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Other: **EPODOC; WPI; Internet**

(54) Abstract Title**: Breathable insulation with infrared reflective coating**

(57) Thermal insulation comprises moisture vapour permeable, liquid water and air impermeable substrate 1 bearing a vapour permeable, liquid impermeable, low emissivity coating 2. Preferably, the coated substrate 3 is bonded 4 to on a non-woven fabric 5, to form a laminate 6. Preferably the coating 2 contains IR reflective, metal or mineral pigments. The insulation is used in buildings.

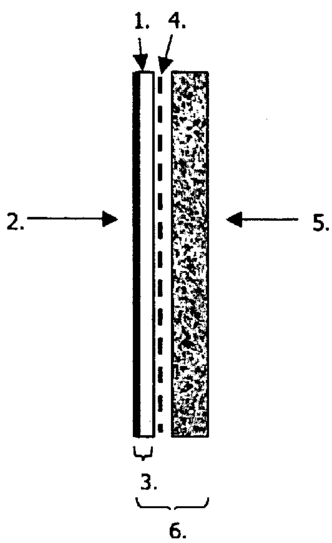

Figure 1.

GB 2 452 059 A

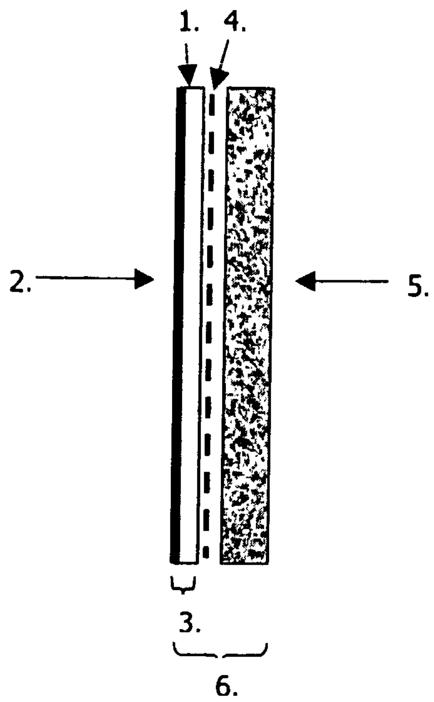

Figure 1.

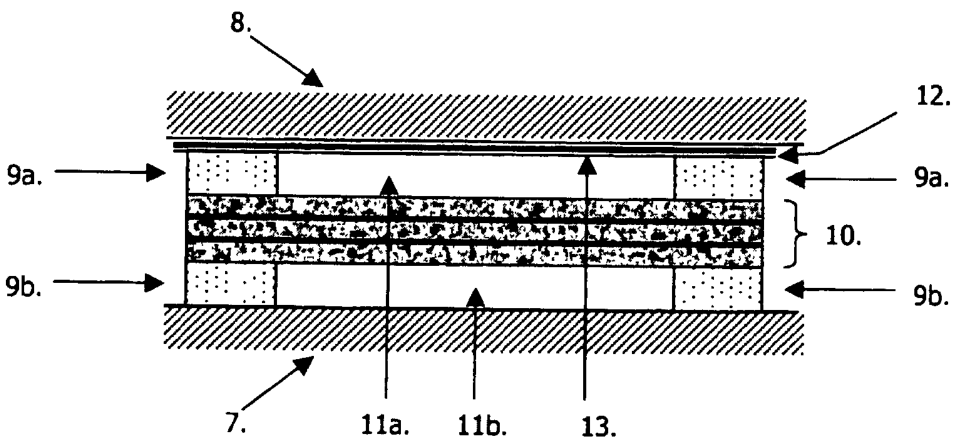

Figure 2.

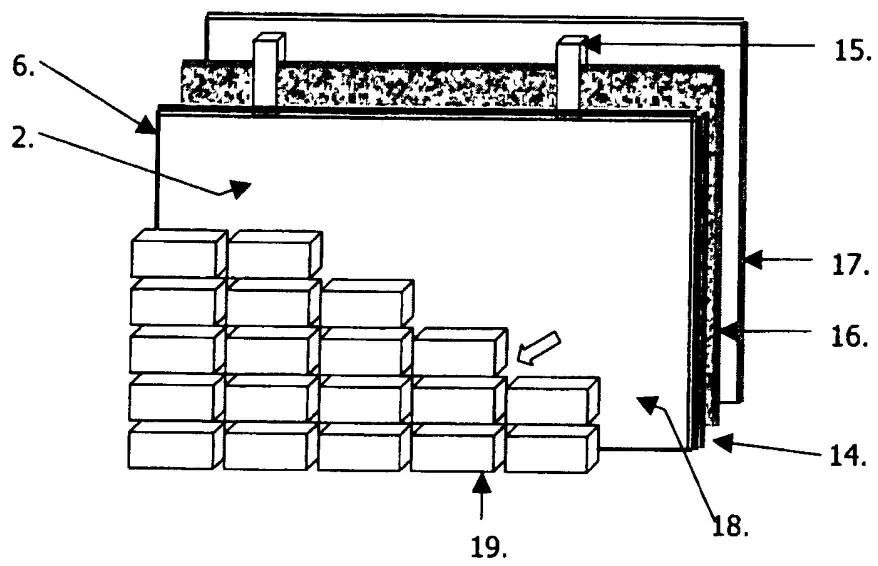

Figure 3.

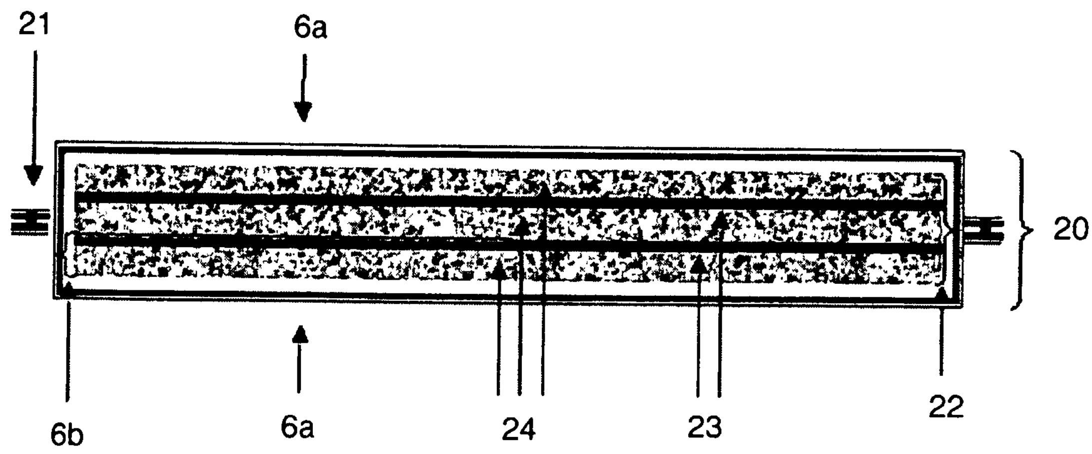

Figure 4

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Insulation Materials

This invention relates to the building and construction industries and more particularly but not exclusively to insulation materials, structures and products incorporating infrared reflective insulation for insulating roofs, walls and floors of buildings.

There is much focus on the subject of energy efficient buildings, both industrial and domestic dwellings. A leading organisation in the design of energy efficient building is the Passivhaus Institut in Darmstadt, Germany which has links to the Building Research Establishment (BRE) in the U.K. amongst others. A Passivhaus takes into account energy efficiency from its early design phase and includes the following basic features:

Compact form and good insulation	All components of the exterior shell of the house are insulated to achieve a U-factor that does not exceed 0.15 $W/(m^2K)$.
Building envelope air-tightness	Air leakage through unsealed joints must be less than 0.6 times the house volume per hour.

Such energy efficient buildings incorporate very high levels of insulation in all external-facing surfaces of the structure – roofs, walls and floors. Energy efficient buildings seek, by design, to use insulation to limit heat loss by the three routes of heat transfer, namely convection, conduction and radiation and in addition to limit heat loss through the mass transfer of air by uncontrolled leakage of air from the building.

Air leakage is seen as an increasingly important factor in energy efficiency and is now included in U.K building regulations "The Building Regulations 2000: Conservation of fuel and power", Approved Documents Part L introduced in April 2006.

The combination of high levels of insulation and low levels of air leakage saves energy by limiting the loss of heat from the building in cold climates and by limiting the requirement for air conditioning in warm climates. However, it increases problems of excessive moisture build-up within the building. A typical family of four people in a house can generate between 7 and 15 litres of water vapour on an average day. If the relative humidity of the air inside the house is allowed to increase uncontrollably, then problems due to excess moisture such as condensation, mould growth and an unhealthy atmosphere can occur.

To deal with excessive moisture a number of mechanical solutions are commonly used ranging from simple extract fans which pump warm, moist air from the building and hence lose valuable heat, to de-humidification systems fitted with heat exchangers to recover the heat from the warm, moist air being vented. Such systems themselves are not without problems, including noise and the requirement for maintenance in addition to using energy to function.

Insulation is commonly provided between and, or over or under rafters at roof level, or between and over joists at the floor level of the roof loft. Similarly, insulation may be provided between and over the studs of beams of walls and floors of timber or metal framed buildings.

Insulation may comprise glass or mineral wool batts or sheets. These are open structures, meaning that they incorporate fibres which have air spaces between the fibres that provide pathways for air to flow through the insulation structure as a whole. These insulation materials therefore cannot in themselves contribute to the reduction of air leakage in a building.

Rigid foam boards in which still air or other gas is trapped in a polymer matrix, usually polyurethane (PUR), are commonly used as insulation products. However, although these products have low thermal conductivities, typically 0.023 $W/m^2.K$, they are difficult to fit neatly between rafters or joists due to inconsistencies in rafter spacing and the natural bending and warping of the timbers. Air leakage will therefore occur through the gaps between the PUR rigid board and the timbers. Similarly air leakage can occur through gaps between adjacent PUR boards fitted over or under rafters, for example, especially if the roof is a complex shape requiring cutting of the PUR boards.

It is therefore advantageous for any thermal insulation installed in a building to contribute significantly to a reduction in air leakage whilst also allowing the passage of moisture vapour through it and hence through the building envelope. Excessive moisture can then diffuse through the insulation structure, reducing or obviating the requirement for mechanical ventilation systems.

It is known that materials that have infra-red reflective or low emissivity surfaces can contribute to the thermal insulation of a building. Unventilated air spaces or cavities are good barriers to thermal conduction whilst providing low emissivity surfaces adjacent to those air spaces improves the thermal barrier properties by reducing heat transfer across the air space by radiation. The properties of non-ventilated air spaces are well known and are described for example in

BS EN ISO 6946:1996 which gives the relevant equations for the thermal resistance of air spaces depending on their thickness and angle, and the emissivity of the adjacent surfaces. In this patent application the term reflective refers to infra-red reflective materials or surfaces, indicating reflection of electromagnetic radiation in the wavelength region 0.75 μm to 1000 μm. Emissivity is an expression of the amount of energy radiated by a surface such that an ideal surface emitting the highest theoretical level of radiant energy would have an emissivity, ε, of 1 and an ideal surface emitting no radiant energy would have an emissivity of 0. In practice all objects have an emissivity between 0 and 1. Further, in this patent application the term reflective is used to indicate a low emissivity surface i.e. a surface with ε less than 0.5. For reference, non-reflective materials such as wood, painted surfaces, glass, stone etc typically will have emissivities greater than 0.7.

Patent Application WO 2006/024013 A1, assigned to E.I. du Pont de Nemours (Du Pont), describes how a moisture vapour permeable, low emissivity composite can be made by depositing a reflective metal layer onto a moisture vapour permeable sheet, especially a flash-spun, high density polyethylene sheet manufactured and marketed under the trade-name Tyvek® by E.I du Pont de Nemours and Company, Inc. (Wilmington, DE). Such a reflective layer, if left exposed on the surface of the base layer is prone to degradation, by oxidation for example, with a consequent loss of reflectivity or increase in emissivity. WO 2006/024013 A1 therefore discloses a method of providing a protective coating to the reflective layer without blocking the majority of the micropores of the base sheet which would otherwise result in a loss of moisture vapour permeability. However, the process of providing the protective layer over the reflective metal layer without blocking the micropores of the underlying sheet is complex and difficult to achieve, requiring the use of monomers and / or oligomeric or other low molecular weight precursors, preferably radiation polymerisable and capable of rapid evaporation in a vacuum vapour deposition process to form the coating. The coating is then polymerised or cross linked by exposure to a radiation source, such as electron beam or ultraviolet for example. Furthermore, whilst it provides sufficient protection to the reflective aluminium layer for the intended application as a reflective wall breather membrane or reflective house wrap, it does also reduce the moisture vapour permeability of the microporous substrate.

European patent specification EP 1 331 316 A1 assigned to Thermal Economics Limited, describes how a breathable reflective material comprising aluminium in the form of a foil, laminate, veneer or vapour deposited coating on a textile substrate may be used as a reflective breather membrane in a wall cavity of a frame construction of a building. The aluminium layer optionally may be coated with a protective layer to protect the metal surface. In EP 1 331 316 A1, moisture vapour permeability, also referred to as "breathability", is provided in two ways, by microperforation of an aluminium layer attached to a moisture vapour permeable support layer such as a textile layer or by vapour deposition of an aluminium layer directly onto the textile layer. Although, the moisture vapour permeable layer provides a low emissivity surface next to an air cavity in the building, the coated textile structure is not resistant to the passage of liquid water or air and so cannot contribute significantly to a reduction in heat loss by air leakage for example.

UK Patent GB 2 388 815 B, ascribed to Don & Low Ltd., discloses moisture vapour permeable or moisture vapour impermeable, reflective film laminates for use in the construction industry. The moisture vapour permeability may be provided by a microporous film or, preferably, by microperforation of the reflective film layer. The reflective layer is formed by deposition of a metal layer on the base film, for example by plasma deposition of aluminium, or by a metal or metallic material provided as an additive to a polymer melt. The reflective layer may be protected by bonding a second film layer over the reflective layer to form an ABA type structure where B is the reflective layer or material. However, only film layers comprising thermoplastic synthetic polymer materials are described and, where moisture vapour permeability is required, refererence is made only to microporous or microperforated versions of those film layers. Reflective layers added to microporous films are prone to mechanical and oxidative degradation and protection is difficult without blocking the micropores of the film, as referred to already in the Du Pont patent application WO 2006/024013 A1. The Don & Low Patent does not address this issue but states a preference for microperforated film based structures. The advantage of microperforated film based structures is that the reflective metal layer can be well protected by providing an overlying film layer sandwiching the reflective material and thereby enabling it to withstand long periods of exposure even in aggressive environmental conditions. However, the microperforation of the film components means that the resistance to the passage of liquid water of products incorporating such film components is poor. The preferred structure disclosed in the Don & Low Patent, a reflective microperforated film thermally intermittently laminated to a polypropylene spunbond is manufactured commercially in the U.K. under the trade mark "Reflectashield"® by Don & Low Ltd. and has demonstrably poor liquid water resistance due to the presence of the microperforations in the reflective film components. Microperforation of insulation products or components also limits their usefulness in obviating or significantly reducing heat loss by air leakage. Although microperforated products have found use as roofing underlays, due to their poor performance their use in this application within Europe is now negligible. The use of Don & Low's

Reflectashield® product is therefore confined to wall breather membranes where the requirements for air and liquid water resistance are modest.

WO 2004/054799 ascribed to Building Product Design Ltd. and Spunchem Africa Pty Ltd describes how a heat reflective aluminium foil, applied to a surface of a moisture vapour permeable substrate such as a nonwoven fabric, may be made porous by stretching the composite between rollers producing multiple discrete cracks in the foil surface. The properties of the finished product are not disclosed quantitatively nor is the issue of protection of the reflective surface addressed. Nevertheless it is clear that moisture vapour permeability is created in an otherwise moisture impermeable material by the creation of apertures in the form of "cracks" in the foil surface. Thus the resultant laminate is functionally equivalent to the microperforated reflective laminate described in Don & Low Patent GB 2 388 815 B and equally would find limited application due to relatively low air and liquid water resistances.

The main object of the present invention is to provide an improved reflective, air and liquid water impermeable, moisture vapour permeable insulation material, in particular a laminated insulation material for use in the building or construction industries which obviates or mitigates the aforementioned problems.

Another object of this invention is to provide an improved reflective, air and liquid water impermeable, moisture vapour permeable insulation material in particular a laminated insulation material for use in the building or construction industries in which the reliance on components derived from mineral oil or gas is at least substantially reduced.

A further object of of this invention is to provide an improved reflective, air and liquid water impermeable, moisture vapour permeable insulation material, in particular a laminated insulation material for use in the building or construction industries which has significantly increased resistance to UV light exposure as compared to those currently available products based on UV-stabilised polypropylene or polyethylene materials.

In this specification the terms "building" and "construction" include domestic dwellings and industrial buildings, temporary dwellings or temporary industrial buildings, huts, agricultural constructions, such as barns, textile fabric building structures, caravans and mobile homes, and building and construction components used in buildings, such as water tanks and piping.

According to a first aspect, the invention resides in an insulation material for use in, or when used in, building and/or construction, the material including a moisture vapour permeable, liquid water impermeable, monolithic, dimensionally stable, substrate layer bearing an overlying moisture vapour permeable, liquid water impermeable, reflective or low emissivity film or membrane layer applied as a thin organic coating containing infra-red reflective matter, for example reflective particles and/or platelets and/or flakes.

In order more readily to meet the strength requirements of the building and construction industries, the substrate layer is ideally laminated to a strong support layer, i.e. a support layer having a strength which is greater than that of the substrate layer.

Accordingly, in a second aspect, the invention resides in an insulation material for use in, or when used in, building and/or construction, the material including a moisture vapour permeable, liquid water impermeable, monolithic, dimensionally stable, substrate layer bearing an overlying moisture vapour permeable, liquid water impermeable, reflective or low emissivity film or membrane layer applied as a thin organic coating containing infra-red reflective particles and/or, platelets and/or flakes, the substrate layer being laminated to a support layer having a strength which is greater than that of the substrate layer.

In order to facilitate preservation of the moisture vapour permeability of the substrate layer and not damage the coating layer, the support layer is advantageously laminated to the substrate layer by intermittent adhesive bonding.

In this specification, the terms sheet, film and membrane are regarded as equivalent terms unless otherwise stated and refer to the reflective coated substrate film layer, prior to lamination to the support layer.

The invention also comprehends use of any of the reflective coated substrate film layers defined herein in the building and construction industries in general and in a building in particular.

The substrate film layer of the invention may comprise films made from organic biopolymers such as suitable carbohydrates (starch, cellulose, glycogen, hemi-cellulose, chitin, fructans, inulin, lignin and/or pectin based materials), gums, proteins (animal or vegetable), colloids and hydrocolloids, polylactic, polygalactic and/or cellulose films in single sheet or multi-layer or composite sheets forms, including sheets based on paper technology. Multi-layer substrate films of the invention may be formed by coextrusion and/or by laminating. Particularly preferred materials for forming the substrate layer are cellulose and its derivatives and regenerated cellulose, for example that marketed by Innovia Films Limited under the trade mark Cellophane™.

The thickness of the substrate film layer may vary depending on the anticipated application with ~~but~~ any values in the range from 15 µm to 350 µm being appropriate as the application may be. Layers at the thinner end of the thickness range have the advantage of lower cost per unit area as well as higher moisture vapour permeability for a given composition.

The adherent coating layer may be formed from solvent or water based dispersions or solutions or from 100% actives systems requiring no solvent, by any of the known coating techniques without limit such as wire-rod coating, knife-over-roll, reverse-roll, gravure or other appropriate printing application techniques, extrusion, foam or spray coating.

Furthermore, the actual material of the coating layer may be cellulose derivatives, synthetic organic polymers, naturally occurring polymers and their derivatives. Cellulose derivatives includes cellulose ethers, esters and nitrocellulose for example. Suitable synthetic organic polymers include polyacrylic esters, polyvinyl acetate copolymers, polyurethanes, polyamides, polysulfones and polyvinyl alcohol copolymers. Naturally occurring polymers includes starches, chitin, fructan, lignin, gums and proteins and their derivatives.

Alternatively the coating layer may be comprised of a block copolymer and is preferably selected from materials which allow high transfer of moisture vapour by molecular diffusion. Suitable block copolymers will typically have polymer chains comprising high and low crystallinity sections. Examples of suitable block copolymers are styrene butadiene resins and hydrophilic polyurethanes such as polyester urethanes, polyether urethanes, polycarbonate urethanes and polyurethane urea polymers or combinations of these.

Thus, expressed in another way, the invention resides in a substantially planar, self-supporting layer of a sheet or film for use as, or when used as, an insulation material, including a substrate film layer bearing an overlying substantially continuous adherent thin coating layer comprising a block copolymer encapsulating a particulate metal or metal-coated pigment providing an emissivity on the coated surface of the substrate film layer less than 0.5, the reflective coated substrate film layer having a moisture vapour permeability greater than 1000 g/m^2/day (Lyssy test: 100%/15% RH, 23 C), the substrate film layer being preferably laminated to a support layer.

The advantages of applying the coating layer onto the substrate layer, as opposed to using a film consisting of the coating layer only, are those of cost, strength and dimensional stability. Generally the preferred materials forming the polymeric coating are expensive, soft and highly elastic.

In accordance with the invention therefore, it is advantageous to provide such layers in the form of a thin coating on the surface of a lower cost, stronger and more dimensionally stable substrate layer such as regenerated cellulose. Moreover, there are additional advantages when the incorporation of expensive reflective pigments is considered. It is possible to add such pigments to the substrate film layer directly rather than to a coating layer. However, since the substrate layer is necessarily a heavier weight or thicker gauge than is obtainable in a thin coating layer and indeed needs to be sufficiently thick to provide the strength to withstand subsequent handling and processing for its intended application, proportionally more of the expensive reflective pigments must be used to attain the same emissivity performance. It follows that it is advantageous to provide the required low emissivity through the economic use of smaller quantities of reflective pigment dispersed in a thin coating layer.

The reflective pigment dispersed in the coating layer is preferably a metal pigment or pigment which includes a reflective metallic surface. A wide range of metals may be used as pigments including, but not confined to, aluminium, bronze, stainless steel, brass, gold, nickel, silver, tin, copper or mixtures thereof. Alternatively mineral pigments such as glass or mica coated with reflective metal surfaces may be used. The reflective pigments are preferably in a flake or platelet form.

The emissivity of the coating layer for any particular reflective pigment and coating polymer is primarily dependent upon two variables, the amount of reflective pigment present in the coating and the thickness of the coating. Higher levels of reflective pigment will give lower emissivities but increased cost, and above critical addition levels the pigment may be insufficiently bound within the coating matrix. Expressing the amount of reflective pigment as a pigment to binder ratio, the pigment : binder ratio may be in the range from 3:1 to 1:10. The term "binder" is used to mean the dry or solvent-less polymer matrix forming the coating within which the pigment is dispersed. Coatings layers having lower pigment to binder ratios may still provide suitable low emissivity surfaces by increasing the coating layer weight per unit area which may range from 0.8 g/m^2 to 2.5 g/m^2.

Such reflective, liquid water impermeable, moisture vapour permeable materials are the subject of UK patent application number 0709974.0 by Innovia Films Limited, the subject matter of which is incorporated into the specification of the present application by reference.

The reflective, air and liquid water impermeable, moisture vapour permeable membrane formed by the reflective coated substrate film layer of the invention is not suitable for use in the building or construction industry as an unsupported layer. The membrane may have adequate tensile strength for use in construction industry applications but will typically have poor tear strength. Single films, whether formed by melt processes such as blowing or casting or by extrusion and regeneration from solutions, exhibit directional orientation at the molecular level. This molecular orientation is the main factor contributing to directionality in the physical properties of the film so that when considering tensile strength, for example, machine direction values frequently exceed those measured in the cross direction of the material as formed. Conversely, tear strengths are frequently lower when measured in the machine direction than in the cross direction so that any tear initiated in the film tends to orient itself along the weakest orientation and requires only low forces to propagate. Tear strength is important in building construction since such sheet materials are frequently fixed in position for use by nails or staples so that the puncture holes act as initiation points for tearing. The membrane therefore needs to be attached or laminated to a support layer to provide the physical robustness required for the intended application in the building and construction industries.

From a further aspect, the invention resides in a laminated insulation material for use in, or when used in, building and/or construction, and including a moisture vapour permeable, liquid water impermeable substrate layer bearing an overlying moisture vapour permeable, liquid water impermeable, reflective coating layer, the substrate layer being laminated to a support layer and the product components being predominantly derived from sustainable or renewable materials.

Such sustainable or renewable materials are those derived predominantly from natural biological materials.

By means of this aspect of the invention, the components of the reflective laminate which are derived from minerals, mineral oil or gas comprise a small minority of the laminated insulation material.

In order that the invention may be more readily understood, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is a cross-section of a laminated insulation material constructed in accordance with the invention;

Figure 2 is a cross-section of a test apparatus for measuring the thermal conductivity of multi-foil insulation without and including the laminated insulation material of Figure 1, together with associated unventilated air cavities;

Figure 3 is a perspective view from the front of a cavity wall frame structure of a building and incorporating the laminated insulation material of Figure 1 in a wall membrane; and

Figure 4 is a diagrammatic side view of a multi-layer insulation product including having outer layers formed by laminated insulation material of Figure 1.

Referring to Figure 1, there is shown an air and liquid water impermeable, moisture vapour permeable monolithic, dimensionally stable membrane constituting a substrate film layer 1 which forms the substrate for, and bears, an overlying adherent thin reflective or low emissivity coating layer 2 containing a dispersion of an infra-red reflective pigment (not visible) dispersed within the coating layer 2. The two component layers 1 and 2 combined form a moisture vapour permeable reflective coated substrate film layer 3. An intermittent adhesive 4 attaches the membrane constituting a moisture vapour permeable reflective coated film substrate layer 3 to a strong support layer 5 to form a laminated insulation material 6.

The invention will now be further explained by reference to the following Examples 1 to 4.

In these examples, emissivity has been measured to ASTM C1371-98 using a model AE Emissometer manufactured and supplied by Devices and Services Company, Dallas, Texas, U.S.A., calibrated using the low and high emissivity standards provided by the test equipment supplier and measured with the reflective coated side of the test sample facing the radiation source.

Moisture vapour permeability or moisture vapour transmission rate (MVTR) was measured using a Lyssy Model L80-5000 Water Vapor Permeability Tester at 100%/15% RH, i.e. 85% RH difference and 23 C.

EXAMPLE 1 - Membrane component (reflective coated substrate film layer) only

A membrane component was prepared using a 35 µm thick regenerated cellulose film (Cellophane™ film by Innovia Films Limited). This was gravure coated with a 0.9 g/m^2 polyurethane coating containing a reflective aluminium pigment, Mirato TF4679, at a pigment to binder ratio of 1:1. The emissivity, ε, of the reflective coated surface of the reflective membrane was 0.42 and the MVTR was 1444 g/m^2/24 hours.

EXAMPLE 2 - Membrane component + support layer component

The same gauge of regenerated cellulose film was coated using the same materials and the same pigment to binder ratio of 1:1 but with the coating layer weight increased to 2.2 g/m^2. The reflective film was then laminated using rotary gravure hot melt adhesive technology to a 50 g/m^2 basis weight polypropylene spunbonded nonwoven fabric as the support layer with the non-coated side of the membrane contacting the support layer. The adhesive coat weight was approximately 10 g/m^2 using an intermittent dot pattern to maintain the moisture vapour permeability of the laminate. The finished laminated insulation material therefore presented two opposing surfaces, one comprising the 50 g/m^2 polypropylene spunbonded fabric, the other comprising the reflective coating layer. The finished laminated insulation material (laminate) showed a reduced ε of 0.25 and the MVTR was 1198 g/m^2/24 hr. Thus the increase in coating weight, keeping other coating factors constant, gave a beneficial decrease in emissivity. Adhesive lamination of the coated film to the support layer produced only a modest apparent decrease in moisture vapour permeability.

EXAMPLE 3 - Membrane component + support layer component

Using the same materials, the pigment binder ratio was changed to 1.5:1 using the same coating layer weight as in example 2. In other words the content of reflective pigment in the coating was increased compared to example 2 keeping other materials and conditions the same. The reflective membrane was laminated as before to a 50 g/m^2 basis weight polypropylene spunbonded fabric. The laminated insulation material (laminate) had an emissivity of 0.20 and an MVTR of 1037 g/m^2/24 hr. Thus, increasing the reflective pigment content had a significant beneficial effect on the emissivity.

It will be understood that the differences in observed MVTR values will be a function not only of the weight of the reflective coating layer but also of normal process variations in the weight or disposition of the adhesive used to laminate the component layers.

The tensile strength, elongation and tear values of the Examples 2 and 3 were determined primarily by the polypropylene spunbonded fabric support layer and were very similar irrespective of the nature of the reflective coating layer. Typical values for the samples are given in Table 1:

Table 1: Typical physical values for laminates of Examples 2 & 3

	Basis Weight	Tensile Strength		Elongation at peak		Trapezoid tear strength		MVTR
		MD	CD	MD	CD	MD	CD	
	G	N	N	%	%	N	N	g/m^2/24hr
Typical values	93	182	104	19	34	53	66	1118

Test information

Basis weight: BS EN 1849-2:2001.

Tensile strength and elongation values: ISO 9073-3:89.

Trapezoid tear strengths: ISO 9073-4:89.

MVTR: 23°C, 100%/15% RH, Lyssy Model L80-5000 Water Vapor Permeability Tester

EXAMPLE 4 - Membrane component + support layer component

In a forth example a reflective film was then laminated using rotary gravure hot melt adhesive technology to a 100 g/m^2 polypropylene spunbonded nonwoven fabric as the support layer with the non-coated side of the membrane contacting the support layer. The adhesive coat weight was approximately 18 g/m^2 using an intermittent dot pattern to maintain the moisture vapour permeability of the laminate. The finished laminate therefore presented two opposing surfaces, one comprising the 100 g/m^2 polypropylene spunbonded fabric, the other comprising the reflective coating.

A comparison of the properties of the unlaminated reflective **coated substrate film layer** component and of the adhesively laminated insulation material is given in Table 2.

Table 2: Comparison of reflective coated substrate film layer and laminate properties

	Basis Weight	Tensile Strength		Elongation at peak		Trapezoid tear strength		MVTR	Emissivity
		MD	CD	MD	CD	MD	CD		
	G	N	N	N	N	N	N	g/m^2/24hr	E
Reflective film layer	34	100	57	6	17	0.46	0.62	1752	0.18
Reflective laminate	152	220	125	44	50	94	88	1276	0.18

Test information

Basis weight: BS EN 1849-2:2001.

Tensile strength and elongation values: ISO 9073-3:89.

Trapezoid tear strengths: ISO 9073-4:89.

MVTR: 23°C, 100%/15% RH, Lyssy Model L80-5000 Water Vapor Permeability Tester

Emissivity: ASTM C1371-98 using a model AE Emissometer

Thus it can be seen that although the reflective **coated substrate film layer** component prior to lamination has a useable tensile strength, its tear strengths are very low indeed precluding its application as a product by itself. The physical strengths of the laminate are of course greatly improved especially in relation to tear strength whilst the moisture vapour permeability and emissivity are still excellent.

Examples of uses

Outer layers of multi-foil insulation

The laminated insulation materials of the invention described in Examples 2 and 3 are particularly suitable for use as the outer layers of a multi-foil reflective insulation material. Such multi-foil insulation materials are the subject of the applicant's patent application WO 2006/043092 A1 which discloses a thermal insulation structure comprising a plurality of inner water vapour permeable, air impermeable, reflective film layers alternating with a plurality of inner air and water vapour permeable insulating spacer layers which entrap air and separate the reflective layers. The inner layers are sandwiched between outer layers which are moisture vapour permeable, air impermeable layers having low emissivity outer surfaces. The whole multi-foil structure acts as a thermal insulation product limiting heat loss by obviating or minimising air leakage in addition to reducing heat transfer by conduction, convection and radiation , including the thermal benefit of the unventilated air spaces adjacent to the outer low emissivity surfaces whilst allowing excess moisture vapour to escape through it.

While the laminates of Examples 2 and 3 could find use as the inner reflective layers of the multi-foil insulation it would be economically advantageous for this particular application if the reflective membrane were laminated to a lower cost, lighter weight substrate. In the structure of a multi-foil insulation product, it is the outer layers which are required to have the strength to withstand being held in position by nails or staples. The inner reflective layers contribute little or nothing to this and so the use of lighter weight laminates as inner layers is appropriate. A spunbonded nonwoven fabric with a basis weight less than 20 g/m^2 would be an example of a suitable lightweight support layer although a wide range of lightweight materials would be suitable including, without limit, carded nonwoven fabrics, woven or knitted fabrics, nets or scrims, apertured films and papers. An alternative approach would be to laminate the reflective membrane component of the invention directly to the wadding, foam or other material used to form the air permeable layers separating the reflective membrane layers in the insulation structure disclosed in WO 2006/043092 A1. In this case the laminated insulation material (laminate) of this invention comprises the reflective membrane component plus the air permeable spacing or separating layer which then also acts as the support layer.

An example of a low emissivity, air and liquid water impermeable, moisture vapour permeable insulation made using both inner and outer layers of this invention is described in Table 3 below with a currently commercial, moisture impermeable multi-foil insulation made and sold under the trade mark Thinsulex™ by Web Dynamics Limited, for comparison.

Table 3: Physical data of multi-foil insulation products

	Thinsulex™ impermeable multi-foil insulation	Multi-foil insulation product made using reflective layers of this invention

Table 3: Physical data of multi-foil insulation products		
	Thinsulex™ impermeable multi-foil insulation	**Multi-foil insulation product made using reflective layers of this invention**
Emissivity of outer layers	0.4	0.22
Typical moisture vapour permeability of one inner layer, g.m⁻2/24hr	<1	1600
Number of PET wadding layers	5	5
Number of inner reflective layers	4	4
Emissivity of inner reflective layers	0.05	0.22
Total thickness of insulation, mm	30	30
Basis weight of insulation, gm^{-2}	698	720
Thermal conductivity, W/mK (including 2 x 25mm air cavities)	0.0545	0.0533

Laminated insulation materials (laminates) of the invention may also be used as reflective or low emissivity, air and liquid water impermeable, moisture vapour permeable roofing underlays. In this application a strong support layer is required both to withstand the handling required during installation and the forces exerted upon it over a long period once installed. Roofing underlays may be subject to strong wind uplift forces, for example, where low elongation values under tensile stress are an advantage. Spunbonded polypropylene nonwoven fabrics are commonly used as the main components providing mechanical strength to commercially available synthetic roofing underlays. A polypropylene spunbonded fabric or spunbonded fabric layers giving a basis weight either singly or combined of at least 80 g/m^2, preferably ≥100 g/m^2, would be suitable for support layers of the invention for this application.

Thus Example 4 is an example of structure which would be suitable for use as a low emissivity, air and liquid water impermeable, moisture vapour permeable roofing underlay. Such support substrates may advantageously contain additives such as pigments, extenders, flame retardants, heat and UV-stabilisers, and surface modifiers such as hydrophilic or hydrophobic additives, used either singly or in combination. Such a low emissivity roofing underlay is particularly advantageous when used in combination with a low emissivity insulation product, examples of which include multi-foil insulation products or rigid foamed board insulation panels having low emissivity outer surfaces. The reflective roofing underlay is advantageously arranged so that an unventilated air cavity is formed bounded by two low emissivity surfaces, one the low emissivity surface of the roofing underlay, the other of the insulation.

The advantage of a low emissivity roofing underlay in accordance with the invention has been demonstrated by measuring the thermal conductance of a multi-foil insulation product positioned between two expanded polystyrene spacing frames to provide two unventilated air cavities, one above and one below the multi-foil insulation. The thermal conductance of the same multi-foil insulation may then be re-measured but with a low emissivity roofing underlay inserted above the upper air cavity.

Referring to Figure 2, a test apparatus consists of a heated lower test plate, 7 and an upper test plate 8 which contains thermocouples so that the heat flux from the surface of test plate 7 to the surface of the upper plate 8 can be measured. The test apparatus is normally used according to test method BS EN 12667:2001 with the two test plates, 7 and 8, in direct contact with the insulation sample under test. However, to take into account the low emissivity surfaces of the insulation materials relevant here, including the low emissivity roof underlay constructed in accordance with this invention, the test method was adapted so that the multi-foil insulation product 10 was positioned between two expanded polystyrene spacer rings 9a and 9b to form unventilated cavities 11a and 11b above and below the multi-foil insulation. The spacer rings 9a and 9b were 25mm thick therefore forming 25mm thick unventilated air cavities 11a and 11b. With this arrangement the thermal conductivity of the multi-foil insulation 10 together with the unventilated air cavities 11a and 11b was measured. The experiment was then repeated but with a roofing underlay 12 of this invention positioned between the upper spacer ring 9a and the upper test plate 8 so that its low emissivity surface 13 faced into the cavity 11a. The test results are given in Table 4.

Table 4: Effect of low emissivity roof underlay on thermal insulation properties

Test materials	Thickness, mm (incl. cavities)	Conductivity, λ W/mK	Thermal resistance, R m^2K/W

Standard Thinsulex™	78	0.0545	1.43
Standard Thinsulex™ + Low emissivity roofing underlay	78	0.04447	1.75
Note 1: Thinsulex™ = Impermeable multi-foil insulation, 30mm thick, ε (outer surfaces) = 0.4 Note 2: Low emissivity roofing underlay = moisture vapour permeable, coated film + 50g/m^2 polypropylene spunbonded nonwoven fabric support layer, ε (side towards cavity) = 0.22			

Table 4 therefore shows the effect of changing the emissivity of the upper boundary surface of a 25mm thick, unventilated air cavity from >0.8 to 0.22 with the lower boundary surface of the air cavity being formed by one of the outer surfaces of a standard multi-foil insulation product. The thermal resistance of the whole insulation structure, multi-foil insulation plus unventilated air cavities is thus improved by the additional use of a single, low emissivity roof underlay having a thickness of only 0.4mm.

Air leakage is an important factor in energy loss in buildings and a roofing underlay can contribute significantly to a reduction in air leakage. The air permeability of a laminated reflective insulation material (laminate) of this invention is compared in Table 5 to those of two commercially available moisture vapour permeable reflective products: an aluminised microporous product manufactured and marketed by Du Pont under the trade mark Tyvek® Reflex® and a micro-perforated wall breather membrane manufactured under the trade mark Daltex Reflectashield™ by Don & Low Limited.

Table 5: Comparison of air permeability

	Product type	**Air Permeability, mm.s^{-1}**	**N**
Reflective laminate of this invention	Coated non-porous film laminate	Zero	10
Tyvek Reflex	Coated microporous nonwoven	0.3	10
Daltex Reflectashield	Micro-perforated film laminate	19.3	10

Test information:
BS EN ISO 9237:1995 Test area = 5.0 cm^2 Pressure drop = 200 Pa

Since laminates made using the reflective coated film substrate of this invention have zero air permeability, building products such as insulation products and roof underlays made in accordance with this invention can provide a significant contribution to the reduction in air leakage of the building in which they are installed especially if overlaps are battened or taped with an adhesive tape along their length.

The structure described for use as a low emissivity, air and liquid water impermeable, moisture vapour permeable roofing underlay may also be suitable for use in walls as a component variously and interchangeably described as a wall membrane, breather membrane, wall breather membrane or house-wrap and here referred to as a wall membrane. Such membranes are attached to the inner frame structure adjacent to the air cavity between the frame structure and the outer component wall. The frame may be of timber or timber-based components such as oriented strip board for example, but might be of steel. Such a frame structure, showing the location of the wall membrane, is illustrated in Figure 3 by way of explanation. The low emissivity wall membrane of this invention, 6, provides protection for the frame structure consisting of the sheathing board, which may be, for example, oriented strand board, 14, and the studs, 15, between which is placed insulation material 16, located between the sheathing board 14 and plasterboard 17.

Such protection is especially important during construction before the outer wall, 19, is in place. It also protects the frame structure from the effects of any moisture which may condense in the cold air cavity, 18. The low emissivity surface, 2, facing into the cavity, 18, increases the thermal resistance of the air layer in the cavity. This advantage is well understood and is described, for example, in Patent Applications EP 1 331 316 A1 assigned to Thermal Economics, WO 2006/024013 A1 assigned to Du Pont and GB 2 388 815 B assigned to Don & Low Ltd discussed earlier. However, the low emissivity wall membrane of this invention has the advantage of significantly higher moisture vapour permeability combined with very high liquid water resistance than prior art products. This is illustrated in Table 6 in which a coated low-emissivity film of this invention has been compared to a commercially available micro-perforated film laminate sold as a wall membrane under the trade mark Daltex Reflectashield™ and manufactured by Don & Low Limited and to an aluminised microporous product marketed under the trade mark Tyvek® Reflex® and manufactured by Du Pont.

Table 6. Comparison of breathable, low emissivity laminates			
	Reflectashield® (Micro-perforated)	**Tyvek® Reflex® (Microporous)**	**Coated laminate of this invention (Example 4)**
Basis weight, g/m^2	120	85	152
Moisture vapour permeability (MVTR), $Gm^{-2}/24hr$	578	593	1276
Emissivity	0.21	0.19	0.18
Hydrostatic head, cm H_2O	34 average 33 minimum	210 average 185 minimum	>500 >500

Test information

Basis weight: Nominal quoted values for Reflectashield® and Tyvek® Reflex®, confirmed by measuring average of 10 samples to BS EN 1849-2:2001.

MVTR: 23°C, 100%/15% RH, Lyssy Model

Emissivity: ASTM C1371-98, using a model AE Emissometer.

Hydrostatic head: BS EN 20811:92 at 60cm/min taking the endpoint as the first breakthrough. Average of three tests. Laminate of this invention did not show any signs of water breakthrough at a hydrostatic head of 500cm when the test was stopped.

Thus, the data presented in Table 6 shows that the laminate of this invention is considerably superior to the microperforated and microporous products in respect of moisture vapour permeability and hydrostatic head whilst having a very similar emissivity.

The reflective membrane component of this invention may alternatively be laminated directly to a rigid component of a building, for example to the sheathing board of a frame construction building. In this case, the rigid component, for example oriented strip board (OSB) sheathing, is the support layer of the laminate of this invention. This would only be practical for application in a factory environment where frame sections, complete with their wall membrane and optionally with insulation, are manufactured as ready-to-assemble units since the reflective membrane component is insufficiently robust to withstand the rigors of on-site application.

The Applicant's Patent Application 0705558.5 discloses how infra-red reflective structures, alternatively described as low emissivity structures, can increase the thermal insulation of buildings by ensuring that unventilated air spaces are bounded by at least three such low emissivity surfaces. It describes the relationship between the thermal resistance of the unventilated air space and the emissivity of the surfaces adjacent to the air spaces. The low emissivity layers may be arranged to bound one or more unventilated air cavities without the requirement for waddings or other "spacer" or separation layers between the low emissivity layers taking advantage of the very low thermal conductivity value of air, 0.025 W/mK. Laminates of this invention would be suitable for use as low emissivity layers for the invention described in Patent Application 0705558.5 especially in the configuration described as particularly advantageous when both opposing surfaces bounding the air cavity are low emissivity so that one surface will reflect incident radiation whilst the opposing surface will absorb very little incident radiation.

The reflective membrane component (reflective coated film substrate) of this invention is preferably regenerated cellulose and coated, as described, with a thin reflective coating layer. The coating layer of this invention may be synthetic in the sense that it may be derived from oil or mineral-based raw materials whilst the regenerated cellulose which forms the substrate layer is derived from renewable vegetable sources, usually trees. Since oil and minerals are finite resources they are regarded as non-renewable. As they become increasingly scarce, prices will increase and their conservation becomes increasingly important. The use of materials based on natural or renewable raw materials is therefore an advantage and contributes to the reduction in the use of non-renewable materials. If the coating layer is based on synthetic, non-renewable materials, expressing the upper limit of the coating layer weight of this invention, 2.5g/m^2, as a percentage of the lowest substrate weight gives the maximum percentage of non-renewable content for the reflective membrane component of this invention. The lowest thickness of the film substrate of this invention is 15μm. At a density of 1.44 (the density of regenerated cellulose) the substrate basis weight is 21.6g/m^2. Hence the maximum percentage of non-renewable based material in the reflective membrane component of this invention is (2.5 x 100)/(21.6+2.5) = 10.4%. A similar calculation based on a more typical structure, a 0.8g/m2 coating weight on a 20μm regenerated cellulose film gives a non-renewable content of only 2.7%. If the support layer of the insulating material of this invention is also based on renewable raw materials then the percentage of non-renewable material in the laminate of this invention may be extremely low i.e. considerably lower than 1%.

Support layers of this type may be based on wool, cotton, flax, jute, or similar textile fibres or may themselves be based on regenerated cellulose for example, viscose fibres, or may be mixtures of such fibres. The support layer may be in the form of traditional textiles for example woven or knitted fabrics, or may be in the form of nonwoven fabrics including those formed by hydroentanglement, carding and latex bonding technology, needling, latex spray bonding or similar methods of consolidating fibrous webs known in the art used singly or in combination. Support layers comprising predominantly renewable raw material fibres may be combined with a minority of synthetic fibres including bicomponent fibres. The latter may be used to consolidate the fabric by thermally bonding the predominantly renewable fibre web. Alternatively the support layer may be a paper or a wet-laid nonwoven or a material comprising predominantly short length fibres reinforced by longer textile fibres. A paper reinforced by viscose fibres would be an example of such a material.

By using a coated regenerated cellulose film laminated to a renewable support layer i.e. a support layer comprised wholly or predominantly of fibres which are renewable or derived from renewable materials, multi-layer insulation products, roofing underlays, wall membranes and other reflective building insulation products of this invention may be made which are wholly or predominantly based on renewable materials.

An example of such a multi-layer insulation product based predominantly on renewable materials is given in Figure 4 to which reference will now be made.

A multi-layer insulation material constituted by a product 20 includes outer layers of the laminated insulation material of this invention 6a comprising a reflective membrane component (reflective coated film substrate such as 3 in Figure 1) laminated to a needled wool nonwoven or wool felt support layer welded along the long or machine direction edges as indicated at 21, as by ultrasonic bonding for example. The welded outer layers 6a enclose an insulation core 22 comprising alternating layers of laminates 6b of this invention in which a reflective membrane component 23 is laminated to a lightly needled wool fleece or wadding 24 which acts to maintain a space of at least 5mm between the reflective membrane components 23 or 6a. An insulation core 22, comprises three layers of laminate 6b. However, it will be appreciated that the number of such layers 6b may vary according to the insulation performance and application required.

Various modifications may be made to the embodiments and examples herein described with out departing from the scope of the invention as defined ın the appended claims. For example, it will be appreciated that other materials based on renewable components may be used as the support layer for the reflective coated film layer and as the space component 24 to produce a finished reflective insulation product based on predominantly renewable materials.

Claims

1. An insulation material for use in, or when used in, building and/or construction, including a moisture vapour permeable, liquid water and air impermeable, monolithic, dimensionally stable, substrate layer bearing an overlying moisture vapour permeable, liquid water impermeable, low emissivity layer applied as an adherent thin organic coating containing a dispersion of infra-red reflective matter.

2. An insulation material as claimed in claim 1, wherein the substrate layer is laminated to a support layer having a strength which is greater than that of the substrate layer.

3. A laminated insulation material for use in building and/or construction, including a moisture vapour permeable, liquid water and air impermeable, monolithic, dimensionally stable, substrate layer bearing an overlying moisture vapour permeable, liquid water impermeable, low emissivity layer applied as an adherent thin organic coating containing a dispersion of infra-red reflective matter, the substrate layer being laminated to a support layer having a strength which is greater than that of the substrate layer.

4. An insulation material as claimed in claim 2 or claim 3, wherein support layer is laminated to the substrate layer by intermittent adhesive bonding.

5. An insulation material as claimed in any of claims 1 to 4, wherein the substrate film layer is made from an organic biopolymer, selected from carbohydrates, starches, cellulose, glycogen, hemi-cellulose, chitin, fructan, inulin, lignin and/or pectin based materials), gums, proteins (animal or vegetable), colloids, hydrocolloid, polylactic, polygalactic, cellulose or materials based on paper technology.

6. An insulation material as claimed in claim 5, wherein the substrate layer is of cellulose, a cellulose derivative or regenerated cellulose.

7. An insulation material as claimed in any of claims 1 to 6, wherein the substrate film layer has a thickness in the range from 15 μm to 350 μm including any value or sub-range of values falling in this range.

8. An insulation material as claimed in any of claims 1 to 7, wherein the coating layer is formed from solvent or water based dispersions or solutions or from 100% active systems requiring no solvent.

9. An insulation material as claimed in any of claims 1 to 8, wherein the coating layer is selected from any one or more of cellulose derivatives, synthetic organic polymers, naturally occurring polymers and their derivatives.

10. An insulation material as claimed in claim 9, wherein the cellulose derivatives includes cellulose ethers, esters and nitrocellulose.

11. An insulation material as claimed in claim 9, wherein the synthetic organic polymers include polyacrylic esters, polyvinyl acetate copolymers, polyurethanes, polyamides, polysulfones and polyvinyl alcohol copolymers.

12. An insulation material as claimed in claim, wherein the naturally occurring polymers include starches, chitin, fructan, lignin, gums and proteins and their derivatives.

13. An insulation material as claimed in any of claims 1 to 8, wherein the coating layer is a block copolymer.

14. An insulation material as claimed in claim 13, wherein block copolymer is selected from materials which allow high transfer of moisture vapour by molecular diffusion and have polymer chains comprising high and low crystallinity sections.

15. An insulation material as claimed in claim 13, wherein block copolymer is selected from any one or more of styrene butadiene resins and hydrophilic polyurethanes including polyester urethanes, polyether urethanes, polycarbonate urethanes and polyurethane urea polymers.

16. An insulation material as claimed in any of claims 1 to 15, wherein the reflective matter dispersed in the coating layer is a pigment.

17. An insulation material as claimed in claim 16, wherein the pigment is a metal pigment or a pigment which presents a reflective metallic surface.

18. An insulation material as claimed in claim 16, wherein the pigment is a mineral pigment.

19. An insulation material as claimed in claim 18, wherein the mineral pigment is selected from glass or mica having coated reflective metal surfaces.

20. An insulation material as claimed in claim 17 or claim 19, wherein metal pigment or the reflective metallic surface of the pigment is selected from aluminium, bronze, stainless steel, brass, gold, nickel, silver, tin, copper or mixtures thereof.

21. An insulation material as claimed in any of claims 1 to 20, wherein the reflective matter dispersed in the coating layer is in the form of particles, platelets or flakes.

22. An insulation material as claimed in any of claims 1 to 21, wherein the reflective matter and coating layer binder are present in the coating layer in the ratio ranging from 3:1 to 1:10 including any value or sub-range of values falling in this range.

23. An insulation material as claimed in any of claims 1 to 22, wherein the coating layer has a basis weight per unit area in the range from 0.8 g/m^2 to 2.5 g/m^2 including any value or sub-range of values falling in this range.

24. An insulation material as claimed in any of claims 1 to 10, or any of claims 16 to 23 as appendant to any of claims 1 to 10, and being predominantly derived from sustainable or renewable raw materials.

25. An insulation material as claimed in claim 24, wherein the sustainable or renewable raw materials are those derived predominantly from natural biological materials.

26. An insulation material as claimed in claim 24 or 25, and having a percentage of non-renewable material that is lower than 1%.

27. A multi-layer insulation product having outer layers of laminated insulation material as claimed in claim 2 or claim 3 or any claim dependent on claim 2 or claim 3 laminated to a nonwoven fabric support layer by welding along the long or machine direction edges, the welded outer layers 6 enclosing an insulation core including alternating layers of the said insulation material which

includes respective waddings acting to maintain a space between the reflective substrate layers of the insulation materials.

28. A multi-layer insulation product as claimed in claim 27, wherein the non-woven fabric support layer is of needled wool nonwoven or wool felt.

29. A multi-layer insulation product as claimed in claim 27 or 28, wherein each wadding is a lightly needled wool fleece.

30. A multi-layer insulation product as claimed in any of claims 27 to 29, wherein the space between the reflective substrate layers of the insulation materials is at least 5mm.

31. A laminated insulation material as claimed in claim 2 or claim 3 or any claim dependent on claim 2 or claim 3, for use in, or as, roofing insulation or a roofing underlay in a building.

32. A laminated insulation material as claimed in claim 2 or claim 3 or any claim dependent on claim 2 or claim 3 for use in, or as, wall insulation in a building.

33. A laminated insulation material as claimed in claim 2 or claim 3 or any claim dependent on claim 2 or claim 3 for use in, or as, floor insulation in a building.

34. A laminated insulation material substantially as hereinbefore described with reference to Figure 1 or Figure 3 of the accompanying drawings.

35. A multi-layer insulation product substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

36. A building incorporating an insulation material as claimed in any of claims 1 to 26 or claims 31 to 34.

37. A building incorporating a multi-layer insulation product as claimed in any of claims 27 to 30 or claim 35.

Application No: GB0716402.3 **Examiner:** Mr Robert Black

Claims searched: 1-37 **Date of search:** 8 January 2008

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 16, 17 and 20 at least	AU 0705627 B2 (KO) see especially the abstract and page 5 lines 1-14
X	1, 16-18 at least	GB 2432812 A (HUNT) see especially page 4 lines 20-28, page 8 lines 1-10, page 10 line 27 to page 11 line 20, page 13 lines 4-25, page 15 lines 8-12, page 19 line 27 to page 20 line 15, page 21 lines 1-10 and 23-27, page 22 lines 5-7, and page 25 lines 16-28
A	31-33	US 5766721 A (BUSSEY) see especially the abstract, the figures and column 4 lines 48-63
A	1 and 31	NAHB, "DuPont demonstrates Tyvek wrap systems at IBS", Nations's building news, National association of home builders [online] available at http://www.nahb.org/news_details.aspx?sectionID=910&newsID=3882&print=true [viewed 20/12/07] Tyvek Attic Wrap displayed at the International Builder's show, February 2007
A	1 and 31	DuPont, "The Sealed Attic System with DuPont Tyvek AtticWrap", Building science bulletin, available at http://www2.dupont.com/Tyvek_Construction/en_US/assets/downloads/AWSBK14127.pdf [viewed 20/12/07]

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

E04B; E04D; E04F; E21D; F16L

The following online and other databases have been used in the preparation of this search report

EPODOC; WPI; Internet

International Classification:

Subclass	Subgroup	Valid From
F16L	0059/08	01/01/2006
E04B	0001/76	01/01/2006
E04B	0002/00	01/01/2006
E04B	0005/00	01/01/2006
E04B	0007/00	01/01/2006