Invention: COMPOSITE AEROGEL THERMAL INSULATION SYSTEM

Abstract: The present invention provides methods and systems to effectively insulate hot or cold surfaces in industrial, domestic and building systems. It provides composite thermal insulation systems, which comprises at least two-layer thermal insulation cladding, with at least two layers each containing from 25 to 95% by weight of aerogel and from 5 to 75% by weight of inorganic fibres, wherein the layers of the thermal insulation cladding are joined to one another by means of an inorganic binder.

COMPOSITE AEROGEL THERMAL INSULATION SYSTEM


[0002] The present invention relates to composite thermal insulation systems, which comprises at least two-layer thermal insulation cladding, with at least two layers each containing from 25 to 95% by weight of aerogel and from 5 to 75% by weight of inorganic fibres, wherein the layers of the thermal insulation cladding are joined to one another by means of an inorganic binder.

[0003] In times of high energy costs, an effective thermal insulation system that reduces energy loss in both new buildings and the industrial plants are increasingly important. Composite insulation systems of this patent application may be used to keep heat inside a closed system, keep heat out of a closed system or minimize heat losses in or out in partially closed systems. Such composite thermal insulation systems comprise an insulation layer, preferably in the form of boards or flexible blankets, which are usually adhesively bonded to the insulated surface. Layers of render may be applied to the insulation layer in order to protect the insulation layer against weathering influences. It is usual to apply a base render which is reinforced with a woven fabric layer and is covered...
by a layer of covering render. Both render layers together are applied in thicknesses of from about 2 to about 7 mm, preferably less than 3 mm, when synthetic resin renders are used, while mineral render systems can reach thicknesses in the range from about 8 mm to about 20 mm. Different embodiments of the present application describe implementation of the invention in industrial settings or building settings. However, such embodiments are not limited to those settings. They are simply meant to illustrate the applicability of the present invention. Any surface that requires or benefits from thermal or acoustic insulation can make use of these embodiments and various embodiments of this application should be understood in such context. In a preferred embodiment, the composite insulation systems described herein are located and/or attached to the interior face of an external building wall. The strengths of insulation board and/or the load-bearing capacity of the surface of the building are generally not sufficient to ensure reliable long-term stability of a composite thermal insulation system having insulation elements which are merely adhesively bonded. For this reason, such insulation elements generally have to be secured, i.e. joined to the surface to be insulated (pipes, process equipment, exterior wall, roofs, ceilings, floors) by means of insulation fasteners. Here, partial adhesive bonding of the insulation elements to the supporting substrate, namely the exterior wall, serves only to aid mounting, with the stiffness of the insulation elements to withstand the shear stresses resulting from shrinkage of the render being increased at the same time.

[0004] The insulation fasteners are anchored into the supporting substrate. They have discs having various diameters in the range from about 50 to 140 mm, which are applied to
the side of the thermal insulation cladding farthest from the surface. Their load-bearing
capacity results from a metallic mandrel which at the same time spreads the anchor so as
to produce a frictional bond. The insulation fasteners are introduced either before
application of the reinforced base render layer or immediately after rendering. The discs of
the insulation fasteners are consequently either above or below the layer of render. A
significant advantage of installation of the insulation fasteners after rendering is that the
reinforcing fabric is therefore also held by the insulation fasteners, as a result of which a
more favourable low distribution and thus a possible reduction in the number of insulation
fasteners required per unit area is achieved.

[0005] The number of insulation fasteners is determined as a function of the height of
the structure whose surface is insulated, the intrinsic load which is not insignificantly
determined by the render thickness, the strength of the insulation material and the
diameter of the insulation fasteners. It is usual to install from two to eight insulation
fasteners per square metre, although up to fourteen insulation fasteners per square metre
may be necessary in edge zones. Such edge zones encompass from 1 to 2 m wide region
around the margin of the exterior wall to be insulated. A further increase in the number of
insulation fasteners necessary can result from the use of cut-to-size insulation elements
which is required for practical construction reasons. The costs for the composite thermal
insulation system increase with the number of insulation fasteners required, both in respect
of the materials required and in respect of the working time, since precise placement of the
insulation fasteners is necessary.
A further disadvantageous effect of the insulation fasteners embedded in or arranged underneath the layer of render is that the insulation fasteners show up on the surface due to reduced coverage in the case of weathering or penetration of moisture through the render. When the insulation fasteners are arranged in an irregular pattern, this gives disadvantageous visual effects.

Many insulation materials have been used in the past for the insulation layer of a composite thermal insulation system. In particular, polymeric foams, e.g. foams based on polyurethanes or polystyrene, mineral wool, glass fibres and also natural materials such as hemp, cork or perlites are used as insulation materials. However, conventional exterior wall insulation systems meet the desired requirements for the thermal insulation values only when appropriately thick layers of the respective material are used. Such massive buildups on the exterior walls, however, often spoil the overall aesthetic impression of the building and are therefore undesirable. Furthermore, such massive buildups mean that windows and doors have to be displaced and less light can shine into the interior rooms, which leads to a significant impairment of the quality of living.

It is known that hydrogels, e.g. silica hydrogels, which can be produced by precipitation of gel from water glass, can be dried under supercritical conditions to form microporous, three-dimensionally crosslinked silicon dioxide particles. Under the conditions of the supercritical drying, the surface tension of the fluid present in the
microporous, three-dimensionally crosslinked particles is completely or largely eliminated. The objective here is to avoid shrinkage of the microporous three-dimensionally crosslinked particles to a significant extent during drying, since characteristic properties of the microporous, three-dimensionally crosslinked particles are entirely or partly lost on shrinkage. Such a product obtained by supercritical drying is, in the case of gels, referred to as an aerogel. Unlike conventional drying without special precautions, in which the gels experience a large volume contraction and form xerogels, only a small volume contraction (less than 15% by volume) thus takes place during drying in the vicinity of the critical point.

Aerogels, in particular those based on silicates, are already being used in composite thermal insulation systems because of their very good insulating properties and have the advantage that they lead to a significantly lower buildup of the wall at a given insulation performance. A typical value for the thermal conductivity of silicate aerogels in air at atmospheric pressure is in the range from 0.017 to 0.021 W/(m-K). The differences in the thermal conductivity of the silicate aerogels are essentially determined by the different size of the pores resulting from the production process, which is in the range from 10 to 100 nm.

The prior art for the production of aerogels by means of supercritical drying is comprehensively described in, for example, Reviews in Chemical Engineering, Volume 5, Nos. 1-4, pp. 157-198 (1988), in which the pioneering work of Kistler is also described.
WO-A-95 06 617 relates to hydrophobic silica aerogels which can be obtained by reacting a water glass solution with an acid at a pH of from 7.5 to 11, removing most of the ionic constituents from the hydrogel formed by washing with water or dilute aqueous solutions of inorganic bases while maintaining the pH of the hydrogel in the range from 7.5 to 11, displacing the aqueous phase present in the hydrogel by an alcohol and subsequently drying the resulting alcogel under supercritical conditions.

The production of insulation boards from pulverulent aerogels and organic or inorganic binders and optionally further aggregates is known. For example, WO 1996/6015997 describes a composite material which comprises from 10 to 95% by weight of aerogel particles and at least one inorganic binder. However, such boards have the disadvantage that relatively large amounts of binders have to be used to obtain a stable board. However, this leads to the thermal insulation properties being significantly worsened compared to the aerogels; thermal conductivities of 0.15 W/(m-K) are reported in the examples.

Owing to a high degree of hydrophobicization, commercially available silicate aerogel powders have a high organic content. The hydrophobicization is necessary to be able to dry aerogels subcritically after they have been produced, without formation of xerogels occurring, i.e. severe shrinkage and thus a loss of the good thermal insulation properties (see "Aerogels", N. Husing, U. Schubert, Ullmann's Encyclopedia of Industrial Chemistry, Sixth Edition, 2000 Electronic Release, Wiley-VCH, Weinheim 2000). The
organic component introduced into the aerogels by the high level of hydrophobicization is problematical in terms of the burning behaviour. Commercially available silicate aerogel powders, for example Nanogel® from Cabot, are classified according to DIN 4102-1 into the burning class B1 (not readily flammable). However, for high-rise buildings up to a height of 100 metres, non-flammable systems (at least a burning class A2) are required. Industrial thermal insulation materials with high levels of organic content can also exhibit exothermic temperature rises in excess of 111 C when used at application temperatures up to and including 650C according to ASTM C411. The ASTM specification for mineral wool type insulation (ASTM C547) indicates that such a situation would entail a reduction in maximum operating temperature in order to avoid the aforementioned exothermic temperature rise. Control of organic content within composite aerogel materials is thus critical in achieving maximum operating temperatures. Other methods of determining maximum use temperature for industrial insulation materials are outlined in ASTM C447, which typically uses linear shrinkage under thermal load as a main criteria for determining maximum use temperature. The maximum temperature achievable while maintaining linear shrinkage values less than 2.0% is typically accepted as the maximum operating temperature for the thermal insulation material. Panels of aerogel insulation bonded with rigidized inorganic binders are expected to exhibit reduced shrinkage under thermal load relative to the parent insulation material.

[0013] Composite aerogel mats reinforced with fibres are at present being marketed commercially under the trade name Spaceloft® by Aspen Aerogel Inc. Thus, for example,
US 2002/0094426 describes a composite aerogel mat and its use. However, such mats are available only in low thicknesses (about 1 cm) because of the production process and the necessity of supercritical drying. Production by supercritical drying has the advantage that the aerogel has to be hydrophobicized to a lesser extent, which is advantageous in terms of the burning behaviour. However, these mats have the disadvantage that they have to be applied in a number of layers in order to achieve a satisfactory insulation performance. Here, each layer has to be fastened individually to the wall by means of insulation fasteners, which is labour intensive and expensive and can also lead to heat bridges. Furthermore, the fibres used in the commercially available composite aerogel mats generally comprise organic polymers and are thus problematical in terms of the burning behaviour.

Furthermore, WO 2010/046074 discloses a composite thermal insulation system for insulating a wall of a building, which system comprises a first thermal insulation board containing from 20 to 90% by weight of aerogel and a second thermal insulation board which contains mineral wool. In an alternative embodiment, the system can also comprise at least one composite board which contains mineral wool and from 20 to 90% by weight of aerogels.

It was therefore an object of the present invention to provide a composite thermal insulation system for the thermal insulation of an exterior wall of a building, which system has a very low thermal conductivity and thus achieves very good insulation
performance even at low layer thicknesses. The thermal insulation cladding should have such a structure that it is very easy to work by the user and can thus be matched on the building site to the circumstances of the building. At the same time, the thermal insulation cladding should have a high flexural strength and ideally be flat in order to achieve a very high long-term mechanical stability of the composite thermal insulation system.

[0016] This object has been achieved by a composite thermal insulation system for the thermal insulation of an exterior wall of a building, which comprises at least two-layer thermal insulation cladding, with at least two layers each containing from 25 to 95% by weight of aerogel and from 5 to 75% by weight of inorganic fibres and from 0 to 70% by weight of inorganic fillers, wherein the layers of the thermal insulation cladding are joined to one another by means of an inorganic binder.

[0017] The objective in respect of all requirements has been able to be achieved completely by the composite thermal insulation system of the invention. It has surprisingly been found that the composite thermal insulation system of the invention has a high long-term mechanical stability even when the thermal insulation cladding is adhesively bonded to the building, in particular by means of a mortar. In general, mechanical fastening points such as insulation fasteners can be dispensed with. Furthermore, it was surprising that the structure according to the invention makes it possible to obtain a composite thermal insulation system which is non-combustible. In a preferred embodiment, the composite thermal insulation system comes under burning class A2 in accordance with DIN 4102-1,
having a gross heat of combustion of less than 4 MJ per square metre and thus being suitable, inter alia, as a composite thermal insulation system for high-rise buildings.

[0018] The gross heat of combustion of the composite thermal insulation system is determined in accordance with DIN EN ISO 1716. This describes a method in which the specific heat of combustion of building materials is measured at constant volume in a bomb calorimeter. The gross heat of combustion is also referred to as the PCS (pouvoir calorifique supérieur) value or calorific potential. It is thus advantageous for the composite thermal insulation system to have a gross heat of combustion of less than 6 MJ per kilogram and preferably less than 4 MJ per kilogram. In preferred embodiment, the gross heat of combustion is less than 3 MJ per kilogram, particularly preferably less than 2 MJ per kilogram and in particular less than 1 MJ kilogram. Furthermore, the gross heat of combustion of the inorganic binders is less than 4 MJ per square meter of the surface of the composite insulation system and preferably less than 3 MJ and most preferably less than 2 MJ. Any coating materials that may be used in the embodiments of the present application has a gross heat of combustion of less than 10 MJ per square meter of the surface of the composite insulation system and preferably less than 6 MJ and most preferably less than 4 MJ. Coatings and binders are used in such quantities to serve their primary coating or binding purpose and at the same time allow minimal fuel content that may contribute to gross heat of combustion.
To achieve low PCS values, preference is given to using aerogels which are formulated to have intrinsically low gross heat of combustion. These can be obtained, for example, by controlling the content of low mass percentages of common surface treatment agents in silica aerogels \( \text{e.g.} \) trimethylsilyl moieties, making intrinsically low gross heat of combustion aerogel formulations with co-polymers of methylsilicate and other silicate polymers, or calcining various formulations of hydrophobic aerogel materials in the presence of oxygen to remove various quantities of hydrocarbon content responsible for the hydrophobic properties. In a preferred embodiment, the use of supercritical drying of an alcogel treated with a minimum of hydrophobic content is preferred to meet the requirements for burning class A2. Such a process is disclosed, for example, in WO 9506617. These processes make it possible to obtain aerogels having a low degree of hydrophobicization and thus a low gross heat of combustion.

In yet another preferred embodiment, the aerogels, which are preferably present in powder form, can subsequently be mixed with inorganic fibres and pressed to form boards, with an inorganic binder preferably being added. In particular, the inorganic fibres are mixed with the aerogels during production and before drying of the latter, enabling board-shaped components to be produced directly. In this regard, reference is made to US 6068882.

The thermal insulation cladding preferably has at least two layers, preferably at least three layers, which each contain from 35 to 65\% by weight of aerogel, from 15 to
65% by weight of inorganic fibres and from 0 to 50% by weight of inorganic fillers, in particular from 40 to 60% by weight of aerogel, from 25 to 50% by weight of inorganic fibres and from 0 to 35% by weight of inorganic fillers.

[0022] In a particular embodiment, the composite thermal insulation system of the invention comprises an at least three-layer thermal insulation cladding, with at least three layers each containing from 25 to 95% by weight of aerogel, from 5 to 75% by weight of inorganic fibres, from 0 to 20% by weight of organic fibers and from 0 to 80% by weight of inorganic fillers and each layer having a thickness in the range from 0.5 to 2 cm.

[0023] As regards the aerogels, all aerogels based on metal oxides are particularly suitable for the present invention. The aerogel is preferably at least one aerogel based on silicon, aluminium and/or titanium, in particular a silicate aerogel.

[0024] Shown in Table 1 are the fiber-reinforced aerogel products that have been used in conjunction with inorganic binders to produce bonded panels and/or rigidized shapes with thicknesses in excess of 10 mm. All commercially available aerogel/xerogel products are capable of being bonded with inorganic adhesives to afford a substantially thick bonded panel and/or shape. It is important to note that the use of inorganic adhesives, which have been utilized mainly for their negligible or near zero fuel content, are not solely relegated to the bonding of non-combustible or Euroclass A2 rated aerogel materials only. Composite aerogel materials with substantially reduced inorganic fiber
content (and subsequently higher heat of combustion values) can also be bonded with inorganic adhesives to form bonded panels and/or shapes. In order to maintain Euroclass A2 reaction-to-fire classification, a determination of non-combustibility, it becomes necessary to utilize inorganic adhesives for such products as Pyrogel® XT and Spaceloft®.

Table 1. Fiber reinforced aerogel products used to produce bonded insulation panels and/or shapes with inorganic binders.

<table>
<thead>
<tr>
<th>Product</th>
<th>Maximum Use Temperature (°C)</th>
<th>Typical Heat of Combustion Value (cal/gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrogel 10350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrogel 6350</td>
<td>250</td>
<td>2300</td>
</tr>
<tr>
<td>Pyrogel 3350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrogel XT</td>
<td>650</td>
<td>600</td>
</tr>
<tr>
<td>Spaceloft A2</td>
<td>200</td>
<td>650</td>
</tr>
<tr>
<td>Spaceloft / Cryogel</td>
<td>200</td>
<td>1800</td>
</tr>
</tbody>
</table>

Inorganic Adhesives: A number of inorganic binders or adhesives may be employed to produce bonded panels and/or shapes with thicknesses in excess of 10 mm. Such binders may be water based or based on other solvents. The water-based adhesives range from pure sodium silicate with various silica to sodium oxide ratios, to
commercially available silicate based mixtures containing various inorganic fillers. Shown in Table 2 are the adhesives used in aerogel panelization and their respective product composition.

Table 2. Inorganic adhesives utilized in bonding aerogel materials.

<table>
<thead>
<tr>
<th>Product</th>
<th>Manufacturer</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Silicate N</td>
<td>PQ Corporation</td>
<td>SiO2:Na2O = 3.22</td>
</tr>
<tr>
<td>Sodium Silicate D</td>
<td></td>
<td>SiO2:Na2O = 2.00</td>
</tr>
<tr>
<td>Stixso RR</td>
<td></td>
<td>SiO2:Na2O = 3.25</td>
</tr>
<tr>
<td>Supercalstik</td>
<td>Industrial Insulation Group</td>
<td>Sodium Silicate / Calcium Carbonate</td>
</tr>
<tr>
<td>Fosters 81-27</td>
<td>Specialty Construction</td>
<td>Sodium Silicate w/Kaolin Clay</td>
</tr>
<tr>
<td></td>
<td>Brands</td>
<td></td>
</tr>
<tr>
<td>Rutland Black</td>
<td>Rutland Company</td>
<td>Sodium Silicate w/Mica Filler</td>
</tr>
<tr>
<td>Childers CP-97</td>
<td>Specialty Construction</td>
<td>Sodium Silicate w/Talc Filler</td>
</tr>
<tr>
<td></td>
<td>Brands</td>
<td></td>
</tr>
<tr>
<td>Kasil</td>
<td>PQ Corporation</td>
<td>Potassium Silicate</td>
</tr>
</tbody>
</table>

[0026] Method of Application and Curing: The adhesives listed above can be applied to the surface of a composite aerogel using standard HVLP spray or direct application methods. It is typically advantageous to include a very small percentage (<0.02 wt%) of a
wetting agent within the inorganic binder. These wetting agents typically serve to reduce the interfacial surface tension of aqueous-based adhesive, enabling slight wet-out of the inherently hydrophobic aerogel surface and thus providing for substantially improved bond strengths. Failure to use a wetting agent typically results in weakened bond strengths at equivalent loadings due mainly to poor spreading of the substantially aqueous adhesive on lower surface energy substrates such as hydrophobic aerogel. Any type of anionic, cationic or non-ionic surfactants can be used. A list of common wettings that can be used are shown in Table 3.

Table 3. Surfactant/Wetting agents used to improve the compatibility of aqueous inorganic adhesives with an aerogel substrate.

<table>
<thead>
<tr>
<th>Surfactant/Wetting Agent</th>
<th>Type</th>
<th>Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brij</td>
<td>Non-ionic</td>
<td>Polyoxethylene glycol alkyl ether</td>
</tr>
<tr>
<td>Triton X-100</td>
<td>Non-ionic</td>
<td>Polyoxylethylene glycol octylphenol ether</td>
</tr>
<tr>
<td>Dow Corning Q2-5211</td>
<td>Non-ionic</td>
<td>Silicone polyether</td>
</tr>
<tr>
<td>CTAB</td>
<td>Cationic</td>
<td>Cetyl trimethylammonium bromide</td>
</tr>
<tr>
<td>SDS</td>
<td>Anionic</td>
<td>Sodium Dodecyl sulfate</td>
</tr>
</tbody>
</table>

In order to produce aerogel panels and/or shapes with thicknesses in excess of 10 mm, inorganic adhesives with the aforementioned surfactant/wetting agent are applied at a level between 10 and 600 grams (dry coat weight) per square meter, preferably between 50 and 400 grams per square meter, more preferably between 100 and 300
grams per square meter. Any and all of the inorganic adhesives can be diluted with water to provide for improved wet-out and to enable and ease application via spray methods.

[0028] Sodium or potassium silicate based adhesives can affect bonding by two distinct methods: (1) chemical polymerization or (2) evaporation of water/dehydration. Evaporation of residual water content in the aqueous-based adhesive can be conducted using common heating methods such as convection, radiative or dielectric heating. It is preferable to initially treat wet panels and/or shapes at a temperature of not more than 200F. Initial exposure of wetted panels/shapes above 200F resulted in diminished bond strengths due to the blistering and foaming of the silicate bond formed via the rapid/flash evaporation of water. After removing a minimum of 80% of the water from the inorganic adhesive at temperatures below 200F, it is possible and preferable to subsequently heat treat the bonded panel at temperatures between 200 and 700F, more preferably between 300 and 400F. Accelerated cure times can be achieved with all inorganic aqueous based adhesives using microwave curing techniques. Bonded panels and/or shapes using all of the adhesives listed in Table 2 have been produced with a cure time as low as 2 minutes using an off-the-shelf domestic (1.2 kW) microwave and a PVC or cardboard mandrel.

[0029] Inorganic silicate based adhesives can also affect bonding via chemically induced polymerization methods. A common method to polymerize monomeric alkaline silicates is via neutralization with acidic compounds. Chemical setting agents that react in such a manner include the following: mineral acids (phosphoric, hydrochloric, sulfuric),
organic acids, carbon dioxide (liquid, gas), or weakly acidic salts such as sodium bicarbonate, sodium tetraborate, aluminum sulfate or magnesium sulfate. Polymerization of alkaline silicates can also be affected at room temperature via treatment with sodium silico fluoride. Rapid curing of alkaline silicates can also be affected via treatment with non-enolizable aldehydes which undergo rapid disproportionation (i.e. Cannizarro) to generate acidic by-products, polymerizing the alkali silicate to form a substantially insoluble silica bond.

[0030] Flat panel or board-type insulation for horizontal, vertical or slanted surfaces may be prepared by the methods and structures of the present invention. When considering the insulation of flat surfaces, such as walls, ceilings, beams, doors and roofs, the construction of a flat panel, board-type insulation element is useful. Such insulation structure can also be located on the interior or exterior of the building. The creation of said structure, or system; comprising a composite of aerogel insulation, inorganic binder, coating material and potentially an exterior covering material; can be performed in many ways as explained by the different embodiments of the present application.

[0031] After the overall size of the insulation system is determined, a fiber-reinforced aerogel material is cut to this particular length and width (assuming that it is rectangular in shape, although it could be any shape to match the geometry of the building section that is to be insulated). Next, a certain amount of inorganic, or mostly inorganic binder is applied to one or both sides of each insulation layer, not including the exterior facing layers (i.e.,
the side facing the building and the side facing away from the building). The covering weight for this inorganic adhesive can be between 1.0-750 g/m². This insulation system may comprise a minimum of two layers of aerogel blanket. The maximum layers is limited only by the handling considerations. Typically, 20 or more layers of aerogel blanket may be combined using the described approach.

[0032] Once the layers of aerogel have been coated with the inorganic adhesive, each layer is stacked upon one another and the edges are aligned such that all of the layers create one geometric shape with smooth edges (such as rectangle, in this case). It is possible to trim the edges of said insulation element in post-production, after the inorganic binder has cooled/cured and either before or after the coating material and/or exterior covering material is applied. Weights may optionally be applied over the surface of the adhered layers to ensure that the insulation system layers are bonded tightly together, but they are not necessary. The flat panel type insulation system is then cured either at room temperature (allowing the solvent, usually water, in the inorganic binder to evaporate) or is accelerated by placing in an oven at 30-115°C. The temperature and duration of curing may be varied depending on the number of aerogel layers, amount and solids content of the inorganic binder and the geometry and/or shape of the aerogel system.

[0033] Once the inorganic binder is completely cured, it creates a semi-rigid, high-flexural strength board-type insulation element that is multiple layers of aerogel thick. At this time, a covering/coating material may be applied. This coating is polymeric in nature
and applied via spray, dip, gravure roll, meyer roll, knife-over-roll, knife-over-web, curtain, roll or extrusion coated. Initially, this coating material was applied via roll coating.

[0034] The board-type insulation element can be fastened to a vertical, horizontal or slanted structure via mechanical or chemical bonding - mechanical is typically preferred. Pin type fasteners are used to either puncture directly through the aerogel insulation system or fit into pre-drilled, pre-routed or pre-cut holes in the insulation system. The specific tip or type of pin fastener is selected based on the substrate that the aerogel system will be fastened to. Oftentimes, a hole will have to be drilled into the substrate in order for the pin to enter, expand and anchor itself via friction fit into the substrate structure. A disc is typically located on the opposite side of this pin type fastener. This disc is meant to distribute the load imparted by the fastener and physically hold the aerogel insulation system onto the substrate.

[0035] If needed, specific shapes can be cut out of a flat panel insulation system section. Cut-outs around windows, doors or vents; reliefs below eaves or drain-spouts or trimming of a panel to length at the end of a wall are all possible with this multi-layered solution. A static, hand-held utility knife is functional and probably the most common tool that would be used to cut the insulation panels.

[0036] For ease and quickness of installation on straight runs of pipe sections, creating a cylindrical geometry insulation element is most appropriate. This system takes
advantage of the flexibility of the aerogel blankets and the rigidity imparted by the inorganic binder between the aerogel layers.

[0037] A cylindrical form that matches the pipe diameter to be insulated in the final application was used to assist in the creation of this system. Aerogel layers are cut to length such that they made one or more revolutions around said form and one or more pieces of aerogel were used to create the final insulation element thickness (10-80mm). To construct this pipe-cover system, a certain amount of inorganic binder was applied to the surfaces of the aerogel layers that do not comprise the extreme inner or extreme outer surface of the finished insulation system cylinder, i.e., all of the aerogel surfaces that came into direct contact with another aerogel surface were covered. Then this/these piece(s) were wrapped around the cylindrical form as tension was applied to the aerogel plies tangentially to the form surface. Simultaneously, pressure was applied normal to the surface of the form, directly where the already-wrapped and yet-to-be wrapped aerogel layers meet. These two forces ensured that there were no air-gaps within the insulation system and that the aerogel layers were tightly wound and fastened together.

[0038] Temporary, mechanical straps may be affixed around the outer surface of the newly formed aerogel cylinder and the cylindrical form. These straps were used to ensure that the aerogel did not unwind during curing since the inorganic binder did not have enough wet-bonding strength to hold the aerogel in place prior to curing.
Curing of the inorganic binder may be performed at both ambient and elevated temperatures. An oven may be used to accelerate the curing process by evaporating the water solvent from the inorganic binder. Temperatures of 90-110°F were used and depending on the number of layers, thickness of aerogel plies, end-use pipe diameter and aerogel cylinder length, cure times varied from 1-7 hrs. Such cure times may be further reduced by controlling water content in the binder, use of higher curing temperatures and/or use of chemical curing agents.

Once the inorganic binder was fully cured, the resulting insulation element was a rigid, cylindrical, multi-layer unit of aerogel layers. This unit could have been further processed by way of a dust-mitigation coating or surface mesh or fabric treatment.

In another embodiment, a cylindrical shaped structure made with the above mentioned methods may be cut in half, down the pipe axis, using a cutting means such as a band-saw capable of cutting large diameter (2-20" OD) pipe sections. These two "clam-shell" sections maintain their hemi-cylindrical shape due to the rigidity imparted by the inorganic binder.

The clam-shell pieces of pipe-cover were installed around the appropriately sized pipe by way of mechanical strap fastening. Each section of the pipe insulation element was ~1m long and was comprised of two clam shell pieces, each clam shell covering 180° of pipe. The clam shell sections were held on the pipe by hand and
matched up with one another such that they started and finished flush to one another on both ends (ends are opposite one another along the pipe axis). Three stainless steel bands were used (0.5" wide x 0.020" thick) to permanently attach the cylindrical insulation element around the pipe in the circumferential direction. One band was placed in the center of the 1m length and two bands were placed 1-2" from either end of the pipe-cover insulation section.

An exterior pipe cladding or covering material could then be applied such as aluminum, stainless steel, painted metal or a synthetic material. The function of this cladding material would be to protect the insulation system from the elements, foot traffic or other damage during its service life.

Once the inorganic binder in a cylindrical pipe cover section is cured, it may be cut into individual gores using a band saw that was capable of cutting large diameter pipe insulation sections. A "gore" is an angled piece of insulation that, when laid flat, has a width that changes periodically with as a function of the piece length. When wrapped into a cylinder, they give the shape of a lop-sided ring that is longer (or thicker, when considering the aspect ratio of a "ring") on one side and shorter (or thinner) on the other.

These gore sections were then stacked upon one another such that all of the thin sections were matched up, creating the inner throat of a cylindrical pipe elbow. The thicker sections were all oriented such that they aligned to create the outer heel section of
a cylindrical elbow. This geometry was created based on the dimensions used to cut the
cylindrical pipe-cover. A smaller elbow (3" OD pipe, 90° elbow) has 3 gores and a larger
elbow (16" OD, 90°) has up to 12 gores. Once these gore sections were cut, the inorganic
binder was applied to the end surfaces (the surfaces that did not comprise the inner or
outer diameter surface of the hollow cylinder pipe-cover) and each gore was then stacked
upon another to create a rigid, three dimensional, cylindrical elbow structure.

[0046] A similar curing process was used to cure the inorganic binder as may be used
in the creation of the cylindrical pipe-cover sections. The elbow sections may be then cut
in half, along the pipe axis, with a band saw to form two "clam shell" sections of elbow-
shaped pipe-cover.

[0047] The thermal insulation cladding and the resultant systems of the present
application, comprised of at least two layers, can be formed into various panels and/or
geometrical shapes. While substantially planar panels, cylindrical shape, and gored/mitred
elbows are typically required in practice, other shapes such as curved, concave, convex,
beveled and/or s-curved panels are possible and are within the scope of the present
application. These varying geometries are used to closely match the surface to be
insulated such that the insulated surface is visually pleasing and consistent with the
original design of the structure. The inorganic binder helps creation of these shapes from
a flexible aerogel blanket material. This binder lends rigidity and a high-flexural strength to
the insulation system. A mechanical form, in the shape of the surface to be insulated,
used to impart the specific geometry to the insulation system. This form is used during the adhesion and/or curing process where the insulation layers are stacked up and adhered together.

[0048] In a preferred embodiment, the at least two-layer thermal insulation cladding is a board which is prefabricated and is joined to the other constituents on the building site to form a composite thermal insulation system. The thermal insulation cladding preferably has a thickness of from 250 mm to 10 mm, in particular from 100 mm to 20 mm and particularly preferably from 80 mm to 30 mm. The dimensions of the board can vary within wide ranges and the board preferably has a height of from 2000 to 800 mm and a width of from 1200 mm to 400 mm.

[0049] The inorganic binder by means of which the layers of the thermal insulation cladding are joined preferably has a layer thickness in the range from 0.05 to 1 cm, in particular from 0.1 to 0.6 cm and preferably from 0.15 to 0.4 cm. This can be mixed with fillers to form a mortar before application to the board and/or be provided with fillers by application and/or spraying after installation. In a further embodiment, the inorganic binder comprises polymers, in particular polar polymers and redispersible polymer powders, preferably homopolymers or copolymers composed of vinyl acetate, styrene, butadiene, ethylene, vinyl esters of Versatic acid and/or urea-formaldehyde condensation products, silicone and silicate resins and/or melamine-formaldehyde condensation products. Furthermore, the binder can contain thickeners, water retention agents, dispersants,
rheology improvers, antifoams, retardants, accelerators, additives, pigments and organic or inorganic fibres.

[0050] Joining of the at least two layers of the thermal insulation cladding by means of an inorganic binder has the advantage that a very good mechanical bond between the layers is achieved. Furthermore, a high flexural strength of the thermal insulation cladding is achieved. The at least two-layer thermal insulation cladding is preferably a board, so that this can be more easily transported to the site of use and processed there. Overall, significant use properties of the thermal insulation cladding are improved in this way. In a preferred embodiment, the inorganic binder by means of which the layers of the thermal insulation cladding are joined is at least one component selected from the group consisting of potassium water glass, sodium water glass, cement, in particular portland cement, and alkali-activated aluminosilicates, preferably potassium water glass.

[0051] To improve the insulation properties further, it is also possible, for the purposes of the invention, to add up to 50% by weight, preferably up to 10% by weight and in particular up to 5% by weight, based on the thermal insulation cladding, of pigments which scatter, absorb or reflect infrared radiation in the wavelength range from 3 to 10 μm. In particular, this can be carbon black. In this respect, reference is made to EP 0396076 A1, whose contents are hereby incorporated by reference into the application.
A preferred value of the thermal conductivity of the thermal insulation cladding of the invention in air at atmospheric pressure is \(< 0.020\) W/(m-K), in particular \(< 0.018\) W/(m-K) and particularly preferably \(< 0.016\) W/(m-K).

For the mechanical stability of the thermal insulation cladding, it is essential for the purposes of the invention for the cladding to contain fibres. In the case of inorganic fibres, these can be, in a preferred embodiment, glass fibres, rock fibres, metal fibres, boron fibres, ceramic fibres and/or basalt fibres, in particular glass fibres. It is also possible to mix a proportion of organic fibres into the thermal insulation cladding. Particularly suitable organic fibres are fibres based on polyethylene, polypropylene, polyacrylonitrile, polyamide, aramid or polyester. When adding the organic fibres, preference is given to the amount of organic fibres being selected so that the gross heat of combustion of the composite thermal insulation system is less than \(10\) MJ per kilogram. In a preferred embodiment, the composite thermal insulation system more particularly comprises \(< 1\%\) by weight of organic fibres and preferably no organic fibres, since, in particular, the simple workability, for example by means of a knife, is adversely affected by the flexibility of the organic fibres.

Furthermore, the thermal insulation cladding can contain inorganic fillers. These can be, for example, magnesium dioxide, titanium dioxide, titanium carbide, silicon carbide, iron(III) oxide, iron(I) oxide, zirconium silicate, zirconium oxide, tin oxide, manganese oxide or mixtures thereof, in particular magnesium dioxide or titanium dioxide.
In a preferred embodiment, the thermal insulation cladding is coated on the side facing the building and/or the side facing away from the building, preferably on the side facing the building and the side facing away from the building, with a polymeric material, in particular an acrylate coating, silicone-containing coating, phenol-containing coating, vinyl acetate coating, ethylene-vinyl acetate coating, styrene acrylate coating, styrene-butadiene coating, polyvinyl alcohol coating, polyvinyl chloride coating, acrylamide coating or mixtures thereof, with the coatings also being able to contain crosslinkers. With regard to the coating, it should preferably be ensured that the amount of polymeric material used is selected so that the gross heat of combustion of the coating is less than 4 MJ per square metre.

The inorganic binder for coating the thermal insulation cladding is in particular a hydraulic binder, preferably cement, in particular portland cement. Furthermore, geopolymers are also possible as binders. These are alkali-activated aluminosilicate binders, i.e. mineral materials which are formed by reaction of at least two components. The first component is one or more hydraulic, reactive solids containing SiO₂ and Al₂O₃, e.g. fly ash and/or metakaolin and/or cement. The second component is an alkaline activator, e.g. sodium water glass or sodium hydroxide. In the presence of water, contact of the two components results in curing by formation of an aluminosilicate-containing, amorphous to partially crystalline network, which is water-resistant. Furthermore, hydraulic lime can also be used as inorganic binder.
[0057] For coating of the thermal insulation cladding, the inorganic binder is preferably mixed with fillers to produce a mortar before application to the board and/or is provided with fillers by application and/or spraying after application to the board. In a further embodiment, the inorganic binder comprises polymers, in particular polar polymers and redispersed polymer powders, preferably homopolymers or copolymers composed of vinyl acetate, styrene, butadiene, ethylene, vinyl esters of Versatic acid and/or urea-formaldehyde condensation products and/or melamine-formaldehyde condensation products. Furthermore, the binder can contain thickeners, water retention agents, dispersants, rheology improvers, antifoams, retarders, accelerators, additives, pigments and organic or inorganic fibres.

[0058] In an embodiment, the inorganic binders described herein may be used to bind the insulation systems described herein to any surface that is to be insulated.

[0059] A further aspect of the present invention is a process for producing a thermal insulation cladding according to the invention, in which the at least two layers of the thermal insulation cladding are firstly joined by means of the inorganic binder and the thermal insulation cladding is subsequently coated if appropriate. The thermal insulation cladding is preferably simultaneously coated from both sides.
The process can, in particular, be carried out continuously and/or in an automated manner. It has been found that the process allows very wide variation in respect of the thickness of the thermal insulation cladding. As a result of the optionally simultaneous coating of the thermal insulation cladding on both sides, the cladding is stabilized particularly well and warping of the thermal insulation cladding is prevented.

Joining of the layers of the thermal insulation cladding can be carried out under pressure using all methods known for this purpose to a person skilled in the art. In particular, the at least two-layer thermal insulation cladding can be pressed between two counterrotating rollers. The surface of the rollers can be smooth. However, it can also be advantageous for the rollers to have a surface structure and the structure to be embossed on the surface of the thermal insulation cladding after joining of the layers. The adhesion on fastening to the surface of a building and the adhesion of the render can be improved in this way. It is also particularly advantageous for the side facing the building and/or the side facing away from the building of the thermal insulation cladding to be coated with an organic or inorganic binder after joining.

In a preferred embodiment, when the thermal insulation cladding is coated with any inorganic binder, a binder accelerator is brought into contact with the inorganic binder before and/or after application of the inorganic binder. Here, the accelerator is preferably brought into contact with the binder, preferably by spraying, shortly before application to the thermal insulation cladding. However, it is also possible for the accelerator to be
incorporated beforehand into the inorganic binder. In a further preferred embodiment, the accelerator is applied only after the binder layer has been applied to the thermal insulation cladding. This can once again preferably be effected by spraying. The accelerator can be, for example, a sulphate, nitrate, nitrite, formate, aluminate, silicate or hydroxide or a mixture thereof. Particular preference is given to aluminium salts such as aluminium sulphate and aluminium hydroxide, which are particularly preferably used as aqueous solutions.

[0063] The use of an accelerator has the advantage that the thermal insulation cladding has a high strength after a very short time. Hydraulic binders in particular in this way acquire optimal conditions during further curing since premature loss of water does not occur. Drying of the boards in an oven is not necessary in this case. This process according to the invention thus conserves resources particularly well and also leads to a significant cost reduction and improved stiffness of the board, based on the amount of inorganic binder used.

[0064] It is also possible for the thermal insulation cladding of the invention to comprise further layers; in particular, these layers can comprise glass fibres or rock wool. In a particular embodiment, the composite thermal insulation system of the invention has less than 4, in particular less than 2 and particularly preferably no, mechanical fastening points per square metre for joining to the wall of the building.
The thermal insulation cladding is preferably fastened to the exterior wall of the building by adhesive bonding. A mineral adhesive and reinforcing composition, in particular a composition based on white hydrated lime and cement, is, for example, suitable for this purpose. Furthermore, it is also possible to use an adhesive composition based on synthetic resin. In a preferred embodiment, from 1 to 50% by weight, in particular from 2 to 40% by weight, particularly preferably from 3 to 30% by weight and more preferably from 4 to 20% by weight, of aerogel, in particular silicate aerogel in powder form, is mixed into the adhesive. In this way, the layer thickness of the total composite thermal insulation system can be reduced further while maintaining the same heat transmission coefficient.

Suitable renders for the composite thermal insulation system of the invention are, in particular, mineral renders or decorative renders based on silicone resin. In a preferred embodiment, from 1 to 50% by weight, in particular from 2 to 40% by weight, particularly preferably from 3 to 30% by weight and more preferably from 4 to 20% by weight, of aerogel, in particular silicate aerogel in powder form, are mixed into the render. The thickness of the total composite thermal insulation system can be reduced further in this way at a given heat transmission coefficient.

The thermal insulation cladding in this case preferably contains from 5 to 75% by weight of inorganic fibres and from 0 to 70% by weight of inorganic fillers. In this context, further preference is given to the composite thermal insulation system having a
gross heat of combustion of less than 10 MJ per kilogram. In a preferred embodiment, the
gross heat of combustion is less than 4 MJ per kilogram or less than 3MJ per kilogram.

[0068] The preferred embodiments disclosed in respect of the main claim can correspondingly be advantageously applied to the abovementioned alternative embodiments of the invention and are in this context likewise to be considered to be preferred.

[0069] Overall, a composite thermal insulation system which has improved use properties is proposed. Owing to the structure, the thermal insulation cladding has a high flexural strength and the composite thermal insulation system of the invention has a high long-term mechanical stability. A further advantage of the system of the invention is that, in a preferred embodiment, it comes within the burning class A2 in accordance with DIN 4102-1 and can thus also be used as composite thermal insulation system for high-rise buildings.

The following examples illustrate the present invention.

[0070] Example One. Prototypes on panelized aerogels composites have been prepared utilizing Childers CP-97 and Pyrogel 6350 from Aspen Aerogels. Inorganic adhesive was applied to the surface of two plies of aerogel composite at a nominal loading of 75, 150 and 300 grams per square meter using HVLP spray application methods. The
wet panel was then cured at 90°C for 30 minutes, followed by an addition 16 hour heat treatment at 200°C.

[0071] The glued plies were subject to various conditions like high temperature treatment around 200°C, humidity environment (95% RH, 50°C) and later evaluated for their thermal conductivity and tensile strength using an Universal Instron test apparatus. Thermal conductivity was measured via methods outlined in ASTM C518 at 37.5°C. The shear strength of the plies were measured in accordance with the methods outlined in ASTM C800 and ASTM D5034.

[0072] Panelization and thickness expansion of Pyrogel 6350 in such a manner resulted in a substantially thick insulation system with thermal conductivity values unchanged or within 10% of that observed for the individual components.

Table 4. Shear strength of panelized Pyrogel 6350 bonded with Childers CP-97

<table>
<thead>
<tr>
<th>Glue Loading (GSM)</th>
<th>Shear Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>1.8</td>
</tr>
<tr>
<td>150</td>
<td>2.4</td>
</tr>
<tr>
<td>300</td>
<td>4.4</td>
</tr>
</tbody>
</table>

[0073] Example Two. Thickness expansion of Spaceloft A2, a non-combustible insulation blanket available from Aspen Aerogels, has also been conducted using inorganic binders. Specifically, a series of 10mm thick insulation samples measuring 20 x
20 cm were bonded to form a 50mm monolithic insulation system via application of sodium silicate N at each interply interface. The materials were allowed to dry at 80°C for 12 hours in a laboratory convection oven, followed by subsequent heat treatment at 120°C. The shear strength of panelized Spaceloft A2 prepared in such a fashion is shown in Table 5 as a function of nominal glue loading.

<table>
<thead>
<tr>
<th>Sodium Silicate N Loading (g/m2)</th>
<th>Shear Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>2.8</td>
</tr>
<tr>
<td>300</td>
<td>4.8</td>
</tr>
<tr>
<td>500</td>
<td>7.0</td>
</tr>
<tr>
<td>600</td>
<td>8.8</td>
</tr>
</tbody>
</table>

[0074] The thermal conductivity of the resulting 50mm Spaceloft A2 panels (prepared with 300 g/m2 sodium silicate N) was acquired according to the methods of ASTM C518 (3). The thermal conductivity values were within 10% of that observed for the individual layers. The heat of combustion values of a bonded 50mm panel of Spaceloft A2 was also determined according to the methods outlined in ISO 1716. Panels prepared in such a fashion exhibited an average heat of combustion value of 530 cal/g.

[0075] Example Three. Thickness expansion of Pyrogel XT using inorganic binders has also been conducted in a similar manner. Specifically, 20 x 20 cm samples of 10mm Pyrogel XT have been formed into 20mm rigid panels using sodium silicate N (containing
0.02 wt% Q2-521 (wetting agent) at nominal loadings of 300, 500 and 600 grams per square meter. Application of the adhesive to the interfacial area, followed by heat treatment in a convection oven at 80°C for 6 hours and a subsequent high temperature heat treatment at 120°C for 18 hours, resulted in a rigid panel with moderate shear strengths (Table 6).

Table 6. Shear strength of panelized Pyrogel XT bonded with sodium silicate N.

<table>
<thead>
<tr>
<th>Sodium Silicate N Loading</th>
<th>Shear Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>4.9</td>
</tr>
<tr>
<td>500</td>
<td>7.0</td>
</tr>
<tr>
<td>600</td>
<td>8.6</td>
</tr>
</tbody>
</table>

[0076] Example Four. Rapid set of inorganic adhesives or binders can be achieved via chemical setting methods. These methods typically entail the use of acidic compounds to promote silica polymerization and/or the addition of multivalent ions to promote rapid precipitation. Such a strategy was used to rapidly fabricate insulation systems of Spaceloft A2 with thicknesses in excess of 10mm. Specifically, a 10:1 (wt:wt) mixture of sodium silicate N and 40% glyoxal in water was applied to the interfacial area of two plies of Spaceloft A2. After a period of 10 minutes at room temperature the binder underwent a highly exothermic disproportionation (Cannizzaro) reaction to produce a mildly acidic byproduct, glycolic acid (4). The formation of this acid lowered the pH of inorganic binder, promoted silica polymerization and formed a rigid, largely insoluble bond.
Panels prepared in such a fashion were rapidly heat treated at 120°C for 15 minutes and were assessed for shear strength according to the methods outlined in ASTM D5034. Use of chemical set methods such as this one will significantly reduce the cure time of inorganic binders to produce bonds that have strengths equivalent to those produced via evaporation/dehydration methods.

Table 7. Shear strength of Spaceloft A2 panels bonded with sodium silicate N and using rapid set methods with glyoxal.

<table>
<thead>
<tr>
<th>Sodium Silicate N Loading (g/m²)</th>
<th>Shear Strength (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>5.8</td>
</tr>
<tr>
<td>500</td>
<td>6.6</td>
</tr>
<tr>
<td>600</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Example Five. Substantially thick insulation systems comprised of Spaceloft aerogel blankets are produced via the application Kasil (potassium silicate) or sodium silicate N to the interfacial area of each ply. These adhesives are typically utilized at a nominal loading of 100-600 m²/gram, more preferably at a loading of 200-400 m²/gram. They are used in conjunction with a Q2-5211 wetting agent at a loading of 0.02 wt%. This mixture is applied using spray and/or direct application methods. Wet plies are contacted together and subsequently dried via heat treatment at 80°C for 16 hours in a convection oven to form a rigid monolithic aerogel insulation system.

Example Six. The following example illustrates an aspect of the invention as depicted in Figure 1. Fig. 1 schematically shows the structure of a composite thermal
insulation system according to the invention. The composite thermal insulation system is affixed to a wall (1) of a building. Layer 2 is a reinforcing mortar based on white hydrated lime and cement (Heck K + A P/us® from BASF Wall System GmbH), to which 5% by weight of silicate aerogel powder (Nanogel® from Cabot Corporation) have been added and which has a layer thickness of from about 5 to 10 mm. The thermal insulation cladding is formed by five boards (3a to 3e). The boards 3a to 3e each have a layer thickness of 10 mm and comprise 50% by weight of silicate aerogel, 15% by weight of inorganic filler (magnesium oxide) and 35% by weight of glass fibres. A process for producing the boards 3a to 3e is disclosed in US 2002094426. The boards 3a to 3e are joined to one another by means of a potassium water glass binder (5), with in each case about 120 g of potassium water glass binder (5), based on the solids content thereof, being used per square metre of wall area for adhesively bonding two layers. A layer of a polymeric material (acrylate dispersion; not shown in Fig. 1) is present on both sides of the thermal insulation cladding between layers 2 and 3a and between layers 3e and 4, with about 90 g having been applied to each of the two sides of the thermal insulation cladding (3a to 3e), based on the solids content of the dispersion, per square metre of wall area. Layer 4 is a decorative render based on silicone resin (Heck SHP® from BASF Wall System GmbH), to which 8% by weight of silicate aerogel powder (Nanogel® from Cabot Corporation) have been added and which has a layer thickness of about 4 mm.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 illustrates an embodiment of the present application in relation to buildings.
Fig 2. Illustrates thermal conductivity of Pyrogel 6350 after panelization with Childers CP-97.

Fig 3. Illustrates thermal conductivity of 50mm panels of Spaceloft A2 bonded with sodium silicate N.

Fig. 4. Reaction of glyoxal with sodium silicate N to generate acid catalyst for curing.
Claims

1. Composite thermal insulation system, which comprises at least two-layer thermal insulation cladding, with at least two layers each containing from 25 to 95% by weight of aerogel and from 5 to 75% by weight of inorganic fibres and from 0 to 70% by weight of inorganic fillers, characterized in that the layers of the thermal insulation cladding are joined to one another by means of an inorganic binder.

2. Composite thermal insulation system according to Claim 1, characterized in that the inorganic binder is at least one component selected from the group consisting of potassium water glass, sodium water glass, cement and alkali-activated aluminosilicates.

3. Composite thermal insulation system according to Claim 1 or 2, characterized in that the aerogel is at least one aerogel based on silicon, aluminium and/or titanium.

4. Composite thermal insulation system according to any of Claims 1 to 3, characterized in that the inorganic filler is magnesium dioxide, titanium dioxide, titanium carbide, silicon carbide, iron(III) oxide, iron(I) oxide, zirconium silicate, zirconium oxide, tin oxide, manganese oxide or a mixture thereof.

5. Composite thermal insulation system according to any of Claims 1 to 4, characterized in that the inorganic fibres are glass fibres, rock fibres, metal fibres,
boron fibres, ceramic fibres and/or basalt fibres.

6. Composite thermal insulation system according to any of Claims 1 to 5, characterized in that the thermal insulation cladding is coated on at least one side with a polymeric material.

7. Composite thermal insulation system according to any of Claims 1 to 5, characterized in that the thermal insulation cladding is coated on at least one side with an inorganic binder.

8. Composite thermal insulation system according to any of Claims 1 to 7, characterized in that the thermal insulation cladding is an at least three-layer thermal insulation cladding, where at least three layers contain from 25 to 95% by weight of aerogel, from 5 to 75% by weight of inorganic fibres and from 0 to 70% by weight of inorganic fillers and each layer has a layer thickness in the range from 0.5 to 2 cm.

9. Composite thermal insulation system according to any of Claims 1 to 8, characterized in that the composite thermal insulation system has less than 4 mechanical fastening points per square metre for joining to a surface to be insulated.
10. Composite thermal insulation system according to any of Claims 1 to 9, characterized in that the each layer of insulation cladding has a gross heat of combustion of less than 10 MJ per kilogram.

11. Composite thermal insulation system according to any of Claims 1 to 9, characterized in that the each layer of insulation cladding has a gross heat of combustion of less than 6 MJ per kilogram.

12. Composite thermal insulation system according to any of Claims 1 to 11, wherein the system is located next to the interior face of an external building wall.
Fig. 1
Fig 2.

1 = After exposure to 95% RH, 50°C, 3 days
2 = After exposure to 220°C, 3 days

Glued PG6350

Thermal Conductivity (mW/mK)
Fig. 3.
Fig. 4.
A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B32B 27/20 (2012.01)
USPC - 428/500

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - B32B 3/00, 5/02, 5/16, 5/22, 5/28, 9/04, 27/00, 27/06, 27/20, 27/38 (2012.01)
USPC - 428/323, 328, 331, 411.1, 413, 414, 417, 473.5, 485, 500, 515

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

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

MicroPatent, Google Patents, Public PatFT and AppFT

C. DOCUMENTS CONSIDERED D. BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 6,068,882 A (RYU) 30 May 2000 (30.05.2000) entire document</td>
<td>1-3</td>
</tr>
</tbody>
</table>

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

Date of the actual completion of the international search 17 May 2012

Date of mailing of the international search report 30 May 2012

Name and mailing address of the ISA/US

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Authorized officer: Blaine R. Copenheaver
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Form PCT/ISA/210 (second sheet) (July 2009)
This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2.☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.☒ Claims Nos.: 4-12
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

This International Searching Authority found multiple inventions in this international application, as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2.☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Form PCT/ISA210 (continuation of first sheet (2)) (July 2009)