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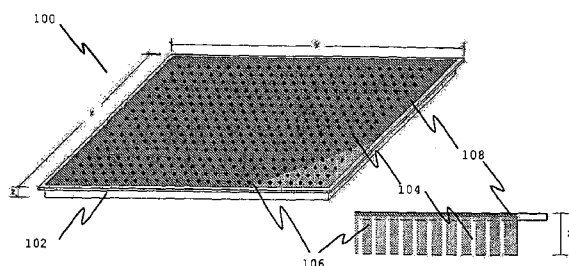


Figure 2h

(57) Abstract: The acoustic tile includes a tray having perforations and having an interior region, in which the interior region includes an infill material and an acoustic barrier, and where the infill material is a latent heat storage material. The infill material can be disposed in a first region or regions of the tray and the perforations can be disposed in a second region or regions of the tray. The first region or regions can be separated from the second regions or regions by a barrier. The first region can be around an edge region of the tray and the second region can be a central region of the tray. The first region or regions can be that part or parts of the tray not including the second region or regions. The tray can include a plurality of corrugated sections having the infill material disposed in spaces formed by the corrugated core structure and perforations in the region of the tray between the corrugations. The acoustic barrier can be in contact with the part of the tray having the perforations. The acoustic barrier can be an acoustic quilt, fleece or mat. The latent heat storage material can comprise magnesia cement and a phase change material, in which the magnesia cement is formed from magnesium oxide, magnesium chloride, and water. In particular, the molar ratio of magnesium chloride to water is equal to or greater than 1:17. This corresponds to the magnesium chloride being dissolved in the water to give a solution having a Baume equal to or less than 26°, respectively. The molar ratio of magnesium chloride to magnesium oxide can be in the range of about 1:1 to about 1:5. The latent heat storage material can additionally comprise fillers, and/or intumescent agents, and/or secondary binders. The latent heat storage material can comprise a PFA binder and a phase change material, in which the binder comprises dry inert powder, phosphogypsum, and an alkaline salt of any metal, and water. The latent heat storage material can additionally comprise fillers, and/or intumescent agents.



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Acoustic composite panel assembly containing phase change materials

Field of Invention

This invention relates to an acoustic composite panel assembly including a phase change material for use in construction. It is particularly applicable, but in no way
5 limited, to tiles including ceiling tiles.

Background of the Invention

Phase change materials and compositions are well known: these are materials which reversibly undergo a change of state and act as a sink for thermal energy, absorbing or releasing heat as necessary. For example, they can be used to
10 regulate temperatures within a desired range, or provide a degree of protection against extremes of heat or cold.

Paraffin wax and similar organic compounds have been used as phase change materials for building applications (such as in wallboards, sheetrock, drywall,
15 plasterboard, and fibreboard for absorbing or releasing heat energy into or from a room environment). However, these materials are flammable: this is particularly true for phase change materials comprising various readily combustible paraffins. This is a major drawback since it increases the combustibility of the articles.

20 There have been a wide variety of attempts to make the microcapsules more flame-resistant. U.S. Pat. No. 5,435,376 describes microencapsulated latent-heat storage materials which are not combustible. However, non-combustible latent-heat storage materials of this type generally store an insufficient amount of heat. The specification furthermore discloses mixtures of latent-heat storage materials and
25 flame inhibitors as capsule core for textiles, shoes, boots and building insulation. This admixture of flame retardants only results in a slight improvement in the combustion values, or none at all.

U.S. Patent Appl. Pub. No. 2003/0211796A1 discloses an approach that involves coating articles containing microencapsulated organic latent-heat storage materials with a flame-inhibiting finish comprising intumescent coating materials of the type used as flame-inhibiting finishes for steel constructions, ceilings, walls, wood and cables. Their mode of action is based on the formation of an expanded, insulating layer of low-flammability material which forms under the action of heat and which protects the substrate against ingress of oxygen and/or overheating and thus prevents or delays the burning of combustible substrates. Conventional systems consist of a film-forming binder, a char former, a blowing agent and an acid former as essential components. Char formers are compounds which decompose to form carbon (carbonization) after reaction with the acid liberated by the acid former. Such compounds are, for example, carbohydrates, such as mono-, di- and tri-pentaerythritol, polycondensates of pentaerythritol, sugars, starch and starch derivatives. Acid formers are compounds having a high phosphorus content which liberate phosphoric acid at elevated temperature. Such compounds are, for example, ammonium polyphosphates, urea phosphate and diammonium phosphate. Preference is given to polyphosphates since they have a greater content of active phosphorus. Blowing agents, the foam-forming substances, liberate non-combustible gas on decomposition. Blowing agents are, for example, chlorinated paraffins or nitrogen-containing compounds, such as urea, dicyanamide, guanidine or crystalline melamine. It is advantageous to use blowing agents having different decomposition temperatures in order to extend the duration of gas liberation and thus to increase the foam height. Also suitable are components whose mode of action is not restricted to a single function, such as melamine polyphosphate, which acts both as acid former and as blowing agent. Further examples are described in GB2007689A, EP139401A, and U.S. Patent. No. 3,969,291.

Magnesia cement-based products are known to have good fire-resistance, for example, European Patent Application Number EP2060389A1 describes a laminate panel for flooring, wall or ceiling systems having a fire-proof core layer disposed between an upper surface layer and a lower backing layer. The core layer comprises a composition derived from a colloidal mixture of magnesium oxide, magnesium chloride and water.

A publication by Dr Mark A. Shand entitled "Magnesia Cements", referred to in WO2009/059908, details the three main types of magnesia cements, one of which is the Magnesium Oxychloride cement, otherwise known as Sorel cement. Shand suggests that superior mechanical properties are obtained from the "5-form" whose formula is given as $5\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O}$. According to Shand, this is formed using magnesium oxide, magnesium chloride and water in a molar ratio of 5:1:13.

WO2008/063904 discloses an approach for making the five-phase magnesium oxychloride cement composition ($5\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O}$) by mixing a magnesium chloride brine solution with a magnesium oxide composition in a selected stoichiometric ratio of magnesium chloride, magnesium oxide, and water. The cement kinetics are controlled to form the five-phase magnesium oxychloride cement composition and results in an improved and stable cement composition. The key element would appear to be the utilisation of a magnesium chloride brine solution having a specific gravity in the range from about 28° Baumé to about 34° Baumé, most preferably at least about 30° Baumé. After 24h, at least 98% of the five-phase compound is present, which minimises the amount of poorly water-resistant three-phase compound. Various fillers can be optionally added to give fire-proofing compositions.

20

Use of magnesia cement and related components is disclosed in WO2009/059908, which is concerned with the fire retardation properties of compositions including those comprising phase change material and magnesia cement. A high concentration of the 5-form is said to be preferable in inventive compositions comprising Sorel cement where superior mechanical properties are needed. The process for making these materials involves adding the phase change material to the magnesium chloride brine solution before the formation of the magnesium oxychloride cement is initiated by adding the magnesium oxide powder. These magnesia cements containing the phase change material (Examples 1 and 10-13) have molar ratios of magnesium oxide:magnesium chloride:water in the range of between about 5:1:13 (Examples 1, 10 and 11 to 8:1:16 (Examples 12 and 13).

30

GB2344341A discloses a forming mixture comprising a dry, inert powder, such as fly ash, pulverised rock or recycled building waste, phosphogypsum and an alkaline salt. Additives such as cellulose derivatives, PVA resin, microfibres, starch ethers, water repelling agents, colour or flame-retardants, may be included. An aerating agent e.g. a carbonate may be added to yield thermally insulating materials. The addition of a phase change material is not contemplated.

U.S. Pat. Nos. 6,099,894, 6,171,647 and 6,270,836 describe a magnesium oxide gel and other metal oxide gels as a coating for microencapsulated phase change, which results in improved flame protection of the capsules.

Sound absorption within a space

One of the key functions of an acoustic metal ceiling is to create a pleasant working environment or atmosphere. Depending on the intended purpose of a room, reverberation times, which depend on the total absorption capacity of a room, can be optimised. Airborne sound absorption is based on the conversion of sound energy into heat by friction, which takes place in absorbing materials and systems. Airborne sound insulation or barriers thus reduce the passage of airborne sound because of the presence of a solid separation element. This insulation effect increases with the density of the material. Sound energy is also reflected by the insulation element and the systematic deployment of reflecting materials can positively influence the overall acoustics of a room. Acoustic metal ceiling tiles therefore influence the acoustic characteristics of a room to meet specific expectations.

25

Any conversation that takes place in a space produces sound waves of a certain energy. These sound waves spread out from the source towards the ceiling, walls, floor and any objects within the space. Part of this energy is absorbed by these elements, while the remainder is reflected.

30

If a room is small and a lot of sound is absorbed at each reflection, then the resulting environment will tend to be quiet and have a short reverberation time. Conversely if the room has a larger volume and little sound is absorbed at each surface reflection, then the room will sound 'noisier' and have a longer reverberation time.

5

Reverberation Time

This is a measure of how decaying sound persists in a room and it tells us something about how 'lively' or 'lifeless' a room's acoustics will be and how loud or quiet noise levels will sound. For any room, depending upon its size and whether it is primarily for speech or music, there will be an optimum reverberation time range. For example, the reverberation time for speech must not be too long (0.8 seconds is a good upper limit) otherwise successive speech sounds will overlap with a consequential loss of intelligibility. However if the reverberation time is too short (< 0.4 seconds) then the space could seem 'lifeless', with no obvious reinforcement from the room, and this will make for extreme difficulty in conversation particularly when addressing a group of people over distance such as occurs in teaching spaces or in meeting rooms. For teachers who take classes for perhaps 5 or 6 hours per day in 'lifeless' environments, the consequence can be fatigue, sore throats and lack of motivation.

20

Music activities however benefit from longer reverberation time with a consequential blending of successive notes and the resulting fullness of tone. However if the reverberation time is much too long then the received sound will lose clarity and appear 'muddy', and if it is too short, then the sound will be 'dry', the performers will seem distant and the sound will lack 'warmth' and 'envelopment'.

25

So, whatever the application, for any space the reverberation time should be optimised for its use and be neither too long nor too short. Too much sound absorption, when it is not needed, is just as unacceptable as too little when it is!

30

Sound Insulation between spaces

Sound insulation concerns the reduction of sound transmitted from one room to another. When related to suspended ceilings, the plenum, which is the space between the structural soffit and the suspended ceiling, is an important path for sound transmission.

The reduction of this sound depends on the thickness and density of the elements which protect against the transmission of sound waves. The heavier (thicker) the element is, the lower will be the sound that is transmitted through it and hence the better will be its sound reduction ability.

The air tightness of any joints also influences considerably the quality of the insulation. If there are significant gaps or cracks within or around the element then the sound transmission will be enhanced and the potential sound reduction severely reduced. Think of an open window, and how a lot of sound is easily transmitted through it.

Suspended ceilings are unusual in that the sound reduction through them can be measured in two entirely different ways depending upon the location of the sound source.

Sound Reduction Index (R or SRI) is the measure when sound passes through the ceiling once. This may be when the source of sound is in the void above the ceiling, or the sound could be coming from the floor above.

Sound Attenuation - weighted suspended ceiling normalised level difference (Dncw) – is a single-number rating of the laboratory measurement of room-to-room airborne sound insulation of a suspended ceiling with a plenum above it. The rating is determined in accordance with EN ISO 717-1 from measurements made in accordance with EN 20140-9 over the third-octave band frequency range 100-3150 Hz. This is therefore the measure when the source of sound is in an adjacent area and the sound transmits through the ceiling twice via the common ceiling void. In most cases the quoted value (in dB) for a suspended ceiling is the sound

attenuation performance. In practice, sound attenuation is mainly used as continuous suspended ceilings are very common.

5 The necessary level of sound attenuation depends on the user's need for speech privacy as well as the background noise in the receiving space. The best design approach is to create a good balance between the performances of the walls and the ceilings. Lightweight ceiling constructions only provide a low sound attenuation. Hence it is important to pay attention to the Dncw value of a ceiling in order to reach the required room to room sound insulation.

10

Perforations

In order for sound originating inside a room to reach acoustic material within or above a ceiling tile, perforations are required in the face of the ceiling tile visible from within the room. Proper sizing of the perforation pattern and acoustic inlay will ensure that the absorptive properties of a metal ceiling are commensurate with needs. Airborne sound absorption is taken to mean the conversion of sound energy into heat as a result of friction in the absorptive materials and systems. The sound absorption coefficient is defined as the ratio between non-reflected and incident sound energy and has a value between 0 and 1

20

US2005/040152 discloses a ceiling unit of lamellar design with sound-absorbing material there between hung on a closed casing for storing heat. The lamellar design is closed at the bottom by a perforated ceiling sheet, which forms the viewed ceiling of the room. The casing contains a phase change material (PCM) which melts when accommodating heat and reversely delivers latent heat to the surrounding on solidification. The casing also contains a heating or a cooling pipe to deliver or remove heat from the unit as required. It is the delivery or removal of heat through these pipes that controls the temperature of the room, rather than the PCM and the unit is designed to give up its heat or cold in a slow manner, over several hours. To this end, the air void between the casing and the perforations provides an insulation barrier preventing or reducing the heat flow to the PCM. The sound

30

absorbing material will also have a negative influence on the thermal performance of the tile.

Summary of the Invention

5 According to a first aspect of the present invention there is provided an acoustic composite panel assembly comprising:

(i) a panel front having a first face and an opposing second face, said panel front comprising a thermally conductive material and further comprising perforations;

10 (ii) a latent heat storage material comprising a phase change material;

(iii) an acoustic barrier;

wherein the latent heat storage material is in heat conducting contact with the panel front. This

arrangement provides for the first time a panel which both has the benefit of a latent
15 heat storage capacity and acoustic damping properties in the same panel

Preferably the panel front incorporates depending edges to form a tray construction. A tray construction is particularly useful for use as ceiling tiles.

20 Preferably said latent heat storage material is disposed in a first region or regions of the panel assembly and said perforations are disposed in a second region or regions of the panel assembly, and more preferably the first region or regions are separated from the second region or regions by one or more barriers. This enables the latent heat storage material and the acoustic barrier to both be in contact with
25 respective parts of the front panel.

Preferably said first region or regions are the part or parts of the panel assembly not formed by said second region or regions.

30 Preferably the second region is formed in a shape selected from the group comprising:-

a rectangle;

a circle;

a polygon;
an ellipse;
a cruciform;
a saltire; or combinations thereof.

5

In an alternative preferred embodiment the heat storage material is disposed in a series of strips arranged across the panel assembly.

10 In a further alternative preferred embodiment said perforations penetrate both the front of the panel assembly and the latent heat storage material. This arrangement means that acoustic barrier material may be positioned behind the latent heat storage material.

15 In a preferred embodiment the latent heat storage material extends over substantially entirely the whole of the panel front within the composite panel assembly. This arrangement provides for a greater latent heat storage than in arrangements where the latent heat storage material only covers part of the panel front.

20 Preferably the acoustic barrier is disposed over the latent heat storage material on a side furthest from the front face of the panel assembly.

25 In an alternative arrangement the panel assembly comprises a plurality of corrugated sections, and preferably the latent heat storage material and perforations occupy alternate regions formed by the corrugated sections.

Preferably the profile of the corrugated sections is selected from the group comprising:-

30 crenulated shapes;
sinusoidal shapes
saw-toothed shapes; and combinations thereof.

Preferably the acoustic barrier comprises an acoustic quilt, fleece or mat, and more preferably the acoustic barrier comprises a non-woven fleece having a range from 15g/m^2 to 75g/m^2 , and more preferably the acoustic mat has a density of between 15kg/m^3 and 75kg/m^3 .

5

Preferably the region occupied by the latent heat storage material incorporates a plurality of support elements embedded in the latent heat storage material to provide support to that layer and the plurality of support elements segregate the latent heat storage material layer into discrete sections. This arrangement tends to reduce or
10 eliminate any warping or distortion caused in the panel during the curing of any binder in the latent heat storage material.

Preferably the plurality of support elements extend from the opposing second face of the front panel into and substantially through the latent heat storage material layer.

15

Preferably some or all of the plurality of support elements comprise heat conduction elements, formed from a thermally conductive material and adapted to convey heat between the panel front and the latent heat storage material layer. This greatly increases the effectiveness of the latent heat storage capacity by conducting heat
20 through what would otherwise be an insulator.

Preferably the plurality of support elements comprise structures selected from the group comprising:-

25 honeycomb structures:
 polygonal structures formed from regular or irregular polygons;
 fins;
 ribs;
 ribbons;
 crenulations;
30 mesh;
 protrusions; and combinations thereof.

Preferably the acoustic composite panel assembly further comprises a lid and wherein the lid is bonded to or otherwise attached to the front panel. Where the lid is made of a fire resistant material the lid can enclose the contents of the panel assembly to form a fire resistant encasement.

5

Preferably the latent heat storage material is formed from a mixture comprising a binder, a phase change material and water.

Preferably the binder is selected from the group comprising:-

10

- a cement;
- an Ordinary Portland Cement (OPC);
- a magnesia cement;
- a pozzolan cement;
- a magnesium chloride solution; and mixtures thereof.

15

In a preferred embodiment the binder comprises a magnesia cement formed from magnesium chloride, magnesium oxide and water, and preferably the molar ratio of said magnesium chloride to said water used in the preparation of the magnesia cement is in the range 1:15 to 1:36.

20

More preferably the molar ratio of said magnesium chloride to said water used in the preparation of the magnesia cement is in the range of 1:17 to 1: 32.

25

In a particularly preferred embodiment, during the preparation of the magnesia cement, the said magnesium chloride is dissolved in said water to give a solution having a Baumé value in the range 12° to 27.5°, and more preferably the Baumé value of the magnesium chloride solution used in the preparation of the magnesia cement is in the range of 15° to 26°.

30

Preferably the molar ratio of said magnesium chloride to said magnesium oxide used in the preparation of the magnesia cement is in the range 1:1 to 1:5.5.

Preferably the weight ratio of magnesium chloride : magnesium oxide : water : organic phase change material is about 1:1:2.3:1± 20%.

In an alternative preferred embodiment the binder comprises a pozzolan cement.

5

Preferably the pozzolan cement comprises calcium oxide and a pozzolan and water, and wherein said calcium oxide and said pozzolan used in the preparation of the pozzolan cement are present in a ratio of 1:1 to 1:10 (CaO:pozzolan) by weight.

10 Preferably the said calcium oxide and the said pozzolan used in the preparation of the pozzolan cement are present in a ratio of 1:1 to 1:4 (CaO:pozzolan) by weight.

Preferably the ratio of binder (i.e. CaO + Pozzolan) to water is in the range 1:1 to 1:5 binder to water by weight.

15

Preferably the pozzolan is selected from the group comprising:-

pulverised flue ash (PFA);

kaolin, including metakaolin;

rice husk ask (RHA);

20

pozzolana;

silica fume;

ground granulated blast furnace slag; and mixtures thereof.

Preferably the binder additionally comprises glass fibre.

25

Preferably the latent heat storage material further comprises one or more fillers.

From the foregoing, it may be appreciated that a need has arisen for products that allow for a reduction in the consumption of energy derived from fossil fuels, and which can be manufactured in a way that has a low impact on the environment.
30 Phase change materials work by absorbing heat from a room where the temperature exceeds a comfortable working environment. The heat is stored as latent heat and

thermal mass, and released as the temperature of the building falls. This is a continuous cycle involving no mechanical intervention.

5 According to various embodiments, but not necessarily all, the present invention discloses an acoustic tile including a tray having perforations and having an interior region, in which the interior region includes an infill material and an acoustic barrier, and where the infill material is a latent heat storage material

10 The infill material can be disposed in a first region or regions of the tray and the perforations can be disposed in a second region or regions of the tray.

The first region or regions can be separated from the second regions or regions by a barrier.

15 The first region can be around an edge region of the tray and the second region can be a central region of the tray.

The first region or regions can be that part or parts of the tray not including the second region or regions.

20

The tray can include a plurality of corrugated sections having the infill material disposed in spaces formed by the corrugated core structure and perforations in the region of the tray between the corrugations. In the context of this disclosure the term 'plurality' means one or more.

25

The acoustic barrier is preferably in contact with the part of the tray having the perforations. The acoustic barrier can be an acoustic quilt, fleece or mat.

- The latent heat storage material can comprise magnesia cement and a phase change material, in which the magnesia cement is formed from magnesium oxide, magnesium chloride, and water. In particular, the molar ratio of magnesium chloride to water is equal to or greater than 1:17. This corresponds to the magnesium chloride being dissolved in the water to give a solution having a Baumé equal to or less than 26°. The molar ratio of magnesium chloride to magnesium oxide can be in the range of about 1:1 to about 1:5. The latent heat storage material can additionally comprise fillers, and/or intumescent agents, and/or secondary binders.
- 5
- 10 The latent heat storage material can comprise a PFA binder and a phase change material, in which the binder comprises dry inert powder, phosphogypsum, and an alkaline salt of any metal, and water. The latent heat storage material can additionally comprise fillers, and/or intumescent agents.
- 15 The phase change material can be a microencapsulated formulation.

The acoustic tile can be a ceiling tile, particularly a ceiling tile which forms part of a suspended ceiling.

- 20 The acoustic tile can be a ceiling tile having one or more corrugated sections.

Brief Description of Drawings

- For a more complete explanation of the present invention and the technical advantages thereof, reference is now made to the following description and the accompanying drawing in which:
- 25

Figure 1 shows an acoustic tile of the present invention including a tray having perforations and an infill component disposed around an edge region and which surrounds a central region having perforations;

Figures 2a-h show various embodiments of an acoustic tile of the present invention;

Figure 3 shows an acoustic tile of the present invention having a tray including a plurality of corrugated sections having an infill component disposed within them and perforations in the region of the tray between the corrugations;

5 Figure 4 shows an acoustic tile of the present invention having a tray including a plurality of corrugated sections having an indented, square notched or crenulated shape;

Figure 5 shows an acoustic tile of the present invention having a tray including a plurality of corrugated sections having a generally sinusoidal shape;

10 Figure 6 and 7 show a portion of a tile containing latent heat storage material with a honeycomb support structure within the storage material;

Figure 8 shows ribbed, ribboned and finned wall sections as support elements;

Figure 9 shows a section with square mesh honeycomb support within the latent heat storage material.

15 **Description of the preferred embodiments**

Latent heat storage compositions useful for use in the present invention and their technical advantages may be better understood by referring to the following disclosure. These represent the best ways known to the applicant of putting the invention into practice, but they are not the only ways that this can be done. A wide
20 variety of latent heat storage materials can be used in the present invention. Some suitable examples are described in PCT/GB2010/001917 (Berry and Scanlon), the entire text of which is hereby imported by reference and is intended to form an integral part of this disclosure.

25 Turning first to methods of preparation of various suitable example latent heat storage materials consisting of a binder, a phase change material and water. In one formulation, in a first step magnesium chloride is dissolved in water of reasonable purity (such as tap water) by mixing for a minimum of 15 minutes at high speed and then left for a minimum of 24 hours to ensure that the magnesium chloride is
30 completely dissolved. The dissolution step is performed under ambient conditions,

typically 10 - 13°C for the tap water and 15 - 18°C for the resulting solution. Magnesium chloride hexahydrate preparations are commercially available and suitable for use in the present invention. For example NEDMAG(RTM) C flakes, which are small white flakes of magnesium chloride hexahydrate ($\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$) with a MgCl_2 content of 47%, are available from Nedmag Industries Mining & Manufacturing B.V. The Baumé is measured in order to be able to determine the quantity of magnesium oxide to be added in the next step (see below). The proportion of magnesium oxide in the binder affects its density and to some extent determines the quantity of the phase change material and thus the enthalpy measure of the finished binder. The Baumé measures the density of a liquid, which can be either heavier or lighter than water. In the case of the present description, the liquid density is heavier than water. Typically the weight ratio of magnesium chloride : water is about 1:1, which gives a Baumé reading of 26°; this corresponds to a molar ratio of magnesium chloride : water of about 1:17. The preferred Baumé range is between 12° and 27.5°.

In a second step magnesium oxide is added to the magnesium chloride solution prepared in the first step and stirred for a minimum of 10 minutes with a high speed paddle drill. Magnesium oxide preparations are commercially available and suitable for use in the present invention. For example, Baymag magnesium oxide is available from Baymag Inc. and comprises 94-98% (wt/wt) of magnesium oxide and 1.5 – 4% (wt/wt) of calcium oxide.

In a third step the phase change material (PCM) is added directly after the $\text{MgO}:\text{MgCl}_2$ solution has been stirred for at least 15 minutes, and is mixed vigorously. This differs from the process disclosed in WO2009/059908 in which the PCM is added to the magnesium chloride solution. Preferred PCM's are organic, water insoluble materials that undergo solid-liquid/liquid-solid phase changes at temperatures in the range of 0° to 80°C. Candidate materials include substantially water insoluble fatty alcohols, glycols, ethers, fatty acids, amides, fatty acid esters, linear hydrocarbons, branched hydrocarbons, cyclic hydrocarbons, halogenated hydrocarbons and mixtures of these materials. Alkanes (often referred to as

paraffins), esters and alcohols are particularly preferred. Alkanes are preferably substantially n-alkanes that are most often commercially available as mixtures of substances of different chain lengths, with the major component, which can be determined by gas chromatography, between C₁₀ and C₅₀, usually between C₁₂ and C₃₂. Examples of the major component of an alkane organic phase change materials include n-octacosane, n-docosane, n-eicosane, n-octadecane, n-heptadecane, n-hexadecane, n-pentadecane and n-tetradecane. It is also possible to include a halogenated hydrocarbon along with the main organic phase change material to provide additional fire protection, for example as disclosed in U.S. Pat. No. 5,435,376. Suitable ester organic phase change materials comprise of one or more C₁ – C₁₀ alkyl esters of C₁₀ – C₂₄ fatty acids, particularly methyl esters where the major component is methyl behenate, methyl arachidate, methyl stearate, methyl palmitate, methyl myristate or methyl laurate. Alcohol organic phase change materials include one or more alcohols where the major component is, for example, n-decanol, n-dodecanol, n-tetradecanol, n-hexadecanol, and n-octadecanol. These materials are substantially water insoluble, which means they can be formulated in an emulsion form or encapsulated form.

Including a phase change material in the binder mix decreases its fire resistant properties and also alters the physical characteristics of the binder when cured. It is therefore desirable that the enthalpy of phase change is high (typically >50 kJ/kg, preferably >100 kJ/kg and most preferably >150 kJ/kg) so that smaller quantities of PCM can be used in the binder. Preferably, the phase change material is a commercially available encapsulated formulation, such as Micronal®, which has an enthalpy of 110kJ/kg or Encapsulance, which has a higher enthalpy, in the range of 150 - 160kJ/kg. These materials are provided in granular form and may be added to the magnesia cement binder straight out of the container. Using a weight ratio of magnesia cement materials : PCM in the range of 1:2 to 1:3 gives a binder product having an enthalpy measure of about 50 kJ/kg. The quantity of PCM used is chosen so that the enthalpy measure of the binder is at or below 50kJ/kg. This typically corresponds to a minimum European fire rating of Euroclass D, which is described as having an "Acceptable contribution to fire" (the class system is rated on a scale of

A1, A2, B, C, D, E and F, where A1 has no contribution to fire and where F has no performance requirements).

In a fourth step the mixture, which provides a heat absorbing material that in its liquid state, is typically moulded or cast to suit any shape or form for use and baked for no more than 24h at about 40°C so that the binder composition dries slowly.

Some Examples of PCM/magnesia cement binder compositions, and the corresponding molar ratios for the magnesia, are given in Tables 1 to 3.

Table 1. Where the Baumé of the Solution is 26°:

	Example 1	Example 2
Nedmag MgCl ₂ (grams)	500	500
Water (grams)	500	500
Baymag MgO – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	400	250
BASF Micronal mPCM	600	600
Enthalpy Measure (kJ/kg)	29.5	48.9
Euroclass Fire Rating	C	D

Table 2. Where the Baumé of the Solution is 23°:

	Example 3	Example 4
NEDMAG (RTM) MgCl ₂ (g)	262	262
Water (g)	338	338
Baymag MgO – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	250	50
CIBA Encapulance mPCM	1000	1000

Enthalpy Measure (kJ/kg)	68.1	102.6
Euroclass Fire Rating	E	E/F

Table 2a. Where the Baumé of the Solution is 19°:

	Example 4a
Nedmag MgCl ₂ (grams)	1000
Water (grams)	1800
Baymag MgO – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	1000
BASF Micronal mPCM	1500
Enthalpy Measure (kJ/kg)	72.8

In another Example (Example 4b), the magnesium chloride solution is prepared from 1000g Nedmag and 2300g water, giving a Baumé value of 15° and corresponding to a molar ratio of magnesium chloride : water of 1:32.0. In a further Example (Example 4c), the magnesium chloride solution is prepared from 1000g Nedmag and 1400g giving a Baumé value of 22° water and corresponding to a molar ratio of magnesium chloride : water of 1:21.8. Example 4b, 4c and 4d serve to illustrate the relative amounts of magnesium chloride and water used to form magnesium chloride solutions of various Baumé values. These solutions can be used in various formulations as required or, as will be seen below, can be used as a binder in their own right, without the addition of any magnesium oxide or other metal oxide or hydroxide. They are not intended to be fully documented examples and some PCM will be required to make a latent heat storage material.

Table 3. Molar ratios for MgO:MgCl₂:H₂O and weight ratios for cement:PCM in Examples 1-4a

Baumé	Example	MgO	MgCl ₂	H ₂ O	Enthalpy	Euroclass	Cement:PCM
26°	1	4.0	1.00	17.3	29.5	C	2.3
26°	2	2.5	1.00	17.3	48.9	D	2.1
23°	3	4.8	1.00	20.6	68.1	E	0.85
23°	4	1.0	1.00	20.6	102.6	E/F	0.65
19°	4a	5.0	1.00	26.3	72.8		2.53
15°	4b		1.00	32.0			
22°	4c		1.00	21.8			

- 5 In Examples 1 and 2, the molar ratio of magnesium chloride : water is 1:17.3, corresponding to a Baumé value of 26°, and in Examples 3 and 4, the molar ratio of magnesium chloride : water is 1:20.6, corresponding to a Baumé value of 23°. This is lower than the Baumé value of 28° to 34° taught in WO2008/063904.
- 10 In Example 4c, the molar ratio of magnesium chloride : water is 1:21.8, corresponding to a Baumé value of 22°. In Example 4a, the molar ratio of magnesium chloride : water is 1:26.3, corresponding to a Baumé value of 19°. In Example 4b, the molar ratio of magnesium chloride: water is 1:32.0, corresponding to a Baumé value of 15°.
- 15
- In Examples 1, 3 and 4a the molar ratio of magnesium chloride : magnesium oxide is between about 1:4 and 1:5. The molar ratio of MgO:MgCl₂:H₂O in the magnesia cement of the present invention thus varies in the ranges 4-5:1:17.3-26.3. This is considerably different from the magnesia cements utilised in Examples 10 and 11 of
- 20 WO2009/059908 (a ratio of 5.3:1:12) and Examples 12 and 13 of WO2009/059908 (a ratio of 8:1:16).

The molar ratio of the added magnesium oxide : magnesium chloride is generally in the range of about 4:1 to about 5:1, but much lower molar ratios (as low as about 1:1) are utilised when a larger quantity of phase change material is to be incorporated into the binder as in Examples 2 and 4. The greater the volume of phase change material that can be incorporated into the present invention, the higher the enthalpy measure and subsequently the greater the heat storage capacity of the material. In addition, where the Baumé of the solution is reduced to 23°, the volume of magnesium oxide in the binder is also reduced as a result (to keep the molar ratio of magnesium chloride : magnesium oxide in the same range) as in Example 4. Therefore a higher volume of phase change material can be incorporated into the mixture. The increase in water content of the solution will evaporate during the curing stages of the binder/mixture.

For the high Baumé formulations of Examples 1 and 2, a weight ratio of magnesia cement materials : PCM in the range of 1:2 to 1:3 gives a binder product having an enthalpy measure of about 50 kJ/kg. For the lower Baumé formulation of Example 4a, a weight ratio of magnesia cement materials : PCM in the same range gives a binder product having an enthalpy measure of about 70 kJ/kg. The binder product of the present invention is thus rather superior to that disclosed in WO2009/059908 in which the weight ratio of magnesia cement materials : PCM in the range of 1:0 to 1:2 and the enthalpy measures are in the range of 13 to 33 kJ/kg.

The microencapsulated phase change material alone is highly flammable, and in Examples 3 and 4 the Euroclass fire rating is low: casting the mixture into aluminium, copper or graphite encasements prior to baking protects the binder from fire and gives the binder a practical format with high thermal conductivity benefits for a number of applications.

In a further formulation in which a high enthalpy is secondary to the density and strength requirements, aggregate fillers such as, but not limited to, silica sand, stone dust including limestone, quartz, perlite, marble, ceramic powders, glass fibre or wood fibre strands or graphite can be added to the binder with the phase change

material mixture. This gives the material additional strength and durability characteristics for other applications where aluminium, copper or graphite casing are not necessary or practical. Table 4 provides details of formulations containing quartz, and the corresponding molar ratios for the magnesia are given in Table 5.

- 5 Table 4. Where the Baumé of the Solution is 26° and incorporating Quartz into Binder mixture

	Example 5	Example 6
NEDMAG(RTM) MgCl ₂ (g)	150	500
Water (g)	150	500
Baymag MgO – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	150	400
CIBA Encapulance mPCM	150	600
Quartz	150	100
Enthalpy Measure (kJ/kg)	48.8	47.0
Euroclass Fire Rating	C	C

Table 5. Molar ratios for MgO:MgCl₂:H₂O and weight ratios for cement:PCM in Examples 5 and 6

Baumé	Example	MgO	MgCl ₂	H ₂ O	Enthalpy	Euroclass	Cement:PCM
26°	5	5.0	1.00	17.3	48.8	C	3.0
26°	6	4.0	1.00	17.3	47.0	C	2.3

10

The molar ratio of MgO:MgCl₂:H₂O in the magnesia cement of this second embodiment thus varies in the ranges 4-5:1:17.3, considerably different from the magnesia cements utilised in Examples 10 and 11 of WO2009/059908 (a ratio of 5.3:1:12) and Examples 12 and 13 of WO2009/059908 (a ratio of 8:1:16).

15

- Prior to the baking step, these formulations can be cast to form the required composite panel assemblies such as wall and floor tiles. For completeness these formulations may also be used to form floor coatings and screeds, worktops, furniture, exterior cladding and siding panels, construction boards and building blocks and internal and external architectural mouldings. Also organic fillers including, but again not limited to, wood dust, flax sheaves, hemp and straw can be added as fillers in the manufacture of a construction board for interior/exterior walls and also ceilings.
- 5
- 10 In a further formulation in which the enthalpy of the binder exceeds 50kJ/kg, the fire rating reduces to Euroclasses E and F and is therefore limited in its use as a building material. In order to overcome this, intumescent agent of the type disclosed in U.S. Patent Appl. Pub. No. 2003/0211796A1 is added, again with mixing, to the binder and phase change material mixture. Typical intumescent agents are latex aqueous
- 15 dispersions. Preferred intumescent agents include Thermasorb and A/D Firefilm III from Carbolite, which are water-based intumescent agents. Example 8 shows how the addition of Thermasorb alters the Euroclass Fire Rating for a magnesia cement containing Encapsulacel from E (Example 7 in the absence of Thermasorb) to C.
- 20 Table 6. Where the Baumé of the Solution is 26° and incorporating intumescent into the Binder mixture of example 8 only.

	Example 7	Example 8
NEDMAG(RTM) MgCl ₂ (g)	300	300
Water (grams)	300	300
Baymag MgO – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	250	250
CIBA Encapsulacel mPCM	1000	1000
Intumescent – Carbolite Thermasorb (grams)	0	200
Enthalpy Measure (kJ/kg)	66.3	48.9
Euroclass Fire Rating	E	C

Table 7. Molar ratios for MgO:MgCl₂:H₂O and weight ratios for cement:PCM in Examples 7 and 8

Baumé	Example	MgO	MgCl ₂	H ₂ O	Enthalpy	Euroclass	Cement:PCM
26°	7	4.20	1.00	17.3	66.3	E	0.85
26°	8	4.20	1.00	17.3	48.9	C	0.85

For high enthalpy binders with poor Euroclass Fire Ratings, the mixtures are cast
 5 into an encasement that preferably comprises aluminium or copper or a combination thereof prior to the baking step. These materials have good thermal conductivity (aluminium – 237 (W/m k), copper – 401 (W/m k) as apposed to other encasements made with plain steel, for an example, which has a thermal conductivity value of 45-65 (W/m k). They therefore maximise the efficiency of the phase change material.

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The encasements can be formed into embodiments including, but not limited to, ceiling tiles, chilled ceiling systems, heating and cooling exchange units, wall panels, computer room floor tiles, raised access floor panels, curtain walling sections, suspended ceiling sections, extrusions for lightweight concrete floors, window and
 15 door frames, sleeving for heating and ventilation pipe work or ducting, and telecommunication and data rooms.

In a fourth formulation, a binder formulation having very high enthalpy, for example over 100kJ/kg, or over 150kJ/kg, utilising a secondary binder of the type disclosed in
 20 GB2344341 (PFA binder) is detailed in Examples 9 and 10.

Table 8. Where a secondary binder is utilised.

	Example 9	Example 10	Example 11
NEDMAG(RTM) MgCl ₂ (g)	50	44	0
Water (g)	50	56	100
Baume of MgCl ₂ :H ₂ O Solution	26	23	-
Baymag MgO (grams) – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	50	44	-
CIBA Encapulance M PCM (grams)	150	150	250
PFA Binder (grams)	50	50	50
Enthalpy Measure (kJ/kg)	144	101	155
Euroclass Fire Rating	E/F	E/F	F

Table 9. Molar ratios for MgO:MgCl₂:H₂O and weight ratios for cement:PCM in Examples 9 and 10

Baumé	Example	MgO	MgCl ₂	H ₂ O	Enthalpy	Euroclass	Cement:PCM
26°	9	5.04	1.00	17.3	144	E/F	1.00
23°	10	5.04	1.00	20.4	101	E/F	0.96

5

This gives a binder having a Euroclass fire rating of E/F. This secondary binder comprises dry, inert powder such as fly ash, pulverised rock or recycled building waste, phosphogypsum which is a by product of phosphoric acid production for phosphate fertiliser, and an alkaline salt of any metal and so may also be an industrial waste or by-product, for example, cellulose production. The dry, inert powder may be a major proportion by weight and may comprise 65-85%, preferably 74 – 76% by weight of the secondary binder. The alkaline salt may comprise 0.2 – 1.0%, preferably 0.4 – 0.6% by weight of the secondary binder. By way of example and not restricted to, a secondary compound comprising fly-ash (75%), phosphogypsum (24.5%) and alkaline salt (0.5%) would be preferred for a variety of

15

constructional materials. A suitable secondary binder is available from AMPC International Technologies (Cyprus) Ltd and has the product code IST. It is a quick setting, fireproof, lightweight, high thermal resistance compound.

5 In the formulation process where a magnesium cement binder and phase change material is used (Examples 9 and 10), the secondary binder is added when both of the aforementioned components have been mixed. It is recommended that the mixture of magnesium cement binder, phase change material and secondary binder is stirred vigorously for a further 10 – 15 minutes at high speed after the secondary
10 binder has been added. This is to ensure that there is even dispersion of the secondary binder within the mixture. In this formulation, the weight: weight ratio of secondary binder to phase change material is 1:3.

The use of a secondary binder provides components that can be used in cooling
15 systems, both passive and mechanical. These include chilled beam systems, ceiling tiles and computer/raised access floor panels, wall panels for computer data and server rooms, isolated telecommunication rooms. The important aspect of using the secondary binder with the phase change material is that it has to be in an encasement which is made from either aluminium, copper, steel, rigid PVC, timber,
20 plastics, glass, graphite, concrete, and cementitious or gypsum floor screeds.

In a fifth formulation, inclusion of the secondary binder alone along with the phase change material and therefore excluding the magnesium cement binder yields higher enthalpy results of 150kJ/kg and above (see Example 11 above). This is
25 because the nature of the secondary binder allows for a higher volume of phase change material by weight to be added to a small volume by weight of the secondary binder. However the drawback of the secondary binder when used in this formulation is that it has limited / non-existent fire resistant properties and therefore will only achieve Euroclass classification F. As such the formulation can
30 only be used in embodiments that consist of an encasement of some description that meets the local or national minimum building regulation standard. An example

of encasement materials include but not limited to aluminium, copper, steel, graphite, timber, and rigid P.V.C.

5 Where the formulation does not include the magnesium cement binder, the secondary binder and water are mixed for 5 – 10 minutes at high speed prior to the phase change material being added. After adding the phase change material the mixture is mixed for a further 10 – 15 minutes.

10 In this formulation, the weight ratio of secondary binder to phase change material is 1:5. The average mean enthalpy of preparations of this type are far superior than any achieved using a Sorel cement formulation. However this needs to be encased in aluminium or copper to give fire resistance.

15 In these high enthalpy embodiments, an intumescent agent of the type described above may also be added.

20 In a further formulation pozzolan cements can be used as a binder. In this formulation, in a first step, a pozzolan i.e. Pulverised Fuel Ash (PFA), Rice Husk Ash (RHA) or Metakaolin, is blended with Calcium Oxide (CaO)/lime in a ratio range of 1:1 to 1:4 (CaO: pozzolan) by weight to form the basis for a high strength pozzolan cement or alternatively a ratio of 1:5 to 1:10 by weight for a weaker formulation where strength is not a requirement, such as when the latent heat storage material is used in an encasement or composite panel assembly as described below.

25 The blend of pozzolan and CaO is suspended in water of a reasonable purity such as tap water, in which Calcium Hydroxide ($\text{Ca}(\text{OH})_2$) is formed, by mixing for a minimum of 15 minutes to form the pozzolan cement.

Microencapsulated phase change material such as Micronal[®] from chemical company BASF, is slowly mixed to the pozzolan cement. The addition of glass fibres can be added to the pozzolan with PCM to prevent cracking during the curing stages.

5

Fillers can be added to the pozzolan cement/PCM composition where a higher density and strength characteristics are required. The said fillers can include but are not limited to, quartz, stone, limestone, silica sand, stone dust, perlite, marble or graphite.

10

Some examples of pozzolan cement/PCM compositions as well as magnesia cements and magnesium chloride binder compositions are given in Tables 10, 11 and 12 and Tables A - F.

15 Table 10: Where Pozzolan used is Pulverised Fuel Ash (PFA)

	Example 11A	Example 12	Example 13
Pulverised Fuel Ash (PFA) (grams)	100	100	400
Calcium Oxide (CaO) (grams)	100	100	100
Water (grams)	600	400	1000
Silica Sand (grams)	100	-	-
BASF Micronal [®] PCM (grams)	700	400	1000

Table 11: Where Pozzolan used is Rice Husk Ash (RHA)

	Example 14	Example 15	Example 16
Rice Husk Ash (RHA) (grams)	100	100	400
Calcium Oxide (CaO) (grams)	100	100	100
Water (grams)	600	400	1000
Silica Sand (grams)	100	-	-
BASF Micronal® PCM (grams)	700	400	1000

5

Table 12: Where Pozzolan used is Kaolin

	Example 17	Example 18	Example 19
Kaolin (grams)	100	100	400
Calcium Oxide (CaO) (grams)	100	100	100
Water (grams)	600	400	1000
Silica Sand (grams)	100	-	-
BASF Micronal® PCM (grams)	700	400	1000

Table A

Sample using Organic Microencapsulated Phase Change Material	Sample 1
BASF Micronal® DS 5000X (grams)	3000
MgCl ₂ (H ₂ O) _x solution, Baume 15° (grams)	2000
Pulverised Fuel Ash (High lime) (grams)	400
Calcium Oxide (grams)	100
Glass Fibre Strands (grams)	10
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	914.10kJ/m ²
1 kWh cooling capacity:	4.01m ²

Table A1

Sample using Organic Microencapsulated Phase Change Material	Sample 1a
BASF Micronal® DS 5000X (grams)	1500
Portland Cement (grams)	300
Pulverised Fuel Ash (High lime) (grams)	400
Calcium Oxide (grams)	100
Glass Fibre Strands (grams)	10
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	457.05kJ/m ²
1 kWh cooling capacity:	8.10m ²

Table A2

Sample using Organic Microencapsulated Phase Change Material	Sample 1b	Sample 1c
BASF Micronal® DS 5000X (grams)	4500	15000
MgCl ₂ (H ₂ O) _x solution, Baume 19° (grams)	3000	
MgCl ₂ (H ₂ O) _x (grams)		500
Water (grams)		20000
Magnesium Oxide (grams)	500	500
Glass Fibre Strands (grams)	10	
Based on 30mm thick panel, with a density of 1000kg/m ³ :		
Heat Storage Capacity:	1372kJ/m ²	1650kJ/m ²
1 kWh cooling capacity:	2.7m ²	2.24m ²

Table A3

Sample using Organic Microencapsulated Phase Change Material	Sample 1d
BASF Micronal® DS 5000X (grams)	6000
MgCl ₂ (H ₂ O) _x solution, Baume 19° (grams)	4000
Pulverised Fuel Ash (High lime) (grams)	800
Calcium Oxide (grams)	200
Magnesium Oxide (grams)	500
Glass Fibre Strands (grams)	10
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	1828.2kJ/m ²
1 kWh cooling capacity:	2.02m ²

Table B

Sample using Organic Phase Change Material	Sample 2
Rubitherm® RT21 (grams)	3000
MgCl ₂ (H ₂ O) _x solution, Baume 15° (grams)	2000
Pulverised Fuel Ash (High lime) (grams)	400
Calcium Oxide (grams)	100
Glass Fibre Strands (grams)	10
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	1113.54kJ/m ²
1 kWh cooling capacity:	3.33m ²

Table C

Sample using Inorganic Microencapsulated Phase Change Material	Sample 3
Capzo International BV – Thermusol® HD60 GE (grams)	3000
Water (H ₂ O) grams)	2000
Rice Husk Ash (grams)	1000
Calcium Oxide (grams)	200
Glass Fibre Strands (grams)	50
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	1662kJ/m ²
1 kWh cooling capacity:	2.22m ²

Table D

Sample using Eutectic Phase Change Material	Sample 4
Rubitherm® SP25 A8 (grams)	3000
MgCl ₂ (H ₂ O) _x solution, Baume 15° (grams)	2000
Pulverised Fuel Ash (High lime) (grams)	400
Calcium Oxide (grams)	100
Glass Fibre Strands (grams)	10
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	1495.8kJ/m ²
1 kWh cooling capacity:	2.48m ²

5 Table E provides an example of a latent heat storage material using magnesium chloride as a binder.

Table E

Sample using Organic Microencapsulated Phase Change Material	Sample 5
Ciba Encapsulance® (grams)	3000
MgCl ₂ (H ₂ O) _x solution, Baume 23° (grams)	1500
Glass Fibre Strands (grams)	10
Based on 20mm thick panel, with a density of 1000kg/m ³ :	
Heat Storage Capacity:	1246.5kJ/m ²
1 kWh cooling capacity:	2.97m ²

Table F

Sample using Organic Microencapsulated Phase Change Material and Baumé of 12°	Sample 6
BASF Micronal® DS 5000X (grams)	2500
NEDMAG(RTM) MgCl ₂ (grams)	1000
Glass Fibre Strands (grams)	10
Baymag MgO – comprising of: Magnesium Oxide: 94 – 98% (wt/wt) Calcium Oxide: 1.5 – 4%	1000
Water	2750

Table G 1:10 CaO:pozzolan example

	1:10 (Cao: pozzolan) example
Calcium Oxide (CaO) (grams)	100
Pulverised Fuel Ash (PFA) (grams)	1000
Ordinary Portland Cement (OPC) (grams)	100
Water (grams)	4000
BASF Micronal mPCM (grams)	4000

5 Table H Various ratios of CaO to Pozzolan

	Ratio 0.1 : 1	Ratio 1 : 5
Calcium Oxide (CaO) (grams)	100	100
Pulverised Fuel Ash (PFA) (grams)	500	500
Water (grams)	6000	3000
BASF Micronal mPCM (grams)	5000	2500

In the foregoing, Examples 1, 5, 6 and 8 (using magnesia cement) have enthalpy values below about 50 kJ/kg, and have a Euroclass C rating. This means they can be used to form board materials and other building materials.

- 5 Formulations having higher enthalpy values and/or lower Euroclass fire resistance need to be encased, for example, aluminium, copper, graphite or mild steel. These encasements include acoustic tiles, particularly acoustic ceiling tiles and ceiling tiles which form part of a suspended ceiling.
- 10 Embodiments of the invention will now be described in relation to the accompanying figures. It will be appreciated that acoustic composite panel assemblies can take a variety of forms, and examples provided below are described in relation to acoustic ceiling tiles. According to various embodiments, but not necessarily all, the present invention provides an acoustic tile including a tray having perforations, the tile
- 15 having an interior region including an infill material and an acoustic barrier, and where the infill material is a latent heat storage material.

The infill material can be disposed in a first region or regions of the tray, and the perforations can be disposed in a second region or regions of the tray. The term

20 'perforations' in this context has a broad meaning. Perforations are required so that sounds in the space below the tile can escape through the face of the tile and make contact with the acoustic barrier within the acoustic composite panel assembly. Thus any aperture or series of apertures that enable this to take place fall within the meaning of the term 'perforations'.

25

The first region can be around an edge region of the tray, and the second region can be a central region. For example, and referring now to Figures 1, 2a and 2b, which show embodiments of an acoustic tile 100 including a tray 102 having perforations

30 104 and an infill component 106 in which the infill component is disposed around an edge region, which surrounds a central region having perforations. An acoustic barrier 108 (shown as the shaded area in Figures 2a and b) is located in the central

region adjacent to and behind the perforations, as viewed from the room side of the tile.

5 The first region or regions can be separated from the second region or regions by a barrier. For example, and referring now to Figures 2a and b, strips 110 are bonded to the tray around a periphery of the central region to separate the infill component from the central region having the perforations and housing the acoustic barrier.

10 The first region or regions can be that part of the tray not including the second region or regions. For example, and referring to Figure 2c, the second region having the perforations extends to the edge of the tray and the first region having the infill component occupies the remaining regions of the tray.

15 The shape of the second region having the perforations can be chosen to provide a number of decorative effects on the tile. For example, the second region can have a square, rectangular or diamond shape (as shown in Figures 1, 2a and 2c) or it can have an elliptical or circular shape (as shown in Figure 2b). Other shapes, including polygonal shapes, can be used.

20 The first region having the infill material can have a cruciform (+-shaped) or saltire shape (X-shaped), for example, as shown in Figures 2d and 2f, respectively. Detail of the barriers 110 separating the first region or regions from the second region of regions is shown in Figure 2e. These can be metal and can be bonded to the tray.

25 The infill material can also take other shapes. For example, the infill material can be in the form of strips arranged across the tray, as shown in Figure 2g, the second regions between the strips have the perforations.

The infill material can occupy the interior region of the tray. For example, and referring to Figure 2h, perforations in the tray penetrate the infill material, and the acoustic barrier is disposed on top of the infill material, as indicated by the shading.

5 Referring now to Figure 3, which shows embodiments of an acoustic tile 300, tray 102 includes a plurality of corrugated sections 302 having an infill component 106 disposed within them and perforations 104 in the region of the tray between the corrugations. An acoustic quilt or mat 108 is located adjacent to the corrugated sections.

10

In Figure 4, the corrugated sections have an indented, square notched or crenulated shape, but saw-tooth or other repeating shapes may be used. Thus in Figure 5, the corrugated sections have a generally sinusoidal shape.

15 In Figures 1-5, the tile is shown in a generally horizontal arrangement for use as a ceiling tile, but it is to be understood that the tile may be used in any spatial arrangement, including on a wall or on a floor.

The region or regions of the panel assembly occupied by the latent heat storage
20 material can incorporate a plurality of support elements. Various types of support elements are shown in Figures 6 to 9 inclusive. Referring now to Figure 6, which shows an encasement having a tray part 402 and a lid part 404 forming in combination an interior region, where the interior region includes a honeycomb structure 408. Whilst this is shown as a substantially square section it could be
25 formed in any particular shape as dictated by the designs described above.

Referring now to Figure 7, which shows a plan view of a honeycomb structure 408, the structure of which includes a number of cells 410 partitioned by partition walls 412 and extending across the interior region. Individual cells tessellate or interlock
30 with their neighbours. The shape of a section of the cell can be a polygonal shape.

The shape can be, for example, a square shape, a rectangular shape, a triangular shape, or a hexagonal shape.

Referring to Figure 8 this shows a plan view of alternative heat conducting elements
5 508, being ribbed, ribboned or finned wall structures extending substantially across the interior region, with latent heat storage material 510 filling the space between each element.

In Figures 6 to 9, the partition walls can comprise a metal, for example aluminium,
10 copper, mild steel or stainless steel or a plastic such as glass-reinforced plastic (known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) reinforced plastic, and Kevlar reinforced plastic. Thermally conductive plastics are also known, and can be used in the present invention. The partition walls extend substantially through the layer of latent heat storage material.

15

Referring now to Figure 9, which shows an encasement having a tray part 602 and a lid part 604 forming an interior region, the interior region includes a polygonal structure 608 having cells of a square shape.

20 Referring again to Figures 6 to 9, the latent heat storage material 406, 510 and 606 is disposed in the cells, ribbed, ribboned or finned interior region. The interior region of the tray is enclosed at its side by edges. Although only part of the edges 402A, 602A is shown in Figures 6 and 9, it will be appreciated that these edges surround substantially all sides of the encasement, to form what is, in effect, a tray. The tray
25 has a front panel which has a first, front face, which is usually the side of the assembly which is on view when the panel assembly is in its "in use" position. The front panel also has an opposing, second face which faces inside the tray. The terms "panel front" and "front panel" are used interchangeably in this context.

Although the examples shown in Figures 6 to 9 are substantially square, the regions occupied by support elements can be any suitable shape, including the shapes of the first regions described above.

5 Example ceiling tile sizes can be 300mm x 300mm 595mm x 595mm, 600mm x 600mm or 600mm x 1200mm to suit standard manufactured sizes, but can also be of any size. The tiles can be used in either a new build or retrofit project without the need to replace the suspended ceiling grid. The number of ceiling tiles required in a project is determined by the cooling capacity requirements of the building.

10

The encasement is formed from a material providing strength, heat conductance and fire-resistance. A number of such materials will suggest themselves to the person of ordinary skill in the art; particularly suitable materials include aluminium, copper, graphite, mild steel or stainless steel. Such an encasement can be used as
15 a ceiling tile, particularly a ceiling tile which forms part of a suspended ceiling. It is also equally applicable to floor tiles or to the group of structures set out above.

The tile can, for example, incorporate an aluminium honeycomb (hexagonal cells) or mesh core (square cells) or incorporate ribbed, ribboned or finned wall sections.
20 These can be bonded with a two part solvent free polyurethane or acrylic adhesive to what will be the underside of the surface finish of the tile and that should preferably be made of aluminium, copper, graphite, mild steel, magnesium oxide board or calcium silicate board, or gypsum plasterboard. Around the perimeter of the tile, an edge strip 402A can be incorporated which is applied to the same height
25 as the honeycomb core. The cells within the honeycomb or mesh core, or the ribbed, ribboned or finned sections are filled with the latent heat storage material. Dependent on the latent heat storage material, which will have different fire retardant properties, a lid component can be bonded with, for example, a two part solvent free polyurethane or acrylic adhesive, to the adjacent side of the honeycomb
30 or mesh core, and/or the edges of the front panel, thus encasing the latent heat storage material. The lid can be made of different materials but preferably aluminium, copper, graphite, mild steel, stainless steel, magnesium oxide board,

calcium silicate board, gypsum plasterboard or woven glass fibre mesh. Alternatively, the lid can be formed from or incorporate an insulating material such as mineral wool, Expanded Polystyrene (EPS), polyurethane (PU), polyisocyanurate (PIR) or Aerogel blanket.

5

The infill component may be any suitable latent heat storage material including, but not limited to, one of the latent heat storage material storage materials described above. To achieve an enthalpy below 50kJ/kg, a formulation based on a magnesia cement, a microencapsulated PCM and quartz fillers as described in Example 5 can be used to form the infill component, providing an enthalpy of 48.8kJ/kg and achieves a Euroclass C fire rating.

10

To achieve an enthalpy in the range 50 – 100kJ/kg, formulations based on the magnesia cements disclosed above, such as those of Examples 3, 4 and 7, can be used to form the infill component. These are cast into suitably sized sheets, cured and cut into sections that are substantially the same shape as the interior region and will fit inside the tile. For example they can be cast into 1200mm x 2400mm sheets, cured and cut into 600mm x 600mm or 600mm x 1200mm or 500mm x 500mm sections. These sections are then adhered to the internal surface of the tray, for example, using a PVA based adhesive.

15

20

To achieve an enthalpy of over 100kJ/kg, formulations incorporating the PFA binder disclosed above, such as those of examples 9, 10 and 11, can be used to form the infill component. These can be cast directly into the tray part of the tile and left to cure.

25

For the chilled ceiling tile, a high enthalpy compound, such as that described in example 11 above which has an enthalpy of 155kJ/kg, can be cast around the copy pipes.

30

The tray can comprise a material providing strength, heat conductance and fire-resistance. A number of such materials will suggest themselves to the person of ordinary skill in the art; particularly suitable materials include aluminium, copper, graphite and mild steel.

5

The tray part can be a material providing heat conductance and strength and optionally fire resistance. A number of such materials will suggest themselves to the person of ordinary skill in the art; particularly suitable materials include aluminium, copper, graphite and mild steel. To further increase flame-resistance, a layer of
10 intumescent material can be formed on the internal surface of the tray part of the tile. In manufacture this is achieved by spraying the intumescent material. Preferred intumescent materials include Carboline Thermosorb or water based A/D Firefilm III. Typically the layer of intumescent material is about 0.5 mm thick.

15 The tray can be formed from a metal sheet by cutting, folding or pressing. For example, the metal sheets can be aluminium sheets manufactured to widths of 1250mm x lengths of 3000mm. The thickness of gauge is generally in the range 0.5 to 3.5mm.

20 The metal sheets are cut, for example by guillotine, to the desired size. For example, the size is 620mm x 620mm, or 620mm x 1220mm, or 520mm x 520mm. The cut sheets are folded at an approximately 90° angle 10mm from each edge or they can be brake pressed to form a tray part with a depth of 10mm (see Figure 1). These sheets can also be pressed to form a tegular tile design, which has a greater
25 depth of between 15mm-20mm (see Figure 2). This provides tiles having dimensions of, for example, 300mm x 300mm, 500mm x 500mm, 595mm x 595mm, 600mm x 600mm, 600mm x 1200mm. Other sizes are also available, depending on application.

Whether it is a flat or tegular design, the tile sits into a T-bar ceiling grid system just like normal suspended ceiling systems. Therefore the tile rests on the flange of the T-bar.

- 5 Acoustic materials used in the acoustic tiles include: acoustic non-woven fleece 46g/m^2 , acoustic mat 25kg/m^3 @ 15mm thick, acoustic mat 60kg/m^3 @ 40mm thick, black fibreglass non-woven mat and black fibreglass non-woven mat with aluminium foil.

- 10 Typical hole diameters for the perforations in these acoustic ceiling tiles include: 0.5mm, 0.7mm, 1.00mm, 1.50mm, 2.00mm, and 2.50mm. Examples of suitable perforations are round holes diagonal, round holes straight, round holes staggered, square holes straight, slot holes straight, rhomboidal holes staggered.

Claims

1. An acoustic composite panel assembly comprising:
 - 5 (i) a panel front having a first face and an opposing second face, said panel front comprising a thermally conductive material and further comprising perforations;
 - (i) a latent heat storage material comprising a phase change material;
 - (iii) an acoustic barrier;
- 10 wherein the latent heat storage material is in heat conducting contact with the panel front.
2. An acoustic composite panel assembly according to Claim 1 wherein the panel front incorporates depending edges to form a tray construction.
- 15 3. An acoustic composite panel assembly according to Claim 1 or Claim 2 wherein said latent heat storage material is disposed in a first region or regions of the panel assembly and said perforations are disposed in a second region or regions of the panel assembly.
- 20 4. An acoustic composite panel assembly according to Claim 3 wherein the first region or regions are separated from the second region or regions by one or more barriers.
- 25 5. An acoustic composite panel assembly according to Claim 3 or Claim 4 wherein said first region or regions are the part or parts of the panel assembly not formed by said second region or regions.
- 30 6. An acoustic composite panel assembly according to any of Claims 3 to 5 inclusive wherein the second region is formed in a shape selected from the group comprising:-
 - a rectangle;
 - a circle;

a polygon;
an ellipse;
a cruciform;
a saltire; or combinations thereof.

5

7. An acoustic composite panel assembly according to any of Claims 2 to 5 inclusive wherein the heat storage material is disposed in a series of strips arranged across the panel assembly.

10 8. An acoustic composite panel assembly according to Claim 1 or Claim 2 wherein said perforations penetrate both the front of the panel assembly and the latent heat storage material.

15 9. An acoustic panel assembly according to Claim 8 wherein the latent heat storage material extends over substantially entirely the whole of the panel front within the composite panel assembly.

20 10. An acoustic composite panel assembly according to Claim 8 or Claim 9 wherein the acoustic barrier is disposed over the latent heat storage material on a side furthest from the front face of the panel assembly.

11. An acoustic composite panel assembly according to Claim 1 or Claim 2 wherein the panel assembly comprises a plurality of corrugated sections.

25 12. An acoustic composite panel assembly according to Claim 11 wherein latent heat storage material and perforations occupy alternate regions formed by the corrugated sections.

30 13. An acoustic composite panel assembly according to Claim 10 or Claim 11 wherein the profile of the corrugated sections is selected from the group comprising:-

crenulated shapes;
sinusoidal shapes

saw-toothed shapes; and combinations thereof.

14. An acoustic composite panel assembly according to any preceding claim wherein the acoustic barrier comprises an acoustic quilt, fleece or mat.

5

15. An acoustic composite panel assembly according to Claim 14 wherein the acoustic barrier comprises a non-woven fleece having a range from 15g/m² to 75g/m².

10 16. An acoustic composite panel assembly according to Claim 15 wherein the acoustic mat has a density of between 15kg/m³ and 75kg/m³.

17. An acoustic composite panel assembly according to any preceding claim wherein the region occupied by the latent heat storage material incorporates a plurality of support elements embedded in the latent heat storage material to provide support to that layer.

15

18. An acoustic composite panel assembly according to Claim 17 wherein the plurality of support elements segregate the latent heat storage material layer into discrete sections.

20

19. An acoustic composite panel assembly as claimed in Claim 17 or Claim 18 wherein the plurality of support elements extend from the opposing second face of the front panel into and substantially through the latent heat storage material layer.

25

20. An acoustic composite panel according to any of Claims 17 to 19 inclusive wherein some or all of the plurality of support elements comprise heat conduction elements, formed from a thermally conductive material and adapted to convey heat between the panel front and the latent heat storage material layer.

30

21. An acoustic composite panel assembly according to any of Claims 17 to 20 inclusive wherein the plurality of support elements comprise structures selected from the group comprising:-

honeycomb structures:

polygonal structures formed from regular or irregular polygons;

fins;

ribs;

5 ribbons;

crenulations;

mesh;

protrusions; and combinations thereof.

10 22. An acoustic composite panel assembly according to any preceding claim further comprising a lid and wherein the lid is bonded to or otherwise attached to the front panel.

15 23. An acoustic composite panel assembly according to any preceding claim wherein the latent heat storage material is formed from a mixture comprising a binder, a phase change material and water.

24. An acoustic composite panel assembly according to claim 23 wherein the binder is selected from the group comprising:-

20 a cement;

an Ordinary Portland Cement (OPC);

a magnesia cement;

a pozzolan cement;

a magnesium chloride solution; and mixtures thereof.

25

25. An acoustic composite panel assembly according to Claim 24 wherein the binder comprises a magnesia cement formed from magnesium chloride, magnesium oxide and water.

30 26. An acoustic composite panel assembly according to Claim 25 wherein the molar ratio of said magnesium chloride to said water used in the preparation of the magnesia cement is in the range 1:15 to 1:36.

27. An acoustic composite panel assembly according to Claim 26 wherein the molar ratio of said magnesium chloride to said water used in the preparation of the magnesia cement is in the range of 1:17 to 1: 32.
- 5 28. An acoustic composite panel assembly according to any of Claims 25 to 27 inclusive wherein, during the preparation of the magnesia cement, the said magnesium chloride is dissolved in said water to give a solution having a Baumé value in the range 12° to 27.5°.
- 10 29. An acoustic composite panel assembly according to Claim 28 wherein the Baumé value of the magnesium chloride solution used in the preparation of the magnesia cement is in the range of 15° to 26°.
- 15 30. An acoustic composite panel assembly according to any of Claims 25 to 29 inclusive wherein the molar ratio of said magnesium chloride to said magnesium oxide used in the preparation of the magnesia cement is in the range 1:1 to 1:5.5.
- 20 31. An acoustic composite panel assembly according to Claims 28, 29 or 30 wherein the weight ratio of magnesium chloride : magnesium oxide : water : organic phase change material is about 1:1:2.3:1± 20%.
32. An acoustic composite panel assembly comprising according to Claim 24 wherein the binder comprises a pozzolan cement.
- 25 33. An acoustic composite panel assembly according to Claim 32 wherein the pozzolan cement comprises calcium oxide and a pozzolan and water, and wherein said calcium oxide and said pozzolan used in the preparation of the pozzolan cement are present in a ratio of 1:1 to 1:10 (CaO:pozzolan) by weight.
- 30 34. An acoustic composite panel assembly according to Claim 33 wherein the said calcium oxide and the said pozzolan used in the preparation of the pozzolan cement are present in a ratio of 1:1 to 1:4 (CaO:pozzolan) by weight.

35. An acoustic composite panel assembly according to any of Claims 32 to 34 inclusive wherein the ratio of binder (i.e. CaO + Pozzolan) to water is in the range 1:1 to 1:5 binder to water by weight.
- 5 36. An acoustic composite panel assembly according to any of Claims 32 to 35 inclusive wherein the pozzolan is selected from the group comprising:-
pulverised flue ash (PFA);
kaolin, including metakaolin;
rice husk ask (RHA);
10 pozzolana;
silica fume;
ground granulated blast furnace slag; and mixtures thereof.
- 15 37. An acoustic composite panel assembly according to any Claims 32 to 36 inclusive additionally comprising glass fibre.
- 20 38. An acoustic composite panel assembly according to any of Claims 23 to 37 inclusive wherein the latent heat storage material further comprises one or more fillers.
39. An acoustic composite panel assembly substantially as herein described with reference to and as illustrated in any combination of the accompanying drawings.

Figure 1

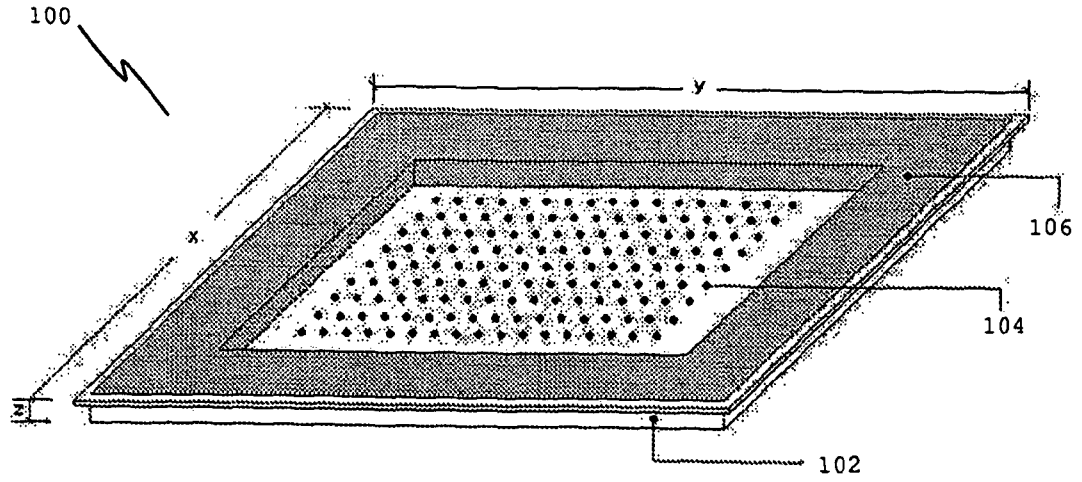


Figure 2a

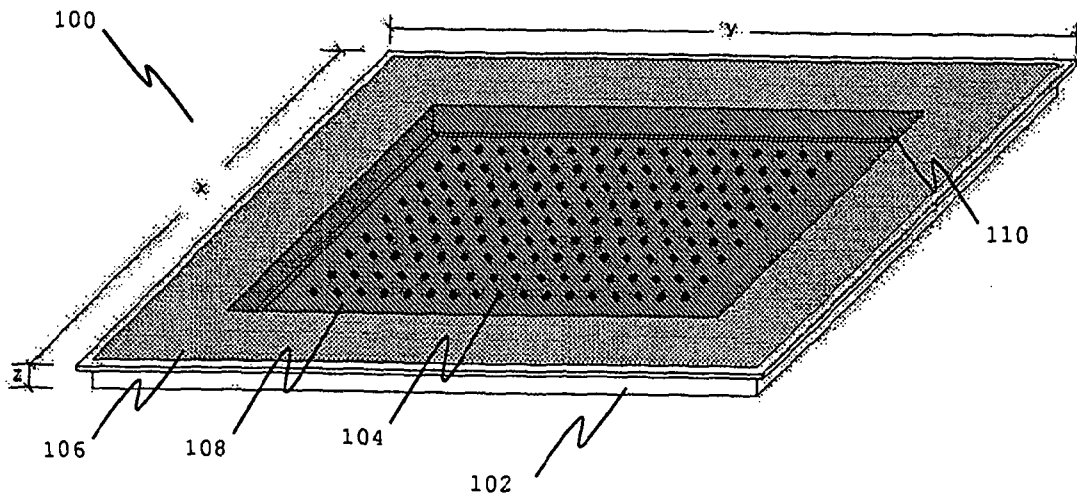


Figure 2b

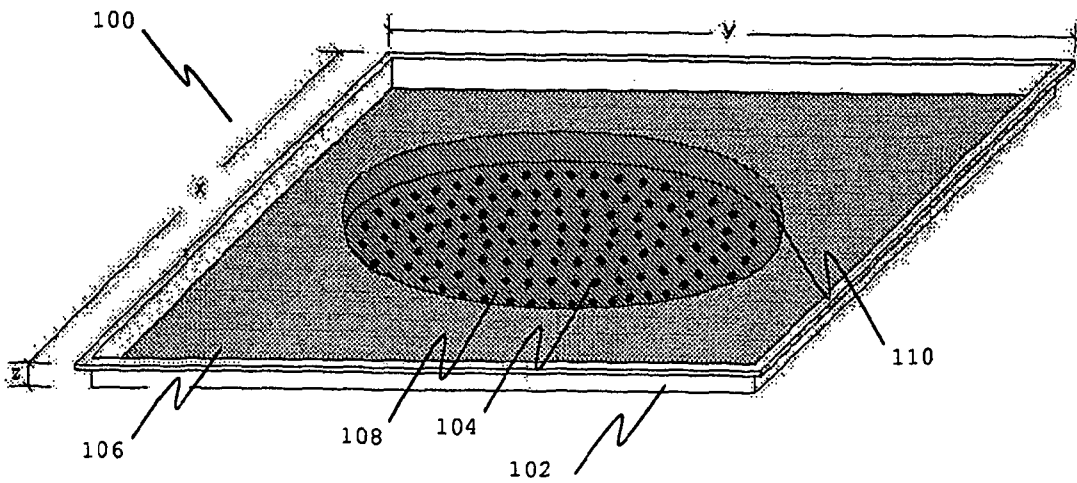


Figure 2c

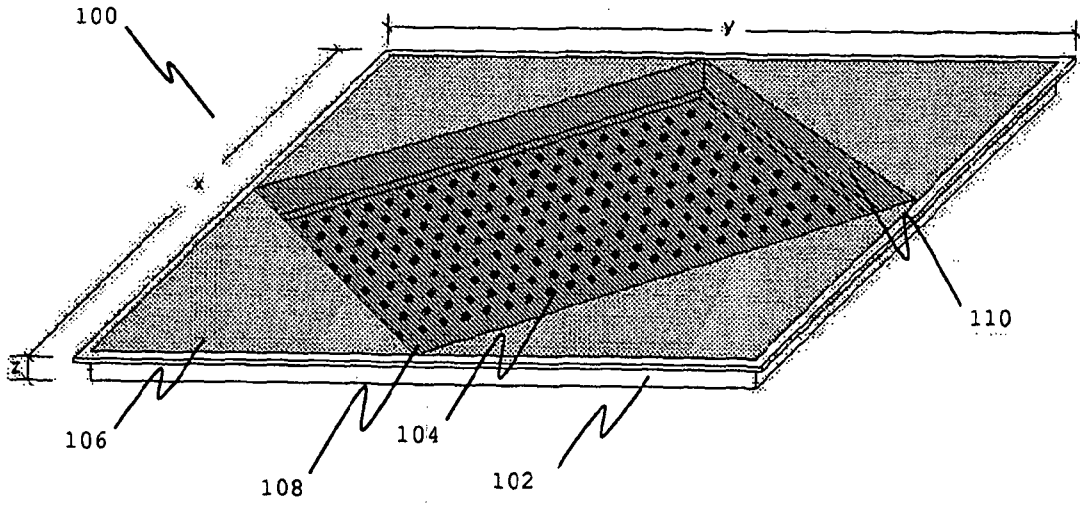


Figure 2d

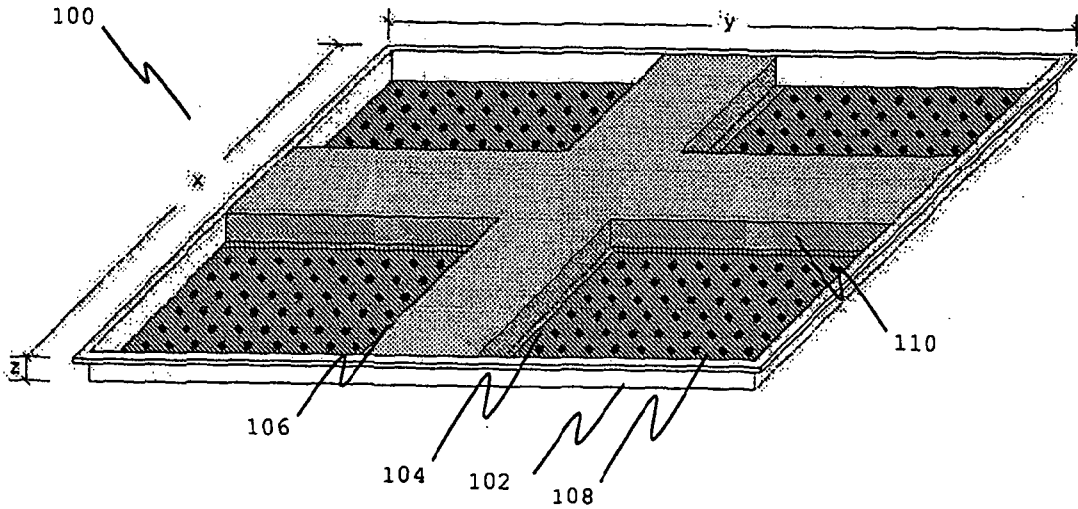


Figure 2e

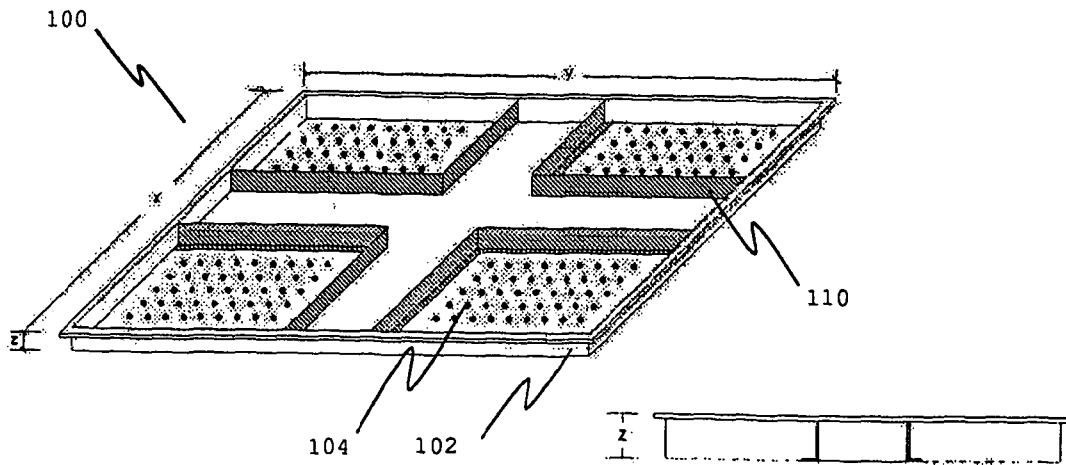


Figure 2f

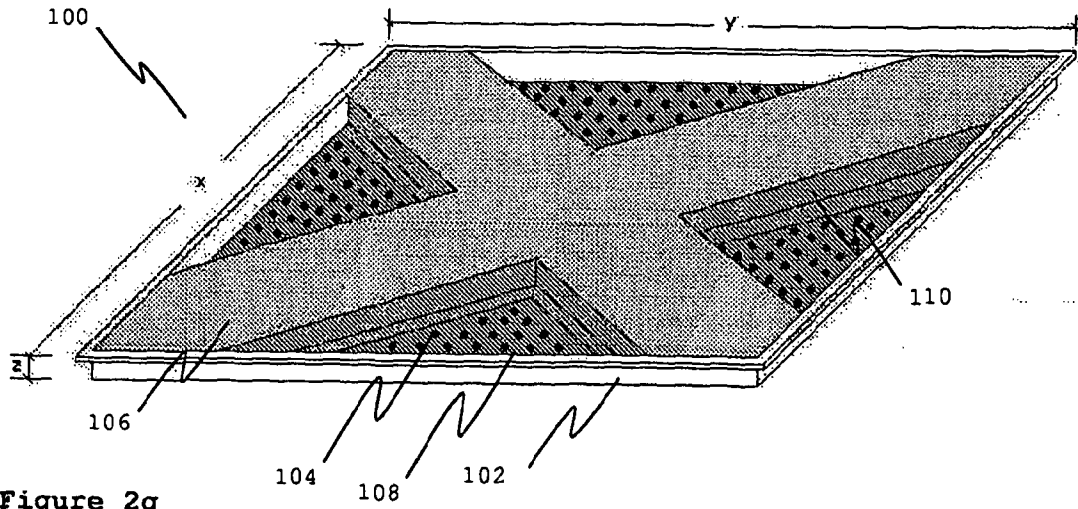


Figure 2g

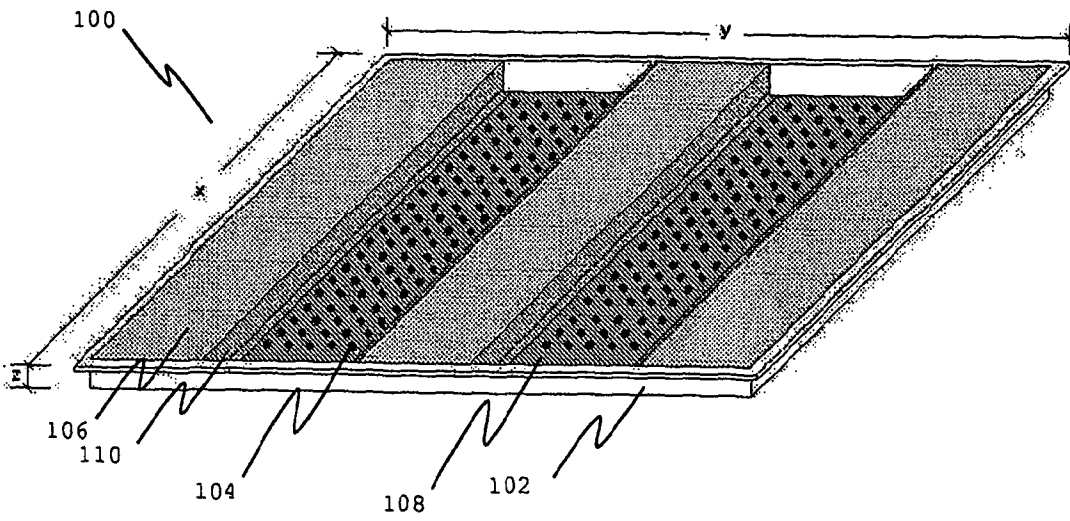


Figure 2h

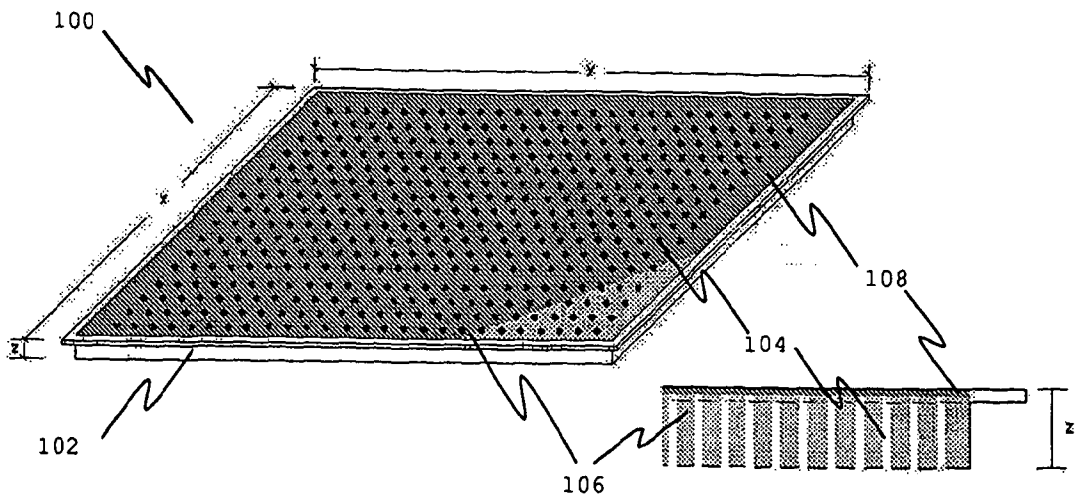


Figure 3

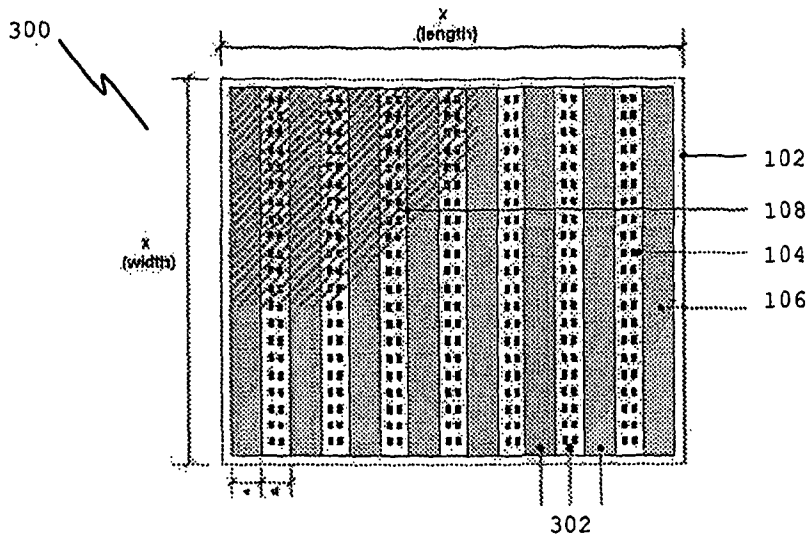


Figure 4

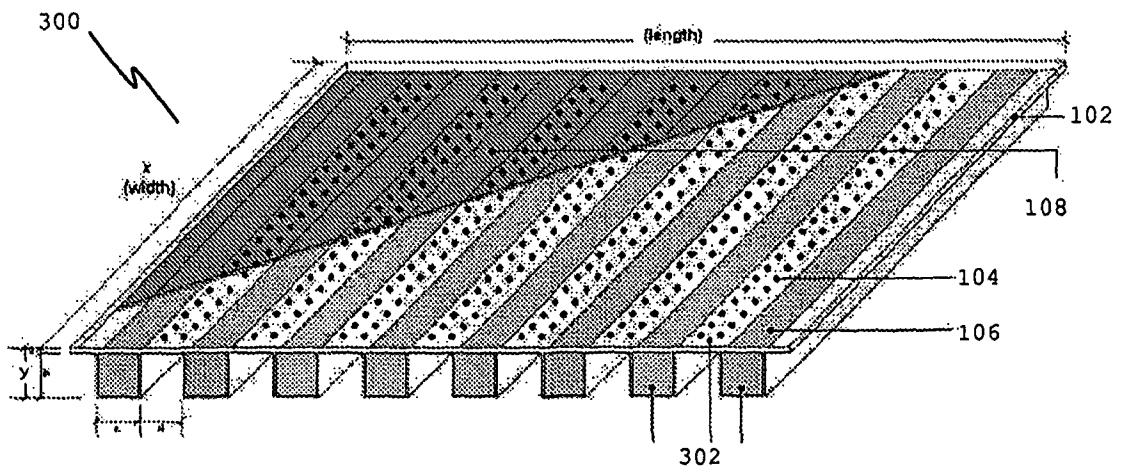


Figure 5

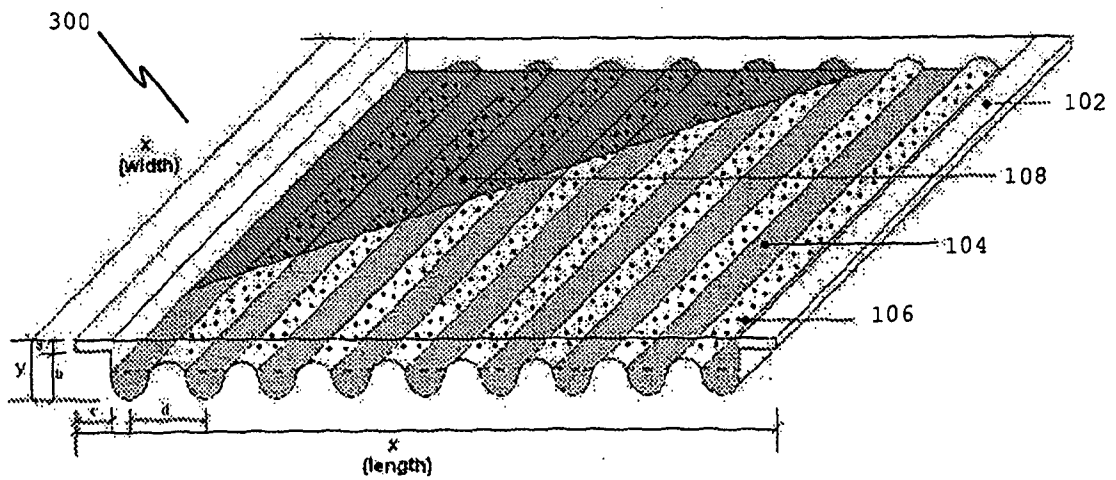


Figure 6

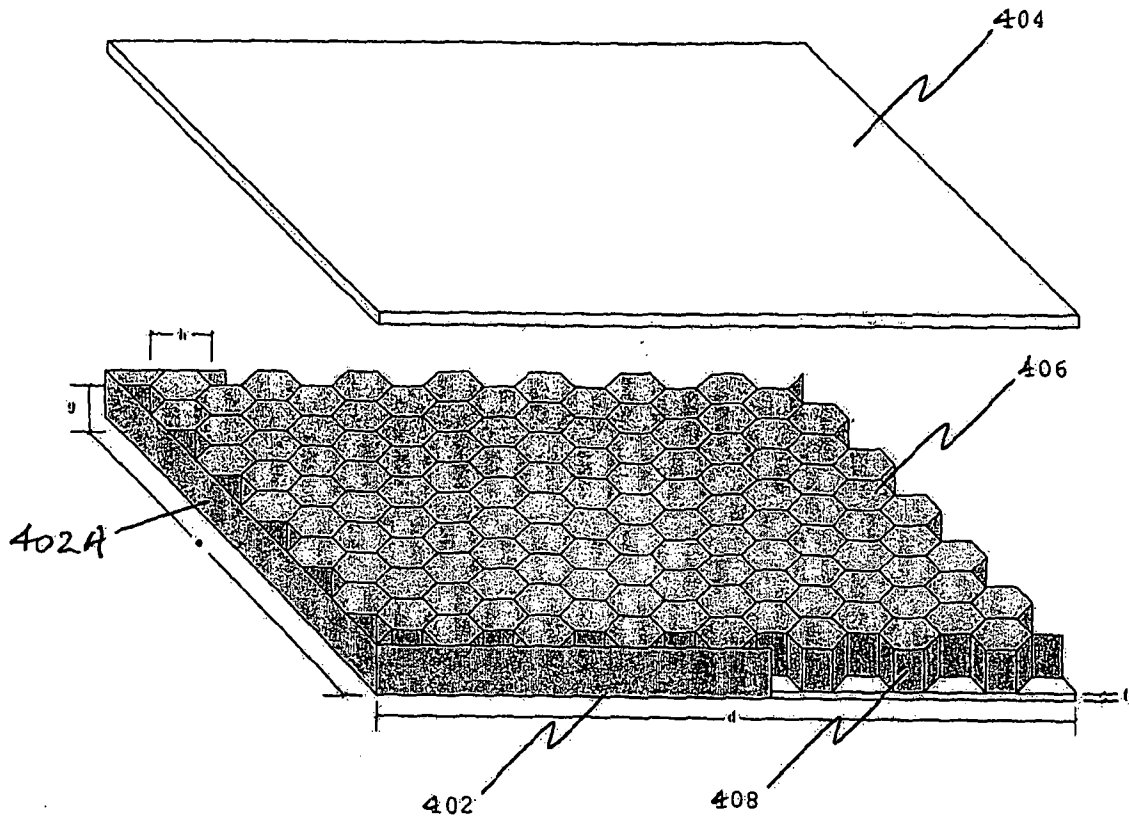


Figure 7

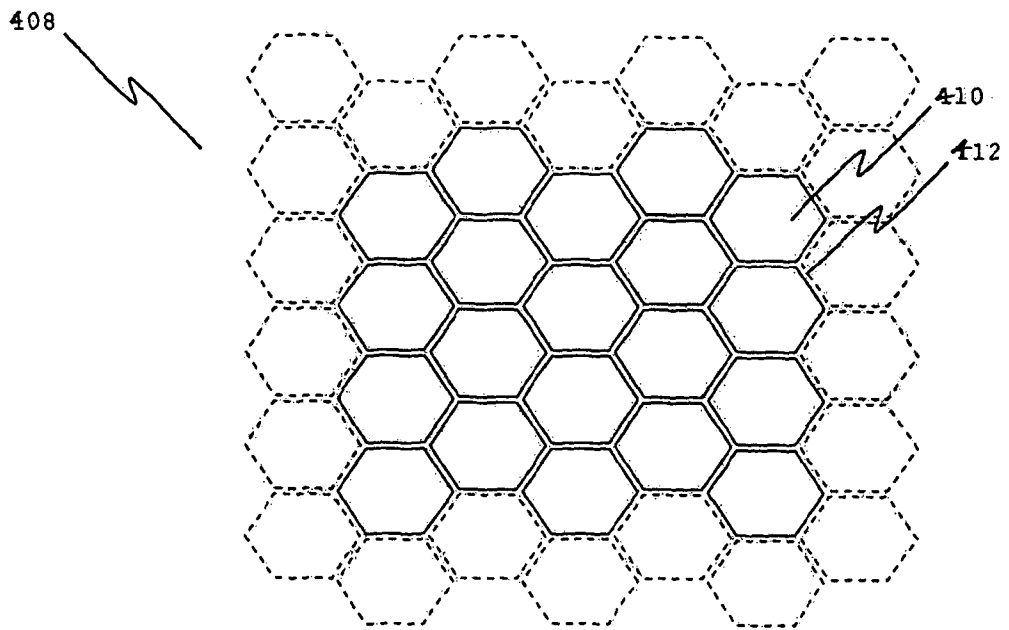


Figure 8

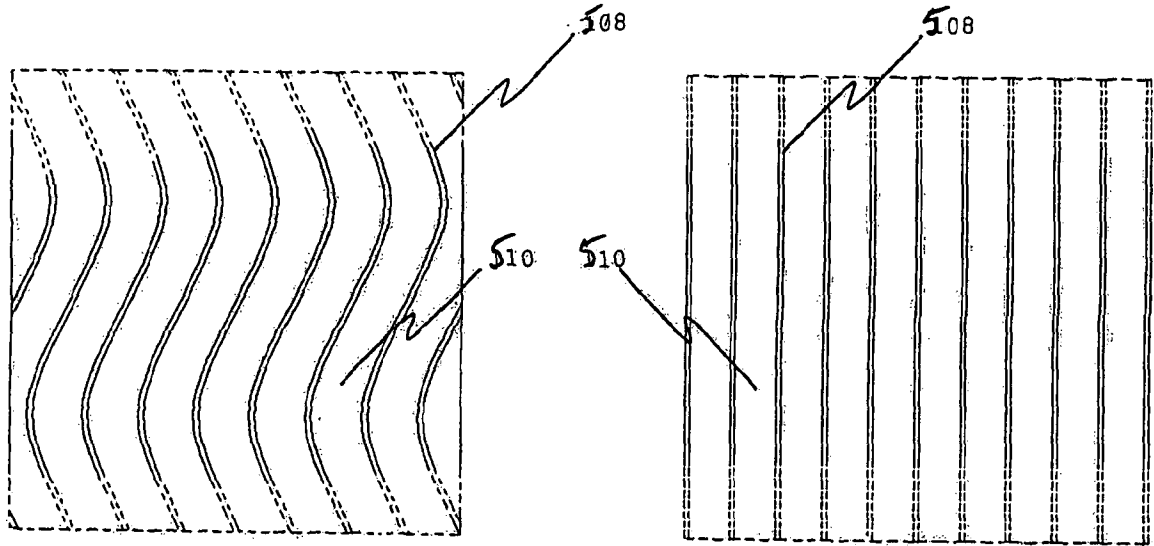


Figure 9

