within the cavity in each of the first side, second side, third side and fourth side.

In some embodiments the first side is rectangular in plan, the second is rectangular in plan, the third side is rectangular in plan, and including at least a fourth side, which is rectangular in plan and fifth side, which is rectangular in plan, wherein the first rectangular side is arranged perpendicularly to the second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side, the second rectangular side is arranged parallel to the fourth rectangular side, the third rectangular side is arranged parallel to the fifth rectangular side, the second rectangular side is arranged perpendicular to the third rectangular side and the fifth rectangular side, the fourth rectangular side is arranged perpendicular to the third rectangular side and the fifth rectangular side, the arrangement being such that the first rectangular side, second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side form one half of a hollow cuboid shape in the form of an open sided box having a recess,

and the receptacle has an internal cavity that extends into each of the first rectangular side, second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side, and PCM is stored within the cavity in each of the first rectangular side, second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side.

A PCM element for use in a thermally insulated transportation container, the PCM element comprising a recessed pyramid shape having an open side.

A PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first side, a second side and a third side, wherein the first side is triangular in plan, the second side is triangular in plan and the third triangular side is triangular in plan, wherein the first side, second side and third side form a recessed pyramid shape having an open side, and PCM is stored within the in each of the first side, second side and third side.

According to another aspect there is provided a PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first side, a second side and a third side, wherein the first side is triangular in plan, the second side is triangular in plan and the third triangular side is triangular in plan, wherein the first side, second side and third side form a recessed pyramid shape having an open side, and PCM is stored within the in each of the first side, second side and third side.

According to another aspect there is provided a thermally insulated container including at least one PCM element according to any configuration described herein. The container can include a main body. The container can include an opening member, for example in the form of a lid. The lid can be arranged to pivot with respect to the main body.

The main body can include an outer shell. The main body can include an inner liner. The main body can include thermal insulation panels, for example located between the inner liner and the outer shell. The main body can include a storage volume, which is arranged

to receive at least one PCM element, and preferably a set of PCM elements. The storage volume can be located within the inner liner.

Embodiments of the invention will now be described by way of example only with reference to the drawings, wherein:

5 Figure 1 is an isometric view of a set of PCM elements and a thermally insulated container according to a first embodiment of the invention;

Figure 2a is an isometric view of the set of PCM elements from the embodiment of Figure 1 fitted together to form a hollow cuboid structure that can fit into a thermally insulated transportation container;

10 Figure 2b is a longitudinal cross-section of the arrangement shown in Figure 2a;

Figure 2b is a transverse cross-section of the arrangement shown in Figure 2a;

15 Figures 3a and 3b are longitudinal cross-sections of the embodiment of Figure 1, when the set of PCM elements is located in a storage volume of the thermally insulated transportation container, said set of PCM elements being fitted together to form a hollow cuboid structure;

Figures 4a and 4b are transverse cross-sections of the embodiment of Figure 1, when the set of PCM elements is located in a storage volume of the thermally insulated transportation container, said set of PCM elements being fitted together to form a hollow cuboid structure;

20 Figure 5 is an isometric view of a set of PCM elements and a thermally insulated container according to a second embodiment of the invention;

Figure 6 is an isometric view of a set of PCM elements and a thermally insulated container according to a third embodiment of the invention;

Figure 7 is an isometric view of a set of PCM elements and a thermally insulated container according to a fourth embodiment of the invention; and

Figure 8 is an isometric view of a set of PCM elements and a thermally insulated container according to a fifth embodiment of the invention.

- 5 A thermally insulated container 1 (hereinafter referred to as the container 1) according to a first embodiment of the invention is shown in Figs. 1 to 4b.

The container 1 is a thermally insulated transportation container that can be used to transport temperature sensitive goods, such as vaccines and transplant organs, for which it is required or desirable that they are maintained within a certain temperate range, for
10 example at a temperature of between +2°C and +8°C. Insulated containers for different temperatures will be generally similar in construction, but may be modified as described in more detail below to maintain the required temperatures. For example, for some applications the internal temperature may be maintained in the range +15°C to + 25°C whereas for other applications, the internal temperature may be maintained in the range -
15 25°C to -15°C.

The container 1 consists of a main body 3 and an opening member in the form of a lid 5, which is arranged to pivot with respect to the main body 3.

The main body 3 includes an outer shell 7, an inner liner 9 and thermal insulation panels 11 located between the inner liner 9 and the outer shell 7. A storage volume 13, which is
20 arranged to receive a set of phase change material (PCM) elements 10, is located within the inner liner 9.

The outer shell 7 provides structural rigidity and mechanical protection to the container. The outer shell 7 comprises a generally hollow cuboid shape, which is typically roto-moulded. The outer shell 7 includes a base, and side walls (a front side wall, a rear side wall, a right lateral side wall, and a left lateral side wall). An upper part of the main body
25 3 is open. The lid 5 is located adjacent an upper part of the main body 3 and is arranged

to pivot between open and closed positions, to selectively provide access to temperature sensitive goods stored within the container 1.

The outer shell 7 is made from a plastics material, such as polyethylene foam. Typically, the wall thickness of the outer shell 7 is in the range 3mm - 5mm.

- 5 The outer shell 7 includes channels 15 formed in its outer surface, which are each arranged to receive a respective strap 17 of a harness 19, that can be used to carry the container 1 and maintain the lid 5 in a closed condition. Each channel 15 comprises a relatively shallow depression formed in the outer surface of the outer shell 7, for example each channel may have a depth in the range 2mm – 10mm. The channels are formed
10 during the moulding process, and the thickness of the outer shell 7 at the channels are typically in the range 3mm – 5mm.

- The outer shell 7 can include an arrangement of ribs 18, wherein the thickness of the outer shell at the ribs is locally increased. The purpose of the ribs 18 is to better control part shrinkage following the roto-moulding manufacturing process. At least some, and
15 preferably each of the outer shell 7 walls include an arrangement of ribs 18. The ribs 18 also improve the rigidity of the container body 3 and can help to protect the container from damage. Preferably each outer shell 7 wall includes at least one rib 18. The ribs 18 can be arranged on each wall in the form of at least one rectangle, and preferably define a plurality of rectangles.

- 20 The lid 5 is pivotally attached to the main body 3, adjacent the open side of the main body 3. Typically the lid 5 is hinged to an upper part of the main body, and is preferably hinged to the rear side wall. Additionally, or alternatively, the harness 19 can pivotally attach the lid 5 to the main body 3, and therefore functions as hinge.

- The lid 5 includes an outer shell 27, which is typically roto-moulded. The outer shell 27
25 is made from a plastics material, such as polyethylene foam. Typically, the wall thickness of the outer shell 27 is in the range 3mm - 5mm. The lid 5 includes an inner shell 29, which is typically roto-moulded. The inner shell 29 is made from a plastics material, such

- as polyethylene foam. Typically, the wall thickness of the inner shell 29 is in the range 3mm - 5mm. The inner shell 29 is releasably attached to an inner side of the outer shell 27. The inner shell 29 and outer shell 27 define a cavity 31 that is arranged to receive a thermal insulation panel 35 and an additional thermal insulation panel 37. The thermal insulation panels 35,37 insulate the lid 5 thereby reducing the rate at which heat enters the payload volume via the lid 5. A seal 36 is provided to seal the inner shell 29 to the outer shell 27. The seal 36 is arranged to minimise / eliminate moisture ingress into the lid 5. The seal 36 can be arranged to hook over an upper part of the inner shell 27, to retain the location of the seal 36.
- 10 The thermal insulation panels 11 each have a low thermal conductivity value, and therefore thermally insulate the payload volume. Each thermal insulation panel 11 comprises a vacuum insulation panel (VIP) 11.

The thermal insulation panels 11 are located within the outer shell 7, to thermally insulate the payload volume. In the current embodiment, five thermal insulation panels 11 are inserted into the outer shell 7. One thermal insulation panel 11 is located at the base of the outer shell 7, and each other thermal insulation panel 11 is mounted against a respective one of the outer shell 7 vertical side walls (see Fig. 3b). It can be seen that the insulation panels 11 are sized to fit snugly within the outer shell 7, thereby providing high quality insulation to the payload volume 13. The inner liner 9 is then inserted into the container to help maintain the positions of the thermal insulation panels 11 with respect to the outer shell 7.

The thermal insulation panel 35 is preferably a vacuum insulation panel, and is similar in structure to the thermal insulation panels 11. The additional thermal insulation panel 37 typically comprises foam, and helps to maintain the position of the thermal insulation panel 35, by filling the gap 31 between the thermal insulation panel 35 and the outer shell 27 of the lid 5. Accordingly, the lid 5 provides excellent thermal insulation for the payload volume 13.

The inner liner 9 comprises a thin walled inner container that sits within the outer shell 7 (see Figs. 14 to 16). The inner liner 9 includes a base, a front side wall, a rear side wall, a right lateral side wall, and a left lateral side wall. The inner liner 9 is open at its upper end. The inner liner 9 is made from thermally insulating material, and typically a plastics material such as polyethylene terephthalate (PET) or polycarbonate. The inner liner 9 is arranged to contain any spillages, for example any leaks from the goods transported or from the PCM elements 10 located within the inner liner 9. Since the inner liner 9 is made from a plastics material, the inner liner 9 is easy to clean. The inner liner 9 is transparent or is at least partly transparent. Since the thermal insulation panels 11 are located between the inner liner 9 and the outer shell 7, having a transparent inner liner 9, enables visual inspection of the thermal insulation panels 11. This can provide an indication as to whether any of the thermal insulation panels have been damaged during transit and may need replacing prior to the container being reused.

A seal is provided, which seals the outer shell 7 to the inner liner 9. In particular, the seal seals the upper support to an upper part of the outer shell 7. The seal minimises / eliminates the ingress of moisture between the outer shell 7 and inner liner 9, that is, in the space housing the thermal insulation panels 11. The seal can engage at least one of the thermal insulation panels 11, and preferably engages each of the thermal insulation panels 11 mounted adjacent the vertical side walls of the outer shell 7. The seal, or a further seal, seals the inner liner 9 to the lid 5, in particular to the inner shell 29, thereby minimising /eliminating the ingress of moisture into the inner liner 9 via a gap between the lid 5 and the inner liner 9.

The container 1 includes a set of phase change material (PCM) elements 10. The set of PCM elements 10 is arranged to fit together to form an enclosed cuboid structure 12 (see Figure 2a) having a central cavity that provides an internal payload volume 14 (see Figures 3b and 4b) that is arranged to store the temperature sensitive goods during transit. The enclosed cuboid structure 12 having a central cavity 14 is hereinafter referred to as “the hollow cuboid structure 12”. The set of PCM elements includes a plurality of PCM elements 10. In this embodiment, the set of PCM elements consists of first, second, third

and fourth PCM elements 10. This is a fewer number of PCM elements than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element receptacles 10a, thus leading to a reduction in weight of the overall container 1. This is important since thermally insulated transportation containers 1 are flown by aeroplane over long distances and therefore a reduction in overall weight of the container reduces the amount of fuel required to transport the container 1 over the life of the container 1.

- 10 Each of the first, second, third and fourth PCM elements 10 has the structure described below.

Each of the first, second, third and fourth PCM elements 10 comprises one quarter of the hollow cuboid structure 12 when the PCM elements 10 are fitted together.

- 15 Each PCM element 10 comprises a hollow receptacle 10a made from a polymer such as polyethylene and is filled with a PCM. The PCM used is dependent on the temperature characteristics that the payload requires. For example, when the goods being transported need to be kept at a temperature in the range +2°C to +8°C, the following PCMs can be used: filtered water, preferably having two acticides: DB20, which is fast acting, and MBS, which is slower acting; and a paraffin wax (for example, mostly n-tetradecane).
- 20 Each PCM element 10 is filled via an opening in the container, which is then sealed. In some arrangements the opening is sealed by crimping or with a foil seal and covered with a protective polythene cap. Alternatively, the cap can be spun welded to the container body, or can comprise a screw cap or bung.

The receptacle 10a is moulded, for example can be formed by a blow moulding process.

- 25 The receptacle 10a has a first side 20, a second side 22 and a third side 24, and a cavity 40 that extends into each of the first, second and third sides.

The receptacle 10a comprises a thin walled structure. By “thin walled”, it is meant walls having a thickness typically in the range 0.5mm to 3mm. The thin walls are formed by the moulding process. The first side of the receptacle 10a comprises an inner wall 20a and an outer wall 20b, the cavity is located between the inner and outer walls 20a,20b and the PCM material is stored in the cavity between the inner and outer walls 20a,20b. The second side of the receptacle 10a comprises an inner wall 22a and an outer wall 22b, the cavity is located between the inner and outer walls 22a,22b and the PCM material is stored in the cavity between the inner and outer walls 22a,22b. The third side of the receptacle 10a comprises an inner wall 24a and an outer wall 24b, the cavity is located between the inner and outer walls 24a,24b and the PCM material is stored in the cavity between the inner and outer walls 24a,24b. Thus, in its liquid form, when filling the receptacle 10a, PCM is able to flow into each of the first, second and third sides 20,22,24 since the cavity is continuous through the first, second and third sides 20,22,24.

Each of the outer walls 20a,22a,24a can be generally planar. Each of the inner walls 20b,22b,24b can be generally planar.

The receptacle 10a for each PCM element 10 has a recessed pyramidal shape (see Figure 1). Each of the first, second and third sides 20,22,24 is triangular in plan. The first side 20 is contiguous with the second side 22. The second side 22 is contiguous with the third side 24. The first side 20 is contiguous with the third side 24. The first, second and third sides have a common corner 28. The receptacle 10a is open at one side 30, and has a recess 32. The inner walls 22a,22a,24a of the first, second and third sides 20,22,24 of the receptacle define recess 32. The open side 30 is triangular shaped in plan, and is defined by edges of the first, second and third sides 20,22,24 of the receptacle 10a.

Another advantage of using recessed pyramidal PCM elements 10 is that PCM elements 10 are stackable. This can be useful for when storing the PCM elements 10, or when conditioning them in a freezer, since less space is required than if the PCM elements 10 were not stackable. For example, one of the first PCM element and the second PCM element can nest within the recess of the other one of the first PCM element and the second PCM element. Each PCM element in the set of PCM elements can nest within the

recess of an adjacent PCM element when being stacked for example for storage or thermal conditioning in a freezer.

The receptacle 10a is preferably substantially rigid. That is, the receptacle 10a substantially maintains its shape in a non-frozen condition.

- 5 The receptacle 10a can include a lifting notch 16, to assist a user to lift the PCM element 10 from the container 1. For example, the user can insert at least one finger, or a lifting tool, into the notch 16 to remove the PCM element 10 from the container.

In some embodiments, one of the first side 20, second side 22 and third side 24 of the PCM element can have a different thickness T from the other two of the first side 20, second side 22 and third side 24 of the PCM element. The thickness T of a given side of the PCM element 10 is the perpendicular distance measured from the outer surface of the outer wall to the inner surface of the inner wall (i.e. the surface that defines the recess). This enables more PCM material to be stored in a thicker side of the PCM element. For example, the side 20,22,24 of the PCM element that is used for the top side of the hollow cuboid structure 12 can be thicker than the sides 20,22,24 of the PCM element 10 that are used for the vertical side walls of the hollow cuboid structure 12. This is desirable because the lid 5 of the thermally insulated transportation container 1 can allow more heat to enter the container 1 than other better insulated parts of the container 1, and also heat rises once in the container 1 thereby creating greater heat stress at the upper part of the hollow cuboid structure 12. Accordingly, having more PCM material at the top of the hollow cuboid structure 12 can help to increase the time to failure, i.e. the time it takes for the temperature within the hollow cuboid structure 12 to exceed the upper threshold of the safe temperature range for the goods being transported. Thus the thickness T of each side 20,22,24 of the PCM element can be tuned to its position within the hollow cuboid structure 12 to position more PCM where most needed, and less PCM where thermal insulation is better. This helps to maximise the time to failure without increasing the weight of the thermally insulated transportation container, i.e. without simply increasing the total amount of PCM used. It also helps to improve the temperature homogeneity within the payload volume 14.

In some embodiments, the PCM elements 10 can be arranged to have the side 20,22,24 of the PCM element that is used for the base of the hollow cuboid structure 12 to have a greater thickness T than the sides of the PCM element that are used for the vertical side walls of the hollow cuboid structure. This can help to improve the homogeneity of temperature with the hollow cuboid structure over a longer period of time.

An advantage of the invention is that for each of the temperature ranges +2°C to +8°C; -25°C to -15°C; +15°C to +25°C it is only necessary to have one set of PCM panels (one different set for each temperature range) for any destination, that is regardless as to whether the container is being sent to a relatively hot country or a relatively cold country. This is because of the thermal stability achieved by the invention.

In use, prior to loading the container 1, each of the PCM elements 10 is conditioned by cooling (or heating) to predetermined temperatures. For example, PCM elements 10 containing a PCM that changes phase at 0°C, are cooled to a temperature of around -20°C.

The hollow cuboid structure 12 is arranged to fit into the storage volume 13, which is defined by the inner liner 9. Typically, the hollow cuboid structure 12 is constructed by mounting two of the four PCM elements 10 towards the base of the inner liner 9 to create a partial cuboid structure that is open. The goods to be transported are loaded into the payload volume 14, and the remaining two PCM elements are mounted on top of the two PCM elements 10 already located in the container 1, to enclose the payload volume 14, and to complete the hollow cuboid structure 12. In the condition wherein the PCM elements 10 are fitted together to form the hollow cuboid structure 12 the recesses 32 and open sides 30 face inwards and define the payload volume 14.

The set of PCM element 10 to fit together in a releasable manner, thereby enabling the hollow cuboid structure to be disassembled for reuse. This can be achieved, for example by simply mounting the PCM elements 10 together so that upper PCM elements 10 rest on lower PCM elements 10, with out and additional fixing means.

An advantage of using recessed pyramidal PCM elements helps to ensure that, in a condition wherein the PCM elements 10 are fitted together to form the hollow cuboid structure 12, the joints between PCM elements 10 overlie parts of the walls of the thermally insulated transportation container that are heavily insulated and are kept away
5 from parts that are not as well insulated, such as vertical edges of the transportation container and where a lid/door abuts a main body of the thermally insulated container. That is, the joints are not aligned with the parts that are less thermally insulated. This can be appreciated by looking at Figures 2a, 3b, and 4b, and the following further explanation. Close to the vertical edges of the storage volume, i.e. those areas where two
10 vacuum insulation panels 11 meet, there is less thermal insulation when compared with a central portion of the vacuum insulation panel 11. This occurs since edges of the vacuum insulation panel 11 has a polymer that extends around the edges of the panel 11. The polymer at the edges provides less thermal insulation than central portions of the panel 11, and thus provides a thermal pathway for conducting heat into / out of the container 1.
15 There may also be a small air gap between two adjacent vacuum insulation panels 11, which enables heat transfer by way of convection currents. It can be seen from Figures 2a, 3b, and 4b that the joints between two PCM elements 10 are not aligned with the vertical edges of the vacuum insulation panels, and hence container. Instead, the joints extend diagonally across central portions of the vacuum insulation panels 11. This helps
20 to reduce the ability of heat to penetrate into the payload volume 14.

In a condition wherein the PCM elements 10 are fitted together to form the hollow cuboid structure, the first side 20 of the first PCM element forms part of a first (Top) side of the hollow cuboid structure 12, the second side 22 of the first PCM element forms part of a second (Left) side of the hollow cuboid structure 12, and the third side 24 of the first
25 PCM element forms part of a third (Rear) side of the hollow cuboid structure 12.

The first side 20 of the second PCM element forms part of a fourth (Base) side of the hollow cuboid structure 12, the second side 22 of the second PCM element forms part of the third (Rear) side of the hollow cuboid structure 12, and the third side 24 of the second PCM element forms part of a fifth (Right) side of the hollow cuboid structure 12.

The first side 20 of the third PCM element forms part of the fourth (Base) side of the hollow cuboid structure 12, the second side 22 of the third PCM element forms at of the second (Left) side of the hollow cuboid structure 12, and the third side 24 of the third PCM element forms part of a sixth (Front) side of the hollow cuboid structure 12.

- 5 The first side 20 of the fourth PCM element forms part of the first (Top) side of the hollow cuboid structure 12, the second side 22 of the fourth PCM element forms part of the sixth (Front) side of the hollow cuboid structure 12, and the third side 24 of the fourth PCM element forms part of a fifth (Right) side of the hollow cuboid structure.

Thus a first (Top) side of the hollow cuboid structure 12 is split diagonally into first and
10 second parts, that is a tapering edge of the first PCM element 10 abuts a tapering edge of the fourth PCM element 10. A second (Left) side of the hollow cuboid structure 12 is split diagonally into first and second parts, that is a tapering edge of the first PCM element 10 abuts a tapering edge of the third PCM element 10. A third (Rear) side of the hollow cuboid structure 12 is split diagonally into first and second parts, that is a tapering
15 edge of the first PCM element 10 abuts a tapering edge of the second PCM element 10. A fourth (Base) side of the hollow cuboid structure 12 is split diagonally into first and second parts, that is a tapering edge of the second PCM element 10 abuts a tapering edge of the third PCM element 10. A fifth (Right) side of the hollow cuboid structure is split diagonally into first and second parts, that is a tapering edge of the second PCM element
20 10 abuts a tapering edge of the fourth PCM element 10. A sixth (Front) side of the hollow cuboid structure 12 is split diagonally into first and second parts, that is a tapering edge of the third PCM element 10 abuts a tapering edge of the fourth PCM element 10.

The inventors undertook thermal simulation comparison tests between hollow cuboid structures located in a thermally insulated container comprising a set of four of the
25 recessed pyramidal PCM elements 10 and hollow cuboid structures comprising a set of six of the prior art flat plate PCM elements similar to those shown in WO2010/055295. Each hollow cuboid structure used the same PCM, the same amount of PCM by weight, the thermally insulated container was identical in each case, and the payload volume 14 was empty of temperature sensitive goods (i.e. air only in the payload volume).

Three different arrangements of recessed pyramidal PCM elements 10 were compared with three equivalent arrangements of prior art flat plate PCM elements. For each test, temperature measurements were made periodically throughout the duration of the tests at the following locations of the hollow cuboid structure: top corner 1, top corner 2, and mid centre of the payload volume 14. On the basis of these temperature measurements, the inventors compared the time to failure, which is the time from the start of the test (when temperature is 2°C in the payload volume 14) to the time when any one of the temperature sensors reaches 8°C (upper threshold value of the acceptable temperature range for the goods), and the temperature spread within the payload volume 14 at the time of failure. The inventors were seeking to identify which arrangement of PCM elements had the longest time to failure and/or the minimum temperature spread within the payload volume 14.

The results of the tests are set out in Tables 1 and 2 below.

In Tables 1 and 2, for the pyramidal arrangements, the column headed “Plate top / bottom thickness” refers to the thickness T of the first side 20 of the PCM element 10 and hence the thickness of the top and base sides of the hollow cuboid structure, and the column headed “Plate vertical side wall thickness” refers to the thickness T of each of the second and third sides 22,24 of the PCM element 10, and hence the thickness of the vertical sides (front, rear, left and right) of the hollow cuboid structure 12. For the flat plate arrangements, the column headed “Plate top / bottom thickness” refers to the thickness T of the flat plate PCM element used for the top side of the hollow cuboid structure and the thickness T of the flat plate PCM element used for the base side. The column headed “Plate vertical side wall thickness” refers to the thickness T of each of plate used for the vertical side walls of the hollow cuboid structure. Thus the test considers the impact of having a consistent wall thickness T for the hollow cuboid structure 12 against having a thicker top side and base side, and thinner vertical sides (front, rear, left and right) for both the recessed pyramidal PCM elements 10 and the flat plate PCM elements.

Number of Plates	Plate top/ bottom thickness (mm)	Plate vertical side wall thickness (mm)	Hours (h) to Temperature 8°C			System Failure	Ranking
			Top Corner 1	Top Corner 2	Mid Centre		
6 Plates	22.5	22.5	95.25		106.43	95.25	5
6 Plates	25	20	96.11		102.23	96.11	4
6 Plates	30	17	89.00		92.71	89.00	6
4 Plates	21.5	21.5	99.28	100.71	102.14	99.28	2
4 Plates	25	20	101.28	103.88	111.69	101.28	1
4 Plates	27	19	97.31	97.80	103.24	97.31	3

Table 1

Number of Plates	Plate top/ bottom thickness (mm)	Plate vertical side wall thickness (mm)	Temperature 8°C at fail			Temp Spread
			Top Corner 1	Top Corner 2	Mid Centre	
6 Plates	22.5	22.5	8.01		6.68	1.33
6 Plates	25	20	8.00		7.20	0.80
6 Plates	30	17	8.01		7.03	0.98
4 Plates	21.5	21.5	8.01	7.66	7.19	0.82
4 Plates	25	20	8.00	7.82	7.19	0.81
4 Plates	27	19	8.00	7.90	7.26	0.74

5

Table 2

The temperature sensor at Top Corner 1 (TC1), is located at the top of the hollow cuboid structure 12 at an air gap corner, which is the top corner wherein corners of three recessed pyramidal PCM elements 10 meet. The temperature sensor at Top Corner 2 (TC2), is measured at seamless top corner, that is a top corner of the hollow cuboid structure 12 that is formed by a corner of a single recessed pyramidal PCM element 10. There is no data for Top Corner 2 for the 6 x flat plate PCM elements, since each top corner of the hollow cuboid structure 12 is similar.

It can be seen from Table 1 above that in each case the set of recessed pyramidal PCM elements 10 outperforms its equivalent flat plate arrangement in relation to time to failure

by several hours, and that the best performing arrangement is the 25 x 20 arrangement. That is, the arrangement wherein the first side 20 has a thickness T of 25mm, and is used for a top or base side of the hollow cuboid structure 12, and the second and third sides 22,24, which are used for vertical sides of the hollow cuboid structure 12, have a
5 thickness of 20mm.

It can be seen from Table 2 above that for each arrangement the set of recessed pyramidal PCM elements 10 either outperforms or is equal to its equivalent flat plate arrangement in relation to temperature spread within the payload volume 14. Table 2 also shows that the best performing arrangement in terms of temperature homogeneity (i.e.
10 minimum temperature spread) within the payload volume 14 is the 27 x 19 arrangement.

Thus there is a significant improvement in thermal performance by using recessed pyramidal PCM elements 10 instead of prior art flat plate PCM elements, in particular recessed pyramidal PCM elements 10 that are arranged to form the hollow cuboid structure 12 having thicker top and base sides and thinner vertical sides, in addition to the
15 reduction in plastic material required to produce the receptacles 10a.

The container 1 can include a data logger, for example that is mounted on the lid 5. The data logger is arranged to receive signals from at least one temperature sensor, and to record temperature readings throughout transportation so it will be clear to the user if the temperature should stray outside of the desired temperature range at any time during
20 transportation. Preferably, the container 1 includes a temperature sensor (not shown), which measures the internal temperature of the payload volume 14, and the data logger records the internal temperature throughout transportation. Preferably, the container 1 includes a temperature sensor (not shown), which measures ambient temperature, and the data logger records ambient temperature throughout transportation.

25 A thermally insulated transportation container 1 according to a second embodiment of the invention is shown in Figure 5. The container 1 is similar to the container 1 shown in the first embodiment, except for the arrangement of each PCM element 110 in the set of PCM elements. In the second embodiment the set of PCM elements 110, comprises first

and second PCM elements 110, each of which comprises one half of the hollow cuboid structure 12. This is a fewer number of PCM elements 110 than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this
5 leads to a reduction in the total amount of plastics material required to form the PCM element receptacles, thus leading to a reduction in weight of the overall structure.

Each of the first and second PCM elements 110 includes first, second and third sides 120,122,124. Each of the first, second and third sides 120,122,124 has PCM stored therein in a similar manner to the first embodiment. That is, the PCM is located in a
10 cavity that extends into each of the first, second and third sides 120,122,124.

For each PCM element 110, each of the first, second and third sides 120,122,124 is rectangular in plan. A first edge of the first side 120 is contiguous with a first edge of the second side 122. A second edge of the first side 120 is contiguous with a first edge of the third side 124. A second edge of the second side 122 is contiguous with a second edge of
15 the third side 124. The first side 120 of the PCM element 110 is perpendicular to each of the second and third sides 122,124 of the PCM element. The second side 122 of the PCM element is perpendicular to the third side 124 of the PCM element. There is a recess 132 defined by the first, second and third sides 120,122,124.

In a condition wherein the first and second PCM elements are fitted together to form the
20 hollow cuboid structure 12, the first side 120 of the first PCM element 110 forms a first (Top) side of the hollow cuboid structure 12, the second side 122 of the first PCM element forms a second (Left) side of the hollow cuboid structure 12, and the third side 124 of the first PCM element forms a third (Rear) side of the hollow cuboid structure 12. The first side 120 of the second PCM element 110 forms a fourth (Base) side of the
25 hollow cuboid structure 12, the second side 122 of the second PCM element forms a fifth (Right) side of the hollow cuboid structure 12, and the third side 124 of the second PCM element forms a sixth (Front) side of the hollow cuboid structure. Thus the first PCM element 110 comprises the top, left and rear sides of the hollow cuboid structure 12 and the second PCM element 110 comprises the bottom, right and front sides of the hollow

cuboid structure 12. The first and second PCM elements can be mounted together in a manner such that the top side of the first PCM element rests on upper edges of the front and right sides of the second PCM element, and lower edges of the left side and the rear side of the first PCM element rests on the base side of the second PCM element.

- 5 A thermally insulated transportation container 1 according to a third embodiment of the invention is shown in Figure 6. The container 1 is similar to the container 1 shown in the first embodiment, except for the arrangement of each PCM element 210 in the set of PCM elements. In the third embodiment the set of PCM elements 210, comprises first and second PCM elements 210, each of which comprises one half of the hollow cuboid
- 10 structure 12. This is a fewer number of PCM elements 210 than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure 12. Since there are fewer PCM elements 210 to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element receptacles, thus leading to a reduction in weight of the overall
- 15 structure.

Each of the first and second PCM elements 210 includes first, second and third sides 220,222,224. Each of the first, second and third sides 220,222,224 has PCM stored therein in a similar manner to the first embodiment. That is, the PCM is located in a cavity that extends into each of the first, second and third sides 220,222,224.

- 20 For each PCM element 210 each of the first, second and third sides 220,222,224 is rectangular in plan. A first edge of the first side 220 is contiguous with a first edge of the second side 222. A second edge of the first side 220 is contiguous with a first edge of the third side 224. The second and third sides 222,224 are parallel with one another and are spaced apart by the first side 220. The first side 220 is perpendicular to each of the
- 25 second and third sides 222,224. Accordingly, each of the PCM elements has a substantially U-shaped structure. There is a recess 232 defined by the first, second and third sides 220,222,224.

In a condition wherein the first and second PCM elements 210 are fitted together to form the hollow cuboid structure 12, the first side 220 of the first PCM element forms a first (Top) side of the hollow cuboid structure 12, the second side 222 of the first PCM element forms a second (Rear) side of the hollow cuboid structure 12, and the third side 224 of the first PCM element forms a third (Front) side of the hollow cuboid structure 12. The first side 220 of the second PCM element forms a fourth (Base) side of the hollow cuboid structure 12, the second side 222 of the second PCM element forms a fifth (Right) side of the hollow cuboid structure 12, and the third side 224 of the second PCM element forms a sixth (Left) side of the hollow cuboid structure.

10 A thermally insulated transportation container 1 according to a fourth embodiment of the invention is shown in Figure 7. The container 1 is similar to the container 1 shown in the first embodiment, except for the arrangement of each PCM element 310 in the set of PCM elements. In the fourth embodiment the set of PCM elements 310, comprises first and second PCM elements 310, each of which comprises one half of the hollow cuboid structure 12. This is a fewer number of PCM elements than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element receptacles, thus leading to a reduction in weight of the overall structure.

20 Each of the first and second PCM elements 310 includes first, second, third and fourth sides 320,322,324,326. Each of the first, second, third and fourth sides 320,322,324,326 has PCM stored therein in a similar manner to the first embodiment. That is, the PCM is located in a cavity that extends into each of the first, second, third and fourth sides 320,322,324,326.

25 For each PCM element 310 each of the first and second sides 320,322 is rectangular in plan. Each of the third and fourth sides 324,326 is triangular in plan. A first edge of the first side 320 is contiguous with a first edge of the second side 322. The first side 320 is perpendicular to the second side 322. A first edge of the third side 324 is contiguous with a second edge of the first side 320. A second edge of the third side 324 is contiguous

with a second edge of the second side 322. A third edge of the third side 324 is located at an open side of the PCM element. A first edge of the fourth side 326 is contiguous with a third edge of the first side 320. A second edge of the fourth side 326 is contiguous with a third edge of the second side 322. A third edge of the fourth side 326 is located at an open side of the PCM element. The third side 324 is parallel with the fourth side 326. The third side 324 is perpendicular to the first side 320 and the second side 322. The fourth side 326 is perpendicular to the first side 320 and the second side 322. A recess 332 is defined by the first, second, third and fourth sides 320,322,324,326 of the PCM element. The openside is rectangular in plan. Each PCM element comprises a recessed wedge shape.

In a condition wherein the first and second PCM elements 310 are fitted together to form the hollow cuboid structure 12, the first side 320 of the first PCM element forms a first (Top) side of the hollow cuboid structure 12, the second side 322 of the first PCM element forms the second (Right) side of the hollow cuboid structure 12, the third side 324 of the first PCM element forms part of a third (Front) side of the hollow cuboid structure 12, and the fourth side 326 of the first PCM element forms part of a fourth (Rear) side of the hollow cuboid structure 12. The first side 320 of the second PCM element forms a fifth (Base) side of the hollow cuboid structure 12, the second side 322 of the second PCM element forms a sixth (Left) side of the hollow cuboid structure 12, the third side 324 of the second PCM element forms part of the third (Front) side of the hollow cuboid structure 12, and the fourth side 326 of the second PCM element forms part of the fourth (Rear) side of the hollow cuboid structure 12.

Thus the third (Front) side of the hollow cuboid structure 12 is split diagonally into first and second parts, that is a tapering edge of the first PCM element abuts a tapering edge of the second PCM element. The fourth side of the hollow cuboid structure 12 is split diagonally into first and second parts, that is a tapering edge of the second PCM element abuts a tapering edge of the first PCM element. An advantage of each of this arrangement options is that the joints between the first and second PCM elements 310 overlie parts of the walls of the thermally insulated transportation container that are heavily insulated and

are kept away from parts that are not as well insulated, such as vertical edges of the transportation container and where a lid/door abuts a main body of the thermally insulated container. That is, the joints are not aligned with the parts that are less insulated.

- 5 A thermally insulated transportation container 1 according to a fifth embodiment of the invention is shown in Figure 8. The container 1 is similar to the container 1 shown in the first embodiment, except for the arrangement of each PCM element 410 in the set of PCM elements. In the fifth embodiment the set of PCM elements 410, comprises first and second PCM elements 410, each of which comprises one half of the hollow cuboid
- 10 structure 12. This is a fewer number of PCM elements than required for the prior art flat plate arrangement, which requires at least six flat plates to form the hollow cuboid structure. Since there are fewer PCM elements to make the hollow cuboid structure, this leads to a reduction in the total amount of plastics material required to form the PCM element receptacles, thus leading to a reduction in weight of the overall structure.
- 15 Each of the first and second PCM elements 310 includes first, second, third, fourth and fifth sides 420,422,424,426,428. Each of the first, second, third, fourth and fifth sides 420,422,424,426,428 has PCM stored therein in a similar manner to the first embodiment. That is, the PCM is located in a cavity that extends into each of the first, second, third, fourth and fifth sides 420,422,424,426,428.
- 20 Each of the first and second PCM elements comprises a recessed cuboid structure, which is open at one side. That is, each of the first and second PCM elements comprises an open sided box. The two open sided boxes can be fitted together to form the hollow cuboid structure 12.

For each PCM element 410 each of the first, second, third, fourth and fifth sides

25 420,422,424,426,428 is rectangular in plan. The first side 420 is arranged perpendicularly to the second, third, fourth and fifth sides 422,424,426,428. The second side 422 is parallel to the fourth side 426. The third side 424 is parallel to the fifth side 428. The

second side 422 is perpendicular to the third side 424 and the fifth side 428. The fourth side 426 is perpendicular to the third side 424 and the fifth side 428.

In a condition wherein the first and second PCM elements 410 are fitted together to form the hollow cuboid structure 12, the first side 420 of the first PCM element forms a first (Top) side of the hollow cuboid structure 12, the second side 422 of the first PCM element forms part of a second (Right) side of the hollow cuboid structure 12, the third side 424 of the first PCM element forms part of a third (Rear) side of the hollow cuboid structure 12, the fourth side 426 of the first PCM element forms part of a fourth (Left) side of the hollow cuboid structure 12, and the fifth side 428 of the first PCM element forms part of a fifth (Front) side of the hollow cuboid structure 12. The first side 420 of the second PCM element forms a sixth (Base) side of the hollow cuboid structure 12, the second side 422 of the second PCM element forms part of the second (Right) side of the hollow cuboid structure 12, the third side 424 of the second PCM element forms part of the third (Rear) side of the hollow cuboid structure 12, the fourth side 426 of the second PCM element forms part of the fourth (Left) side of the hollow cuboid structure 12, and the fifth side 428 of the second PCM element forms part of the fifth (Front) side of the hollow cuboid structure 12.

It will be appreciated by the skilled person that modifications can be made to the above embodiments that fall within the scope of the invention, for example other 3D shapes of the PCM elements could provide a similar technical effect.

The description presents exemplary embodiments and, together with the drawings, serves to explain principles of the invention. However, the scope of the invention is not intended to be limited to the precise details of the embodiments or exact adherence with all method installation steps, since variations will be apparent to a skilled person and are deemed also to be covered by the claims. Terms for components used herein should be given a broad interpretation that also encompasses equivalent functions and features. In some cases, several alternative terms (synonyms) for structural features have been provided but such terms are not intended to be exhaustive.

- Descriptive terms should also be given the broadest possible interpretation; e.g. the term "comprising" as used in this specification means "including" such that interpreting each statement in this specification that includes the term "comprising", features other than that or those prefaced by the term may also be present. Related terms such as "comprise" and "comprises" are to be interpreted in the same manner. Directional terms such as "vertical", "horizontal", "up", "down", "upper" and "lower" may be used for convenience of explanation usually with reference to the illustrations and are not intended to be ultimately limiting if an equivalent function can be achieved with an alternative dimension and/or direction.
- 10 The description herein refers to embodiments with particular combinations of configuration steps or features, however, it is envisaged that further combinations and cross-combinations of compatible steps or features between embodiments will be possible. Indeed, isolated features may function independently as an invention from other features and not necessarily require implementation as a complete combination. Any
- 15 feature from an embodiment can be isolated from that embodiment and included in any other embodiment.

- The term "at least one of" is to be interpreted in the sense of "and/or". For example, the term "at least one of X and Y" is to be interpreted as meaning any one of the following: X alone; Y alone; or the combination of X and Y. As another example, the term "at least
- 20 one of X, Y and Z" is to be interpreted as meaning any one of the following: X alone; Y alone; Z alone; the combination of X and Y; the combination of transmission X and Z; the combination of Y and Z; or the combination of X, Y, Z.

CLAIMS

1. A set of phase change material (PCM) elements for use in a thermally insulated transportation container that transports temperature sensitive goods, wherein the set of PCM elements is arranged to fit together to form a hollow cuboid structure, the hollow cuboid structure having a first side, second side, third side, fourth side, fifth side and sixth side defining an enclosed payload volume that is arranged to receive the temperature sensitive goods, wherein at least one, and preferably each, of the PCM elements in the set of PCM elements comprises a sealed or sealable receptacle having at least a first side, a second side and a third side, wherein the receptacle has an internal cavity that extends into each of the first side, second side and third side, and PCM is stored within the cavity in each of the first side, second side and third side.
2. The set of PCM elements of claim 1, wherein for at least one, and preferably each, of the PCM elements, the first side, second side, third side defines a structure having an open side and a recess, and, in a condition wherein the set of PCM elements are fitted together to form the hollow cuboid structure, the recesses and open sides are arranged to face inwards and define the payload volume.
3. The set of PCM elements of claim 1 or 2, wherein for at least one, and preferably each, of the PCM elements, one of the first side, second side and third side of has a different thickness from the other two of the first side, second side and third side.
4. The set of PCM elements of any one of the preceding claims, wherein each PCM element in the set of PCM elements is identical.
5. The set of PCM elements of any one of the preceding claims, wherein the PCM elements are stackable.
6. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, the first side is orthogonal to the second side.
7. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, the first side, second side and third side meet at a common corner.

8. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, the receptacle includes a plastics material, such as polyethylene.
9. The set of PCM elements of any one of the preceding claims, wherein the receptacle for at least one, and preferably each, of the PCM elements is moulded, and preferably blow moulded.
10. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, each of the first side, second side and third side comprises an inner wall and an outer wall, the cavity is located between the inner and outer walls for each of the first side, second side and third side, and the PCM material is stored in the cavity between the inner and outer walls for each of the first side, second side and third side.
11. The set of PCM elements of claim 10, wherein the outer wall of each side of the PCM element is planar; and/or the inner wall of each side of the PCM element is planar.
12. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, the receptacle is rigid.
13. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, at least one of the first side, second side, and third side is triangular in plan.
14. The set of PCM elements of any one of the preceding claims, wherein the set of PCM elements comprises, or consists of, a first PCM element, a second PCM element, a third PCM element and a fourth PCM element.
15. The set of PCM elements of any one of the preceding claims, wherein for at least one, and preferably each, of the PCM elements, a first edge of the first side is contiguous with a first edge of the second side, a second edge of the second side is contiguous with a first edge of the third side, and a second edge of the first side is contiguous with a second edge of the third side.

16. The set of PCM elements of any one of the preceding claims, wherein at least one, and preferably each, of the PCM elements comprises a recessed pyramidal shape, which is open at one side.

17. The set of PCM elements of claim 16, wherein, in a condition wherein the PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms part of a first side of the hollow cuboid structure, the second side of the first PCM element forms part of a second side of the hollow cuboid structure, and the third side of the first PCM element forms part of a third side of the hollow cuboid structure.

18. The set of PCM elements of claim 17, wherein, the first side of the second PCM element forms part of the fourth side of the hollow cuboid structure, the second side of the second PCM element forms part of a third side of the hollow cuboid structure, and the third side of the second PCM element forms part of a fifth side of the hollow cuboid structure.

19. The set of PCM elements of claim 18, wherein, the first side of the third PCM element forms part of the fourth side of the hollow cuboid structure, the second side of the third PCM element forms at of the second side of the hollow cuboid structure, and the third side of the third PCM element forms part of a sixth side of the hollow cuboid structure.

20. The set of PCM elements of claim 19, wherein, the first side of the fourth PCM element forms part of the first side of the hollow cuboid structure, the second side of the fourth PCM element forms part of the sixth side of the hollow cuboid structure, and the third side of the fourth PCM element forms part of a fifth side of the hollow cuboid structure.

21. The set of PCM elements of any one of claims 1 to 13, wherein the set of PCM elements comprises, or consists of, a first PCM element and a second PCM element.

22. The set of PCM elements of claim 21, wherein for at least one, and preferably each, of the PCM elements, each of the first, second and third sides is rectangular in plan; a first edge of the first side is contiguous with a first edge of the second side, a second edge of the first side is contiguous with a first edge of the third side, a second edge of the second side is contiguous with a second edge of the third side; the first side of the is perpendicular to each of the second and third sides, the second side is perpendicular to the third side; a recess defined by the first, second and third sides.

23. The set of PCM elements of claim 21 or 22, wherein, in a condition wherein the PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms the first side of the hollow cuboid structure, the second side of the first PCM element forms the second side of the hollow cuboid structure, and the third side of the first PCM element forms the third side of the hollow cuboid structure.

24. The set of PCM elements of claim 23, wherein, the first side of the second PCM element forms the fourth side of the hollow cuboid structure, the second side of the second PCM element forms the fifth side of the hollow cuboid structure, and the third side of the second PCM element forms the sixth side of the hollow cuboid structure.

25. The set of PCM elements of claim 21, wherein for at least one, and preferably each, of the PCM elements, the second and third sides are parallel with one another and the first side is perpendicular to each of the second and third sides.

26. The set of PCM elements of claim 21 or 22, wherein at least one, and preferably each, of the PCM elements has a substantially U-shaped structure.

27. The set of PCM elements of claim 25 or 26, wherein, in a condition wherein the PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms the first side of the hollow cuboid structure, the second side of the first PCM element forms the second side of the hollow cuboid structure, and the third side of the first PCM element forms the third side of the hollow cuboid structure.

28. The set of PCM elements of claim 27, wherein, the first side of the second PCM element forms the fourth side of the hollow cuboid structure, the second side of the second PCM element forms the fifth side of the hollow cuboid structure, and the third side of the second PCM element forms the sixth side of the hollow cuboid structure.

29. The set of PCM elements of any of the preceding claims, wherein for at least one, and preferably each, of the PCM elements the receptacle includes a fourth side, wherein the internal cavity extends into the fourth side, and PCM is stored within the cavity in the fourth side.

30. The set of PCM elements of claim 29, wherein at least one, and preferably each, of the PCM elements comprises a recessed wedge shape.

31. The set of PCM elements of claim 29 or 30, wherein for at least one, and preferably each PCM, the first and second sides are rectangular in plan and the third and fourth sides are triangular in plan.

32. The set of PCM elements of any one of claims 29 to 31, wherein for at least one, and preferably each, of the first and second PCM elements, the first side is perpendicular to the second side, the third side is perpendicular to the first and second sides, the fourth side is perpendicular to the first and second sides, and the third and fourth sides are parallel to one another.

33. The set of PCM elements of any one of claims 29 to 32, wherein for at least one, and preferably each, of the PCM elements, a first edge of the first side is contiguous with a first edge of the second side, a first edge of the third side is contiguous with a second edge of the first side, a second edge of the third side is contiguous with a second edge of the second side, a third edge of the third side is located at an open side of the PCM element, a first edge of the fourth side is contiguous with a third edge of the first side, a second edge of the fourth side is contiguous with a third edge of the second side, a third edge of the fourth side is located at the open side of the PCM element, a recess is defined by the first, second, third and fourth sides of the PCM element.

34. The set of PCM elements of any one of claims 29 to 33, when dependent on claim 21, wherein, in a condition wherein the PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms the first side of the hollow cuboid structure, the second side of the first PCM element forms the second side of the hollow cuboid structure, the third side of the first PCM element forms part of the third side of the hollow cuboid structure, and the fourth side of the first PCM element forms part of the fourth side of the hollow cuboid structure.

35. The set of PCM elements of claim 34, the first side of the second PCM element forms the fifth side of the hollow cuboid structure, the second side of the second PCM element forms the sixth side of the hollow cuboid structure, the third side of the second PCM element forms part of the third side of the hollow cuboid structure, and the fourth side of the second PCM element forms part of the fourth side of the hollow cuboid structure.

36. The set of PCM elements of claim 29, wherein the receptacle for at least one, and preferably each, of the PCM elements includes a fifth side, wherein the internal cavity extends into the fifth side, and PCM is stored within the cavity in the fifth side.

37. The set of PCM elements of claim 36, wherein at least one, and preferably each, of the PCM elements comprises a recessed cuboid structure, which is open at one side.

38. The set of PCM elements of claim 36 or 37, wherein for at least one, and preferably each, of the PCM elements the first, second, third, fourth and fifth sides are rectangular in plan, the first side is arranged perpendicularly to the second, third, fourth and fifth sides, the second side is parallel to the fourth side, the third side is parallel to the fifth side, the second side is perpendicular to the third side and the fifth side, and the fourth side is perpendicular to the third side and the fifth side.

39. The set of PCM elements of any one of claims 36 to 38, wherein, in a condition wherein the first and second PCM elements are fitted together to form the hollow cuboid structure, the first side of the first PCM element forms a first side of the hollow cuboid structure, the second side of the first PCM element forms part of a second side of the hollow cuboid structure, the third side of the first PCM element forms part of a third side of the hollow cuboid structure, the fourth side of the first PCM element forms part of a fourth side of the hollow cuboid structure, and the fifth side of the first PCM element forms part of a fifth side of the hollow cuboid structure; the first side of the second PCM element forms a sixth side of the hollow cuboid structure, the second side of the second PCM element forms part of the second side of the hollow cuboid structure, the third side of the second PCM element forms part of the third side of the hollow cuboid structure, the fourth side of the second PCM element forms part of the fourth side of the hollow cuboid structure, and the fifth side of the second PCM element forms part of the fifth side of the hollow cuboid structure.

40. The set of PCM elements of any one of the preceding claims, wherein the PCM is arranged to maintain the temperature sensitive goods at a temperature in one of the following ranges: +2°C to +8°C; -25°C to -15°C; +15°C to +25°C.

41. A thermally insulated transportation container arranged to transport temperature sensitive goods, said container including: a rigid body having thermally insulated walls that

define a storage volume; means for accessing the storage volume; and a set of PCM elements according to any one of the preceding claims arranged to fit within the storage volume in a condition wherein the PCM elements are fitted together to form of the hollow cuboid structure.

42. The container according to claim 41, wherein at least one thermally insulated container wall comprises at least one part having a higher thermal insulation zone, such as a central part of container side walls, and at least one part having a lower thermal insulation zone, which is arranged in an elongate rectilinear manner, and the set of PCM elements are located within the storage volume such that rectilinear joints between the PCM elements each have a different orientation from the elongate rectilinear lower thermal insulation zone.

43. The container of claim 42, wherein the container includes a plurality of rectilinear lower thermal insulation zones, and the set of PCM elements are located within the storage volume such that rectilinear joints between the PCM elements each have a different orientation from the elongate rectilinear lower thermal insulation zones.

44. The container of claim 42 or 43, wherein the rectilinear lower thermal insulation zones include vertical edges of thermally insulated walls of the container.

45. The container of any one of claims 42 to 44, wherein the rectilinear lower thermal insulation zones include top edges of thermally insulated walls adjacent a lid of the container.

46. The container of any one of claims 37 to 42, wherein the insulation for the walls of the container comprises vacuum insulation panels.

47. The container of any one of claims 41 to 46, wherein the container comprises an outer shell.

48. The container of any one of claims 41 to 47, wherein the container comprises an inner liner.

49. A method for loading a set of PCM elements into a thermally insulated transportation container, the method including:

providing a thermally insulated transportation container having a rigid body having thermally insulated walls that define a storage volume; means for accessing the storage volume; and a set of PCM elements according to any one of claims 1 to 40;

mounting the set of PCM elements within the storage volume to form a hollow cuboid structure.

50. A method according to claim 49, wherein at least one thermally insulated container wall comprises at least one part having a higher thermal insulation zone, such as a central part of container side walls, and at least one part having a lower thermal insulation zone, which is arranged in an elongate rectilinear manner, and locating the set of PCM elements within the storage volume such that rectilinear joints between the PCM elements each have a different orientation from the elongate rectilinear lower thermal insulation zones.

51. A phase change material (PCM) element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first side, a second side and a third side, wherein the receptacle has an internal cavity that extends into each of the first side, second side and third side, and PCM is stored within the cavity in each of the first side, second side and third side.

52. A PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first triangular side, a second triangular side and a third triangular side, wherein the first, second and third triangular sides form a recessed pyramid shape having an open side, and the receptacle has an internal cavity that extends into each of the first side, second side and third triangular sides, and PCM is stored within the cavity in each of the first, second and third triangular sides.

53. According to another aspect there is provided a PCM element for use in a thermally insulated transportation container, the PCM element comprising a recessed pyramid shape having an open side. According to another aspect there is provided a PCM element for use in a thermally insulated transportation container, the PCM element comprising one half of a hollow cuboid shape.

54. A PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first rectangular side, a second rectangular side and a third rectangular side, wherein the first, second and third rectangular sides form one half a hollow cuboid shape, wherein the first rectangular side is arranged perpendicularly to the second and third rectangular sides and the second rectangular side is arranged perpendicularly to the third rectangular side, a first edge of the first rectangular side is contiguous with a first edge of the second rectangular side, a second edge of the first rectangular side is contiguous with a first edge of the third rectangular side, a second edge of the second rectangular side is contiguous with a second edge of the third rectangular side, and the receptacle has an internal cavity that extends into each of the first, second and third rectangular sides, and PCM is stored within the cavity in each of the first, second and third rectangular sides.

55. A PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first rectangular side, a second rectangular side and a third rectangular side, wherein the first rectangular side, second rectangular side and third rectangular side form one half of a hollow cuboid shape, wherein the first rectangular side is arranged perpendicularly to the second rectangular side and third rectangular side and the second rectangular side is arranged parallel to the third rectangular side, a first edge of the first rectangular side is contiguous with a first edge of the second rectangular side and a second edge of the first rectangular side is contiguous with a first edge of the third rectangular side to provide a substantially U-shaped structure, and the receptacle has an internal cavity that extends into each of the first rectangular side, second rectangular side and third rectangular side, and PCM is stored within the cavity in each of the first rectangular side, second rectangular side and third rectangular side.

56. A PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first rectangular side, a second rectangular side, a first triangular side and a second triangular side, wherein the first rectangular side, second rectangular side, first triangular side and second triangular side form one half of a hollow cuboid shape, the first rectangular side is arranged perpendicularly to the second rectangular side, the first triangular side is arranged perpendicular to the first rectangular side and second rectangular side, the second triangular

side is arranged perpendicular to the first rectangular side and second rectangular side, the first triangular side is arranged parallel to the second triangular side, a first edge of the first rectangular side is contiguous with a first edge of the second rectangular side, a first edge of the first triangular side is contiguous with a second edge of the first rectangular side, a second edge of the first triangular side is contiguous with a second edge of the second rectangular side, a first edge of the second triangular side is contiguous with a third edge of the first rectangular side, a second edge of the second triangular side is contiguous with a third edge of the second rectangular side, thereby providing an open sided wedge-shaped structure having a recess, and the receptacle has an internal cavity that extends into each of the first rectangular side, second rectangular side, first triangular side and second triangular side, and PCM is stored within the cavity in each of the first rectangular side, second rectangular side, first triangular side and second triangular side.

57. A PCM element for use in a thermally insulated transportation container,, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first rectangular side, a second rectangular side, a third rectangular side, a fourth rectangular side and fifth rectangular side, wherein the first rectangular side is arranged perpendicularly to the second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side, the second rectangular side is arranged parallel to the fourth rectangular side, the third rectangular side is arranged parallel to the fifth rectangular side, the second rectangular side is arranged perpendicular to the third rectangular side and the fifth rectangular side, the fourth rectangular side is arranged perpendicular to the third rectangular side and the fifth rectangular side, the arrangement being such that the first rectangular side, second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side form one half of a hollow cuboid shape in the form of an open sided box having a recess, and the receptacle has an internal cavity that extends into each of the first rectangular side, second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side, and PCM is stored within the cavity in each of the first rectangular side, second rectangular side, third rectangular side, fourth rectangular side and fifth rectangular side.

58. A PCM element for use in a thermally insulated transportation container, the PCM element comprising: a sealed or sealable moulded plastics receptacle having at least a first side, a second side and a third side, wherein the first side is triangular in plan, the second side is triangular in plan and the third triangular side is triangular in plan, wherein the first side,

second side and third side form a recessed pyramid shape having an open side, and PCM is stored within each of the first side, second side and third side.