

Fundamental

SERIES 8 MODULE 2

CURRENT THINKING ON...

Insulation

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The primary function of thermal insulation in British buildings is to keep them warm. On hot days in summer insulation will also reduce heat gain through the building fabric. The majority of the thermal efficiency requirements of modern buildings are achieved by insulation products. However, structural elements, such as blockwork, flooring and roofing materials play an increasing role in improving buildings' thermal performance. This module focuses upon the use of thermal insulation for heat retention in buildings.

Heat loss and heat gain occur via three heat transfer mechanisms: conduction, convection and radiation.

Conduction

Conduction is the transfer of heat between atoms within a material. Energy is transferred by the movement of free electrons, or vibrations passing between atoms. Atoms must be in close proximity to each other for conduction to be effective and hence conduction is strongest in solid materials and weakest in gases, including gas mixes such as air. This characteristic of gases is exploited in the manufacture of insulants, whereby pockets of air are incorporated into bulk materials, or between fibres to attenuate conduction.

Convection

When heat is applied to a fluid, such as cold air in a wall cavity its density decreases, subjecting it to a lower gravitational force per unit volume than cooler denser air, causing it to rise. The cooler air is in turn drawn up to replace the heated air, creating



an air movement termed natural convection. The natural convection flow will continue taking heat from the wall until equilibrium has been reached, such as the entire body of air reaching the same temperature as the wall surface. Convective heat loss can be reduced by reducing air movement, such as by filling wall cavities with insulation, or optimising the air gap within double glazing. The air gap in double glazing reduces conduction between the panes. As the gap increases, conduction decreases. However, double glazing units with an air gap of over 20mm will tend to have higher 'U' values than

similar units with air gaps of less than 20mm due to convective heat loss in the cavity increasing by more than conductive heat loss is attenuated.

Surface treatments can be applied to reduce convective heat loss. By minimising surface roughness laminar flow of air is promoted in favour of turbulence, which lessens the transfer of heat from the surface of the wall to the air.

Radiation

All surfaces at temperatures above absolute zero radiate heat to their surroundings. Heat and light are forms of electromagnetic radiation.

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Heat occurs at the infra-red end of the spectrum, while light is in the visible portion. As with all forms of electromagnetic radiation, heat radiates across vacuums, air gaps and through mixed constructions. Radiation is the primary heat transfer mechanism for the heating of the Earth by the Sun; and for space heating by underfloor heating and radiant tubes. The rate of radiant heat loss from a surface is dependent upon its temperature and the emissivity of its surface. A surface with an emissivity of 1.0 is defined as a perfect black body, having maximum radiant heat loss for a given surface temperature. A warm surface will both radiate heat to and absorb heat from a cold surface. However, the radiation from the warm surface will be greater than that from the cold surface of similar emissivity, resulting in a net flow of heat from the warm surface to the cold. Surface treatments are applied to insulation materials to reduce their emissivity and hence radiant heat loss.

The optimum insulation solution for a given application will depend upon a number of factors. In buildings, the choice of insulant will be affected by the location of the material relative to occupants, the external environment, sources of moisture, its visibility, the dominant heat transfer mechanism it is intended to mitigate and other objectives it is intended to meet. Other influences include the financial and environmental costs

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of production and installation. As there are so many variables and priorities to take into account, there is a plethora of insulation solutions available on the market to building designers.

Most insulation solutions apply bulk insulation, whereby pockets of air are trapped within a material to resist the flow of heat through it. It is available in a wide range of formats, ranging from liquids, through small fibres to large panels. It includes both naturally occurring materials, such as wool and hemp and synthetic materials such as glass mineral wool and rigid plastic insulation boards.

Foil insulation is an alternative, although often complimentary approach to bulk insulation. Metal foil and other low emissivity materials are used to reduce radiant heat loss. This can be applied in layers with air gaps, bubble wrap or other materials between them reducing conduction across opposing faces. Alternatively, it can be applied to a single face or to both faces of a bulk rigid or flexible insulant, producing a multiple layer insulation solution optimised for reducing conductive, convective and radiative heat loss.

Formats of Insulation Products

Insulation products are available in a range of formats, from innovative paints intended to reduce surface emissivity through to aerated concrete blocks that form a primary structural function, but also have a significant insulating effect. Insulation products can be broadly categorised into the following formats:

- surface treatments;
- liquid foam;
- loose-fill;
- flexible rolls;
- rigid boards;
- structural elements with insulating properties;
- other.

Radiant heat transfer is an important element of heat loss from buildings. Surface treatments are typically applied to insulation materials rather than directly to building elements, to reduce their emissivity and hence heat loss, although there are notable exceptions to this.

Surface treatments such as

aluminium foil can be applied to many types of insulation products to reduce their emissivity. The foil also has important secondary roles in protecting insulation from mechanical damage, moisture ingress and contamination by dust and particles that may reduce its effectiveness. The foil barrier also contains the insulation, attenuating its impact upon the internal environment. This is applicable to the use of foam and glass mineral wool for pipework insulation in occupied spaces, which may otherwise cause respiratory discomfort for susceptible people.

Surface treatments that can be applied directly to building elements, rather than to their insulation include glass coatings and paints. Specialist low emissivity coatings to glazing in windows are generally required to meet Part L of the Building Regulations. The coatings represent highly advanced technology, developed over decades of research and product development. They can be transparent to light or tinted and have low emissivity for infra-red radiation.

Insulating paints are generally intended to reduce heat gain by the internal surface of external walls or radiant heat loss by external surfaces, for example through the incorporation of metallic aluminium pigments. Products that incorporate ceramic beads or spheres intended to provide modest reductions in heat loss through conduction are also available.

Liquid foam insulants may be applied in situ to building elements. They are typically, but not exclusively, used in refurbishment projects where their installation flexibility is an asset for insulating hard to reach spaces. Liquid foam insulation is a blown plastic insulant, most commonly polyurethane. The material produced is similar to a polyurethane rigid board, with excellent insulating properties. The unique advantage of the liquid foam is that it is blown and applied in situ directly onto the building element. It forms a continuous layer of insulation and is able to fill gaps and spaces that would be inaccessible for the application of rigid board materials. This approach is used to reduce

thermal bridging between building elements. Liquid foam insulation is typically installed on the underside of existing roofing materials, between and, if appropriate over rafters, where it will adhere directly with no additional support or fixings. It is also used in the manufacture of garage and industrial doors.

The loose-fill format of insulation products covers a wide range of types of insulant of both natural and synthetic origin. They are in a form that can be poured or blown, such as beads, fibres and particles that are applicable to both new build and refurbishment projects. They will typically be applied in wall cavities, between joists in lofts or other enclosed spaces.

Flexible rolls, batts and blankets are the most wide spread formats of building fabric insulation due to their relatively low cost, good insulation properties, ease of application and long standing use in the construction sector. They are used in both refurbishment and new build projects and are available in both synthetic and natural materials. They may be applied in all building elements, although, with the exception of high density products they tend not to have sufficient compressive strength for use in a load bearing capacity, such as floor slab insulation. In new build projects they can be applied in similar locations to loose-fill materials, i.e. wall cavities and between joists. However, with simple fixings they can also be installed between and under rafters. Specialist formats, such as thin (~10mm) latex, elastomeric and fibre-reinforced silica rolls can also be adhered directly to internal walls and ceilings in refurbishment projects and painted over.

The flexible roll format, even without any surface treatment, tend to achieve better acoustic insulation and fire retention properties than rigid boards. However, without surface treatments, bagging or other form of protection, rolls made from fibres are typically more vulnerable to moisture than rigid board or liquid foam, as closed cell materials are not widely available as standard in this format for building fabric insulation. Exceptions to this are the latex, silica and elastomeric closed cell products

which are hydrophobic and selected natural fibres, which 'breathe' releasing moisture to atmosphere rather than retaining it. However, the former, closed cell roll products tend to be applicable to specialist applications, such as refrigeration or cryogenic pipework and buildings of historic interest where standard products could not achieve the insulation properties required within practical limitations to insulation thickness.

Rigid boards tend to be the least flexible for installation in tight or irregularly shaped spaces, but include some of the highest performing insulation materials. This high performance allows good insulating effect to be achieved with relatively thin sheets, mitigating their installation limitations. Indeed, in selected applications, such as loft conversions, high performance rigid boards may be the only alternative to liquid foam that can meet both the insulating effect and headroom requirements of the Building Regulations. Rigid boards include extruded polystyrene, which has high compressive strength and is suitable for insulating floor slabs. They are also used in the manufacture of common prefabricated building elements, such as panels for temporary or portable buildings and acoustic enclosures. Both synthetic and natural materials are available in this format, although the highest thermal performance tends to be achieved by selected synthetic materials. They are supplied in a range of finishes appropriate to differing applications, including high mechanical strength cladding for insulated structural panels; low emissivity surface treatments for use adjacent to air spaces in cavity walls and roof spaces; adhered to plasterboard for dry lining and untreated for inclusion in full-fill cavity wall, suspended floor and intra-joist applications.

There is a number of building materials and systems that fall under the category of structural elements that have good insulation properties. These include both natural and synthetic materials.

Natural materials, such as cob (a mix of clay, straw and earth), rammed earth (thick, compressed soil walls)



and straw bales tend to require a wall thickness approaching a metre to achieve thermal properties that will meet current building regulations. If both the materials and construction expertise are available locally, they have low embodied energy and low installed costs. Thatch has traditionally been used in the UK as a roofing material, providing both weather-proofing and reasonable insulation properties.

Synthetic materials such as aerated concrete blocks are available with a range of thermal characteristics and compressive strengths, enabling these sometimes conflicting properties to be optimised for each application.

Natural clay bricks with holes increasing their insulation properties are in common use on the continent. These are becoming increasingly available with their cavities filled with a range of insulating materials, such as rock mineral wool, further improving their thermal resistance, but significantly increasing their material cost.

Including highly insulating products such as the above in the structural elements of buildings will be essential for meeting future requirements of the building regulations and for the achievement of zero emission homes by 2016 in particular.

Insulation Materials

The most commonly used insulation materials in the UK are synthetic, mineral wools and glass mineral wool in batt or roll form in particular. However there is a broad range of natural insulation materials available on the market.

Mineral wool includes glass mineral wool made from silica; rock mineral wool made from stone, such as lava rock and slag mineral wool made from residue from steel making industries. They are all produced by melting the raw materials in high temperature furnaces and spinning the melt into fibres from which mats, batts and rolls are made for insulation purposes.

Petrochemical products such as polystyrene, polyethylene, polyurethane (PUR) and polyisocyanurate (PIR) are blown to form rigid insulation boards.

Indicative 'U' values for insulation solutions of a masonry wall (350mm) with gypsum plasterboard with application of 100mm of various types of insulation

Insulant	'U' Value with application of 100mm of insulant (W/m ² K)*	Cost	Sound Attenuation	Fire Protection	Water Resistance
Uninsulated	2.200				
Slag foam	1.173	Medium	Low	Combustible	Good
Aerated concrete block	0.734	Low	High	Good	Good
Straw bale	0.408	Medium	High	Combustible	Poor
Urea Formaldehyde & Phenolic Foams	0.339	High	Low	Combustible	Good
Sheep's wool	0.339	High	High	Good	Good
Mineral wool	0.339	Low	High	Good	Medium
Polyester fibre	0.339	Medium	High	Combustible	Medium
Expanded polystyrene	0.339	Low	Low	Combustible	Good
Extruded polystyrene	0.295	Medium	Low	Combustible	Good
Extruded Polyurethane	0.233	Medium	Low	Combustible	Good
Extruded Polyisocyanurate	0.208	High	Low	Combustible	Good

*Indicative 'U' values calculated using DesignBuilder 2.2.4.001 SBEM 3.5a

Prior to the Montreal Protocol, chlorofluorocarbons with high ozone depletion potential (ODP) were used as blowing agents. These were subsequently replaced by agents with low ODP, but high global warming potential (GWP). However, all forms of blown plastic insulants are now available in a form that uses low ODP and low GWP blowing agents, such as carbon dioxide, nitrogen and compressed air (for in situ applications) which is an important consideration when considering the carbon emission reductions across the full lifecycle of the products.

Expanded polystyrene (EPS) is the lowest cost and longest standing of the blown plastic insulants. However, it is required in greater thickness to achieve a similar level of insulation to PUR and PIR insulants. Liquid Foam is typically a form of PUR that is blown in situ.

Plastics can also be used to manufacture flexible rolls and batts, such as the use of polyester and recycled plastic bottles to form fleece type blankets for loft insulation.

Sheep's wool, cotton, hemp, paper, cellulose, cork, wood-wool, straw, kapok and latex are used to manufacture natural insulation products. Rigid board materials can be made from cellulose, wood-wool

and hemp; flexible rolls from sheep's wool, cotton and hemp; and loose-fill insulation from paper, cork granules and others. Natural insulation materials are often mixed with other products to improve insulation, hydrophobic and other properties. For example, hemp is often mixed with cotton, wood-wool or polyester to achieve various densities and formats of insulation products.

Natural insulation materials of biological origin tend to have low life-cycle carbon emissions compared to synthetic insulants, due in part to their fixing of atmospheric carbon during their growth and relatively low energy input during their manufacture. Natural insulation materials are generally less hazardous to handle, install and live with than synthetic ones.

'U' Values

Approved Documents Parts L1 and L2 of the building regulations address insulation and energy efficiency in buildings. New versions of part L were published in April and will come into force in October. They require further reductions in total emissions to be achieved, but continue to promote design flexibility by including the same maximum area weighted average 'U' value for walls as under the 2006 ADL2 of 0.35 W/m²K for both new

and existing buildings.

A comparison of the insulating properties of a small selection of natural and synthetic insulation materials can be made by comparing the 'U' values achieved by the application of a standardised 100mm of the insulant to a traditional masonry wall, as summarised below. In practice varying combinations and thicknesses of materials, fixings and treatments for thermal bridging would be taken into account when selecting an optimum insulation solution for a solid masonry wall.

There is a broad range of insulation materials available on the market. Consideration must be given to practical installation considerations, such as the availability of materials and of experienced installers; supply and installation costs; damp-proofing and fire-proofing requirements in addition to the thermal performance to be achieved. Many of the insulation retailers, wholesalers and manufacturers provide excellent technical data and support for their products and competent energy engineers should make use of these when selecting the optimum insulation solutions to meet the requirements of clients and the building regulations for new build and refurbishment projects.

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How to obtain CPD accreditation



Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative.

This is the second of ten modules in the eighth series and focuses on insulation. It is accompanied by a set of multiple-choice questions. To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to **Energy in Buildings and Industry** for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course, for a fee of £15 (for members) or £25 (for non-members).

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject. This new series of modules will run until the April 2011 issue.

The modules in the coming months will focus on: heat pumps; training for energy management; district heating; fuel cells; smart meters; air conditioning; LEDs; and power quality). Should you miss any of the modules please let EIBI know (mark.thrower@btinternet.com) and we will send you the missing modules in 'pdf' format to you either by e-mail or on a CD. The first module in the series focused on the CRC Energy Efficiency Commitment.

The previous 70 modules from the first seven series are also available free of charge on CD.

MARK THROWER, MANAGING EDITOR

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Name..... (Mr, Mrs, Ms).....

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Business Address.....

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Completed answers should be mailed to:

**The Education Department, Energy in Buildings & Industry,
P. O. Box 825, GUILDFORD, GU4 8WQ**

SERIES 8 MODULE 2: QUESTIONS

Insulation

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

1. Which of the following is not a heat transfer mechanism?

- conduction convection
 insulation radiation

2. What is the maximum area-weighted average 'U' value for walls under ADL2A?

- 0.30 0.35
 0.45 0.70

3. Which of the following is not a natural insulation material?

- mineral wool sheep's wool
 latex kapok

4. Which material category do polyethylene and polyurethane come under?

- plastics metals
 natural minerals

5. What is the theoretical emissivity of a perfect black body?

- 0.9 0.5
 5.0 1.0

6. Which heat transfer mechanism is unattenuated by vacuum?

- conduction convection
 radiation physical transfer

7. Which heat transfer mechanism is reduced by air pockets in insulation?

- conduction convection
 radiation physical transfer

8. Which heat transfer mechanism increases as the volume of air in a cavity increases?

- conduction convection
 radiation physical transfer

9. What force drives natural convection in a well-sealed wall cavity?

- fan motor centrifugal force
 gravitational force electro-magnetic force

10. What does GWP stand for?

- glass wool products glass wool potential
 global wool products global warming potential

11. What does PIR abbreviate?

- polyvinylchloride polyethylene
 polyisocyanurate polyurethane

12. What does PUR abbreviate?

- polyvinylchloride polyethylene
 polyisocyanurate polyurethane

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