building insulation, temporary insulation systems, such as cargo covers or the like, and insulation lining, for example in shipping boxes or containers.

PCMs are also available in a flexible form in "ice cube" bags. However, any increase in pressure on free-flowing liquids within such bags can transfer to the seams of the bag and lead to catastrophic failure.

There remains a need in the art for improved thermal insulation. It is an object of the invention to address at least one of the above problems or another problem associated with the prior art.

SUMMARY

In one aspect of the disclosure there is provided a flexible insulation material comprising a flexible porous medium defining a pore volume, and a phase change material (PCM) within the pore volume.

It has been found that a PCM can hold its position within a pore volume of a porous medium. This can mitigate or prevent pooling of the PCM.

The insulation material is flexible in the sense that it has at least some ability to flex or bend. Different degrees of flexibility may be desirable for different applications.

Advantageously, in various examples, the flexible insulation material may be capable of bending under its own weight. A suitable method for determining whether a material can bend under its own weight is the Pierce cantilever test ASTM D1388.

In the Pierce cantilever test a specimen of the material to be tested is cut to 200 mm x 25 mm. The sample is then gradually slid over the edge of a platform of a Pierce cantilever device. As the leading edge of the specimen projects from the platform, it may bend under its own weight, until the leading edge of the specimen makes contact with a sloping surface of the device angled downwards at an angle $\theta = 41.5°$. The overhanging length (l) of the specimen is measured using a graduated ruler. The measured length (l) is multiplied by a scaling factor to give a value for the bending stiffness (G) in Nm.

For the purposes of the present specification, a material can bend under its own weight if a leading edge of the material makes contact with the sloping surface in the Pierce cantilever test.

The insulation material may be flexible only in a certain state of the PCM. For example, the insulation material may be flexible, or even bend under its own weight, only when the PCM is in a liquid state.

Advantageously, it has been found in various examples of the disclosure that incorporation of the PCM into the pore volume of the porous medium may allow for flexing where the PCM is in a solid state and would otherwise break.

Advantageously, the insulation material may be flexible in all states of the PCM. For example, the insulation material may be flexible when the PCM is in a liquid state and when the PCM is in a solid state. Typically, different degrees of flexibility will be achieved in different PCM states. For example, the insulation material may bend under its own weight in the sense of the Pierce cantilever test when the PCM is in a liquid state and have a lower degree of flexibility when the PCM is in the solid state.

To enhance flexibility the PCM may advantageously fill only part of the pore volume, with a remaining part of the pore volume comprising air. Suitably, at least 10% or at least 20% or at least 30% or at least 40% or even at least 50% of the pore volume may be filled with PCM. Optionally, up to about 95%, up to 90%, up to 85% or up to 80% of the pore volume may be filled with PCM.

In various examples, the phase change material may fill in the range of from 50 to 95% of the pore volume, in particular in the range of from 40 to 90% of the pore volume, such as in the range of from 50 to 85% of the pore volume. Optionally the remainder of the pore volume may be filled with air.

Suitably, to preserve air in the pore volume, the insulation material may be substantially uncompressed.

porous medium. The greater the total fibre surface area, the greater the amount of phase change material that can held within the fibrous porous medium.

The porous medium may in principle be made of any suitable material but may conveniently comprise a synthetic material. Conveniently, the porous medium may be polymeric, i.e. comprise or consist of one or more polymers (or copolymers).

In various examples, the porous medium comprises a polyolefin, optionally polypropylene.

Suitably, the porous medium may comprises a non-woven material. A variety of such materials are known. In various examples, melt-blown material has been found to provide particularly effective absorption of PCMs.

The PCM may be of any suitable type. A wide range of PCMs are known in the art. Such materials can advantageously act as a temperature moderator. In particular, such materials can be used to store heat by causing a change in the "state" or "phase" of the materials, for example from a solid to a liquid.

By way of illustration, in a solid/liquid PCM, the heat applied to the PCM in a solid state is absorbed by the PCM resulting in an increase in the temperature of the PCM. As the temperature of the PCM reaches its phase change temperature, that is the temperature at which the PCM changes from a solid state to a liquid, the PCM stops increasing in temperature and substantially maintains a constant temperature at its phase change temperature, "consuming" the heat being applied thereto and storing it as latent heat. In reverse, as the PCM drops in temperature, the sensible heat which was consumed by the change to a liquid phase and stored as latent heat is released at the phase change temperature of the PCM as the PCM changes into its solid state. As before, the PCM maintains a substantially constant temperature at its phase change temperature while giving up the stored latent heat of liquification as it turns into its solid state.

Latent heat is the heat gained by a substance without any accompanying rise in temperature during a change of state. In essence, it is the amount of heat

necessary to change a substance from one physical phase to another (more dis-ordered), for example, the solid state to the liquid state. Once the phase change material has completely changed to the more dis-ordered phase, for example a liquid state, the temperature of the PCM begins to rise again as the applied heat is now absorbed as sensible heat.

In various examples of the disclosure, the PCM is organic. However, inorganic PCMs are also known and could suitably be used.

An organic PCM may, for example, comprise paraffin or a paraffin-derived hydrocarbon, a carbohydrate, a lipid, or a mixture thereof. Non-limiting examples of organic PCMs include n-tetradecane (C-14), n-hexadecane (C-16), and n-octadecane (C-18) and olefin.

Alternatively or additionally, the PCM may comprise an inorganic PCM such as an inorganic salt hydrate or eutectic material. Non-limiting examples of inorganic PCMs include calcium chloride hexahydrate, glauber salt, $Na_2SO_4.10H_2O$, $CaCl_2.6H_2O$, $NaHPO_4.12H_2O$, $Na_2S_2O_3.5H_2O$ and $NaCO_3.10H_{20}O$. *Heat and Cold Storage with PCM,* Mehling, H; Cabeza, L.F, ISBN: 978-3-540-68556-2 provides information on various PCMs and phase change temperatures.

In various examples, the PCM is hydrophobic. For example, the PCM may comprise compounds having carbon chains of at least eight, ten or twelve carbon atoms.

One example of an organic, hydrophobic PCM with a phase change temperature of about 21 ºC is CrodaTherm™ 21, available from Croda Industrial Chemicals.

The PCM comprises material that will change phase in a temperature range between an anticipated minimum temperature and an anticipated maximum temperature to be controlled by the insulation material. Suitably, the phase change may be between solid and liquid.

Suitably, the PCM may change phase at a temperature in the range of from -20 to 70 ºC, optionally in the range of from –10 to 60 ºC, for example in the range

of from 2 to 30 ºC. In an example the PCM may change phase at a temperature in the range of from 10 to 30 ºC, optionally in the range of from 15 to 25 ºC. In another example, the PCM may change phase at a temperature in the range of from 0 to 10 ºC, optionally in the range of from 2 to 8 ºC.

Suitably the insulation material may constitute a PCM layer. Discrete amounts of PCM may be distributed, preferably substantially evenly, within a PCM layer.

Suitably, the PCM layer may have a thickness in the range of from 0.5 to 10 mm, such as in the range of from 1 to 5 mm, e.g. in the range of from 1.5. to 3 mm. Suitably, the insulation material may be presented as a sheet or a roll.

From another aspect, the disclosure provides an insulation laminate comprising a layer including flexible insulation material as defined herein and one or more supplementary layers.

The supplementary layers, and indeed the insulation laminate as a whole, may advantageously be flexible, at least when the PCM is in a liquid state and optionally also when the PCM is in a solid state. Optionally, the insulation laminate may bend under its own weight in the sense of the Pierce test cited hereinabove.

Advantageously, the flexible insulation material may be sandwiched between first and second supplementary layers. Conveniently, the flexible insulation material may be surrounded by said one or more layers. This can assist in containing the PCM. Advantageously, the flexible insulation material may be encapsulated by the one or more supplementary layers. For example, the laminate may take the form of a pouch containing the flexible insulation material.

The one or more supplementary layers may comprise a barrier layer for resisting penetration of the PCM from the flexible insulation material layer out of the insulation laminate. A barrier layer may suitably comprise a monolithic or microporous film. Examples of monolithic films include cellulosic films,

polyamide films and ethylene vinyl alcohol films, but a range of suitable films will be apparent to the skilled person.

To enhance insulation performance, the one or more supplementary layers may advantageously comprise a reflective layer having an emissivity of less than 0.5, preferably less than 0.3, more preferably less than 0.25 and most preferably less than 0.20. Suitably, such a reflective layer may comprise an outward-facing reflective surface that is exposed.

Optionally, a reflective layer may be vapour permeable, comprising a vapour permeable substrate bearing a coating having particles of infra-red reflective matter dispersed within a polymeric matrix and providing an exposed low-emissivity surface on an outward face of the reflective layer. Such vapour permeable reflective layers are described in WO 2009/024804.

The one or more supplementary layers may comprise a support layer. A support layer may, for example, comprise a fibrous woven or non-woven material. Suitably, a spunbond layer may be used as a support layer.

A support layer may suitably be laminated, e.g. by intermittent heat or adhesive bonding, to a barrier layer or reflective layer as described herein. Typically a support layer has a greater tensile and/or tear strength than the layer to which it is laminated.

In an example, the one or more supplementary layers may comprise one or more air and/or vapour permeable layers. In particular, the one or more air and/or vapour permeable layers may have a moisture vapour transmission rate (MVTR) of at least 100 g/m^2.24hr, e.g. at least 200 g/m^2.24hr, or even at least 500 g/m^2.24hr as determined using a Lyssy Model L80-5000 Water Vapor Permeability Tester at 100%/15% RH, i.e. 85% RH difference and 23 °C. In various examples, the MVTR may be at most 2000 g/m^2.24hr, e.g. at most 1500 g/m^2.24hr, or even at most 1000 g/m^2.24hr as determined using the aforementioned method.

Advantageously, the laminate may be air and/or vapour permeable. The laminate may, for example, have a moisture vapour transmission rate (MVTR) of at least 100 g/m^2.24hr, e.g. at least 200 g/m^2.24hr, or even at least 500 g/m^2.24hr as determined using a Lyssy Model L80-5000 Water Vapor Permeability Tester at 100%/15% RH, i.e. 85% RH difference and 23 °C. In various examples, the MVTR may be at most 2000 g/m^2.24hr, e.g. at most 1500 g/m^2.24hr, or even at most 1000 g/m^2.24hr as determined using the aforementioned method.

To contain the insulation material, one or more layers of the laminate may be sealed at one or more side edges of the laminate. The layers may be sealed at all edges of the laminate. A sealed pouch of the insulation material may advantageously be provided.

In some examples, at least one of the one or more layers of the insulation laminate may comprise a thermosetting polymer. Advantageously, this can allow the one or more layers to be heat sealed together to form seams.

Suitably, the insulation laminate may be presented as a sheet or a roll.

Another aspect of the disclosure provides a cargo cover comprising an insulation material or insulation laminate as defined herein.

The cargo cover may comprise a plurality of flexible insulation laminates, each laminate being joined to, or arranged to be joined to, at least one other of the laminates, wherein one or more of the laminates is a laminate according to example of the disclosure. Suitably said one or more laminates according to the disclosure may comprise a pouch of the insulating material.

Conveniently, the cargo cover may have a deployed configuration defining a cavity for receiving a pallet of cargo.

Insulation laminates, in particular pouches, may be arranged to provide additional thermal protection by either totally enclosing a load to be transported

(e.g. the walls and the top and bottom of a load) or may be located in discrete areas, such as the walls, to provide protection to the most at risk locations of the load. In the case of cargo covers, this is generally considered to be the top of the load. Insulation laminates may be arranged in any combination of the above locations to provide optimum thermal protection. The laminates or pouches may be joined together to form a continuous insulation layer in order to limit thermal bridging.

In various examples, insulation laminates according to examples of the disclosure may be removably incorporated in a cargo cover to create an integrated PCM cargo cover solution. Insulation laminates may, for example, be integrated by gluing to the inner layers of the cargo cover or by the creation of pockets in the inside of the cover. Such pockets may be formed from fabric, netting, webbing or film.

Another aspect of the disclosure provides a cargo cover comprising one or more pockets for removably receiving an insulation laminate as defined herein.

Advantageously, pockets may be formed from a low emissivity material to further increase the thermal protection provided by the cover. To further enhance thermal performance, low emissivity pockets may be combined with flexible thermal insulation, for example layers of PET wadding, bubble wrap, glass or mineral wool, 3-D spacer fabric or open or closed cell foam.

Optionally, the cargo cover may be as defined or described in PCT/GB2018/050286, which is incorporated herein by reference. For example, the cargo cover may be as described in claim 62 of PCT/GB2018/050286 as originally filed. The insulation laminate of such a cargo cover may be as described in relation to any example of the disclosure herein.

In other applications, the insulation material or insulation laminate may advantageously be deployed so as to be in direct (heat conducting) contact with a product to be insulated. In this manner, a temperature equilibrium can be more readily maintained between the product and the PCM, which may enhance the PCM’s performance.

Yet another aspect of the disclosure provides a container internally lined with an insulation material or insulation laminate as defined herein.

The container may comprise walls that are more rigid than the insulation material or insulation laminate, at least when the PCM is in a liquid state. Suitably, the container may comprise a cardboard box. Alternatively, the container may comprise a metal or wood crate or a shipping container.

The container may be lined on a plurality of sides. Optionally, all sides of the container may be lined so that items shipped therein are surrounded by lining of the insulation material or insulation laminate. For example, the container may have side walls, a bottom wall and a top wall, and each of the side, top and bottom walls may be lined with the insulation material or insulation laminate.

Advantageously, the insulation material or insulation laminate may be flexed to line a plurality of sides of the container. Thus the insulation material or insulation laminate may form a wrap that lines a plurality of sides of a container.

The insulation material or insulation laminate may be affixed to an inner wall of the container, for example with adhesive or other means known in the art.

The disclosure provides a method of making an insulation product, for example an insulation material, laminate, cargo cover or lined container according to any example of the disclosure, the method comprising applying a phase change material (PCM) to pores of a flexible porous material to form a flexible insulation material. The PCM and/or flexible porous material may be as described anywhere herein.

Still a further aspect of the disclosure provides a method of making an insulation product, the method comprising applying a phase change material (PCM) to pores of a flexible porous material to form a flexible insulation material.

Suitably, the method may comprise forming a laminate with the flexible insulation material and one or more supplementary layers, the supplementary layers. The supplementary layers may be as described anywhere herein.

Optionally, the method may comprise sealing one or more side edges of the laminate. In particular, the method may comprise forming a pouch from the one

or more supplementary layers, the pouch enclosing the flexible insulation material.

The insulation material or insulation laminate is then incorporated into the insulation product. For example, a cargo cover may be made as defined or described in PCT/GB2018/050286. For example, the cargo cover may be as described in claim 52 of PCT/GB2018/050286 as originally filed.

Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", mean "including but not limited to", and do not exclude other components, integers or steps. Moreover the singular encompasses the plural unless the context otherwise requires: in particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Preferred features of each example of the disclosure may be as described in connection with any of the other examples. Within the scope of this application it is expressly intended that the various examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all examples and/or features of any example can be combined in any way and/or combination, unless such features are incompatible.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of an insulation pouch in accordance with an embodiment of the invention; and

Figure 2 is an illustration of an automated apparatus for manufacturing insulation pouches.

DETAILED DESCRIPTION