Building Regulations 2005

Technical Guidance Document

L

Conservation of Fuel and Energy

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AN ROINN COMHSHAOIL, OIDHREACHTA AGUS RIALTAIS ÁITIÚIL
DEPARTMENT OF THE ENVIRONMENT, HERITAGE
AND LOCAL GOVERNMENT

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Conservation of Fuel and Energy

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Building Regulations 2005
Technical Guidance Document L
Conservation of Fuel and Energy

Introduction

This document has been published by the Minister for the Environment, Heritage and Local Government under article 7 of the Building Regulations 1997.

It provides guidance in relation to Part L of the Second Schedule to the Regulations as inserted by **Building Regulations (Amendment) Regulations 2005 (S.I. No. 873 of 2005).**

The 2005 Regulations (and this document) partly transpose the **EU Energy Performance of Buildings Directive - EPBD (2002/91/EC of 16 December 2002)**.

The document should be read in conjunction with the Building Regulations 1997-2005 and other documents published under these Regulations.

In general, Building Regulations apply to the construction of new buildings and to extensions and material alterations to existing buildings. In addition, certain parts of the Regulations apply to existing buildings where a material change of use takes place. Otherwise, Building Regulations do not apply to buildings constructed prior to 1 June 1992.

Transitional Arrangements

In general, this document applies to works, or buildings in which a material alteration or change of use takes place, where the work, material alteration or the change of use commences or takes place, as the case may be, on or after 1 July 2006.

Technical Guidance Document L - Conservation of Fuel and Energy (1997 edition) and Technical Guidance Document L - Conservation of Fuel and Energy - Dwellings (2002 edition) cease to have effect from 1 July 2006.

However, these documents may continue to be used in the case of buildings:

- where the work, material alteration or the change of use commences or takes place, as the case may be, on or before 30 June 2006, or

- where planning approval or permission has been applied for on or before 30 June 2006, and substantial work has been completed by 30 June 2008.

"Substantial work has been completed" means that the structure of the external walls has been erected.

The Guidance

The materials, methods of construction, standards and other specifications (including technical specifications) which are referred to in this document are those which are likely to be suitable for the purposes of the Building Regulations (as amended). Where works are carried out in accordance with the guidance in this document, this will, prima facie, indicate compliance with Part L of the Second Schedule to the Building Regulations.

However, the adoption of an approach other than that outlined in the guidance is not precluded provided that the relevant requirements of the Regulations are complied with. Those involved in the design and construction of a building may be required by the relevant building control authority to provide such evidence as is necessary to establish that the requirements of the Regulations are being complied with.

Existing Buildings

In the case of material alterations or change of use of existing buildings, the adoption without modification of the guidance in this document may not, in all circumstances, be appropriate. In particular, the adherence to guidance, including codes, standards or technical specifications intended for application to new work may be unduly restrictive or impracticable.

Buildings of architectural or historical interest are especially likely to give rise to such circumstances. In these situations, alternative approaches based on the principles contained in the document may be more relevant and should be considered.

Technical Specifications

Building Regulations are made for specific purposes, e.g. to provide, in relation to buildings, for the health, safety and welfare of persons, the conservation of energy, and access for people with disabilities.

Technical specifications (including harmonised European Standards, European Technical Approvals, National Standards and Agrement Certificates) are relevant to the extent that they relate to these considerations.

Any reference to a technical specification is a reference to so much of the specification as is relevant in the context in which it arises. Technical specification may also address other aspects not covered by the Regulations.

A reference to a technical specification is to the latest edition (including any amendments, supplements or addenda) current at the date of publication of this Technical Guidance Document. However, if this version of the technical specification is subsequently revised or updated by the issuing body, the new version may be used as a source of guidance provided that it continues to address the relevant requirements of the Regulations.

Materials and Workmanship

Under Part D of the Second Schedule to the Building Regulations, building work to which the regulations apply must be carried out with proper materials and in a workmanlike manner. Guidance in relation to compliance with Part D is contained in Technical Guidance Document D.

Interpretation

In this document, a reference to a section, paragraph, appendix or diagram is, unless otherwise stated, a reference to a section, paragraph, appendix or diagram, as the case may be, of this document. A reference to another Technical Guidance Document is a reference to the latest edition of a document published by the Department of the Environment, Heritage and Local Government under article 7 of the Building Regulations 1997.

Diagrams are used in this document to illustrate particular aspects of construction - they may not show all the details of construction.

Building Regulations - The Requirement

The requirements regarding conservation of fuel and energy are laid out in Part L of the Second Schedule to the Building Regulations 2002 (S.I. No. 284 of 2002) as amended by the Building Regulations (Amendment) Regulations 2005 (S.I. No. 873 of 2005).

The Second Schedule is amended to read as follows:

Conservation of Fuel and Energy	L1	A building shall be designed and constructed so as to ensure that the energy performance of the building is such as to limit the amount of energy required for the operation of the building and the amount of CO_2 emissions associated with this energy use insofar as is reasonably practicable.
Dwellings	L2	For dwellings, the requirement of L1 shall be met by: (a) providing that the CO_2 emissions associated with energy use for space heating, water heating, ventilation and lighting of a new dwelling, calculated using the method published by Sustainable Energy Ireland, are limited insofar as is reasonably practicable; (b) limiting heat loss and, where appropriate, maximising heat gain through the fabric of the building; (c) controlling, as appropriate, the output of the space heating and hot water systems; (d) limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air.
Buildings other than dwellings	L3	For buildings other than dwellings, the requirements of L1 shall be met by: (a) limiting the heat loss and, where appropriate, maximising the heat gains through the fabric of the building; (b) providing energy efficient space and water heating services including adequate control of these services; (c) ensuring that the building is appropriately designed to limit need for cooling and, where air-conditioning or mechanical ventilation is installed, that installed systems are energy efficient, appropriately sized and adequately controlled; (d) limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air; (e) limiting the heat gains by chilled water and refrigerant vessels, and by pipes and ducts that serve air conditioning systems; (f) providing energy efficient artificial lighting systems (other than emergency lighting, display lighting or specialist process lighting) and adequate control of these systems.

Section 0: General Guidance

0.1 APPLICATION OF THE REGULATIONS

0.1.1 The aim of Part L of the First Schedule to the Building Regulations is to limit the use of fossil fuel energy and related CO_2 emissions arising from the operation of buildings, while ensuring that occupants can achieve adequate levels of lighting and thermal comfort. Buildings should be designed and constructed to achieve this aim as far as is practicable.

For dwellings, the primary method of demonstrating compliance is to show that the calculated rate of CO_2 emissions associated with the operation of the dwelling does not exceed a target value specified in this document. In addition, reasonable provision should be made for energy efficiency measures which: –

- limit the heat loss through the fabric of the building;
- limit the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air; and
- control, as appropriate, the demand and output of these services.

For buildings other than dwellings, reasonable provisions should be made;

- to limit the heat loss through the fabric of the building;
- to limit the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air;
- to control, as appropriate, the demand and output of these services;
- to limit the heat gains by chilled water and refrigerant vessels, and by pipes and ducts that serve air-conditioning systems;
- to provide energy efficient artificial lighting systems and adequate control of these systems; and
- to limit the need for space cooling and, where air-conditioning or mechanical ventilation is installed, provide energy efficient and appropriately sized appliances and equipment, and adequate control of these services.

This Technical Guidance Document provides guidance on how to satisfy the requirements of Part L. Section 1 deals with dwellings while Section 2 relates to buildings other than dwellings, including residential buildings other than dwellings.

0.1.2 The 2005 amendment to Part L (Conservation of Fuel and Energy) of the Building Regulations and this Technical Guidance Document L, provide for the implementation of requirements of Articles 3, 4, 5 (part) and 6 of the EU Energy Performance of Buildings Directive - EPBD (2002/91/EC of 16 December 2002).

These requirements include:

- application of a methodology of calculation of the energy performance of buildings on the basis of a general framework set out in an Annex to the EPBD.
  This methodology is being initially introduced for new dwellings only. For buildings other than dwellings, performance requirements for the various aspects relevant to energy performance specified in the Annex to the EPBD are given separately. For these buildings, it is intended that a calculation methodology and energy performance requirement specified as a single parameter ($kgCO_2/m^2/annum$), will be introduced at the next amendment scheduled for 2007;

- setting of minimum energy performance requirements for buildings and the application of these requirements to new buildings;

- ensuring where large buildings of 1000 m^2 floor area undergo major renovation that the renovated systems and components meet minimum thermal performance requirements. The application of Part L to all material alterations of all buildings, irrespective of size, ensures that the EPBD requirements in relation to major renovations of large buildings are more than satisfied.

0.1.3 Where a dwelling has an attached room or space that is to be used for commercial purposes (e.g. workshop, surgery, consulting room or office), such room or space should be treated as part of the dwelling if the commercial part could revert to domestic use on a change of ownership, e.g. where there is direct access between the commercial space and the living accommodation, both are contained within the same thermal envelope and the living accommodation occupies a substantial proportion of the total area of the building.

Where a dwelling forms part of a larger building, Section 1 applies to the individual dwelling, and Section 2 applies to the non-dwelling parts of the building such as common areas (including common areas of apartment blocks), and in the case of mixed-use developments, the commercial or retail space.

0.1.4 The guidance given in this Technical Guidance Document is generally applicable. However, where the works are limited in nature and not likely to greatly affect overall energy consumption over the building's life, compliance may be achieved without implementation of this guidance or equivalent measures in detail. In particular,

- For small extensions, not exceeding 6.5 m^2 in floor area, reasonable provision can be considered to have been made if the new construction is similar to the existing construction.
- Unheated ancillary areas such as porches, garages and the like do not require specific provisions in order to satisfy this Part of the Building Regulations.
- Where the area treated by an Air Conditioning and Mechanical Ventilation (ACMV) system is less than 200 m^2, the guidance in relation to ACMV systems need not be applied;
- Where the total design lighting load does not exceed 1000 W, the guidance in relation to the efficiency and control of artificial lighting need not be applied.

0.1.5 The guidance given in this Technical Guidance Document applies to buildings designed to be heated to temperatures appropriate for human occupancy. Less demanding standards could represent reasonable provision in those buildings or parts of buildings with a low level of heating or where heating provision is not intended. Low level of heating is considered to be where there is an installed heating capacity of less than 10W/m^2. Where the occupancy level or level of heating required when in use cannot be established at construction stage, the building should be treated as fully heated and the provisions of Part L applied accordingly. It should be noted that the provisions of Part L apply where a material change of use occurs and such a change of use may require specific construction measures to comply with Part L. These measures may prove more costly than if carried out at the time of initial construction.

0.1.6 An attached conservatory-style sunspace or the like should generally be treated as an integral part of the building or dwelling to which it is attached. However, where

- thermally separated from the adjacent spaces within the building or dwelling by walls, doors and other opaque elements which have U-values not more than 10% greater than corresponding exposed elements, and
- unheated or, if provided with a heating facility, having provision for automatic temperature and on-off control independent of the heating provision in the main building,

it may be excluded from the assessment of the main dwelling or building for the purposes of assessing compliance with the provisions of Part L. In this case, the main dwelling or building may be assessed separately for compliance. The attached sunspace should be treated as an unheated space for the purposes of this assessment and should also be assessed separately as if it were an extension to an existing dwelling or building (see Paragraphs 1.2.3.3 and 1.2.3.4 and 2.1.3.3 below).

0.1.7 In large complex buildings it may be sensible to consider the provisions for conservation of fuel and energy separately for the different parts of the building in order to establish the measures appropriate to each part.

0.2 TECHNICAL RISKS AND PRECAUTIONS

General

0.2.1 The incorporation of additional thickness of thermal insulation and other energy conservation measures can result in changes in traditional construction practice. Care should be taken in design and construction to ensure that these changes do not increase the risk of certain types of problems, such as rain penetration and condensation.

Some guidance on avoiding such increased risk is given in Appendix B of this document. General guidance on avoiding risks that may arise is also contained in the publication *"Thermal insulation: avoiding risks; Building Research Establishment* (Ref BR 262)".

Guidance in relation to particular issues and methods of construction will be found in relevant standards.

Guidance on construction details is contained in the publication *"Limiting thermal bridging and air leakage; Robust construction details for dwellings and smaller buildings"* published by The Stationery Office, London. In addition, guidance on appropriate details for common domestic constructions will be provided in the HomeBond publication *"Right on the Site No. 28"*.

The guidance given in these documents is not exhaustive and designers and builders may have well-established details using other materials that are equally suitable.

Fire Safety

0.2.2 Part B of the Second Schedule to the Building Regulations prescribes fire safety requirements. In designing and constructing buildings to comply with Part L, these requirements must be met and the guidance in relation to fire safety in TGD B should be fully taken into account. In particular, it is important to ensure that windows, which provide secondary means of escape in accordance with Section 1.5 of TGD B, comply with the dimensional and other guidance for such windows set out in paragraph 1.5.6 of TGD B.

Ventilation

0.2.3 Part F of the Second Schedule to the Building Regulations prescribes ventilation requirements both to meet the needs of the occupants of the building and to prevent excessive condensation in roofs and roofspaces. Technical Guidance Document F provides guidance in relation to ventilation of bathrooms, kitchens and utility rooms of dwellings so as to provide for mechanical extract ventilation or equivalent to these areas. The aim is to minimise the risk of condensation, mould growth or other indoor air quality problems. In addition to following the guidance in TGD F, appropriate heating and ventilation regimes must be employed in occupied dwellings. Advice for house purchasers and occupants on these issues is published separately by both HomeBond and Sustainable Energy Ireland.

Part J of the Second Schedule to the Building Regulations prescribes requirements in relation to the supply of air for combustion appliances, including open-flued appliances which draw air from the room or space in which they are situated. Technical Guidance Document J provides guidance in this regard.

0.3 THERMAL CONDUCTIVITY AND THERMAL TRANSMITTANCE

0.3.1 Thermal conductivity (λ-value) relates to a material or substance, and is a measure of the rate at which heat passes through a uniform slab of unit thickness of that material or substance, when unit temperature difference is maintained between its faces. It is expressed in units of Watts per metre per degree (W/mK).

0.3.2 For the purpose of showing compliance with this Part of the Building Regulations, design λ-values based on manufacturers declared values should be used. For thermally homogeneous materials declared and design values should be determined in accordance with I.S. EN ISO 10456: 1997. Design values for masonry materials should be determined in accordance with I.S. EN 1745: 2002. For insulation materials, values determined in accordance with the appropriate harmonized European standard should be used. Certified λ-values for foamed insulant materials should take account of the blowing agent actually used. The use of HCFC for this purpose is no longer permitted.

For products or components for which no appropriate standard exists, measured values, certified by an approved body or certified laboratory (see TGD D), should be used.

0.3.3 Table 9 and 10 of Appendix A contains λ-values for some common building materials and insulation materials. These are primarily based on data contained in I.S. EN 12524: 2000 or in CIBSE Guide A, Section A3. The values provide a general indication of the thermal conductivity that may be expected for these materials. In the absence of declared values, design values or certified measured values as outlined in paragraph 0.11, values of thermal conductivity given in Table 9 may be used. However, values for specific products may differ from these illustrative values. Indicative λ-values for thermal insulation materials are given in Table 10. These may be used at early design stage for the purpose of assessing likely compliance with this Part of the Regulations. However, compliance should be verified using thermal conductivity values for these materials derived as outlined in Paragraph 0.3.2 above.

0.3.4 Thermal transmittance (U-value) relates to a building component or structure, and is a measure of the rate at which heat passes through that component or structure when unit temperature difference is maintained between the ambient air temperatures on each side. It is expressed in units of Watts per square metre per degree of air temperature difference (W/m^2K).

0.3.5 Thermal transmittance values (U-values) relevant to this Part of the Regulations are those relating to elements exposed directly or indirectly to the outside air. This includes floors directly in contact with the ground, suspended ground floors incorporating ventilated or unventilated voids, and elements exposed indirectly via unheated spaces. The U-value takes account of the effect of the ground, voids and unheated spaces on the rate of heat loss, where appropriate. Heat loss through elements that separate dwellings or other premises that can reasonably be assumed to be heated, is considered to be negligible. Such elements do not need to meet any particular U-value nor should they be taken into account in calculation of CO_2 emissions or overall transmission heat loss.

0.3.6 A range of methods exists for calculating U-values of building elements. Methods of calculation are outlined in Appendix A, together with examples of their use. Alternatively U-values may be based on certified measured values. Measurements of thermal transmission properties of building components generally should be made in accordance with I.S. EN ISO 8990: 1997, or, in the case of windows and doors, I.S. EN ISO 12567-1: 2001.

0.3.7 Any part of a roof that has a pitch of 70^0 or more may be treated as a wall for the purpose of assessing the appropriate level of thermal transmission. Elements separating the building from spaces that can reasonably be assumed to be heated should not be included .

0.3.8 Appendix B contains tables of indicative U-values for certain common constructions. These are derived using the calculation methods referred to in Appendix A, and may be used in place of calculated or measured values, where appropriate. These tables provide a simple way to establish the U-value for a given amount of insulation. Alternatively they may be used to establish the amount of insulation needed to achieve a given U-value. The values in the tables have been derived taking account of typical repeated thermal bridging where appropriate. Where an element incorporates a non-repeating thermal bridge, e.g. where the continuity of insulation is broken or penetrated by material of reduced insulating quality, the U-value derived from the table should be adjusted to account for this thermal bridge. Table 36 in Appendix B contains indicative U-values for external doors, windows and rooflights (roof windows).

0.4 DIMENSIONS

0.4.1 Except where otherwise indicated linear measurements for the calculation of wall, roof and floor areas and building volumes should be taken between the finished internal faces of the appropriate external building elements and, in the case of roofs, in the plane of the insulation. Linear measurements for the calculation of the areas of external door, window and rooflight openings should be taken between internal faces of appropriate cills, lintels and reveals.

0.4.2 “Volume" means the total volume enclosed by all enclosing elements and includes the volume of non-usable spaces such as ducts, stairwells and floor voids in intermediate floors.

0.5 APPLICATION TO BUILDINGS OF ARCHITECTURAL OR HISTORICAL INTEREST

0.5.1 Part L does not apply to works (including extensions) to an existing building which is a "protected structure" or a 'proposed protected structure" within the meaning of the Planning and Development Act 2000 (No 30 of 2000).

Nevertheless, the application of this Part may pose particular difficulties for habitable buildings which, although not protected structures or proposed protected structures, may be of architectural or historical interest.

Works such as the replacement of doors, windows and rooflights, the provision of insulated dry lining and damp-proofing to walls and basements, insulation to the underside of slating and provision of roof vents and ducting of pipework could all affect the character of the structure.

In general, the type of works described above should be carefully assessed for their material and visual impact on the structure.

Historic windows and doors should be repaired rather than replaced, and drylining and damp-proofing should not disrupt or damage historic plasterwork or flagstones and should not introduce further moisture into the structure.

Roof insulation should be achieved without damage to slating (either during the works or from erosion due to condensation) and obtrusive vents should not affect the character of the roof.

In specific cases, relaxation of the values proposed may be acceptable, to the local building control authority, if it can be shown to be necessary in order to preserve the architectural integrity of the particular building.

For more guidance on appropriate measures see "*Planning Guidelines No. 9: Architectural Heritage Protection* - Guidelines for Planning Authorities" published by the Department of the Environment, Heritage and Local Government.

Section 1: Dwellings

1.1: Limitation of CO_2 emissions

1.1.1 This Section provides guidance on the methodology for calculation of CO_2 emissions associated with a standardised use of a new dwelling, and on the appropriate limit for these emissions, as required by Regulations L2(a). Regulation L2(a) and the guidance in this Section only apply to new dwellings. However, the existing requirements in relation to building fabric thermal performance, heating system controls and limitation of losses from system components continue to apply to all works in relation to dwellings to which Part L applies, i.e. new dwellings, extensions to existing dwellings, material alterations and material changes of use - Regulations L2(b), L2(c) and L2(d). For new dwellings, this ensures that each of the main factors influencing overall energy use contribute to the energy performance of the building, insofar as reasonably practical.

Guidance in relation to these requirements is given in Sections 1.2, 1.3 and 1.4, and is similar to that contained in TGD L *Conservation of Fuel and Energy – DWELLINGS (2002)* with the exception that the optional methods of showing compliance with the requirement in relation to building fabric insulation have been reduced from three to two. With the introduction of this Section, the Heat Energy Rating (HER) method is omitted as the HER and the methodology for calculating CO_2 emissions, referenced in this Section, have much in common.

This Section does not apply to works to existing dwellings - including extensions to existing dwellings, conservatory-style sunspaces that are treated as extensions (see Paragraph 0.1.6), material alterations or material change of use.

1.1.2 Carbon Dioxide (CO_2) Emission Rate (CDER): the CDER associated with energy use for space heating, water heating, ventilation and lighting is calculated for standardised temperature and use conditions using a methodology specified in Regulation L2 to be published by Sustainable Energy Ireland (SEI). The methodology is entitled Dwellings Energy Assessment Procedure (DEAP). The CDER so calculated for the dwelling should be less than the Maximum Permitted CO_2 Emission Rate (MPCDER). The CDER and MPCDER are expressed in terms of kilograms of CO_2 per square metre floor area per year (kg CO_2/m^2/annum).

1.1.3 Maximum Permitted CO_2 Emission Rate (MPCDER): the MPCDER for each dwelling is derived as follows:

The carbon dioxide emission rate is calculated using the DEAP methodology for a reference dwelling of the same size and shape as the dwelling to be assessed, but with the relevant characteristics specified in Appendix C. The result of this calculation is the MPCDER for the actual dwelling.

1.1.4 The calculated CDER takes account of the relevant characteristics of the actual dwelling. These include the fuel to be used for space and water heating. Provision is made for 10% of space heating to be supplied by a secondary heating system. Where a chimney or flue is provided and an open fire or other appliance fitted, this appliance is presumed to be the secondary heating system and the efficiency of the actual appliance with its appropriate fuel should be used in the calculation. Where no appliance is actually installed, the presence of the following appliances should be assumed when calculating the CDER:-

- If a gas point is located adjacent to the hearth, a decorative fuel effect fire open to the chimney or flue, with a gross efficiency of 20%.

- If there is no gas point, then an open solid fuel fire in grate with a gross efficiency of 30%.

Where no specific provision is made, the secondary source is presumed to be electricity.

1.1.5 To demonstrate that an acceptable CO_2 emission rate has been achieved, the calculated CDER of the actual dwelling should be no greater than the MPCDER calculated as set out in 1.1.3 above.

1.1.6 Where a building contains more than one dwelling (such as in a terrace of houses or a block of apartments), reasonable provision would be to show that:

- every individual dwelling has a CDER that is no greater than its corresponding MPCDER, or

- the average CDER for all dwellings in the building is no greater than would exist if each dwelling exactly achieved its individual target, i.e. the average of the MPCDER for all dwellings. The average CDER for all dwellings is derived by multiplying the CDER for each individual dwelling by the floor area of that dwelling, adding together and dividing the result by the sum of the floor areas of all dwellings. The average MPCDER for all dwellings is calculated in a similar manner, i.e. the MPCDER for each individual dwelling is multiplied by the floor area of that dwelling, and the sum of these divided by the sum of the floor areas of all dwellings. Common areas in the building are not included in these calculations.

1.1.7 Renewable and Low Carbon Technologies: in appropriate circumstances, the use of renewable and low carbon technologies, such as solar hot water, biofuels (e.g. wood and wood pellets) and heat pumps, can facilitate compliance with this part of the Building Regulations. As these technologies are characterised by zero, or greatly reduced, CO_2 emissions, the calculated CDER is reduced by the extent that they replace traditional CO_2 emitting fuels. However, the space heating and hot water system specifications for the calculation of the MPCDER for the reference dwelling (see Appendix C) are such that the use of these technologies is not reflected in the calculation of the MPCDER. Thus, the MPCDER target value is not reduced. This has the effect of making it easier to achieve compliance with this Part of the Building Regulations when these technologies are used in the actual dwelling being assessed.

1.1.8 Condensing Boilers: the use of high efficiency boilers, (e.g. condensing boilers), also aids compliance with this part of the Regulations. This is so because the maximum efficiency of the boiler assumed in calculating the MPCDER is 78%. Where the efficiency of the boiler actually used is greater than this, achievement of compliance is facilitated.

1.1.9 Constructed Dwellings: the requirement that the calculated CDER not exceed the calculated MPCDER applies to the constructed dwelling. Designers may wish to calculate the CDER at early design stage in order to ensure that the requirement can be achieved by the constructed building. Where the proposed construction matches closely that set out as the basis for calculating the MPCDER (see Appendix C) it would be reasonable to assume that the constructed dwelling will satisfy the requirement, without the need for early calculation. It is also open to professional bodies or other industry interests to develop model dwelling designs that can confidently be adopted without the need to calculate the CDER at design stage. However, the use of constructions set out in Appendix C or other model designs does not preclude the need to verify compliance by calculating both CDER and MPCDER when all relevant details of the final construction are known.

1.2: Limitation of Heat Loss through the Building Fabric

1.2.1 GENERAL

1.2.1.1 This section gives guidance on acceptable levels of provision to ensure that heat loss through the fabric of a dwelling is limited insofar as reasonably practicable. Guidance is given on three main issues:

(a) minimum insulation levels to be achieved by the fabric elements (Paragraphs 1.2.2 and 1.2.3),
(b) limitation of thermal bridging (Paragraphs 1.2.4), and
(c) limitation of uncontrolled air infiltration through the building fabric (Paragraph 1.2.5).

Two alternative ways of showing acceptable levels of insulation of fabric elements are given. The Overall Heat Loss method sets a maximum value for the area-weighted average U-value of all fabric elements and is applicable to new dwellings and to extensions to existing dwellings. The Elemental Heat Loss method sets maximum values for the average U-value of each individual fabric element. In addition to being an alternative method for new dwellings and for extensions to existing dwellings, this method is also applicable to material alterations and material changes of use to existing buildings and to replacement windows and doors, where the Overall Heat Loss method is not applicable.

1.2.1.2 The derivation of U-values, including those applicable where heat loss is to an unheated space, is dealt with in Paragraphs 0.3.5 to 0.3.8 and Appendix A.

Unheated areas which are wholly or largely within the building structure, do not have permanent ventilation openings and are not otherwise subject to excessive air-infiltration or ventilation, e.g. common areas such as stairwells, corridors in buildings containing flats, may be considered as within the insulated fabric. In that case, if the external fabric of these areas is insulated to the same level as that achieved by equivalent adjacent external elements, no particular requirement for insulation between a heated dwelling and unheated areas would arise. It should be noted that heat losses to such unheated areas are taken into account in the calculation of the dwelling CDER (See Section 1.1).

1.2.1.3 The treatment of an attached conservatory-style sunspace is dealt with in Paragraph 0.1.6. Where an attached sunspace is treated as an extension to the main building for the purposes of assessment for compliance with the provisions of Part L (as provided for in Paragraph 0.1.6), the guidance in Paragraph 1.2.3.4 should be followed.

1.2.1.4 This Part of the Building Regulations applies to the replacement of external doors, windows, or rooflights in an existing building. The average U-value of replacement units should not exceed the value of 2.2 W/m^{2}K set out in Table 1. In this context, the repair or renewal of parts of individual elements, e.g. window glass, window casement sash, door leaf, should be considered as repair and not replacement.

1.2.2 OVERALL HEAT LOSS

1.2.2.1 In the case of new dwellings and extensions to existing dwellings, the area-weighted average U-value (U_m) of all fabric elements contributing to heat loss from the dwelling should not exceed the values set out in Table 1. For an individual dwelling or extension, the level depends on the ratio of the total area of these elements (A_t) to the dwelling volume (V). The acceptable level of heat loss is expressed graphically in Diagram 1.

1.2.2.2 In addition to not exceeding the maximum average value set, area-weighted average elemental U-values for individual elements should not exceed the following:

roofs	0.25 W/m^{2}K
walls	0.37 W/m^{2}K
ground floors	0.37 W/m^{2}K.

1.2.3 ELEMENTAL HEAT LOSS

1.2.3.1 An alternative method of showing that an acceptable minimum level of fabric insulation has been achieved is to show that the average U-values of individual fabric elements do not exceed those set out in Table 2.

Diagram 1 *Para. 1.2.2.1*

Maximum average U-value (U_m) in relation to building volume (V) and total area of heat loss elements (A_t)

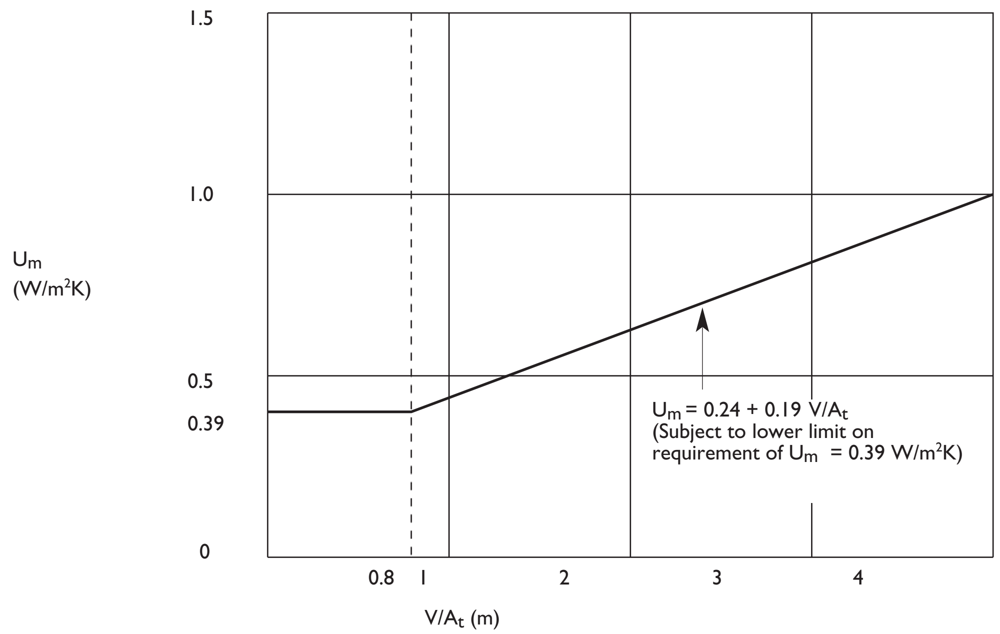


Table 1 **Maximum average U-value (U_m) as a function of building volume (V) and fabric heat-loss area (A_t)**

Area of Heat Loss Elements/ Building Volume (A_t / V) (m^{-1})	Maximum Average U-Value (U_m) ($W/m^2/K$)
1.3 or greater	0.39
1.2	0.40
1.1	0.41
1.0	0.43
0.9	0.45
0.8	0.48
0.7	0.51
0.6	0.56
0.5	0.62
0.4	0.72
0.3	0.87

NOTE: The expression $U_m = 0.24 + 0.19 V/A_t$ can be used to establish U_m for intermediate values of A_t/V and for values below 0.3 m^{-1}.

1.2.3.2 The maximum average U-value for doors, windows and rooflights of 2.2 W/m^2K given in Table 2, applies when the combined area of external door, window and rooflight openings does not exceed 25% of floor area. However, both the permitted combined area of external door, window and rooflight openings and the maximum average U-value of these elements may be varied as set out in Table 3. The area of openings should not be reduced below that required for the provision of adequate daylight. BS 8206: Part 2: 1992 gives advice on adequate daylight provision.

1.2.3.3 In applying paragraph 1.2.3.2 to an extension to an existing dwelling, the relevant floor area may be taken to be:

(a) the combined floor area of the existing dwelling and extension; in this case the combined area of external doors, windows and rooflight openings refers to the area of such openings in the extended dwelling, i.e. the opening area of retained external doors, windows and rooflights together with the opening area of external doors, windows and rooflights in the extension; or

(b) the floor area of the extension alone; in this case the combined area of external doors, window and rooflight openings refers to the area of such openings in the extension alone. In this case, the maximum combined area of external doors, windows and rooflights derived using Table 3 can be increased by an area equivalent to the area of external door, window and rooflight openings of the existing dwellings which have been closed or covered over by the extension.

1.2.3.4 For extensions which

- are thermally separated from the adjacent spaces within the building by walls, doors and other opaque or glazed elements which have U-values not more than 10% greater than corresponding exposed areas of the main dwelling, and

- are unheated or, if provided with a heating facility, have provision for automatic temperature and on-off control independent of the heating provision in the existing building,

the limitation on the combined area of exposed external door, window and rooflight openings does not apply. In this case the average U-value of these elements should not exceed the value of 2.2 W/m²K.

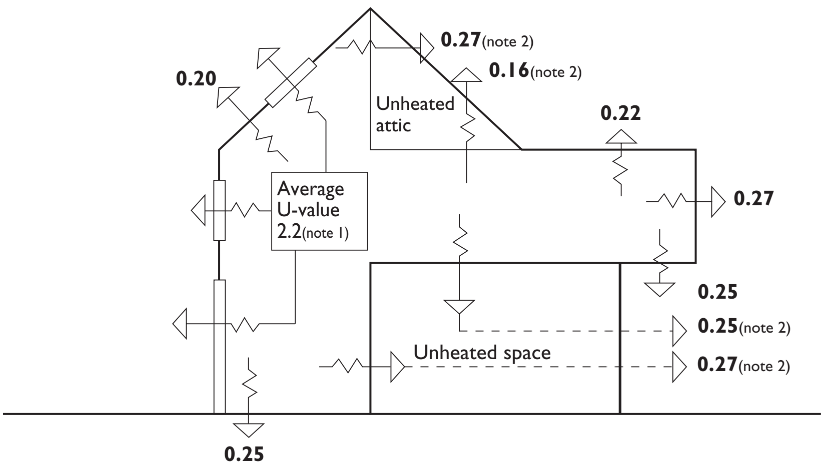
Table 2 **Maximum average elemental U-value (W/m²K) (Elemental Heat Loss Method):**

Fabric Elements	New Buildings & Extensions to Existing Buildings	Material Alterations to, or Material Changes of Use of, Existing Buildings
Pitched roof, insulation horizontal at ceiling level	0.16	0.35
Pitched roof, insulation on slope	0.20	0.35
Flat roof	0.22	0.35
Walls	0.27	0.60
Ground Floors	0.25	-
Other Exposed Floors	0.25	0.60
External doors, windows and rooflights	2.20[1]	2.20

NOTE 1: Permitted average U-value of external doors, windows and rooflights may vary as described in Paragraphs 1.2.3.2 to 1.2.3.4, and Table 3.

Diagram 2 *Para 1.2.3.1*

Elemental Heat Loss Method Summary of average elemental U-values



NOTES

1. Windows, doors and rooflights should have maximum U-value of 2.2 W/m²K and maximum opening area as set out in Table 6. However areas and U-values may be varied provided the total heat loss through these elements is not increased.

2. The U-value includes the effect of unheated voids or other spaces.

1.2.3.5 This Part of the Building Regulations applies to the replacement of external doors, windows, or rooflights in an existing dwelling. The average U-value of replacement units should not exceed the value of 2.2 W/m²K set out in Table 2. In this context, the repair or renewal of parts of individual elements, e.g. window glass, window casement sash, door leaf should be considered as repair and not replacement.

1.2.3.6 Diagram 2 summarises the minimum fabric insulation standards applicable in the Elemental Heat Loss method.

1.2.4 THERMAL BRIDGING

1.2.4.1 To avoid excessive heat losses and local condensation problems, provision should be made to limit local thermal bridging, e.g. around windows, doors and other wall openings, at junctions between elements and at other locations. Any thermal bridge should not pose a risk of surface or interstitial condensation and any excessive increase in heat loss associated with the thermal bridge should be taken account of in the calculation of average U-value.

Paragraph 1.2.4.2 and 1.2.4.3 give guidance on reasonable provision for the limitation of thermal bridging. As an alternative to following the guidance in these paragraphs (and associated reference documents) reasonable provision can be shown by calculation. Appendix D gives information on the calculation procedure, which can be used for this purpose.

1.2.4.2 Use of cill, jamb lintel and junction details set out in the publication *"Right on the Site, Issue No. 28 "* published by HomeBond, the publication *"Limiting thermal bridging and air leakage: Robust construction details for dwellings and smaller buildings,"* published by The Stationery Office, London, or other published details which have been assessed as satisfying the guidance in relation to Temperature Factor and Linear Thermal Transmittance set out in Appendix D, should represent reasonable provision to limit thermal bridging.

Lintel, jamb and cill designs similar to those shown in Diagram 3 would be satisfactory and heat losses due to thermal bridging can be ignored if they are adopted. At lintels, jambs and cills generally a 15 mm thickness of insulation material having λ-value of 0.04 W/mK (or equivalent) will generally be adequate.

Table 3 **Permitted variation in combined area (A_{ope}) and average U-values (U_{ope}) of external doors, windows and rooflights**

Average U-value of windows, doors and rooflights (U_{ope}) (W/m²K)	Maximum combined area of external doors, windows and rooflights (A_{ope}) expressed as % of floor area (A_f)
1.4	42.7
1.6	36.3
1.8	31.5
2.0	27.9
2.1	26.4
2.2	25.0
2.3	23.8
2.4	22.7
2.5	21.6
2.6	20.7
2.7	19.9
2.8	19.1
2.9	18.3
3.0	17.7
3.1	17.0
3.2	16.5
3.3	15.9

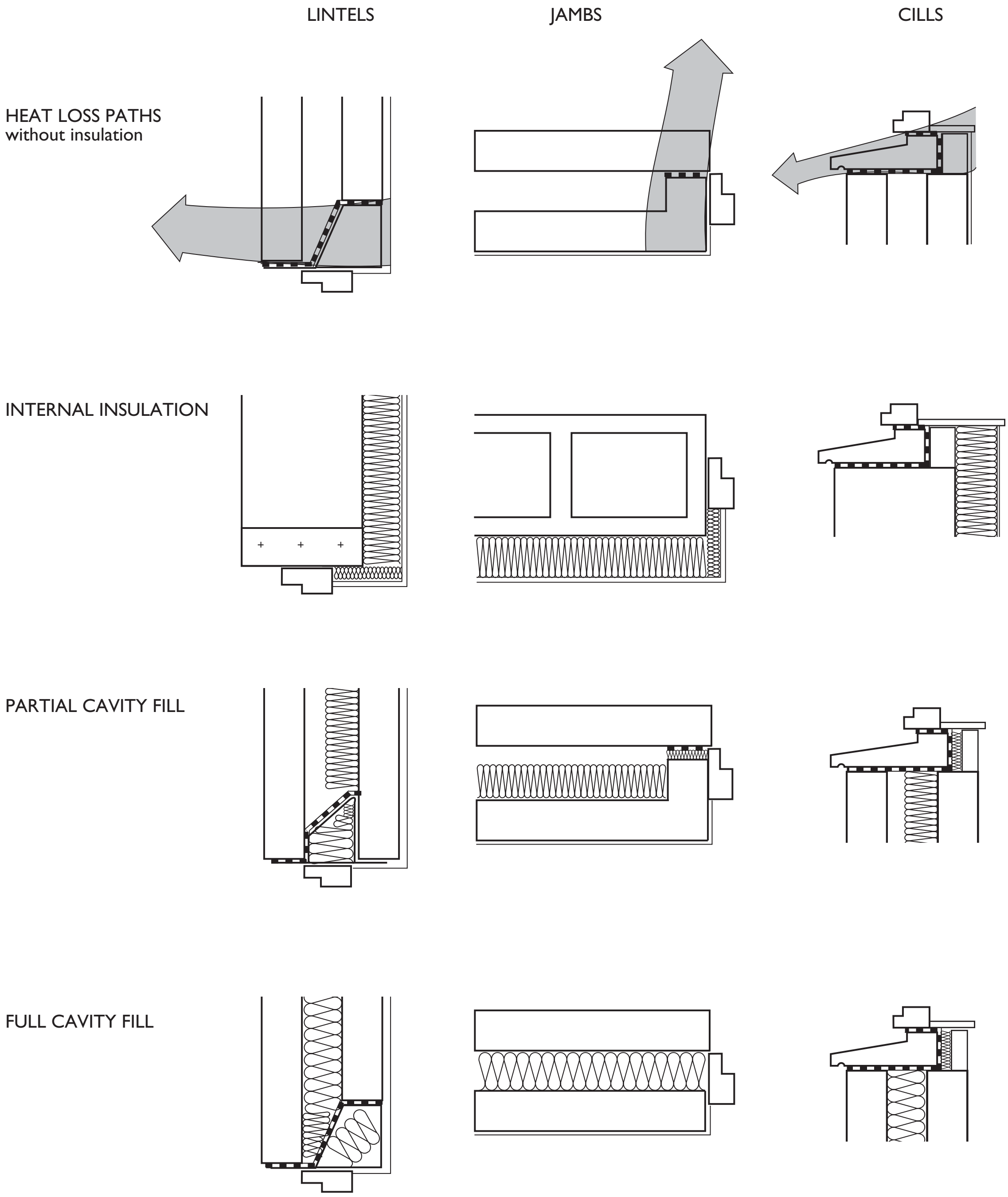
NOTE 1: Intermediate values of "combined areas" or of "U-values" may be estimated by interpolation in the above table. Alternatively the following expression may be used to calculate the appropriate value:
$A_{ope}/A_f = 0.4825/(U_{ope} - 0.27)$.

This expression may also be used to calculate appropriate values outside the range covered by the table.

1.2.4.3 Care should be taken to control the risk of thermal bridging at the edges of floors. All slab-on-ground floors should be provided with edge insulation to the vertical edge of the slab at all external and internal walls. The insulation should have minimum thermal resistance of 0.7 m²K/W (25 mm of insulation with thermal conductivity of 0.035 W/mK, or equivalent). Some large floors may have an acceptable average U-value without the need for added insulation. However, perimeter insulation should always be provided. Perimeter insulation should extend at least 0.5m vertically or 1m horizontally. Where the perimeter insulation is placed horizontally, insulation to the vertical edge of the slab should also be provided as indicated above.

Diagram 3 *Para. 1.2.4*

Lintel, jamb and cill designs



NOTE

1. The internal faces of metal lintels should be covered with at least 15 mm of lightweight plaster; alternatively they can be dry-lined.

1.2.5 AIR INFILTRATION

1.2.5.1 Infiltration of cold outside air should be limited by reducing unintentional air paths as far as is practicable. Measures to ensure this include:

(a) sealing the void between dry-lining and masonry walls at the edges of openings such as windows and doors, and at the junctions with walls, floors and ceilings (e.g. by continuous bands of bonding plaster or battens),

(b) sealing vapour control membranes in timber-frame constructions,

(c) fitting draught-stripping in the frames of openable elements of windows, doors and rooflights,

(d) sealing around loft hatches,

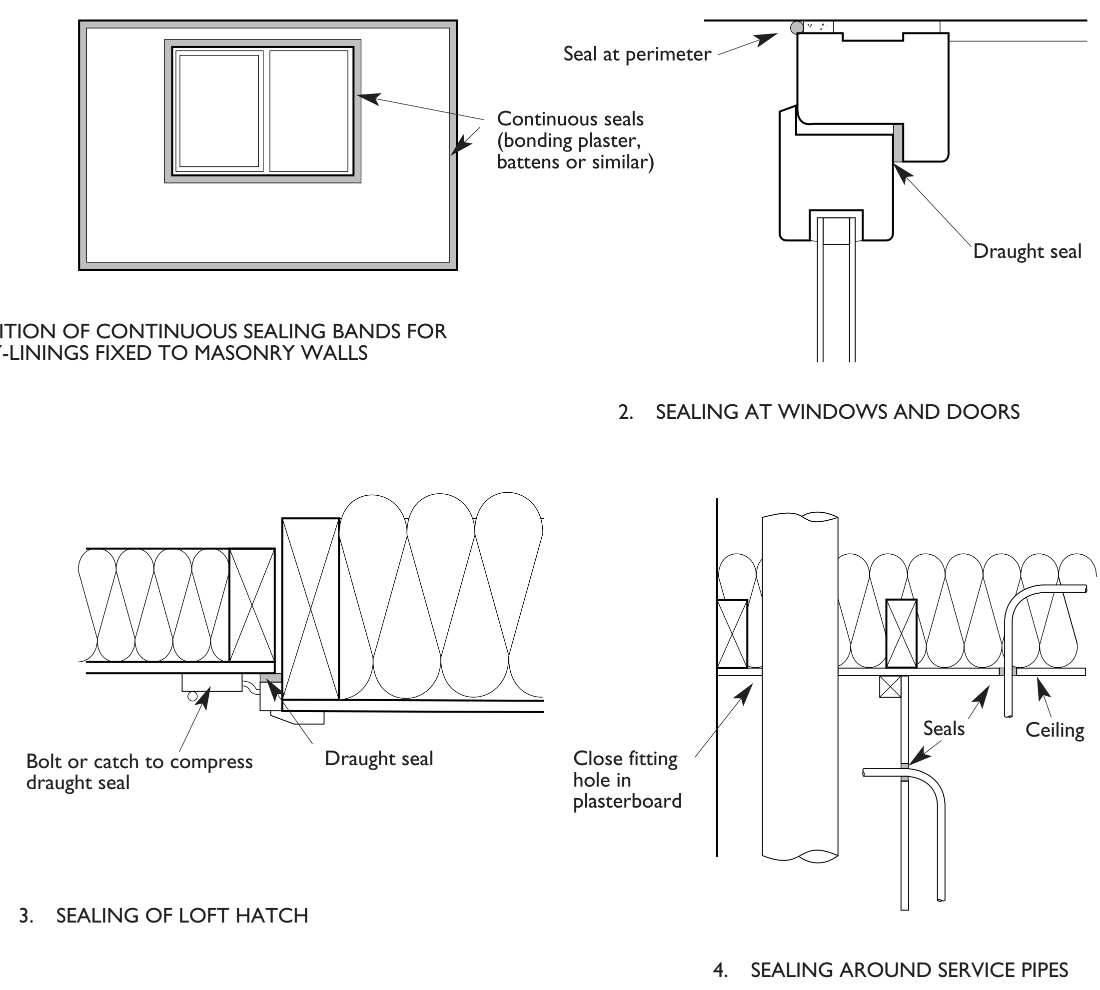
(e) ensuring boxing for concealed services is sealed at floor and ceiling levels and sealing piped services where they penetrate or project into hollow constructions or voids.

Diagram 4 illustrates some of these measures.

Care should be taken to ensure compliance with the ventilation requirements of Part F and Part J.

Diagram 4 *Para. 1.2.5*

Air infiltration measures



1. POSITION OF CONTINUOUS SEALING BANDS FOR DRY-LININGS FIXED TO MASONRY WALLS

2. SEALING AT WINDOWS AND DOORS

3. SEALING OF LOFT HATCH

4. SEALING AROUND SERVICE PIPES

1.3: Controls for Space Heating and Hot Water Supply Systems

1.3.1 Space and water heating systems should be effectively controlled so as to ensure the efficient use of energy by limiting the provision of heat energy use to that required to satisfy user requirements, insofar as reasonably practicable. The aim should be to provide the following minimum level of control:

- automatic control of space heating on basis of room temperature;
- automatic control of heat input to stored hot water on basis of stored water temperature;
- separate and independent automatic time control of space heating and hot water;
- shut down of boiler or other heat source when there is no demand for either space or water heating from that source.

The guidance in Paragraphs 1.3.2 to 1.3.5 below is specifically applicable to fully pumped hot water based central heating systems. Where practicable, an equivalent level of control should be achieved with other systems, having due regard to requirements to ensure safety in use. For solid fuel fired systems, in particular, the control system should be such as to allow safe operation of the boiler at its minimum burning rate, and to provide for any slumber load of the boiler through uncontrolled circulation to a radiator or hot water storage cylinder, or by other appropriate mechanism.

1.3.2 Provision should be made to control heat input on the basis of room temperature, e.g. by the use of room thermostats, thermostatic radiator valves or other equivalent form of sensing device. Independent temperature control should generally be provided for separate zones that normally operate at different temperatures, e.g. living and sleeping zones. Depending on the design and layout of the dwelling, control on the basis of a single zone will generally be satisfactory for smaller dwellings. Where the dwelling floor area exceeds 100 m^2, control on the basis of two independent zones will generally be appropriate. In certain cases additional zone control may be desirable, e.g. zones which experience significant solar or other energy inputs may be controlled separately from zones not experiencing such inputs.

1.3.3 Hot water storage vessels should be fitted with thermostatic control that shuts off the supply of heat when the desired storage temperature is reached.

1.3.4 Separate and independent time control for space heating and for heating of stored water should be provided. Independent time control of space heating zones may be appropriate where independent temperature control applies, but is not generally necessary.

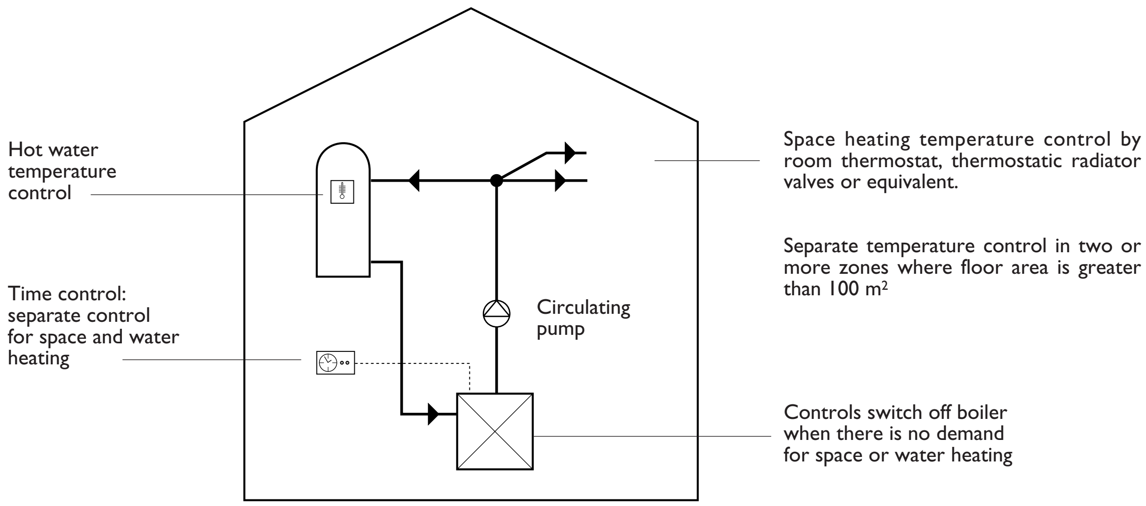
1.3.5 The operation of controls should be such that the boiler is switched off when no heat is required for either space or water heating. Systems controlled by thermostatic radiator valves should be fitted with flow control or other equivalent device to prevent unnecessary boiler cycling.

1.3.6 Alternative methods of meeting the requirement would be to adopt, as appropriate, the relevant measures in the following standards provided the measures adopted include similar zoning, timing, anti-cycling and boiler control features:

- I.S. EN 12828: 2003 *Heating systems in buildings - design for water-based heating systems;*
- BS 5864: 1989 *Specification for installation in domestic premises of gas-fired ducted air heaters of rated output not exceeding 60 kW.*

Diagram 5 *Para. 1.3.1*

Controls for space and water heating in dwellings



NOTES:

1. For dwellings heated other than by central heating boiler, a similar level of control should be achieved.
2. For solid fuel fired systems, sufficient permanent heat load to satisfy slumber conditions must be maintained.

1.4: Insulation of Hot Water Storage Vessels, Pipes and Ducts

1.4.1 All hot water storage vessels, pipes and ducts associated with the provision of heating and hot water in a dwelling should be insulated to prevent heat loss except for hot water pipes and ducts within the normally heated area of the dwelling which contribute to the heat requirement of the dwelling.

1.4.2 Adequate insulation of hot water storage vessels can be achieved by the use of a storage vessel with factory-applied insulation of such characteristics that, when tested on a 120 litre cylinder complying with I.S. 161: 1975 using the method specified in BS1566, Part 1: 2002, Appendix B, standing heat losses are restricted to 1W/litre. Use of a storage vessel with 35 mm, factory-applied coating of PU-foam having zero ozone depletion potential and a minimum density of 30 kg/m³ satisfies this criterion (see Diagram 6). Alternative insulation measures giving equivalent performance may also be used.

1.4.3 Unless the heat loss from a pipe or duct carrying hot water contributes to the useful heat requirement of a room or space, the pipe or duct should be insulated. The following levels of insulation should suffice (see Diagrams 6 and 7):

- pipe or duct insulation meeting the recommendations of BS 5422: 2001 *Methods of specifying thermal insulating materials for pipes, ductwork and equipment (in the temperature range - 400C to + 700C), or*

- for pipes up to 40 mm diameter, insulation with material of such thickness as gives an equivalent reduction in heat loss as that achieved using material having a thermal conductivity at 400C of 0.035 W/mK and a thickness equal to the outside diameter of the pipe, for pipes up to 40 mm diameter, and a minimum of 40 mm for larger pipes.

1.4.4 The hot pipes connected to hot water storage vessels, including the vent pipe and the primary flow and return to the heat exchanger, where fitted, should be insulated, to the standard outlined in Paragraph 1.4.3 above, for at least one metre from their point of connection or up to the point where they are concealed.

1.4.5 It should be noted that water pipes and storage vessels in unheated areas will generally need to be insulated for the purpose of protection against freezing. Guidance on suitable protection measures is given in Report BR 262, *Thermal insulation: avoiding risks* published by BRE.

Diagram 6 *Para. 1.4.1*
Insulation of hot water storage vessels and pipes

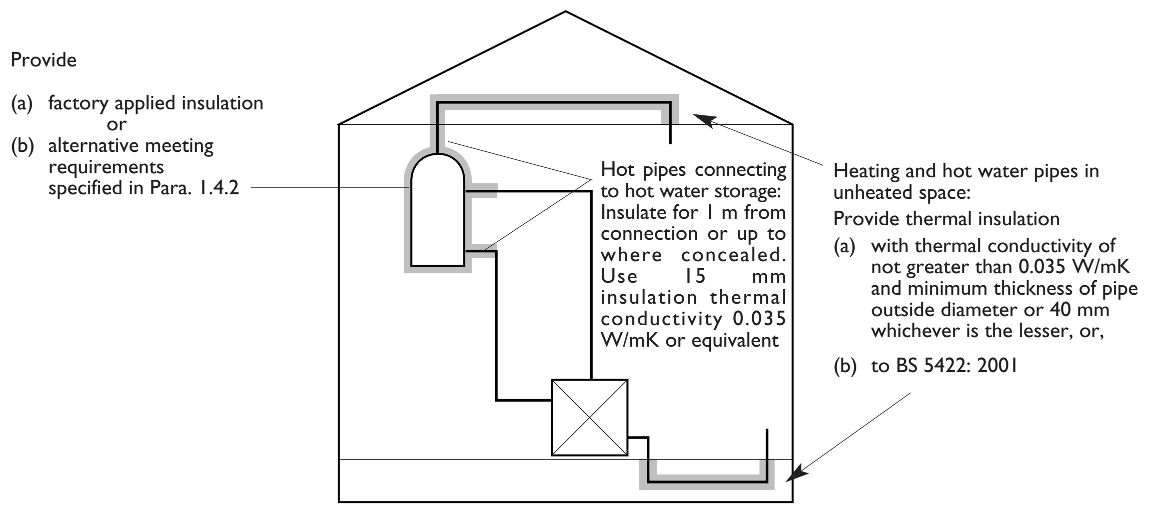
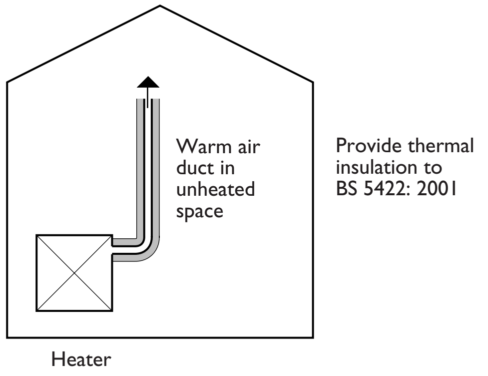


Diagram 7 *Para. 1.4.3*

Insulation of warm air ducts



Section 2:
Buildings other than Dwellings

2.1: Heat Loss and Gain through the Building Fabric

2.1.1 HEAT LOSS - GENERAL

2.1.1.1 The following two methods may be used to demonstrate that an acceptable level of transmission heat loss through the elements bounding the heated building volume is achieved-

(a) The Overall Heat Loss method (paragraph 2.1.2). This method is applicable to new buildings and extensions to existing buildings; or

(b) The Elemental Heat Loss method (paragraph 2.1.3). While this method may be used for any building, it is primarily appropriate for small buildings, e.g. less than 300 m^2 floor area, small sections of large complex buildings, common areas of apartment blocks, material alterations and material changes of use.

For both methods, the guidance regarding the limitation of thermal bridging and uncontrolled air infiltration through the building fabric (paragraphs 2.1.4 and 2.1.5) and the control of overheating (paragraph 2.1.6) should be followed. An example of the use of each method is given in Appendix F.

2.1.1.2 The derivation of U-values, including those applicable where heat loss is to an unheated space, is dealt with in Paragraphs 0.3.5 to 0.3.8 and Appendix A.

Unheated areas which are wholly or largely within the building structure and are not subject to excessive air-infiltration or ventilation, e.g. stairwells, corridors in buildings containing flats, may be considered as within the insulated fabric. In that case, if the external fabric of these areas is insulated to the same level as that achieved by equivalent adjacent elements, no particular requirement for insulation between the heated and unheated areas would arise.

2.1.1.3 The treatment of an attached conservatory-style sunspace is dealt with in Paragraph 0.1.5. Where an attached sunspace is treated as an extension to the main building for the purposes of assessment for compliance with the provisions of Part L (as provided for in Paragraph 0.1.5), the guidance in Paragraph 2.1.3.3 should be followed.

2.1.1.4 This Part of the Building Regulations applies to the replacement of external doors, windows, or rooflights in an existing building. The average U-value of replacement units should not exceed the value of 2.2 W/m^2K. The limitations on opening areas set out in Table 6 do not apply. In this context, the repair or renewal of parts of individual elements, e.g. window glass, window casement sash, door leaf, should be considered as repair and not replacement.

2.1.2 OVERALL HEAT LOSS METHOD

2.1.2.1 This method sets a maximum acceptable level of transmission heat loss through the fabric of a building, in terms of the maximum average U-value (U_m) of all fabric elements contributing to heat loss. The level depends on the ratio of the total area of these elements (A_t) to the building volume (V), and is specified in Table 4. The acceptable level of heat loss is expressed graphically in Diagram 8.

2.1.2.2 In addition to not exceeding the maximum average value set, average elemental U-values should not exceed the following:

- roofs 0.25 W/m^2K
- walls 0.37 W/m^2K
- exposed floors 0.37 W/m^2K
- ground floors 0.37 W/m^2K

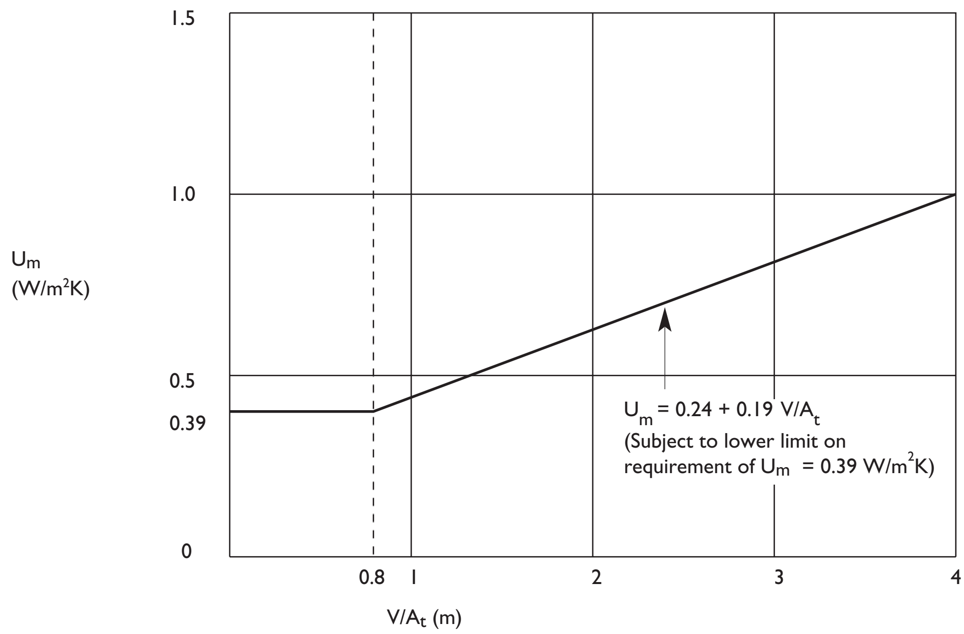
Table 4 **Maximum average U-value (U_m) as a function of building volume (V) and fabric heat-loss area (A_t)**

Area of Heat Loss Elements/ Building Volume (A_t/V) (m^{-1})	Maximum Average U-Value (U_m) (W/m^2K)
1.3	0.39
1.2	0.40
1.1	0.41
1.0	0.43
0.9	0.45
0.8	0.48
0.7	0.51
0.6	0.56
0.5	0.62
0.4	0.72
0.3	0.87

NOTE 1: The expression $U_m = 0.24 + 0.19\ V/A_t$ can be used to establish U_m for intermediate values of A_t/V and for values below 0.3 m^{-1}.

Diagram 8 *Para 2.1.2*

Maximum average U-value (U_m) in relation to building volume (V) and total area of heat loss elements (A_t)



2.1.3 ELEMENTAL HEAT LOSS METHOD

2.1.3.1 To demonstrate acceptable transmission heat loss by this method, maximum average U-values for individual building elements should not exceed those set out in Table 5.

2.1.3.2 The combined area of window, door and rooflight openings should not exceed the values given in Table 6 when the average U-value is 2.2 W/m²K. However, this area may be varied provided the total heat loss through these elements is not increased.

The area of openings provided should take account of the level of daylight provision appropriate to the building. *BS 8206: Part 2* and *CIBSE Lighting Guide (LG10), Daylight and window design*, give advice on adequate daylight provision. Care should be taken in the selection and installation of glazed systems to avoid the risk of condensation. Guidance can be obtained from BRE Report No 262. *Thermal insulation: avoiding risks,* published by BRE.

Table 5 **ELEMENTAL HEAT LOSS METHOD: Maximum average elemental U-value (W/m²K)**

Fabric Elements	New Buildings & Extensions to Existing Buildings	Material Alterations to, or Material Changes of Use of, Existing Buildings
Pitched roof, insulation horizontal at ceiling level	0.16	0.35
Pitched roof, insulation on slope	0.20	0.35
Flat roof	0.22	0.35
Walls	0.27	0.60
Ground Floors	0.25	-
Other Exposed Floors	0.25	0.60
External personnel doors, windows and rooflights	2.20[1]	2.20
Vehicle access and similar large doors	1.5	-

NOTE 1: Permitted average U-value of external personnel doors, windows and rooflights in buildings other than dwellings may vary as described in Paragraph 2.1.3.2.

Table 6 **ELEMENTAL HEAT LOSS METHOD Maximum area of openings for average U-value of 2.2 (W/m²K)**

Building type	Windows and doors as % of the area of exposed wall	Rooflights as % of area of roof
Residential buildings (where people temporarily or permanently reside)	30	20
Places of assembly, offices and shops	40	20
Industrial and storage buildings	15	20

NOTE 1:
1 For the purposes of this calculation, dormer windows in a roof may be included in the rooflight area.
2 Opening area excludes area of openings for vehicle access doors and display windows and similar glazing
3 See paragraph 0.18 for basis for calculating areas.

2.1.3.3 In applying Table 6 to an extension to an existing building, the relevant wall and roof areas may be taken to be:

(a) the combined areas for the existing building and extension; in this case the combined area of external door and window openings refers to the area of such openings in the extended building, i.e. the opening area of retained external doors, windows together with the opening area of external doors, windows in the extension; or

(b) the floor area of the extension alone; in this case the combined area of external doors, window and rooflight openings refers to the area of such openings in the extension alone. In this case the maximum combined area of external door, window and rooflight openings derived using Table 6 can be increased by an area equivalent to the area of external door, window and rooflight openings of the existing building which have been closed or covered over by the extension.

For extensions which

- are thermally separated from the adjacent spaces within the building by walls, doors and other opaque or glazed elements which have U-values not more than 10% greater than corresponding exposed areas of the main building, and

- are unheated or, if provided with a heating facility, have provision for automatic temperature and on-off control independent of the heating provision in the existing building,

the limitation on the combined area of exposed external door, window and rooflight openings does not apply. In this case the average U-value of these elements should not exceed the value of 2.2 W/m²K.

2.1.3.4 There is a wide range of possible designs for external doors, windows and rooflights. Certified U-values should be used, where available. In the absence of certified data U-values should be calculated in accordance with I.S. EN ISO 10077-1: 2000 or I.S. EN ISO 10077-2: 2000, as appropriate (See Appendix A). Alternatively, the indicative U-values for these components given in Table 36 can be used (see Appendix B).

2.1.3.5 Diagram 9 summarises the fabric insulation standards and allowances applicable in the Elemental Heat Loss method.

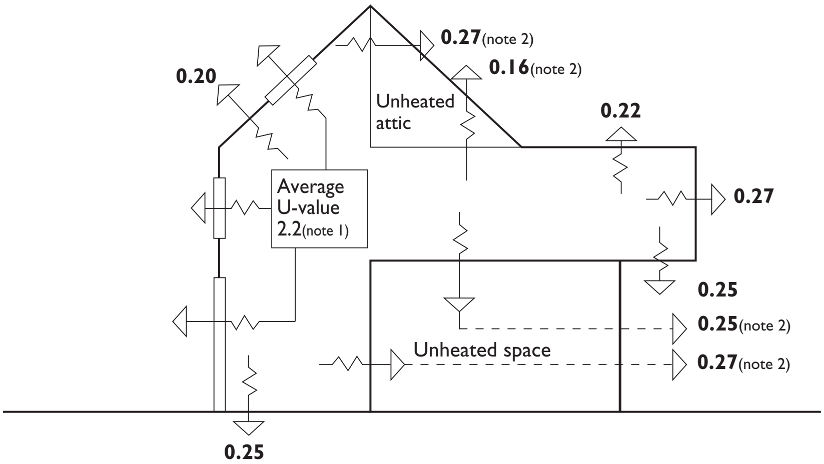
2.1.4 THERMAL BRIDGING

2.1.4.1 To avoid excessive heat losses and local condensation problems, provision should be made to limit local thermal bridging, e.g. around windows, doors and other wall openings, at junctions between elements and at other locations. Any thermal bridge should not pose a risk of surface or interstitial condensation and any excessive increase in heat loss associated with the thermal bridge should be taken account of in the calculation of average U-value.

Paragraphs 2.1.4.2 and 2.1.4.3 give guidance on reasonable provision for the limitation of thermal bridging for typical locations in conventional construction. As an alternative to following the guidance in these paragraphs (and associated

Diagram 9 *Para 2.1.3*

Elemental Heat Loss Method Summary of average elemental U-values



NOTES

1. Windows, doors and rooflights should have maximum U-value of 2.2 W/m^2K and maximum opening area as set out in Table 6. However areas and U-values may be varied provided the total heat loss through these elements is not increased.

2. The U-value includes the effect of unheated voids or other spaces.

reference documents) reasonable provision can be shown by calculation. Appendix D gives information on the calculation procedure which can be used for this purpose.

2.1.4.2 Use of cill, jamb lintel and junction details set out in-

- "*Right on the Site Issue No. 28*", published by HomeBond;
- "Limiting thermal bridging and air leakage: *Robust construction details for dwellings and smaller buildings*" (published by The Stationery Office, London); or
- other published details which have been assessed as satisfying the guidance in relation to Temperature Factor and Linear Thermal Transmittance set out in Appendix D, should represent reasonable provision to limit thermal bridging.

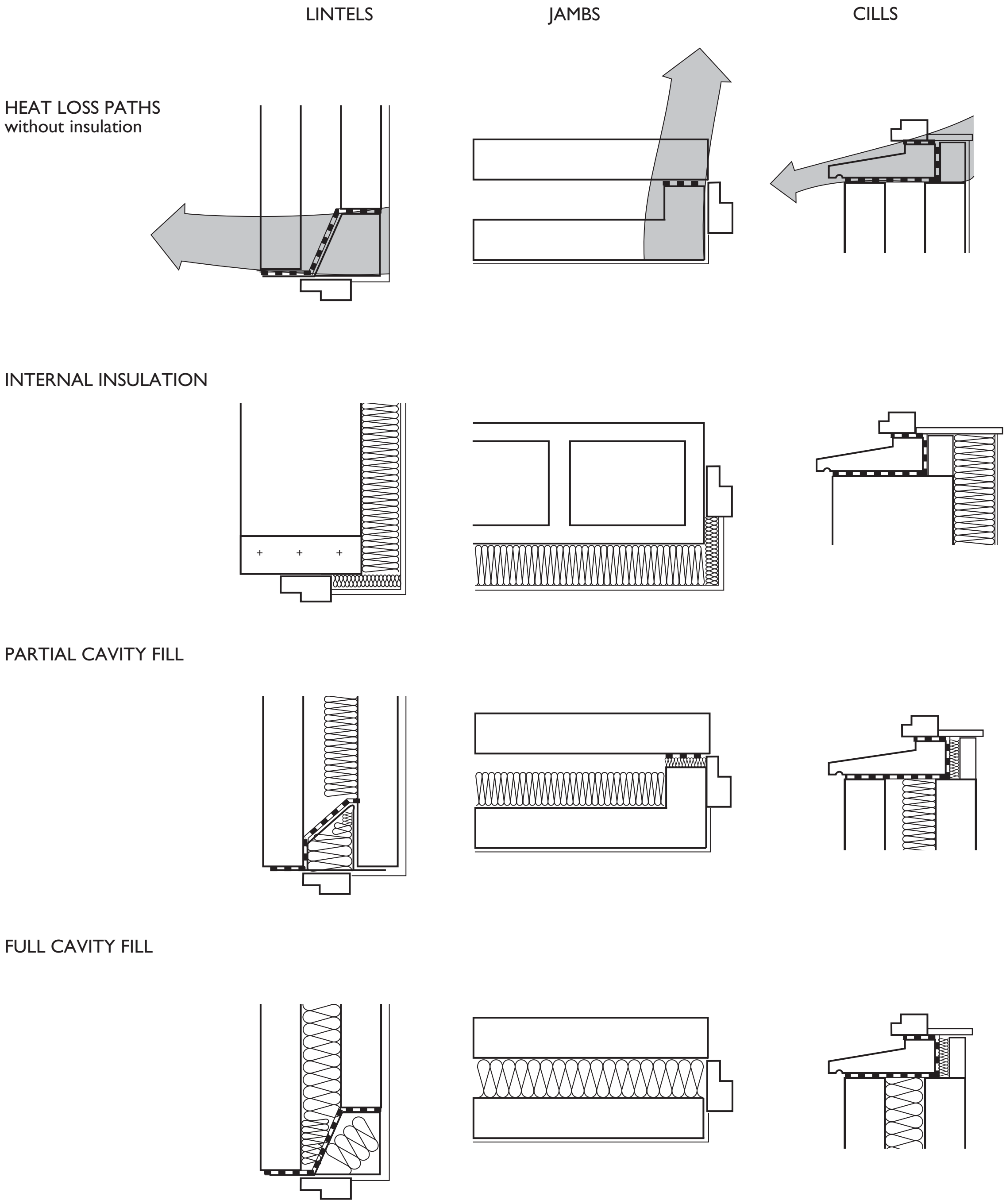
Lintel, jamb and cill designs similar to those shown in Diagram 10 would be satisfactory and heat losses due to thermal bridging can be ignored if they are adopted. At lintels, jambs and cills 15 mm thickness of insulation material having λ value of 0.04 W/mK (or equivalent) will generally be adequate.

2.1.4.3 Care should be taken to control the risk of thermal bridging at the edges of floors. All slab-on-ground floors should be provided with edge insulation to the vertical edge of the slab at all external and internal walls. The insulation should have minimum thermal resistance of 0.7 m^2K/W (25 mm of insulation with thermal conductivity of 0.035 W/mK, or equivalent).

Some large floors may have an acceptable average U-value without the need for added insulation. However, perimeter insulation should always be provided. Perimeter insulation should extend at least 0.5 m vertically or 1 m horizontally. Where the perimeter insulation is placed horizontally, insulation to the vertical edge of the slab should also be provided as indicated above.

Diagram 10 *Para 2.1.4*

Lintel, jamb and cill designs



NOTE

1. The internal faces of metal lintels should be covered with at least 15 mm of lightweight plaster; alternatively they can be dry-lined.

2.1.5 AIR INFILTRATION

2.1.5.1 Infiltration of cold outside air should be limited by reducing unintentional air paths as far as is practicable. A reasonably continuous air barrier should be provided over the whole thermal envelope, including elements separating the building from adjoining heated or unheated areas.

2.1.5.2 For conventional construction measures taken to ensure this should include:

(a) sealing the void between dry-lining and masonry walls at the edges of openings such as windows and doors, and at the junctions with walls, floors and ceilings (e.g. by continuous bands of bonding plaster or battens),

(b) sealing vapour control membranes in timber-frame constructions,

(c) fitting draught-stripping in the frames of openable elements of windows, doors and rooflights,

(d) sealing around access or service hatches which provide access to unheated voids (loft spaces) from the conditioned space,

(e) ensuring ducting for concealed services is sealed at floor and ceiling levels and sealing piped services where they penetrate or project into hollow constructions or voids.

Diagram 11 illustrates some of these measures.

2.1.5.3 Additional guidance on appropriate measures to limit air infiltration in larger office and commercial buildings is given in BRE Report BR 448, *Air tightness in commercial and public buildings*. Guidance on methods to limit air infiltration through twin skin metal cladding and roofing systems is contained in Steel Construction Institute (SCI) Technical Information Sheet No. 311, *The design of twin-skin metal cladding.*

2.1.5.4 Care should be taken to ensure that measures to limit air infiltration do not negatively affect compliance with the ventilation requirements of Part F and Part J.

2.1.6 AVOIDING SOLAR OVERHEATING

2.1.6.1 Buildings should be designed and constructed so that:

(a) those occupied spaces that rely on natural ventilation do not risk unacceptable levels of thermal discomfort due to overheating caused by solar gain, and

(b) those spaces that incorporate mechanical ventilation or cooling do not require excessive plant capacity to maintain the desired space conditions.

Where extensive use of glazing is proposed in the building design, particular care should be exercised to ensure compliance with this aspect of the Regulations.

2.1.6.2 Alternative approaches to showing compliance include:

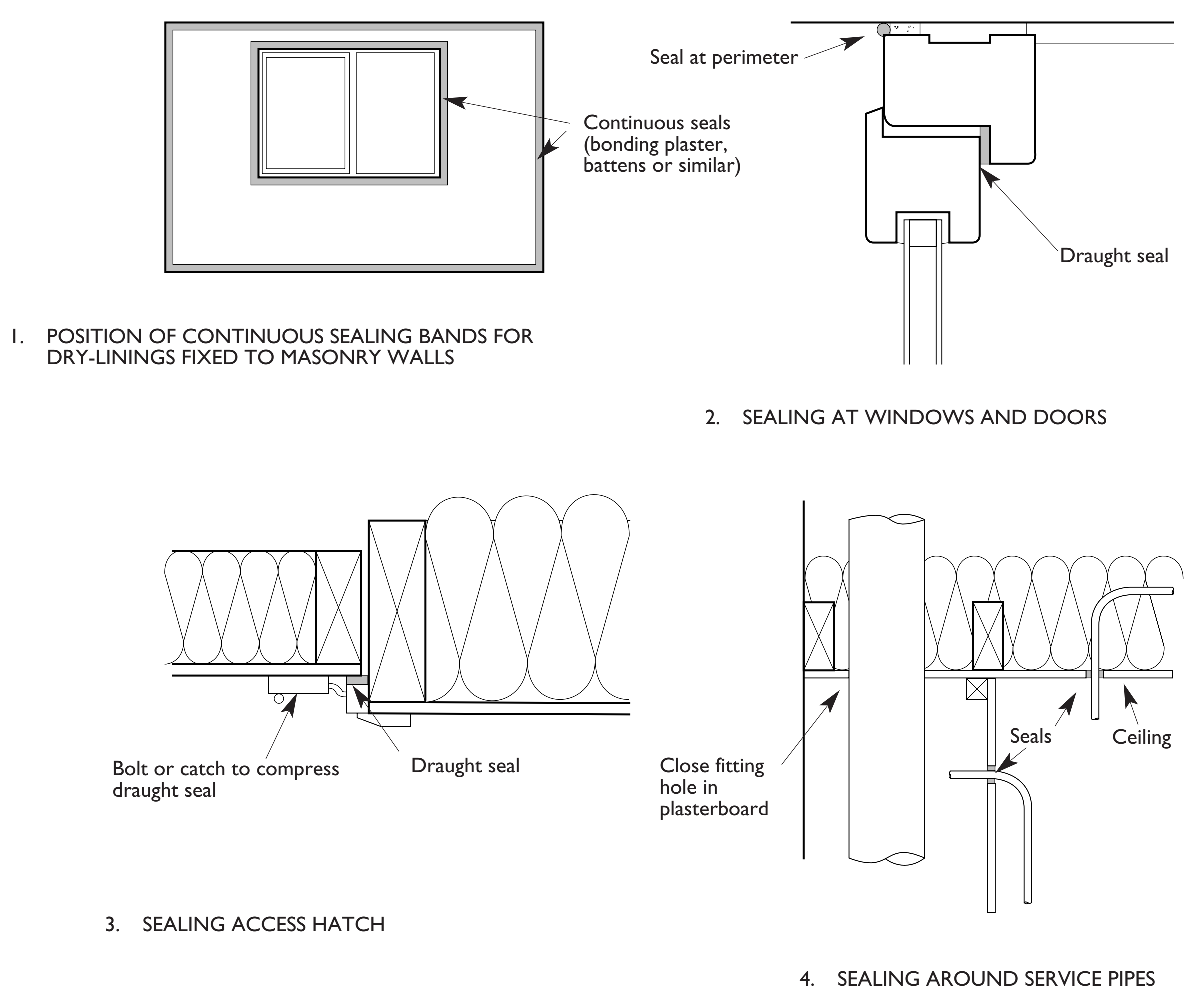
(a) showing that the average daily solar heat load per unit floor area during the period of occupancy would not be greater than 25W/m^2, when the average solar load for glazing of different orientations is taken to be as specified in Table 7. The calculation procedure given in Appendix E can be used to do this. Local weather data averaged over a period of 15 years, at least, can be used instead of the data given in Table 7, where available.

Table 7 **Average solar load between 7.30 and 17.30 for different glazing orientations**

Orientation	Average solar load (W/m^2)
N	125
NE/NW	160
E/W	205
SE/SW	198
S	156
Horizontal	327

NOTE 1: This solar load is not likely to be exceeded on more than 2.5% of days in July. Source: CIBSE Guide A, Section 5.

Diagram 11 *Para 2.1.5*
Air infiltration measures



(b) showing by detailed calculation procedures such as those described in chapter 5 of CIBSE Guide A, that in the absence of mechanical cooling or mechanical ventilation, the space temperature will not exceed 28^{0}C for an unacceptable proportion of the period of occupation. The period for which this temperature can be exceeded depends on the nature of occupancy and the activities within the space. For offices and similarly occupied buildings, a guide figure is 20 hours per annum during the period of occupancy. A range of computer simulation programs exists that facilitate this calculation.

2.1.6.3 Measures that can be effective in reducing the risk of solar overheating include:

(a) using glazing designed to reduce solar gains while not unduly limiting natural light transmittance,

(b) the incorporation of passive measures such as shading (detailed guidance in this regard is given in BRE Report No 364, *Solar shading of buildings)*, and

(c) the use of exposed thermal capacity combined with night ventilation (detailed guidance in this regard is given in Action Energy General Information Report 31 (GIR031) *Avoiding or minimizing the use of air-conditioning).*

2.2: Building Services

2.2.1 HEATING PLANT EFFICIENCY

Heating plant should be designed and installed so that it operates efficiently over the range of loading likely to be encountered. Oil and gas fired boilers should satisfy the efficiency requirements specified in S.I. No. 260 of 1994: *European Communities (Efficiency requirements for new hot water boilers fired with liquid or gaseous fuels) Regulations, 1994.*

2.2.2 CONTROLS FOR SPACE HEATING AND HOT WATER SUPPLY SYSTEMS

2.2.2.1 Space and water heating systems should be effectively controlled so as to limit energy use by these systems to that required to satisfy user requirements and, where appropriate, to protect the building and it's contents from damage due to low temperatures. This section is not intended to apply to control systems for commercial and industrial processes.

2.2.2.2 Buildings should be provided with zone, timing and temperature controls such that, for space heating, each functional area is maintained at the required temperature only during the period when it is occupied. Additional space heating controls may be provided to allow heating during extended unusual occupation hours and to provide for sufficient background heating to prevent condensation or frost damage when the heating system would otherwise be switched off.

2.2.2.3 Hot water systems should be designed and provided with appropriate controls so that they can be operated efficiently. For efficient operation, hot water systems should not be over-sized and should be designed to avoid low-load operation of heating plant. The layout should minimize the length of circulation loops and minimize the length and diameter of dead legs. Designers should have particular regard to the need to limit the risk of promoting the growth of legionella bacteria. Local instantaneous heaters should be used, where appropriate. Consideration should be given to the use of renewable energy, e.g. solar water heating, and to heat recovery from other processes, where applicable. Electric water heating should be avoided except where demand is low.

2.2.2.4 Effective control of space and water heating can be achieved as follows:

(a) in buildings with a heating system of maximum output not exceeding 100 kW, by following the guidance in Action Energy Good Practice Guide 132 (GPG132) *Heating Controls in small commercial and multi-residential buildings published by BRECSU;*

(b) in larger or more complex buildings, by following the guidance contained in CIBSE Guide H: *Building Control Systems* published by CIBSE.

2.2.3 AIR CONDITIONING AND MECHANICAL VENTILATION (ACMV)

2.2.3.1 Buildings that use ACMV systems to treat in excess of 200 m^2 floor area should be designed and constructed such that:

(a) the form and fabric of the building do not result in a requirement for excessive installed capacity of ACMV equipment. In particular, the suitable specification of glazing ratios and solar shading are an important way to limit cooling requirements (see Section 2.1.6 above);

(b) components such as fans, pumps and refrigeration equipment are reasonably efficient and appropriately sized so as to have no more capacity for demand and standby than is necessary for the task;

(c) suitable facilities are provided to manage, control and monitor the operation of the equipment and the systems.

2.2.3.2 ACMV systems can be considered to be adequately sized if the specific fan power (SFP) is less than the values given in the following sub-paragraphs. The SFP is the sum of the design total circuit-Watts of all fans that supply air and exhaust it back to outdoors (i.e., the sum of supply and extract fans), including all losses through switchgear and controls such as inverters, divided by the design ventilation rate through the building.

(a) for ACMV systems in new buildings, the SFP should be no greater than 2.0 W/litre/second.

(b) for new ACMV systems in refurbished buildings, or where an existing ACMV system in an existing building is being substantially altered, the SFP should be no greater than 3.0 W/litre/second.

2.2.3.3 These SFP values are appropriate for typical ventilated spaces intended for human occupancy. Where specialist processes are involved or external pollution levels exceed those normally encountered and, as a result, greater levels of filtration or air cleaning are required, higher SFPs may be appropriate. In the context of this section "specialist processes" can be taken to include any activity which is not typical of the particular building use, which affects a significant area within the building, and where the resulting need for heating, ventilation or air conditioning is significantly different to that typical for the building. When assessing the performance of ACMV systems, areas where the existence or sizing of these systems is determined by process requirements should be excluded from the considered area, together with the plant capacity, or proportion of the plant capacity, that is provided to service those areas. Activities and areas in office buildings considered to represent process requirements would include:

- Staff restaurants and kitchens;
- Large dedicated conference rooms;
- Sports facilities;
- Dedicated computer or communications rooms.

2.2.3.4 Mechanical ventilation systems should be reasonably efficient at part load. This can be achieved by providing efficient variable flow control systems incorporating, for instance, variable speed drives or variable pitch axial fans. More detailed guidance is given in Action Energy General Information, Report 41 (GIR041) *Variable flow control, General Information,* published by BRECSU.

2.2.4 INSULATION OF STORAGE VESSELS, PIPES AND DUCTS

2.2.4.1 This section only applies to pipes, ducts and vessels for the provision of space heating, space cooling (including chilled water and refrigerant pipe work) and hot water supply for normal occupation. It does not apply to pipes, ducts and vessels associated with commercial or industrial processes.

2.2.4.2 Hot water storage vessels, pipes and ducts associated with the provision of heating and hot water in a building should be insulated to limit heat loss, except where the heat flow through the wall of the pipe, duct or vessel is always useful in conditioning the surrounding space. Storage vessels for chilled water and refrigerant, and pipes and ducts that serve air-conditioning systems should be insulated to limit heat gain from the surrounding environment.

2.2.4.3 Provision of insulation to pipes, ducts and storage vessels, in accordance with the standards specified in BS 5422: 2001, should adequately limit heat loss or heat gain, as appropriate. The appropriate insulation level for storage vessels should be taken as that given in BS 5422: 2001 for flat surfaces.

2.2.4.4 It should be noted that water pipes and storage vessels in unheated areas will generally need to be insulated for the purpose of protection against freezing. Guidance on suitable protection measures is given in BRE Report 262, *Thermal insulation: avoiding risks* published by BRE.

2.2.5 ARTIFICIAL LIGHTING

2.2.5.1 The guidance given in Paragraphs 2.2.5.2 and 2.2.5.3 below need not be applied when the total installed lighting capacity is less than 1000 W. In this section the term "efficacy" is used to describe the energy efficiency of a lamp. It is described by the amount of light it produces in lumens with respect to the power it consumes in Watts.

2.2.5.2 General purpose artificial lighting systems shall be designed and controlled so as to ensure the efficient use of energy for this purpose. The efficiency of a general lighting system may be considered acceptable if it complies with one of the following:

(a) 95 % of the artificial lighting capacity in circuit Watts is provided by lighting fittings which use lamps with luminous efficacies not less than those of the types listed in Table 8;

(b) the installed lighting capacity comprises lighting fittings with lamps having an average initial (100 hour) efficacy of not less than 65 lumens per circuit Watt; or

(c) the lighting design is in accordance with the guidance in the "Code for Lighting" published by CIBSE, in particular the guidance on energy efficiency in Section 2.4 of that document.

2.2.5.3 The aim of lighting controls should be to encourage the maximum use of daylight and to avoid unnecessary artificial lighting, particularly when spaces are unoccupied, having regard to the need to ensure that the operation of automatically switched lighting systems does not endanger occupants in a building. In this section reference to switches includes dimmer switches and switching includes dimming.

Adequate control depends on the nature and use pattern of the building. This may be achieved by one, or more, of the following means, used alone or in combination, as appropriate:

(a) local manually operated switches in easily accessible positions within each working area or at boundaries between working areas and general circulation routes. The distance on plan from any local switch to the luminaries it controls should generally be not more than eight metres, or three times the height of the light fitting above the floor if this is greater;

(b) daylight-linked photo-electric switching or dimming for lighting adjacent to windows or other sources of natural light;

(c) remote controlled switches operated by infra red transmitter, sonic, ultrasonic or telephone handset controls;

(d) automatic switching systems which switch the lighting off when they sense the absence of occupants;

(e) time-controlled switches.

For offices and storage buildings, local switching, either manual or remote controlled, is desirable. For some other building uses, e.g. where continuous lighting is required during hours of operation, time switching or daylight-linked photo-electric switching may be more appropriate.

Table 8 **Light sources suitable for general lighting**

Light source	Types and rating
High pressure Sodium	All types and ratings
Metal halide	All types and ratings
Induction lighting	All types and ratings
Tubular fluorescent	26 mm diameter (T8) lamps, and 16 mm diameter (T5) lamps rated above 11W, provided with high efficiency control gear. 38 mm diameter (T12) linear fluorescent lamps 2400 mm in length
Compact fluorescent	All ratings above 11W
Other	Any type and rating with an efficacy greater than 50 lumens per circuit Watt.

APPENDICES

Appendix A: Calculation of U-Values

GENERAL

A1.1 General Guidance on the Calculation of U-values is contained in Report BR 443 *"Conventions for the Calculation of U-values"*. For building elements and components generally, the method of calculating U-values is specified in I.S. EN ISO 6946: 1997. U-values of components involving heat transfer to the ground, e.g. ground floors with or without floor voids, basement walls, are calculated by the method specified in I.S. EN ISO 13370: 1999. A soil thermal conductivity of 2.0 W/mK should be used, unless otherwise verified. U-values for windows, doors and shutters may be calculated using I.S. EN ISO 10077-1: 2000 or I.S. EN ISO 10077-2: 2000. Information on U-values and guidance on calculation procedures contained in the 1999 edition of CIBSE Guide A3: Thermal Properties of Building Structures are based on these standards and may be used to show compliance with this Part.

A method for assessing U-values of light steelframed constructions is given in Digest 465 *"U-values for light steel construction"*, published by BRE. Guidance in relation to the calculation of U-values for various forms of metal clad construction can be found in Technical Paper No. 14 *"Guidance for the design of metal roofing and cladding to comply with Approved Document L2: 2001"* published by MCRMA, Technical Information Sheet No. 312, *"Metal cladding: U-value calculation assessing thermal performance of built-up metal roof and wall cladding systems using rail and bracket spacers"* published by SCI and IP 10/02 *"Metal cladding: assessing thermal performance of built-up systems which use 'Z' spacers"* published by BRE.

A1.2 U-values derived by calculation should be rounded to two significant figures and relevant information on input data should be provided. When calculating U-values the effects of timber joists, structural and other framing, mortar bedding, window frames and other small areas where thermal bridging occurs must be taken into account. Similarly, account must be taken of the effect of small areas where the insulation level is reduced significantly relative to the general level for the component or structure element under consideration. Thermal bridging may be disregarded, however, where the general thermal resistance does not exceed that in the bridged area by more than 0.1 m^2K/W. For example, normal mortar joints need not be taken into account in calculations for brickwork or concrete blockwork where the density of the brick or block material is in excess of 1500 kg/m^3. A ventilation opening in a wall or roof (other than a window, rooflight or door opening), and a meter cupboard recess may be considered as having the same U-value as the element in which it occurs.

A1.3 Examples of the application of the calculation method specified in I.S. EN 6946: 1977 are given below. An example of the calculation of ground floor U-values using I.S. EN ISO 13370: 1999 is also given.

A1.4 Thermal conductivities of common building materials are given in Table 9 and for common insulating materials in Table 10. For the most part, these are taken from I.S. EN 12524: 2000 or CIBSE Guide A3. See paragraph 0.3.3 regarding application of these tables.

SIMPLE STRUCTURE WITHOUT THERMAL BRIDGING

A2.1 To calculate the U-value of a building element (wall or roof) using I.S. EN ISO 6946: 1997, the thermal resistance of each component is calculated, and these thermal resistances, together with surface resistances as appropriate, are then combined to yield the total thermal resistance and U-value. The result is corrected to account for mechanical fixings (e.g. wall ties) or air gaps if required. For an element consisting of homogenous layers with no thermal bridging, the total resistance is simply the sum of individual thermal resistances and surface resistances.

I.S. EN 6946: 1997 provides for corrections to the calculated U-value. In the case of example A1 (see Diagram 12), corrections for air gaps in the insulated layer and for mechanical fasteners may apply. However, if the total correction is less than 3% of the calculated value, the correction may be ignored.

In this case no correction for air gaps applies as it is assumed that the insulation boards meet the dimensional standards set out in I.S. EN ISO 6946: 1997 and that they are installed without gaps greater than 5 mm. The construction involves the use of wall ties that penetrate fully through the insulation layer.

Table 9	**Thermal conductivity of some common building materials**	
Material	Density (kg/m^3)	Thermal Conductivity (W/mK)
General Building Materials		
Clay Brickwork (outer leaf)	1,700	0.77
Clay Brickwork (inner leaf)	1,700	0.56
Concrete block (heavyweight)	2,000	1.33
Concrete block (medium weight)	1,400	0.57
Concrete block (autoclaved aerated)	600	0.18
Cast concrete, high density	2,400	2.00
Cast concrete, medium density	1,800	1.15
Aerated concrete slab	500	0.16
Concrete screed	1,200	0.41
Reinforced concrete (1% steel)	2,300	2.30
Reinforced concrete (2% steel)	2,400	2.50
Wall ties, stainless steel	7,900	17.00
Wall ties, galvanised steel	7,800	50.00
Mortar (protected)	1,750	0.88
Mortar (exposed)	1,750	0.94
External rendering (cement sand)	1,300	0.57
Plaster (gypsum lightweight)	600	0.18
Plaster (gypsum)	1,200	0.43
Plasterboard	900	0.25
Natural Slate	2,500	2.20
Concrete tiles	2,100	1.50
Fibrous cement slates	1,800	0.45
Ceramic tiles	2,300	1.30
Plastic tiles	1,000	0.20
Asphalt	2,100	0.70
Felt bitumen layers	1,100	0.23
Timber, softwood	500	0.13
Timber, hardwood	700	0.18
Wood wool slab	500	0.10
Wood-based panels (plywood, chipboard, etc.)	500	0.13

NOTE: The values in this table are indicative only. Certified values, should be used in preference, if available.

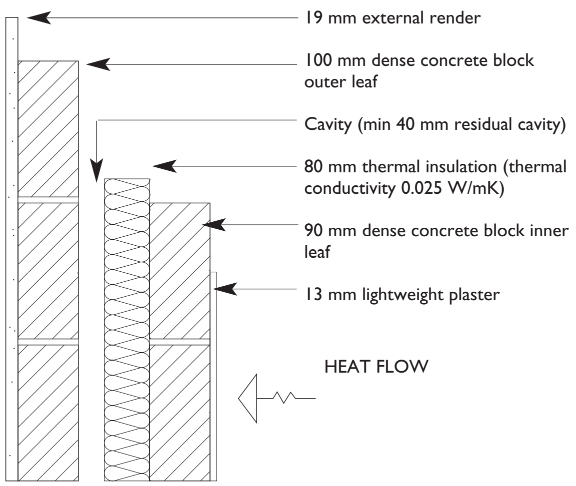
Table 10	**Thermal conductivity of some common insulation materials**	
Material	Density (kg/m^3)	Thermal Conductivity (W/mK)
Insulation		
Expanded polystyrene (EPS) slab (HD)	25	0.035
Expanded polystyrene (EPS) slab (SD)	15	0.037
Extruded polystyrene	30	0.025
Glass fibre / wool quilt	12	0.040
Glass fibre / wool batt	25	0.035
Phenolic foam	30	0.025
Polyurethane board	30	0.025

NOTE: The values in this table are indicative only. These may be used for early design purposes. Certified values, taking ageing into account, where appropriate, should be used in final calculations (see para. 0.3.2.)

Example A1: Masonry cavity wall

Diagram 12 *Para. A.2.1*

Masonry Cavity wall



Layer/Surface	Thickness (m)	Conductivity (W/mK)	Resistance (m^2K/W)
External surface	-----	-----	0.040
External render	0.019	0.57	0.033
Concrete Block	0.100	1.33	0.075
Air cavity	-----	-----	0.180
Insulation	0.080	0.025	3.200
Concrete Block	0.100	1.33	0.075
Plaster (lightweight)	0.013	0.18	0.072
Internal surface	-----	-----	0.130
Total Resistance	-----	-----	3.805
U-value of construction = 1/3.805 = 0.26 W/m²K			

A potential correction factor applies which, assuming the use of 4 mm diameter stainless steel ties at 5 ties per m², is calculated as 0.006 W/m²K. This is less than 3% of the calculated U-value and may be ignored. It should be noted that, if galvanised steel wall ties were used, a correction of 0.02 W/m²K would apply, and the corrected U-value for this construction would be 0.28 W/m²K.

STRUCTURE WITH BRIDGED LAYER(S)

A2.2 For an element in which one or more layers are thermally bridged, the total thermal resistance is calculated in three steps as follows.

(a) The upper thermal resistance is based on the assumption that heat flows through the component in straight lines perpendicular to the element's surfaces. To calculate it, all possible heat flow paths are identified, for each path the resistance of all layers are combined in series to give the total resistance for the path, and the resistances of all paths are then combined in parallel to give the upper resistance of the element.

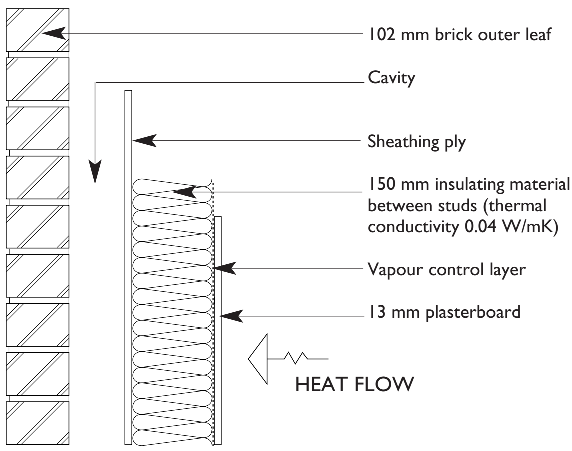
(b) The lower thermal resistance is based on the assumption that all planes parallel to the surfaces of the component are isothermal surfaces. To calculate it, the resistances of all components of each thermally bridged layer are combined in parallel to give the effective resistance for the layer, and the resistances of all layers are then combined in series to give the lower resistance of the element.

(c) The total thermal resistance is the mean of the upper and lower resistances.

Example A2: Timber-frame wall (with one insulating layer bridged)

Diagram 13 *Para. A.2.2*

Timber-frame wall



The thermal resistance of each component is calculated (or, in the case of surface resistances, entered) as follows.

Layer/Surface	Thickness (m)	Conductivity (W/mK)	Resistance (m^2 K / W)
External surface	---	---	0.040
Brick outer leaf	0.102	0.77	0.132
Air cavity	---	---	0.180
Sheathing ply	0.012	0.13	0.092
Mineral wool insulation	0.150	0.04	3.750
Timber studs	0.150	0.13	1.154
Plasterboard	0.013	0.25	0.052
Internal surface	---	---	0.130

Upper resistance

Assuming that heat flows in straight lines perpendicular to the wall surfaces, there are two heat flow paths - through the insulation and through the studs. The resistance of each of these paths is calculated as follows.

Resistance through section containing insulation [m^2 K / W]:

External surface resistance	0.040
Brick outer leaf	0.132
Air cavity	0.180
Sheathing ply	0.092
Mineral wool insulation	3.750
Plasterboard	0.052
Internal surface resistance	0.130
Total	**4.377**

Resistance through section containing timber stud [m^2 K / W]

External surface resistance	0.040
Brick outer leaf	0.132
Air cavity	0.180
Sheathing ply	0.092
Timber studs	1.154
Plasterboard	0.052
Internal surface resistance	0.130
Total	**1.781**

The upper thermal resistance R_u is obtained from:

$R_u = 1 / (F_1 / R_1 + F_2 / R_2)$

where F_1 and F_2 are the fractional areas of heat flow paths 1 and 2, and R_1 and R_2 are the resistances of these paths.

Upper resistance $R_u = 1 / (0.88 / 4.377 + 0.12 / 1.781) = 3.725$ m^2 K / W

Lower resistance

Assuming an isothermal plane on each face of the layer of insulation which is bridged by timber studs, the thermal resistance of this bridged layer, R_b, is calculated from

$R_b = 1 / (F_{ins} / R_{ins} + F_t / R_t)$

where F_{ins} and F_t are the fractional areas of insulation and timber, and R_{ins} and R_t are their resistances.

$R_b = 1 / (0.88 / 3.750 + 0.12 / 1.154) = 2.953$ m^2 K / W

The resistances of all layers are then combined in series to give the lower resistance [m^2 K / W]

External surface resistance	0.040
Brick outer leaf	0.132
Air cavity	0.180
Bracing board	0.092
Bridged insulation layer	2.953
Plasterboard	0.052
Internal surface resistance	0.130
Lower resistance (R_l)	**3.580**

Total resistance

The total resistance R_t is given by:

$R_t = (R_u + R_l) / 2 = (3.725 + 3.580) / 2 = 3.652$ m^2 K / W

The U-value is the reciprocal of the total resistance:

U-value = 1 / 3.652 = 0.27 W/m^2K (to 2 decimal places).

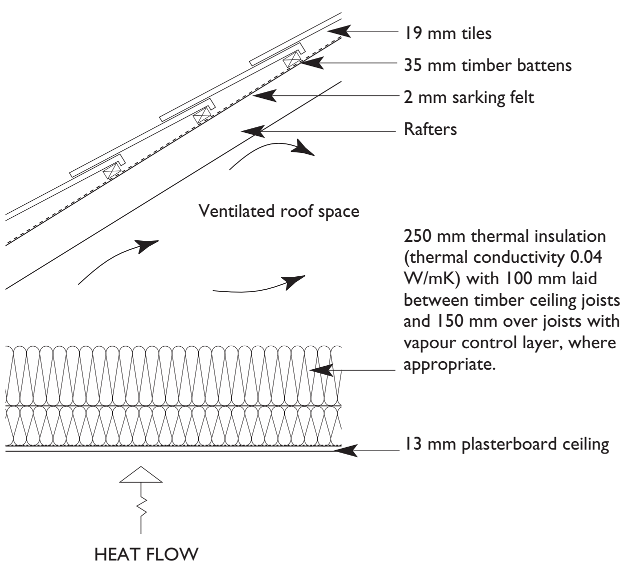
There is a potential correction for air gaps in the insulation layer. I.S. EN ISO 6946: 1997 gives a U-value correction of 0.0065 W/m^2K for this construction. This is less than 3% of the calculated U-value and can be ignored.

Example A3: Domestic pitched roof with insulation at ceiling level (between and over joists).

A pitched roof has 100 mm of mineral wool tightly fitted between 44 mm by 100 mm timber joists spaced 600 mm apart (centres to centres) and 150 mm of mineral wool over the joists. The roof is tiled with felt or boards under the tiles. The ceiling consists of 13 mm of plasterboard. The fractional area of timber at ceiling level is taken as 8%.

Diagram 14 *Para. A.2.2*

Domestic pitched roof



Layer/Surface	Thickness (m)	Conductivity (W/mK)	Resistance (m^2K/W)
External surface	-	-	0.040
Roof space (including sloping construction and roof cavity)	-	-	0.200
Mineral wool (continuous layer)	0.150	0.04	3.750
Mineral wool (between joists)	0.100	0.04	2.500
Timber joists	0.100	0.13	1.154
Plasterboard	0.013	0.25	0.052
Internal surface	-	-	0.100

Upper resistance (R_u)

Resistance through section containing both layers of insulation [m^2K/W]

External surface resistance	0.040
Resistance of roof space	0.200
Resistance of mineral wool over joists	3.750
Resistance of mineral wool between joists	2.500
Resistance of plasterboard	0.052
Inside surface resistance	0.100
Total	**6.642**

Resistance through section containing timber joists

External surface resistance	0.040
Resistance of roof space	0.200
Resistance of mineral wool over joists	3.750
Resistance of timber joists	0.769
Resistance of plasterboard	0.052
Inside surface resistance	0.100
Total	**4.911**

The upper thermal resistance [R_u] is obtained from:

$$R_u = 1 / (F_1 / R_1 + F_2 / R_2)$$

where F_1 and F_2 are the fractional areas of heat flow paths 1 and 2, and R_1 and R_2 are the resistances of these paths.

Upper resistance R_u = 1 / (0.92 / 6.642 + 0.08 / 4.911) = 6.460 m^2 K/W

Lower resistance (R_l)

Assuming an isothermal plane on each face of the layer of insulation which is bridged by timber studs, the thermal resistance of this bridged layer, R_b, is calculated from

$$R_b = 1 / (F_{ins} / R_{ins} + F_t / R_t)$$

where F_{ins} and F_t are the fractional areas of insulation and timber, and R_{ins} and R_t are their resistances.

R_b = 1 / (0.92 / 2.500 + 0.08 / 0.769) = 2.119 m^2K/W

The resistances of all layers are then combined in series to give the lower resistance [m²K/W]

External surface resistance	0.040
Resistance of roof space	0.200
Resistance of mineral wool over joists	3.750
Resistance of bridged layer	2.119
Resistance of plasterboard	0.052
Inside surface resistance	<u>0.100</u>
Lower resistance (R_l)	**6.261**

<u>Total resistance</u>

The total resistance R_t is given by:
$R_t = (R_u + R_l) / 2 = (6.460 + 6.261) / 2 = 6.361$ m²K/W

The U-value is the reciprocal of the total resistance:
U-value = 1 / 6.361 = **0.16 W/m²K** (to 2 decimal places).

I.S. EN ISO 6946: 1997 does not specify any potential correction for this construction.

GROUND FLOORS AND BASEMENTS

A3.1 The U-value of an uninsulated ground floor depends on a number of factors including floor shape and area and the nature of the soil beneath the floor. I.S. EN ISO 13370: 1999 deals with the calculation of U-values of ground floors. Methods are specified for floors directly on the ground and for floors with vented and unvented sub-floor spaces. I.S. EN ISO 13370: 1999 also covers heat loss from basement floors and walls.

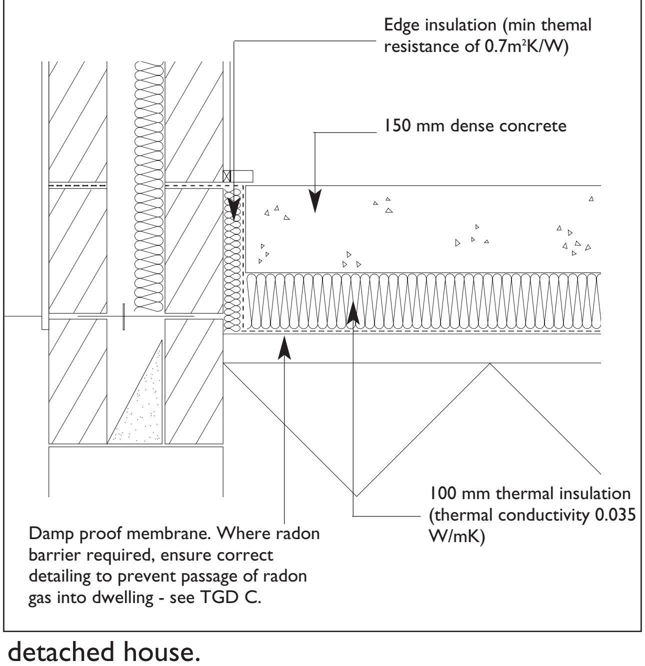
A3.2 In the case of semi-detached or terraced premises, blocks of flats and similar buildings, the floor dimensions can be taken as either those of the individual premises or those of the whole building. When considering extensions to existing buildings the floor dimensions can be taken as those of the extension alone or those of the whole building. Unheated spaces outside the insulated fabric, such as attached porches or garages, should be excluded when deriving floor dimensions but the length of the floor perimeter between the heated building and the unheated space should be included when determining the length of exposed perimeter.

A3.3 Slab-on-ground floors, with minimum provision for edge insulation as specified in Paragraph 1.1.5.3 and 2.1.4.3, achieve a U-value of 0.45 W/m²K without extra insulation provided the ratio of exposed perimeter length to floor area is less than 0.20. In order to achieve a U-value of 0.25 W/m²K this ratio must be less than 0.10.

Example A4: Slab-on-ground floor – full floor insulation.

The slab-on-ground floor consists of a 150 mm dense concrete ground floor slab on 100 mm insulation. The insulation has a thermal conductivity of 0.035 W/mK. The floor dimensions are 8750 mm by 7250 mm with three sides exposed. One 8750 mm side abuts the floor of an adjoining semi-detached house.

Diagram 15 *Para. A.3.1*
Concrete slab-on-ground floor



In accordance with I.S. EN ISO 13370: 1999, the following expression gives the U-value for well-insulated floors:

$U = \lambda/(0.457B' + d_t)$, where

λ	=	thermal conductivity of unfrozen ground (W/mK)
B'	=	2A/P (m)
d_t	=	$w + \lambda(R_{si} + R_f + R_{se})$ (m)
A	=	floor area (m^2)
P	=	heat loss perimeter (m)
w	=	wall thickness (m)

R_{si}, R_f and R_{se} are internal surface resistance, floor construction (including insulation) resistance and external surface resistance respectively. Standard values of R_{si} and R_{se} for floors are given as 0.17 m^2K/W and 0.04 m^2K/W respectively. The standard also states that the thermal resistance of dense concrete slabs and thin floor coverings may be ignored in the calculation and that the thermal conductivity of the ground should be taken as 2.0 W/mK unless otherwise known or specified.

Ignoring the thermal resistance of the dense concrete slab, the thermal resistance of the floor construction (R_f) is equal to the thermal resistance of the insulation alone, i.e. 0.1/0.035 or 2.857 m^2K/W. Taking the wall thickness as 300 mm, this gives

$$d_t = 0.30 + 2.0(0.17 + 2.857 + 0.04) = 6.434 \text{ m.}$$

Also $$B' = 2(8.75 \times 7.25) / (8.75 + 7.25 + 7.25) = 5.457 \text{ m}$$

Therefore $$U = 2.0 / ((0.457 \times 5.457) + 6.434) = 0.22 \text{ W/m}^2\text{K.}$$

The edge insulation to the slab is provided to prevent thermal bridging at the edge of the slab. I.S. EN ISO 13370: 1999 does not consider this edge insulation as contributing to the overall floor insulation and thus reducing the floor U-value. However, edge insulation, which extends below the external ground level, is considered to contribute to a reduction in floor U-value and a method of taking this into account is included in the standard. Foundation walls of insulating lightweight concrete may be taken as edge insulation for this purpose.

ELEMENTS ADJACENT TO UNHEATED SPACES

A4.1 As indicated in paragraph 0.3.5, the procedure for the calculation of U-values of elements adjacent to unheated spaces (previously referred to as semi-exposed elements) is given in I.S. EN ISO 6946: 1997 and I.S. EN ISO 13789: 2000.

The following formulae may be used to derive elemental U-values (taking the unheated space into account) for typical housing situations irrespective of the precise dimensions of the unheated space.

$$U_o = 1 /(1/U - R_u) \quad \text{or} \quad U = 1 /(1/U_o + R_u)$$

Where:

- U – U-value of element adjacent to unheated space (W/m^2K), taking the effect of the unheated space into account.
- U_o – U-value of the element between heated and unheated spaces (W/m^2K) calculated as if there was no unheated space adjacent to the element.
- R_u – effective thermal resistance of unheated space inclusive of all external elements ($m^2 K / W$).

This procedure can be used when the precise details on the structure providing an unheated space are not available, or not crucial.

R_u for typical unheated structures (including garages, access corridors to flats and unheated conservatories) are given in Tables 11, 12 and 13.

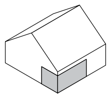
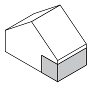
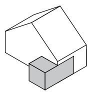
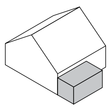
Table 13 applies only where a conservatory - style sunroom is not treated as an integral part of the dwelling i.e. is treated as an extension - see paragraph 1.1.1.2

In the case of room-in-roof construction, the U-value of the walls of the room-in-roof construction and of the ceiling of the room below the space adjacent to these walls can be calculated using this procedure. See Diagram 16.

GENERAL

Table 11 **Typical resistance (R_u) for unheated space.**

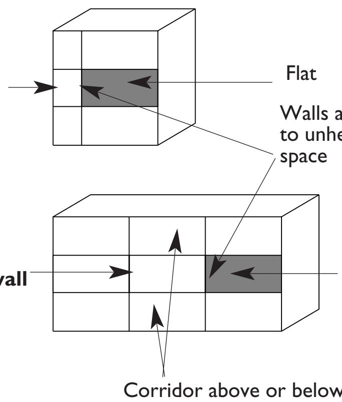
(a) Integral and adjacent single garages or other similar unheated space.

Garage or other similar unheated space		Element between garage and dwelling	R_u
Single fully integral		Side wall, end wall and floor	0.33
Single fully integral		One wall and floor	0.25
Single, partially integral displaced forward		Side wall, end wall and floor	0.26
Single, adjacent		One wall	0.09

The table gives R_u for single garages; use (0.5 x R_u) for double garages when extra garage is not fully integral, and (0.85 x R_u) for fully integral double garages. Single garage means a garage for one car; double garage means a garage for two cars.

Table 12 **Typical resistance (R_u) for unheated space**

(b) Unheated stairwells and access corridors in flats



Unheated space		R_u
Stairwells:		
	Facing wall exposed	0.82
	Facing wall not exposed	0.90
Access corridors:		
	Facing wall exposed, corridor above or below	0.31
	Facing wall exposed, corridors above and below	0.23
	Facing wall not exposed, corridor above or below	0.43

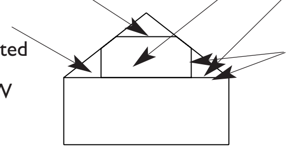
Table 13 **Typical resistance (R_u) for unheated space**

(c) Conservatory-type sunroom

Number of walls between dwelling and conservatory/sunroom	R_u
One	0.06
Two (conservatory in angle of dwelling)	0.14
Three (conservatory in recess)	0.25

Diagram 16 *Para. A.4.1*

Room in roof



Appendix B: Fabric Insulation: Additional Guidance for Common Construction - including Tables of U-values

GENERAL

B.1 This Appendix provides some basic guidance in relation to typical roof, wall and floor constructions. Guidance is not exhaustive and designers and contractors should also have regard to other sources of relevant guidance e.g. BR.262, *Thermal Insulation; avoiding risks, relevant standards and good building practice.*

B.2 For many typical roof, wall and floor constructions, the thickness of insulation required to achieve a particular U-value can be calculated approximately by the use of the appropriate table from this Appendix. The tables can also be used to estimate the U-value achieved by a particular thickness of insulating material. Higher performing insulating materials, i.e. those with lower thermal conductivities, can achieve any given U-value with a lower thickness of insulating material.

B.3 These tables have been derived using the methods described in Appendix A, taking into account the effects of repeated thermal bridging where appropriate. Figures derived from the tables should be corrected to allow for any discrete non-repeating thermal bridging which may exist in the construction. A range of factors are relevant to the determination of U-values and the values given in these tables relate to typical constructions of the type to which the tables refer. The methods described In Appendix A can be used to calculate a more accurate U-value for a particular construction or the amount of insulation required to achieve a particular U-value.

B.4 Intermediate U-values and values of required thickness of insulation can be obtained from the tables by linear interpolation.

Example B1: Partially filled cavity

What is the U-value of the construction shown in Diagram 17.

Diagram 17 *Para. B.2*

Partially filled cavity

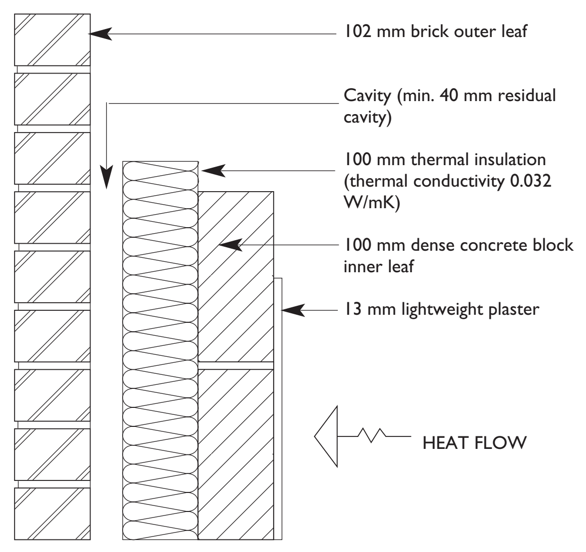
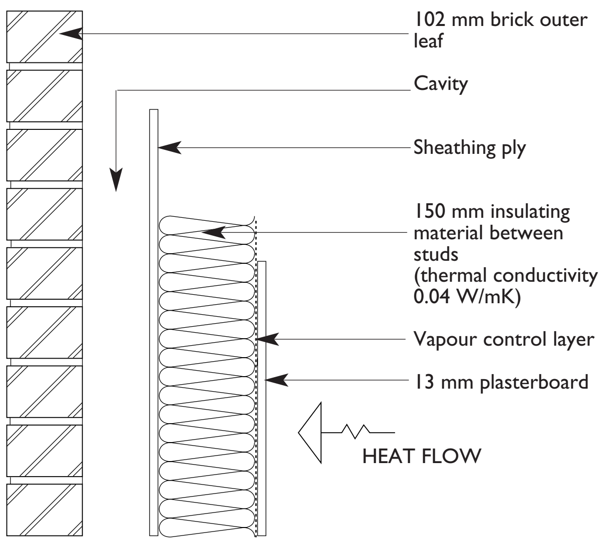


Table 23 gives U-values of 0.29 W/m²K and 0.25 W/m²K for 100 mm insulation of thermal conductivity of 0.035 W/mK and 0.030 W/mK respectively. By linear interpolation, the U-value of this construction, with 100 mm of insulation of thermal conductivity of 0.032 W/mK, is 0.27 W/m²K.

Example B2: Timber frame wall

Diagram 18 *Para. B.2*

Timber frame wall



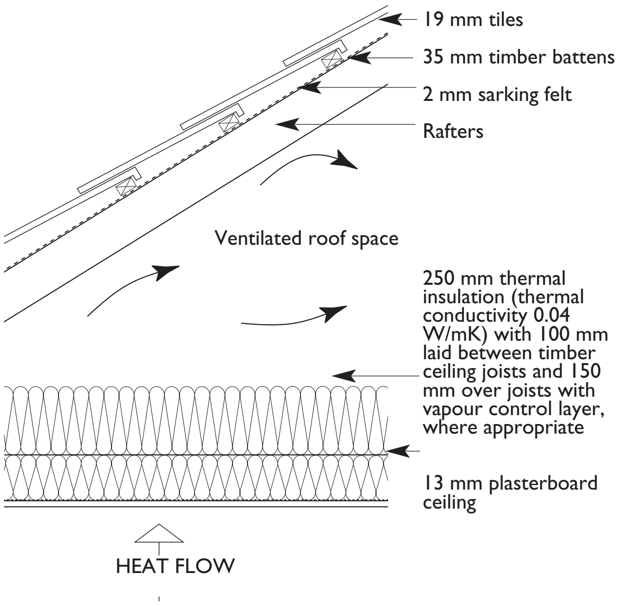
What is the U-value of this construction?

Table 28 gives the U-value for 150 mm of insulation of thermal conductivity of 0.04 W/mK as 0.27 W/m^{2}K.

Example B3: Pitched roof

Diagram 19 *Para. B.2*

Pitched roof



What is the U-value of this construction?

Table 15 gives the U-value for 250 mm of insulation of thermal conductivity of 0.04 W/mK as 0.16 W/m^2 K.

ROOF CONSTRUCTIONS

B.5.1 Construction R1: Tiled or slated pitched roof, ventilated roof space, insulation at ceiling level

B.5.1.1 R1(a) Insulation between and over joists

Diagram 20 *Para. B.5.1.1*

Insulation between and over joists

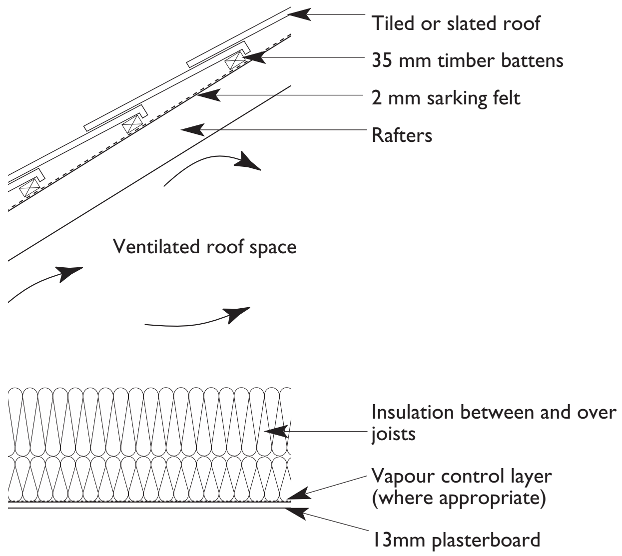


Table 14	**U-values for tiled or slated pitched roof, ventilated roof space, insulation placed between and over joists at ceiling level**				
Total Thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
150	0.27	0.24	0.21	0.18	0.16
175	0.23	0.20	0.18	0.15	0.13
200	0.20	0.18	0.16	0.13	0.11
225	0.18	0.16	0.14	0.12	0.10
250	0.16	0.14	0.12	0.11	0.09
275	0.14	0.13	0.11	0.10	0.08
300	0.13	0.12	0.10	0.09	0.07

This table is derived for roofs with:
Tiles or slates, felt, ventilated roof space, timber joists (λ = 0.13) with the spaces between fully filled with insulation and the balance of insulation above and covering joists. (see Diagram 20). Calculations assume a fractional area of timber thermal bridging of 9%. (includes allowance for loft hatch framing)

Installation guidelines and precautions

Care is required in design and construction, particularly in regard to the following:

Provision of adequate roofspace ventilation

Adequate ventilation is particularly important to ensure the prevention of excessive condensation in cold attic areas. See relevant guidance in TGD F.

Minimising transfer of water vapour from occupied dwelling area to cold attic space

In addition to ensuring adequate ventilation, measures should be taken to limit transfer of water vapour to the cold attic. Care should be taken to seal around all penetrations of pipes, ducts, wiring, etc. through the ceiling, including provision of an effective seal to the attic access hatch. Use of a vapour control layer at ceiling level, on the warm side of the insulation, will assist in limiting vapour transfer, but cannot be relied on as an alternative to ventilation. In particular, a vapour control layer should be used where the roof pitch is less than 15^0, or where the shape of the roof is such that there is difficulty in ensuring adequate ventilation, e.g. room-in-the-roof construction.

Minimising the extent of cold bridging

Particular areas of potential cold bridging include junctions with external walls at eaves and gables, and junctions with solid party walls. Gaps in the insulation should be avoided and the insulation should fit tightly against joists, noggings, bracing etc. Insulation joints should be closely butted and joints in upper and lower layers of insulation should be staggered.

Protecting water tanks and pipework against the risk of freezing

All pipework on the cold side of the insulation should be adequately insulated. Where the cold water cistern is located in the attic, as is normally the case, the top and sides of the cistern should be insulated. The area underneath the cistern should be left uninsulated and continuity of tank and ceiling insulation should be ensured e.g. by overlapping the tank and ceiling insulation. Provision should be made to ensure ventilation of the tank.

Ensuring that there is no danger from overheating of electric cables or fittings

Cables should be installed above the insulation. Cables which pass through or are enclosed in insulation should be adequately rated to ensure that they do not overheat. Recessed fittings should have adequate ventilation or other means to prevent overheating.

Providing for access to tanks, services and fittings in the roofspace

Because the depth of insulation will obscure the location of ceiling joists, provision should be made for access from the access hatch to the cold water tank and to other fittings to which access for occasional maintenance and servicing may be required.

B.5.1.2 R1(b) Insulation between and below joists.

Insulation is laid in one layer between the joists, protruding above them where its depth is greater, and leaving air gaps above the joists. A composite board of plasterboard with insulation backing is used for the ceiling.

Diagram 21 *Para. B.5.1.2*

Insulation between and below joists

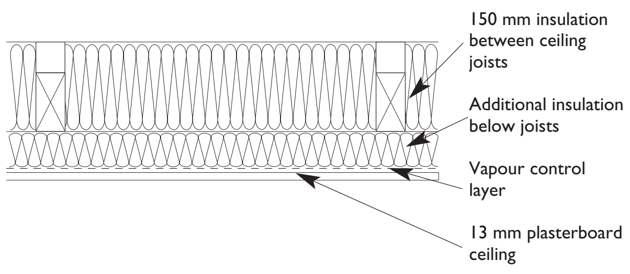


Table 15 **U-values for tiled or slated pitched roof, ventilated roof space, insulation placed between and below joists at ceiling level**

Thickness of insulation below joists (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
10	0.27	0.27	0.27	0.26	0.26
20	0.26	0.25	0.24	0.24	0.22
30	0.24	0.23	0.22	0.21	0.20
40	0.22	0.22	0.21	0.20	0.18
50	0.21	0.20	0.19	0.18	0.17
60	0.20	0.19	0.18	0.17	0.15
70	0.19	0.18	0.17	0.16	0.14
80	0.18	0.17	0.16	0.15	0.13
90	0.17	0.16	0.15	0.14	0.12
100	0.17	0.16	0.15	0.13	0.12
110	0.16	0.15	0.14	0.13	0.11
120	0.15	0.14	0.13	0.12	0.10

This table is derived for roofs as in Table 14 but with 150 mm of insulation (λ = 0.04) between ceiling joists, and the remainder below the joists. Insulation of thickness and thermal conductivity as shown in the table is below joists. (See Diagram 21).

(The insulation thickness shown does not include the thickness of plasterboard in composite boards).

Installation guidelines and precautions.

Similar guidelines and precautions apply as for R1(a) above.

B.5.2 Construction R2: Tiled or slated pitched roof, occupied or unventilated roof space, insulation on roof slope.

B.5.2.1 R2(a) Insulation between and below rafters, 50 mm ventilated cavity between insulation and sarking felt.

Diagram 22 *Para. B.5.2.1*

Insulation between and below rafters

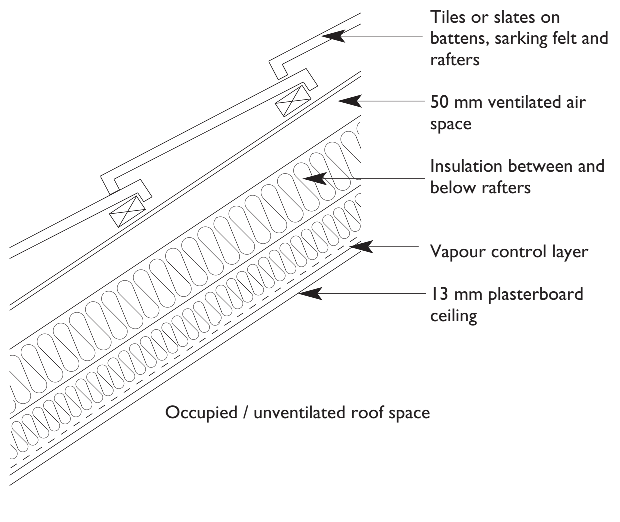


Table 16 **U-values for tiled or slated pitched roof, occupied or unventilated roof space, insulation placed between and below rafters**					
Total thickness of insulation below joists (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m²K)				
120	0.34	0.31	0.27	0.24	0.20
140	0.29	0.26	0.23	0.20	0.16
160	0.25	0.23	0.20	0.17	0.14
180	0.22	0.20	0.17	0.15	0.12
200	0.20	0.18	0.16	0.13	0.11
220	0.18	0.16	0.14	0.12	0.10
240	0.17	0.15	0.13	0.11	0.09
260	0.15	0.14	0.12	0.10	0.08

This table is derived for roofs with:
Tiles or slates, felt, rafters of depth 150 mm (λ = 0.13), 50 mm ventilated air space above insulation, 100 mm insulation between rafters, balance of insulation below and across rafters. (See Diagram 22).

A fractional area of timber of 8% is assumed. Battens may be fixed to the underside of the rafters to increase rafter depth if necessary.

Installation guidelines and precautions.
The insulation is installed in two layers, one between the rafters (and battens) and the second below and across them. To limit water vapour transfer and minimise condensation risks, a vapour control layer is required on the warm side of the insulation. No material of high vapour resistance, e.g. facing layer attached to insulation to facilitate fixing, should be included within the overall thickness of insulation. Care must be taken to prevent roof timbers and access problems interfering with the continuity of insulation and vapour control layer.

Provision should be made for ventilation top and bottom of the 50 mm ventilation gap on the cold side of the insulation.

An alternative construction using a breathable membrane may be used. In this case the membrane should be certified in accordance with Part D of the Building Regulations and installed in accordance with the guidance on the certificate.

Care should be taken to avoid thermal bridging at roof-wall junctions at eaves, gable walls and party walls.

Table 16 assumes that the thermal conductivity of insulation between and below the rafters is the same. If different insulation materials are used, the material on the warm side (i.e. below rafters) should have a vapour resistance no lower than that on the cold side (i.e. between rafters).

B.5.2.2 R2(b): Insulation above and between rafters, slate or tile underlay of breather membrane type.

Diagram 23 *Para.5.2.2*
Insulation above and between rafters

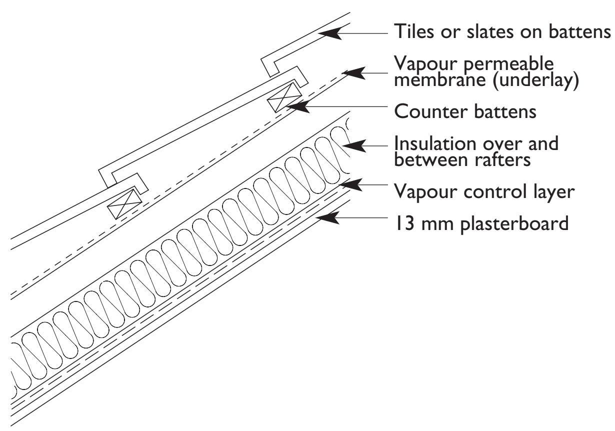


Table 17 **U-values for tiled or slated pitched roof, occupied or unventilated roof space, insulation placed between and above rafters.**					
Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m²K)				
120	0.33	0.30	0.27	0.23	0.20
140	0.28	0.25	0.22	0.19	0.16
160	0.25	0.22	0.19	0.17	0.14
180	0.22	0.20	0.17	0.15	0.12
200	0.20	0.18	0.15	0.13	0.11
220	0.18	0.16	0.14	0.12	0.10
240	0.16	0.15	0.13	0.11	0.09
260	0.15	0.13	0.12	0.10	0.08

This table is derived for roofs with:
Tiles or slates, tiling battens, vapour permeable membrane (as underlay), counter battens, insulation layer over rafters, rafters with insulation fitted between. (See Diagram 18).

Insulation between and over rafters has the same thermal conductivity. A fractional area of timber of 8% is assumed.

Installation guidelines and precautions

The effective performance of this system is critically dependent on the prevention of air and water vapour movement between the warm and cold sides of the insulation. Only systems which are certified or shown by test and calculation as appropriate for this function, (see TGD D, Paragraph 1.1 (a) and (b)) should be used. The precise details of construction are dependent on the insulation and roof underlay materials to be used. Installation should be carried out precisely in accordance with the procedures described in the relevant certificate.

In general, the insulation material must be of low vapour permeability, there should be a tight fit between adjacent insulation boards, and between insulation boards and rafters. All gaps in the insulation (e.g. at eaves, ridge, gable ends, around rooflights and chimneys, etc.) should be sealed with flexible sealant or expanding foam.

Care should be taken to avoid thermal bridging at roof-wall junctions at eaves, gable walls and party walls.

B.5.3 Construction R3: Flat roof, timber joists, insulation below deck

B.5.3.1 R3(a) Insulation between joists, 50 mm air gap between insulation and roof decking

The insulation is laid between the joists. The depth of the joists is increased by means of battens if required.

Diagram 24 *Para. B.5.3.1*

Timber flat roof, insulation between joists

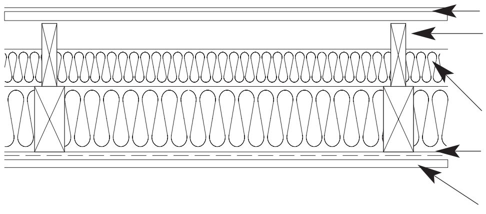


Table 18: **U-values for timber flat roof, insulation between joists, 50 mm ventilated air gap between insulation and roof decking.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
150	0.29	0.26	0.24	0.21	0.18
175	0.25	0.23	0.20	0.18	0.16
200	0.22	0.20	0.18	0.16	0.14
225	0.20	0.18	0.16	0.14	0.12
250	0.18	0.16	0.15	0.13	0.11
275	0.16	0.15	0.13	0.12	0.10
300	0.15	0.14	0.12	0.11	0.09

This table is derived for roofs with:
Weatherproof deck, ventilated air space, insulation as given above between timber joists (λ = 0.13), 13 mm plasterboard (λ = 0.25). (See Diagram 24).
The calculations assume a fractional area of timber of 8%.

Installation guidelines and precautions

A vapour control layer sealed at all joints, edges and penetrations, is required on the warm side of the insulation, and a ventilated air space as specified in TGD F provided above the insulation. Cross ventilation should be provided to each and every void. When installing the insulation, care is needed to ensure that it does not block the ventilation flow paths.

The integrity of the vapour control layer should be ensured by effective sealing of all service penetrations, e.g. electric wiring, or by provision of a services zone immediately above the ceiling, but below the vapour control layer.

The roof insulation should connect with the wall insulation so as to avoid a cold bridge at this point.

B.5.3.2 R3(b) Insulation between and below joists, 50 mm air gap between insulation and roof decking

The insulation may be installed in two layers, one between the joists as described above, and the second below the joists. This lower layer may be in the form of composite boards of plasterboard backed with insulation, with integral vapour barrier, fixed to the joists. The edges of boards should be sealed with vapour-resistant tape.

Table 19: **U-values for timber flat roof, insulation between and below joists, 50 mm ventilated air gap between insulation and roof decking.**

Thickness of insulation below joists (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m²K)				
20	0.34	0.33	0.32	0.31	0.29
40	0.29	0.28	0.27	0.25	0.22
60	0.25	0.24	0.22	0.21	0.18
80	0.22	0.21	0.20	0.18	0.15
100	0.20	0.19	0.17	0.15	0.13
120	0.18	0.17	0.15	0.14	0.12
140	0.17	0.15	0.14	0.12	0.11
160	0.15	0.14	0.13	0.11	0.10

This table is derived for roofs as in Table 19 above, except with 100 mm of insulation (λ = 0.04) between 150 mm joists, and composite board below joists consisting of 10 mm plasterboard (λ= 0.25) backed with insulation as specified in this table.

B.5.4 Construction R4: Sandwich warm deck flat roof

The insulation is installed above the roof deck but below the weatherproof membrane. The structural deck may be of timber, concrete or metal.

Diagram 25 *Para. B.5.4*

Sandwich warm deck flat roof above a concrete structure

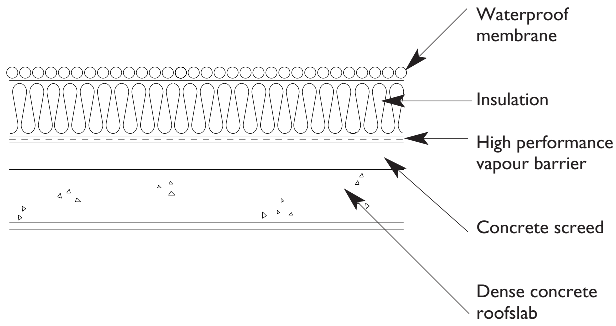


Table 20: **U-values for sandwich warm deck flat roof.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m²K)				
100	0.34	0.30	0.26	0.22	0.18
125	0.28	0.25	0.22	0.18	0.15
150	0.24	0.21	0.18	0.15	0.13
175	0.21	0.18	0.16	0.13	0.11
200	0.18	0.16	0.14	0.12	0.10
225	0.16	0.14	0.13	0.11	0.09
250	0.15	0.13	0.11	0.10	0.08

This table is derived for roofs with:
12 mm felt bitumen layers (λ = 0.23), over insulation as given in the table, over 50 mm screed (λ = 0.41), over 150 mm concrete slab (λ = 2.30), over 13 mm plasterboard (λ = 0.25). (See Diagram 25).

Installation guidelines and precautions

The insulation boards are laid over and normally fully bonded to a high performance vapour barrier complying with BS 747: 2000 which is bonded to the roof deck. The insulation is overlaid with a waterproof membrane, which may consist of a single layer membrane, a fully-bonded built-up bitumen roofing system, or mastic asphalt on an isolating layer. At the perimeter, the vapour barrier is turned up and back over the insulation and bonded to it and the weatherproof membrane. Extreme care is required to ensure that moisture can not penetrate the vapour barrier.

The insulation should not be allowed to get wet during installation.

There should be no insulation below the deck. This could give rise to a risk of condensation on the underside of the vapour barrier.

Thermal bridging at a roof / wall junction should be avoided.

B.5.5 Construction R5: Inverted warm deck flat roof: insulation to falls above both roof deck and weatherproof membrane

Insulation materials should have low water absorption, be frost resistant and should maintain performance in damp conditions over the long term. To balance loss of performance due to the damp conditions and the intermittent cooling effect of water passing through and draining off from the warm side of the insulation, the insulation thickness calculated as necessary for dry conditions should be increased by 20%.

Diagram 26 *Para. B.5.5*

Inverted warm deck roof with concrete structure

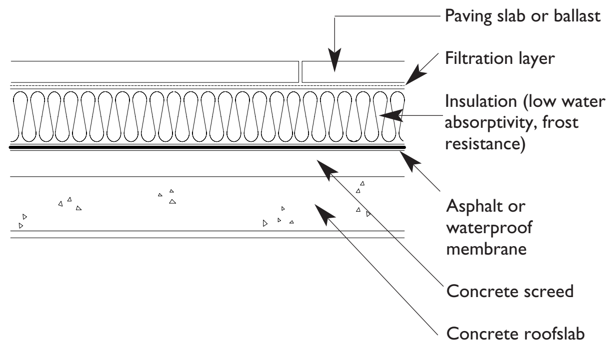


Table 22: **U-values for inverted warm deck flat roof.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
100	0.42	0.39	0.35	0.32	0.28
125	0.37	0.34	0.31	0.28	0.25
150	0.33	0.30	0.28	0.25	0.23
175	0.30	0.28	0.26	0.23	0.21
200	0.28	0.26	0.24	0.22	0.20
225	0.26	0.24	0.23	0.21	0.19
250	0.25	0.23	0.21	0.20	0.18
275	0.24	0.22	0.21	0.19	0.18
300	0.23	0.21	0.20	0.18	0.17

This table is derived for roofs with: 50 mm gravel ballast (λ= 2.0) over 40 mm screed (λ= 0.50) over 40 mm screed (λ= 0.41) over 150 mm concrete (λ= 2.30) over 13 mm plasterboard (λ = 0.25). Insulation thickness derived using correction factor for rain water flow given in I.S. EN 6946. (See Diagram 26).

Installation guidelines and precautions
The insulation is laid on the waterproof membrane. A filtration layer is used to keep out grit, which could eventually damage the waterproof membrane. The insulation must be restrained to prevent wind uplift and protected against ultraviolet degradation. This is usually achieved by use of gravel ballast, paving stones or equivalent restraint and protection. The insulation should have sufficient compressive strength to withstand the weight of the ballast and any other loads.

Rainwater will penetrate the insulation as far as the waterproof membrane. Drainage should be provided to remove this rainwater. To minimise the effect of rain on performance, insulation boards should be tightly jointed (rebated or tongued-and-grooved edges are preferred), and trimmed to give a close fit around upstands and service penetrations.

To avoid condensation problems, the thermal resistance of the construction between the weatherproof membrane and the heated space is at least 0.15 m^2K/W. However, this thermal resistance should not exceed 25% of the thermal resistance of the whole construction.

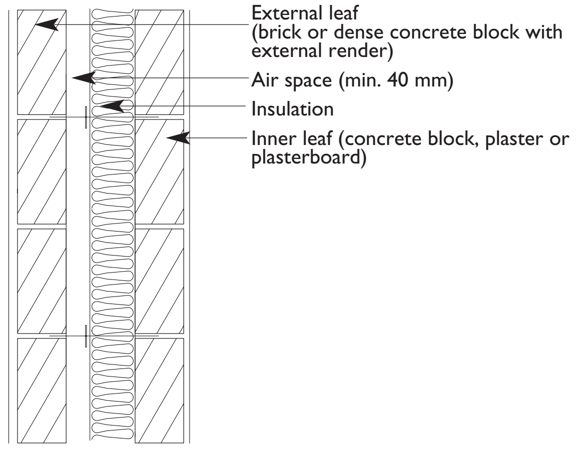
Thermal bridging at roof / wall junctions should be avoided.

WALL CONSTRUCTIONS

B.6.1. W1: Cavity walls, insulation in cavity, cavity retained (partial fill)

B.6.1.1 W1(a) Brick or rendered dense concrete block external leaf, partial fill insulation, dense concrete block inner leaf, plaster or plasterboard internal finish.

Diagram 27 *Para. B.6.1.1*
Cavity wall with partial-fill insulation



The following tables deal with walls with maximum overall cavity width of 150 mm, which is the greatest cavity width for which details of construction are given in I.S. 325 Part 1: 1986, *Code of Practice for the structural use of concrete; Structural use of unreinforced concrete*. Where it is proposed to use wider cavity widths, full structural and thermal design will be necessary.

Table 22: **U-values for brick (or rendered dense concrete block) external leaf, partial fill insulation, dense concrete block inner leaf, plaster (or plasterboard) internal finish.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^2K)				
60	0.48	0.43	0.39	0.33	0.28
80	0.39	0.35	0.31	0.26	0.22
100	0.32	0.29	0.25	0.22	0.18

This table is derived for walls with:
102 mm clay brickwork outer leaf (λ= 0.77), 50 mm air space, insulation as specified in table, 100 mm concrete block inner leaf (density = 1800 kg/m^3, λ = 1.13), 13 mm dense plaster (λ = 0.57). (See Diagram 27). The effects of wall ties are assumed to be negligible.

The insulation thickness required to achieve a given U-value may be reduced by using lightweight concrete insulating blocks for the inner leaf, as shown in the table below.

Table 23: **U-values for construction as Table 23 except for lightweight concrete block inner leaf.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
60	0.40	0.37	0.34	0.30	0.25
80	0.34	0.31	0.27	0.24	0.20
100	0.29	0.26	0.23	0.20	0.17

This table is derived for walls as in Table 22, except heavyweight concrete block inner leaf replaced with 100 mm insulating block (λ = 0.18).
Calculations assume a 7% fractional area of mortar (λ = 0.88) bridging the inner leaf.

Note that the sound attenuation performance of lightweight blocks is not as good as that of heavier blocks. This may limit their suitability for use in the inner leafs of attached dwellings.

Installation guidelines and precautions
Insulation should be tight against the inner leaf. Any excess mortar should be cleaned off before fixing insulation. The insulation layer should be continuous and without gaps. Insulation batts should butt tightly against each other. Mortar droppings on batts should be avoided. Batts should be cut and trimmed to fit tightly around openings, cavity trays, lintels, sleeved vents and other components bridging the cavity, and should be adequately supported in position.

Methods of reducing thermal bridging at openings are illustrated in Section I above. Other critical locations where care should be taken to limit thermal bridging include roof-wall junctions and wall-floor junctions. The method of cavity closure used should not cause thermal bridge at the roof-wall junction. Wall and floor insulation should overlap by 200 mm, or by 100 mm where lightweight insulating blocks are used for inner leaf at this position.

B.6.1.2 W1(b): As W1(a) except with insulation partly in cavity and partly as internal lining.

If composite boards of plasterboard backed with insulation (of similar conductivity to that used in the cavity) are used internally. Table 17 and 18 can be taken as applying to the total insulation thickness (cavity plus internal). If internal insulation is placed between timber studs, total insulation thickness will be slightly higher due to the bridging effect of the studs. Table 19 applies in this case.

Table 24: **U-values for brick (or rendered dense concrete block) external leaf, 60mm partial fill insulation (λ = 0.035), dense concrete block inner leaf, plasterboard fixed to timber studs, insulation between studs.**

Total thickness of insulation below joists (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
40	0.31	0.31	0.29	0.28	0.26
60	0.28	0.27	0.26	0.24	0.22
80	0.25	0.24	0.23	0.21	0.19
100	0.23	0.22	0.20	0.19	0.17
120	0.21	0.20	0.18	0.17	0.15

This table is derived for walls as in Table 22 above, except with 60 mm of insulation of λ = 0.035 in cavity, and insulation as specified in the table applied to the internal surface of the wall between timber studs (λ = 0.13) of fractional area 12%, with a wall finish of 13 mm plasterboard (λ = 0.25).

Lower U-values, or reduced insulation thickness, can be achieved by using insulating concrete blockwork (rather than dense concrete) between the cavity and internal insulation.

Insulation partly in cavity and partly as internal lining helps minimise thermal bridging. Internal insulation limits thermal bridging at floor and roof junctions, whereas cavity insulation minimises thermal bridging at separating walls and internal fixtures.

Installation guidelines and precautions
Installation of insulation in the cavity should follow the guidelines given above for construction W1(a) (partial-fill cavity insulation), and installation of the

internal lining should follow the guidelines given below for construction W4 (hollow-block).

B.6.2. Construction W2: Cavity walls, insulation in cavity, no residual cavity (full-fill)

The insulation fully fills the cavity. Insulation may be in the form of semi-rigid batts installed as wall construction proceeds, or loose-fill material blown into the cavity after the wall is constructed; the former is considered here. Insulation material suitable for cavity fill should not absorb water by capillary action and should not transmit water from outer to inner leaf. Such insulation may extend below dpc level.

Diagram 28 *Para. B.6.2*

Cavity wall with full-fill insulation

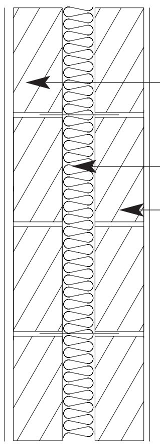


Table 25: **U-values for rendered dense concrete block external leaf, full-fill insulation dense concrete block inner leaf, plaster (or plasterboard) internal finish.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m²K)				
60	0.51	0.46	0.41	0.35	0.29
80	0.41	0.37	0.32	0.27	0.22
100	0.34	0.30	0.26	0.22	0.18
120	0.29	0.26	0.22	0.19	0.16
140	0.25	0.22	0.20	0.17	0.13
160	0.22	0.20	0.17	0.15	0.12

This table is derived for walls with:
20 mm external rendering (λ = 0.57), 102 mm clay brickwork outer leaf (λ = 0.77), insulation as specified in table, 100 mm concrete block inner leaf (medium density - 1800 kg/m^3, λ = 1.13), 13 mm dense plaster (λ= 0.57). The effects of wall ties are assumed to be negligible. (See Diagram 28).

The insulation thickness required to achieve a given U-value may be reduced by using insulating concrete blocks for the inner leaf, as shown in the table below.

Table 26: **U-values for rendered dense concrete block external leaf, full-fill insulation, lightweight concrete block inner leaf, plaster (or plasterboard) internal finish.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m²K)				
60	0.43	0.39	0.35	0.31	0.26
80	0.35	0.32	0.29	0.25	0.21
100	0.30	0.27	0.24	0.21	0.17
120	0.26	0.23	0.21	0.18	0.15
140	0.23	0.21	0.18	0.16	0.13
160	0.21	0.18	0.16	0.14	0.11

This table is derived for walls as above, except heavyweight concrete block inner leaf replaced with 100 mm insulating block (λ = 0.18).
Calculations assume a 7% fractional area of mortar (λ= 0.88) bridging the inner leaf.

Installation guidelines and precautions
Only certified insulation products should be used, and the installation and other requirements specified in such certificates should be fully complied with. In particular, regard should be had to the exposure conditions under which use is certified and any limitations on external finish associated therewith.

Guidance on minimising air gaps and infiltration in partial-fill cavity insulation applies also to full-fill insulation.

Methods of reducing thermal bridging around openings are illustrated in Section 1 above.

B.6.3 Construction W3: Timber frame wall, brick or rendered concrete block external leaf

B.6.3.1 W3(a) Insulation between studs

The insulation is installed between studs, whose depth equals or exceeds the thickness of insulation specified.

In calculating U-values, the fractional area of timber bridging the insulation should be checked. Account should be taken of all timber elements which fully bridge the insulation, including studs, top and bottom rails, noggings, timbers around window and door openings and at junctions with internal partitions, party walls and internal floors. In the table a fractional area of 12% is assumed.

Diagram 29 *Para. B.6.3.1*

Timber frame wall, insulation between framing timbers

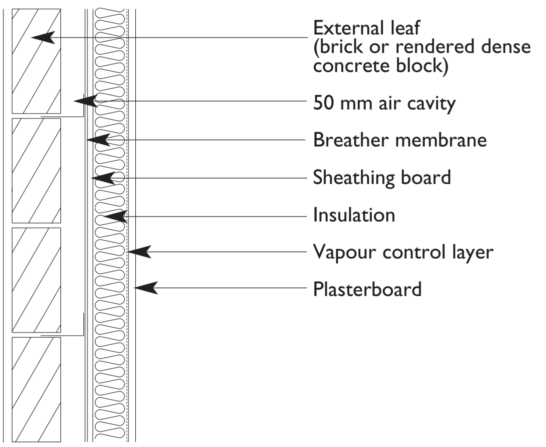


Table 27: **U-values for brick (or rendered dense concrete block) external leaf, timber frame inner leaf, insulation between timber studs, plasterboard internal finish.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
100	0.39	0.36	0.34	0.31	0.28
125	0.33	0.31	0.28	0.26	0.23
150	0.29	0.27	0.24	0.22	0.20
175	0.25	0.23	0.21	0.20	0.18

This table is derived for walls with:
102 mm clay brickwork outer leaf (λ = 0.77), 50 mm air cavity, breather membrane, 12 mm sheathing board (λ = 0.14), insulation between timber studs (λ= 0.13), vapour control layer, 13 mm plasterboard (λ= 0.25). (See Diagram 24). The calculations assume a fractional area of timber thermal bridging of 15%.

Installation guidelines and precautions
Air gaps in the insulation layer, and between it and the vapour barrier, should be avoided. Insulation batts should be friction fitted between studs to minimise gaps between insulation and joists. Adjacent insulation pieces should butt tightly together. Particular care is needed to fill gaps between closely-spaced studs at wall/wall and wall/floor junctions, and at corners of external walls.

A vapour control layer should be installed on the warm side of the installation. There should be no layers of high vapour resistance on the cold side of the insulation.

Care is required to minimise thermal bridging of the insulation by timber noggings and other inserts.

B.6.3.2 W3(b): Insulation between and across studs
Where the chosen stud depth is not sufficient to accommodate the required thickness of insulation, insulation can be installed to the full depth between the studs with additional insulation being provided as an internal lining. This additional insulation may be either in the form of plasterboard/insulation composite board or insulation between timber battens, to which the plasterboard is fixed.

Table 28: **U-values for brick (or rendered dense concrete block) external leaf, timber frame inner leaf, insulation between 100 mm timber studs, additional insulation, plasterboard internal finish.**

Total thickness of insulation across studs (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
20	0.32	0.32	0.31	0.29	0.28
40	0.28	0.27	0.25	0.24	0.22
60	0.24	0.23	0.22	0.20	0.18
80	0.22	0.20	0.19	0.17	0.15
100	0.19	0.18	0.17	0.15	0.13

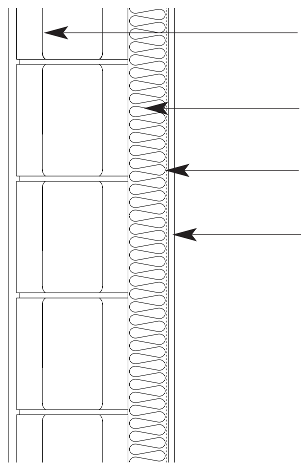
This table is derived for walls as in W3(a) above, except with 100 mm of insulation of λ = 0.04 between 100 mm studs, and an additional layer of insulation as specified in the table across the studs.

The vapour control layer should be on the warm side of the insulation. If different types of insulation are used between and inside the studs, the vapour resistance of the material between the studs should not exceed that of the material across them.

B.6.4 Construction W4: Hollow concrete block wall, rendered externally, internal insulation lining with plasterboard finish.

Diagram 30 *Para. B.6.4*

Hollow-block wall, internal insulation lining



The insulation is installed on the inner face of the masonry walls. It may be installed between preservative-treated timber studs fixed to the wall, or in the form of composite boards of plaster backed with insulation, or as a combination of these.

Installation guidelines and precautions

Air Movement

Air gaps in the insulation layer should be kept to a minimum. If using insulation between timber studs, there should be no gaps between insulation and studs, between insulation and the vapour control layer, between butt joints in the insulation, around service penetrations, etc. If using composite boards, they should be tightly butted at edges, and should provide complete and continuous coverage of the external wall.

When mounting composite boards on plaster dabs or timber battens, there is a danger that air will be able to circulate behind the insulation, reducing its effectiveness. To minimise such air movement, the air gap behind the boards should be sealed along top and bottom, at corners and around window and door openings e.g. with continuous ribbon of plaster or timber studs.

Table 29: **U-values for hollow-block wall, rendered externally, plasterboard fixed to timber studs internally, insulation between studs.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
50	0.67	0.63	0.58	0.53	0.47
75	0.50	0.47	0.43	0.39	0.34
100	0.40	0.37	0.34	0.31	0.27
125	0.34	0.31	0.28	0.25	0.23
150	0.29	0.26	0.24	0.22	0.19
175	0.25	0.23	0.21	0.19	0.17
200	0.22	0.21	0.19	0.17	0.15

Table 30: **U-values of hollow-block wall, rendered externally, composite insulation / plasterboard internally, fixed to timber battens [or plaster dabs]**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
40	0.63	0.58	0.52	0.46	0.39
50	0.55	0.50	0.45	0.39	0.32
60	0.48	0.44	0.39	0.34	0.28
70	0.43	0.39	0.34	0.30	0.25
80	0.39	0.35	0.31	0.26	0.22
90	0.35	0.32	0.28	0.24	0.20
100	0.32	0.29	0.26	0.22	0.18
110	0.30	0.27	0.24	0.20	0.16
120	0.28	0.25	0.22	0.19	0.15
130	0.26	0.23	0.20	0.17	0.14
140	0.25	0.22	0.19	0.16	0.13
150	0.23	0.21	0.18	0.15	0.12

These tables are derived for walls with:
19 mm external rendering (λ = 1.00), 215 mm hollow concrete block (thermal resistance = 0.21 W/m^{2}K), insulation fixed as stated, vapour control layer, 13 mm plasterboard (λ = 0.25). (See Diagram 30).

The calculations assume a fractional area of timber thermal bridging of 12% or plaster dab thermal bridging of 20%. as appropriate of 8%.

Condensation

A vapour control layer (e.g. 500 gauge polythene) should be installed on the warm side of the insulation to minimise the risk of interstitial condensation on the cold masonry behind the insulation. Care should be taken to avoid gaps in the vapour control layer at all joints, edges and service penetrations. The location of service runs in the air gap on the cold side of the insulation should, where possible, be avoided. Where this proves unavoidable for particular service runs, care should be taken to seal around any penetrations of the insulation layer and vapour control layer.

Thermal Bridging

Care should be taken to minimise the impact of thermal bridging.

Methods of reducing thermal bridging around openings are illustrated in Section 1 above.

Other areas where there is a risk of significant thermal bridging include:

Junctions with solid party walls and partitions

Internal partition or party walls of solid dense concrete blockwork can create significant thermal bridge effects at junctions with single leaf masonry external walls. The thermal bridge effect can be adequately limited either by the use of lightweight construction in the internal wall or by returning insulation of minimum thermal resistance 1.00 m^{2}K/W for a distance of at least 1m on the internal wall.

Junctions with intermediate floors

The external walls in the floor space of intermediate floors should be insulated and protected against vapour movement. Along the wall running parallel to the joists, insulation can be placed between the last joist and the wall. Where the joists are perpendicular to the wall, the insulation and vapour control layer should be continuous through the intermediate floor space and should be carefully cut to fit around the joist ends.

Stairs, cupboards and other fittings supported on or abutting the external wall

Insulation should be carried through behind such fittings.

Ducts, e.g. Soil and vent pipe ducts, against external walls

Insulation should be continuous at all such ducts, i.e. the insulation should be carried through on either the external or internal side of such ducts. Where the insulation is on the external side, particular care should be taken to prevent ingress of cold external air where ducts etc. penetrate the insulation.

FLOOR CONSTRUCTIONS

B.7.1 Construction F1: Ground floor: concrete slab-on-ground. Insulation under slab or under screed

Diagram 31 *Para. B.7.1*

Concrete slab-on-ground floor, insulation under slab

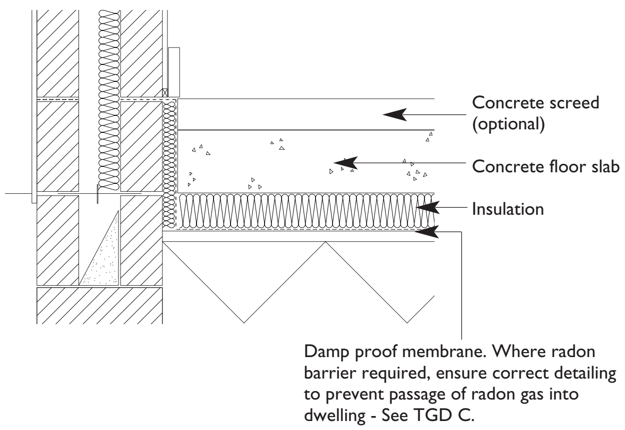
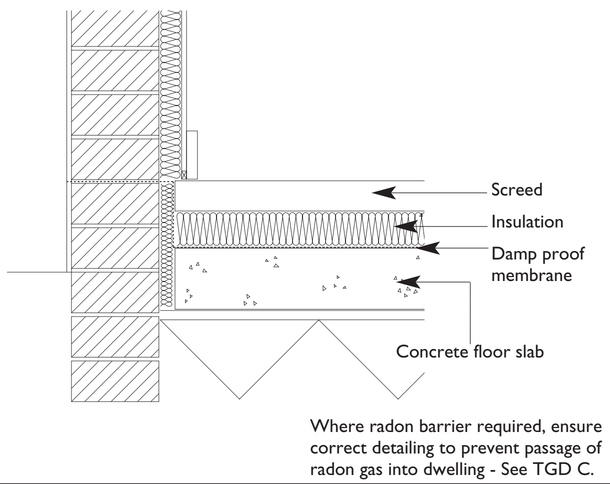


Diagram 32 *Para. B.7.1*

Concrete slab-on-ground floor, insulation under screed



For continuous and uniform insulation under the full ground floor area, the insulation thickness required to achieve prescribed U-values for slab-on-ground floors are given below. These tables apply whether the insulation is located under the slab or under the screed.

Table 32 allows estimation of the U-value of an insulated floor from the ratio of the length of exposed perimeter to floor area and the thermal resistance of the applied insulation. Table 33 gives the thickness of insulation required to achieve a given U-value when the ratio of exposed perimeter to floor area and the thermal conductivity of the material is known. Both tables are derived for uniform full-floor insulation, ground conductivity of 2.0 W/m^{2}K and full thickness of walls taken to be 0.3 m.

Installation guidelines and precautions

The insulation may be placed above or below the dpm/radon barrier. The insulation should not absorb moisture and, where placed below the dpm/radon barrier, should perform well under prolonged damp conditions and should not be degraded by any waterborne contaminants in the soil or fill.

The insulation should have sufficient load-bearing capacity to support the floor and its loading.

The insulation is laid horizontally over the whole area of the floor. Insulation boards should be tightly butted, and cut to fit tightly at edges and around service penetrations.

Table 30: U-value of insulated ground floor as a function of floor area, exposed perimeter and thermal resistance of added insulation (U_{ins}).

Exposed Perimeter/Area (P/A) (m^{-1})	Thermal Resistance of Added Insulation [R_{ins}] (m^2K/W)											
	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.5	4.0
1.00	0.66	0.57	0.50	0.44	0.40	0.36	0.33	0.31	0.28	0.27	0.23	0.21
0.90	0.64	0.55	0.48	0.43	0.39	0.36	0.33	0.30	0.28	0.26	0.23	0.21
0.80	0.62	0.54	0.47	0.42	0.38	0.35	0.32	0.30	0.28	0.26	0.23	0.21
0.70	0.59	0.52	0.46	0.41	0.37	0.34	0.31	0.29	0.27	0.25	0.23	0.20
0.60	0.57	0.50	0.44	0.40	0.36	0.33	0.31	0.28	0.27	0.25	0.22	0.20
0.50	0.53	0.47	0.42	0.38	0.35	0.32	0.30	0.27	0.26	0.24	0.22	0.19
0.40	0.48	0.43	0.39	0.36	0.33	0.30	0.28	0.26	0.25	0.23	0.21	0.19
0.30	0.43	0.39	0.35	0.32	0.30	0.28	0.26	0.24	0.23	0.22	0.20	0.18
0.20	0.35	0.32	0.30	0.28	0.26	0.24	0.23	0.22	0.21	0.20	0.18	0.16

Table 31: Concrete slab-on-ground floors: Insulation thickness required for U-value of 0.25 W/m^2K.

P/A (m^{-1})	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	Insulation thickness (W/mK)				
0.1	10	8	7	6	5
0.2	64	56	48	40	32
0.3	88	77	66	55	44
0.4	100	88	75	63	50
0.5	110	96	82	69	55
0.6	116	101	87	72	56
0.7	120	105	90	75	60
0.8	123	108	93	77	62
0.9	126	110	94	79	63
1.0	128	112	96	80	64

Care should be taken to prevent damage or dislodgement of insulation during floor laying. If the dpm is placed below the insulation, the joints between insulation boards should be taped to prevent wet screed from entering when being poured. If the slab/screed is power-floated, the exposed edges of perimeter insulation should be protected during power-floating, e.g. by boards, or the areas close to the edge of the floor should be hand trowelled.

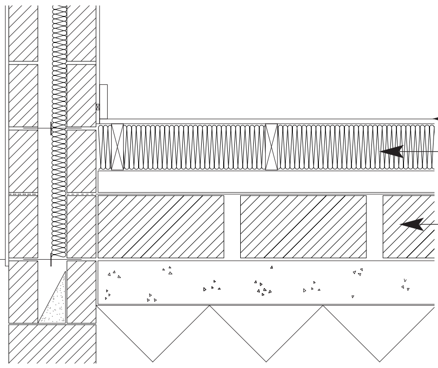
To minimise thermal bridging at floor-wall junctions, edge insulation of minimum thickness 25 mm should be placed vertically at the edge of the screed at the floor perimeter. With internally insulated external walls (including timber-frame), the floor perimeter insulation should meet the wall insulation to avoid a thermal bridge.

With cavity walls, thermal bridging via the inner leaf is difficult to avoid, but adequate provision to limit it should be made by ensuring that cavity insulation and floor insulation overlap by at least 200 mm, or by 100 mm if insulating blocks (of density not greater than 1200 kg/m^3) are used for the inner leaf between the overlapping insulation.

B.7.2 Construction F2: Ground floor: suspended timber floor, insulation between joists.

Diagram 33 *Para. B.7.2*

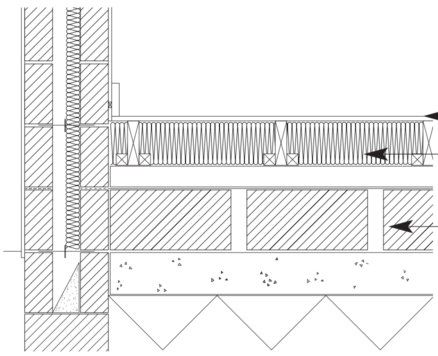
Suspended timber floor with quilt insulation



Note: Where radon barrier required, ensure correct detailing to prevent passage of radon gas into dwelling - See TGD C.

Diagram 34 *Para. B.7.2*

Suspended timber floor with rigid or semi-rigid board insulation



Note: Where radon barrier required, ensure correct detailing to prevent passage of radon gas into dwelling - See TGD C.

Table 32: **Suspended timber ground floors: Insulation thickness required for U-value of 0.25 W/m^{2}K.**

P/A (m/m^2)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-value of Construction (W/m^{2}K)				
0.1	39	35	31	27	23
0.2	96	87	77	68	58
0.3	117	106	94	83	71
0.4	128	116	103	91	78
0.5	135	122	109	96	82
0.6	139	126	113	99	86
0.7	143	129	116	102	88
0.8	146	132	118	104	89
0.9	148	134	120	105	91
1.0	150	135	121	107	92

This table is derived for:
Suspended floor consisting of 20 mm timber flooring (λ = 0.13) on timber joists (λ = 0.13), with insulation between the joists. Ventilated sub-floor space underneath. (See Diagrams 33 and 34).
A fractional area of timber thermal bridging of 11% is assumed.

Installation guidelines and precautions

Where mineral wool quilt insulation is used, the insulation is supported on polypropylene netting or a breather membrane draped over the joists and held against their sides with staples or battens. The full thickness of insulation should extend for the full width between joists. Insulation should not be draped over joists, but cut to fit tightly between them.

Alternatively, rigid or semi-rigid insulation boards, supported on battens nailed to the sides of the joists, may be used.

Thermal bridging, and air circulation around the insulation from the cold vented air space below, should be minimised. The insulation should fit tightly against the joists and the flooring above. Careful placement of supporting battens (or staples) is required to achieve this. At floor-wall junctions the insulation should extend to the walls. The space between the last joist and the wall should be packed with mineral wool to the full depth of the joist. Where internal wall insulation is used, the floor and wall insulation should meet. Where cavity insulation is used, the floor insulation should be turned down on the internal face and overlap the cavity insulation, or insulating blocks used in the wall at this level.

Cross-ventilation should be provided to the sub-floor space to remove moisture.

Water pipes in the sub-floor space should be insulated to prevent freezing.

B.7.3 Construction F3: Ground floor: suspended concrete floor

Diagram 35 *Para. B.7.3*
Suspended reinforced concrete floor, internally insulated walls

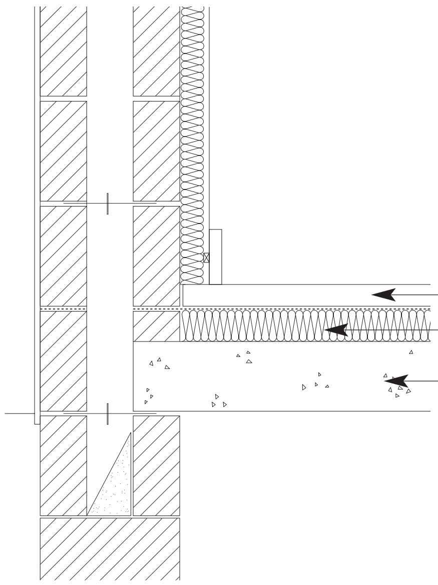


Diagram 36 *Para. B.7.3*
Suspended beam and block floor

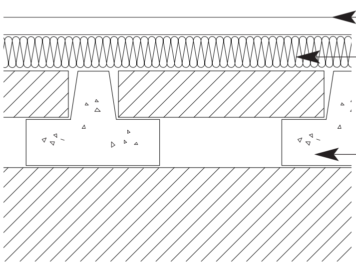


Table 33: **Suspended concrete ground floors: Insulation thickness required for U-value of 0.25 W/m²K.**

P/A (m/m^2)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	Insulation thickness (mm)				
0.1	19	17	14	12	10
0.2	69	60	52	43	35
0.3	87	76	65	54	44
0.4	96	84	72	60	48
0.5	102	89	77	64	51
0.6	106	93	80	67	53
0.7	109	96	82	69	55
0.8	112	98	84	70	56
0.9	114	99	85	71	57
1.0	115	101	86	72	58

This table is derived for floors with:
65 mm screed (λ = 0.41) on insulation on 150 mm cast concrete (λ= 2.20). Full thickness of walls = 0.3 m, U-value of sub-floor walls: 2 W/m²K. Height of floor surface above ground level: 0.3 m. (See Diagrams 35 and 36).
Unventilated sub-floor crawl space underneath.

Installation guidance and precautions
If the walls are internally insulated, it is recommended that the floor insulation be placed above the floor structure, since it can then connect with the wall insulation. Thermal bridging at the floor-wall junction is difficult to avoid when insulation is placed below the floor structure.

If the walls are cavity insulated, floor insulation can not connect with wall insulation, so some thermal bridging is inevitable. It can be minimised by using insulating blocks for the inner leaf between overlapping floor and wall insulation. Insulation and insulating blocks may be either above or below the floor structure, but above is recommended. This will allow the use of less dense blocks (of lower thermal conductivity), since they will not have to support the weight of the floor. Also, above the structure they will be above the dpc, where their lower moisture content will give a lower thermal conductivity than below the dpc. Heat loss from the floor can be further reduced by extending the cavity insulation down to, or below, the lower edge of the suspended floor.

B.7.4 Construction F4: Exposed floor: timber joists, insulation between joists

Diagram 37 *Para. B.7.4*

Exposed timber floor, insulation between joists

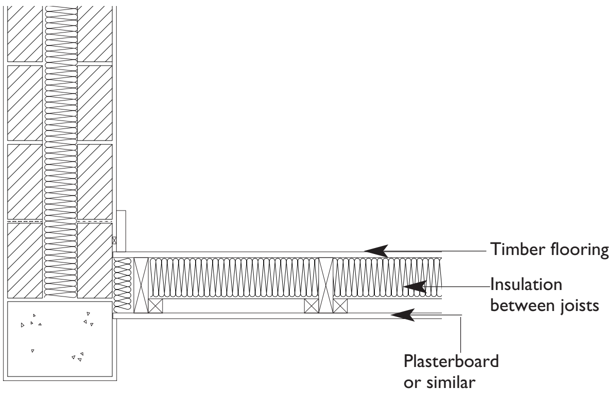


Table 34: **U-values for exposed timber floors, insulation between timber joists, plasterboard finish.**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
100	0.41	0.37	0.34	0.31	0.27
120	0.35	0.32	0.29	0.26	0.23
140	0.31	0.28	0.25	0.23	0.20
160	0.27	0.25	0.23	0.20	0.18
180	0.25	0.22	0.20	0.18	0.16
200	0.22	0.20	0.19	0.17	0.15

This table is derived for floors with:
20 mm timber flooring (λ = 0.13), insulation as specified in table between timber joists (λ = 0.13) of equal depth, 13 mm plasterboard (λ = 0.25). The calculations assume a fractional area of timber thermal bridging of 11%. (See Diagram 37)

Installation guidance and precautions

The flooring on the warm side of the insulation should have a higher vapour resistance than the outer board on the cold side. If necessary, a vapour check should be laid across the warm side of the insulation. Methods of avoiding thermal bridging at junctions with internally insulated and cavity insulated walls are similar to those described for suspended timber ground floors above.

B.7.5 Construction F5: Exposed floor: solid concrete, insulation external

Diagram 38 *Para. B.7.5*

Exposed concrete floor, external insulation

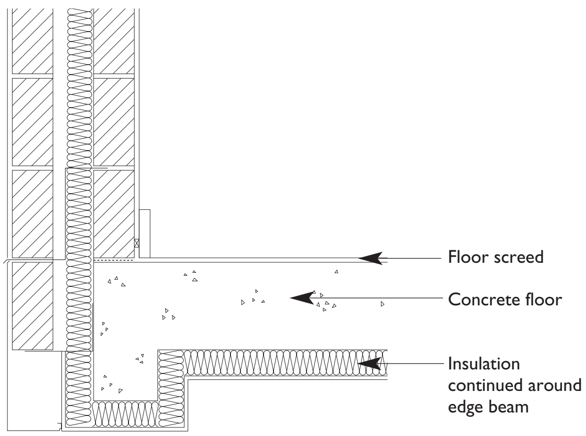


Table 35: **U-values for exposed concrete floors, external insulation, external render**

Total thickness of insulation (mm)	Thermal conductivity of insulation (W/mK)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
60	0.54	0.48	0.42	0.36	0.30
80	0.42	0.38	0.33	0.28	0.23
100	0.35	0.31	0.27	0.23	0.19
120	0.30	0.26	0.23	0.19	0.16
140	0.26	0.23	0.20	0.17	0.14
160	0.23	0.20	0.18	0.15	0.12

This table is derived for floors with:
150 mm cast concrete (λ = 1.35), insulation, 20 mm external render. (See Diagram 38).

Installation guidance and precautions

If the walls are internally insulated, this floor construction is not recommended. Floor insulation should instead be located internally in order to connect with the wall insulation.

With cavity wall insulation, thermal bridging may be minimised by supporting the external leaf independently, and continuing the external floor insulation around the edge beam to connect with the cavity insulation as shown in Diagram 38.

Table 36: **Indicative U-values (W/m²K) for windows, doors and rooflights**

TYPE	EMISSIVITY	GAP WIDTH BETWEEN PANES (mm)	FRAME TYPE: WOOD OR PVC-u	FRAME TYPE: METAL WITH 12 mm THERMAL BREAK	FRAME TYPE: METAL WITHOUT THERMAL BREAK
WINDOWS					
SINGLE	-	-	4.8	-	5.7
DOUBLE (air filled)	0.89 (standard glass)	6	3.1	3.5	4.0
		12	2.8	3.2	3.7
		16	2.7	3.1	3.6
	0.2 (low-E glass)	6	2.7	3.1	3.6
		12	2.3	2.6	3.1
		16	2.1	2.4	2.9
	0.1 (soft low-E glass)	6	2.6	3.0	3.5
		12	2.1	2.4	2.9
		16	1.9	2.2	2.7
DOUBLE (argon filled – 90% argon, 10% air)	0.89 (standard glass)	6	2.9	3.3	3.8
		12	2.7	3.1	3.6
		16	2.6	3.0	3.5
	0.2 (low-E glass)	6	2.5	2.8	3.3
		12	2.1	2.4	2.9
		16	2.0	2.3	2.8
	0.1 (soft low-E glass)	6	2.3	2.7	3.2
		12	1.9	2.2	2.7
		16	1.8	2.1	2.6
TRIPLE (air filled)	0.89 (standard glass)	6	2.4	2.7	3.2
		12	2.1	2.4	2.9
	0.2 (low-E glass)	6	2.1	2.4	2.9
		12	1.7	1.9	2.4
	0.1 (soft low-E glass)	6	2.0	2.3	2.8
		12	1.6	1.8	2.3
TRIPLE (argon filled)	0.89 (standard glass)	6	2.2	2.6	3.1
		12	2.0	2.3	2.8
	0.2 (low-E glass)	6	1.9	2.1	2.6
		12	1.6	1.8	2.3
	0.1 (soft low-E glass)	6	1.8	2.0	2.5
		12	1.5	1.7	2.2
ROOFLIGHTS	(increase on equivalent window U-values)				
Single			+ 0.3	+ 0.3	+ 0.7
double or triple			+ 0.2	+ 0.2	+ 0.7
DOORS					
Solid Wooden		3.0			
Part glazed		Calculate overall door resistance from resistance of individual parts on a proportional basis. U-value is inverse of resistance.			

Appendix C: Reference Values for Calculation of Maximum Permitted Carbon Dioxide Emission Rate

GENERAL

C.1 This appendix provides a set of reference values for the parameters of a DEAP calculation, which are used in connection with establishing a maximum permitted CO_2 emission rate (MPCDER) for the purposes of demonstrating compliance with Regulation L1 for new dwellings. Table 37 is used to define a notional reference dwelling of the same size and shape as the actual dwelling. Table 38 gives an alternative specification for space and/or water heating for the reference dwelling, when a renewable source provides the main space and/or water heating for the dwelling being assessed.

C.2 The CO_2 emissions per unit floor area calculated for this reference dwelling represents the MPCDER for the actual dwelling.

Table 37: **Values of key characteristics of reference dwelling**

Element or system	Value
Size and shape of dwelling	Same as actual dwelling
Opening areas (windows, rooflights and doors)	25% of total floor area, or sum of exposed roof and wall area, whichever is the lesser One opaque door of area 1.85 m^2, any other doors fully glazed
Walls	U = 0.27 W/m^{2}K
Floors (ground or exposed)	U = 0.25 W/m^{2}K
Roofs	U = 0.16 W/m^{2}K
Windows, rooflights and glazed doors	U = 2.2 W/m^{2}K
Opaque door	U = 3.0 W/m^{2}K
Living area fraction	Same as actual dwelling
Shading and orientation	All glazing orientated E/W; average overshading
Number of sheltered sides	2
Allowance for thermal bridging	0.11 x total exposed surface area
Ventilation system	Natural ventilation with intermittent extract fans
Air permeability – Basic Air Change Rate	0.5 air changes per hour
Chimneys	One
Other Open flues	None
Extract fans	3 for dwellings with floor area greater than 100 m^2 2 for smaller dwellings
Main space and water heating system, including system controls and fuel used	Generally as for actual dwelling Boiler efficiency as for actual boiler or 78%, whichever is the lower Where space and/or water heating by renewable sources provided in actual building, the following assumptions should be used for the calculation of MPCDER for reference dwelling: - Where renewable sources provide partial space and/or water heating, it should be assumed that all space and water heating need is met by main space and water heating system. - Where renewable sources meet the main space and/or water heating need, the alternative space and/or water heating system as set out in Table 38 below should be assumed for calculation of MPCDER.
Secondary space heating	The same as applied in calculation of CDER of actual dwelling.

Table 38: **Assumed space and/or water heating for reference dwelling (when renewable source provides main space and/or water heating for dwelling being assessed)**	
Element or system	**Value**
Heating fuel (space and water)	Mains gas
Boiler	Efficiency 78% room-sealed fanned flue
Heating system and controls (when renewable source provides main space heating)	Boiler and radiators; Timer + TRVs with boiler interlock
Hot water system (when renewable source provides main water heating)	Stored hot water, heated by boiler separate time and temperature control for space and water heating
Hot water cylinder	120 litre cylinder insulated with 35 mm of factory applied foam
Primary water heating losses	Primary pipework not insulated, cylinder temperature controlled by thermostat

Appendix D: Thermal Bridging

GENERAL

D.1 This Appendix deals with the assessment of discreet thermal bridging, e.g. at junctions and around openings such as doors and windows. It gives guidance on

- avoidance of mould growth and surface condensation, and
- limiting factors governing additional heat losses.

The guidance is based on IP 01/06 "*Assessing the effects of thermal bridging at junctions and around openings*" published by BRE and can be used to demonstrate adequate provision to limit thermal bridging when the guidance in relation to appropriate detailing of cills, jambs, lintels, junctions between elements and other potential thermal bridges contained in Paragraphs 1.1.5.2 and 1.1.5.3, and associated reference documents, is not followed.

CALCULATION PROCEDURES

D.2 Details should be assessed in accordance with the methods described in I.S. EN ISO 10211-1: 1996 and I.S. EN ISO 10211-2: 2001. This assessment should establish the temperature factor (f_{Rsi}) and linear thermal transmittance (ψ).

The temperature factor (f_{Rsi}) is defined as follows:

$$f_{Rsi} = (T_{si} – T_e) / (T_i – T_e)$$

where:

T_{si} = minimum internal surface temperature,
T_e = external temperature, and
T_i = internal temperature.

The linear thermal transmittance (ψ) is the calculated correction factor for heat loss per unit length of a linear thermal bridge.

MOULD GROWTH AND SURFACE CONDENSATION

D.3 For dwellings, the value of f_{Rsi} should be greater than or equal to 0.75, so as to avoid the risk of mould growth and surface condensation. For three-dimensional corners of ground floors this value may be reduced to 0.70, for all points within 10 mm of the point of lowest $f_{Rsi.}$

ADDITIONAL HEAT LOSS

D.4 The additional heat loss associated with thermal bridges should be limited to less than 16% of the total calculated heat loss through the plane building elements when the Elemental Heat Loss method is used to show compliance. Where the Overall Heat Loss method is used to show compliance, any additional heat loss above this level should be explicitly taken into account in calculating the Overall Heat Loss and the associated average U-value.

D.5 Where the guidance given in Paragraphs 1.1.5.2 and 1.1.5.3 and associated references is followed or where the linear thermal transmittance of all thermal bridges does not exceed those set out in Table 39, it can be assumed that the additional heat loss associated with thermal bridging is not excessive and no further calculation is necessary. Where the linear thermal transmittances of some thermal bridges exceed those set out in Table 39, the overall additional heat loss associated with thermal bridging should be established and allowed for in assessing compliance, as outlined above. In this assessment, any detail that complies with the guidance in Paragraphs 1.1.5.2 and 1.1.5.3 and associated references can be assumed to have the value of ψ set out in Table 39. Alternatively the detail can be assessed and the calculated value used in the calculation of overall heat loss due to thermal bridging.

Table 39 **Maximum values of linear thermal transmittance (ψ) for selected locations**

Detail in external element/junction with external element	Maximum value of Ψ (W/mK)
Windows/doors	
Steel lintel with perforated steel baseplate	0.50
Other lintel (including other steel lintel)	0.30
Cills/jambs	0.06
Junctions with external element	
Ground floor, intermediate floor, party wall	0.16
Eaves (ceiling level)	0.06
Gable (ceiling level)	0.24

Note: For party walls and intermediate floors between dwellings, half of the Ψ-value should be applied to each dwelling when assessing the additional heat loss associated with bridging.

Appendix E: Avoidance of Solar Overheating

E1 This Appendix provides the detail for the procedure referred to in paragraph 2.1.6.2 (a).

E2 When estimating the solar load, the space being considered should be split into perimeter and interior zones. "Perimeter zones" are those defined by a boundary drawn a maximum of 6 m away from the window wall(s). Interior zones are defined by the space between this perimeter boundary and the non-window walls or the perimeter boundary of another perimeter zone.

When calculating the average solar cooling load, the contribution from all windows within that zone should be included, plus the contribution from any rooflight (or part rooflight) that is within the zone boundary.

For interior zones, the contribution from all rooflights (or part rooflights) that is within its zone boundary should be included.

For each zone within the space, the total average solar cooling load per unit floor area should be no greater than 25 W/m^2.

The total average solar cooling load per unit floor area (W/m^2) is calculated as follows:

- The average solar cooling load associated with each glazed area is calculated by multiplying the area of glazing by the solar load for the appropriate orientation (see Table 7) and by a correction factor applicable to the relevant glazing/blind combination (see Paragraph E3 and Table 40);

- The average solar cooling loads thus calculated are added together and the sum divided by the zone floor area to give a total average solar cooling load per unit floor area (W/m^2).

Where the actual glazed area is not known, it can be assumed to equate to the opening area reduced by an allowance for framing. The default reduction should be taken as 10% for windows and 30% for rooflights.

E3 Standard correction factors for intermittent shading using various glass/blind combinations are given in Table 40.

Table 40: **Correction factors for intermittent shading using various glass/blind combinations**

Glazing/blind combination (described from inside to outside)	Correction factor (f_c)
Blind/clear/clear	0.95
Blind/clear/reflecting	0.62
Blind/clear/absorbing	0.66
Blind/low-e/clear	0.92
Blind/low-e/reflecting	0.60
Blind/low-e/absorbing	0.62
Clear/blind/clear	0.69
Clear/blind/reflecting	0.47
Clear/blind/absorbing	0.50
Clear/clear/blind/clear	0.56
Clear/clear/blind/reflecting	0.37
Clear/clear/blind/absorbing	0.39
Clear/clear/blind	0.57
Clear/clear/clear/blind	0.47

Where available, shading coefficient data for a particular device should be used to calculate the correction factor, in preference to using the figures given in Table 40. The correction factor is calculated as follows:

(a) For fixed shading (including units with absorbing or reflecting glass), the correction factor (f_c) is given by

$$f_c = S_c/0.7$$

(b) For moveable shading, the correction factor is given by

$$f_c = 0.5(1 + (S_c/0.7))$$

where S_c is the shading coefficient for the glazing/shading device combination, i.e. the ratio of the instantaneous heat gain at normal incidence by the glazing/shading combination relative to the instantaneous heat gain by a sheet of 4 mm clear glass.

(c) Where there is a combination of fixed and moveable shading, the correction factor is given by
$f_c = (S_{cf} + S_{ctot})/1.4$

where S_{cf} is the shading coefficient of the fixed shading (with glazing) and S_{ctot} is the shading coefficient of the combination of glazing and fixed and moveable shading.

Example E1

E4 A school classroom is 9 m long by 6 m deep, with a floor to ceiling height of 2.9 m. There is glazing on one wall, with rooflights along the internal wall opposite the window wall. The windows are 1200 mm wide by 1000 mm high, and there are six such windows in the external wall, which faces SE. The windows are clear double glazed, with mid-pane blinds, of wooden frames with a framing percentage of 25%. There are three 0.9 m^2 horizontal rooflights, with an internal blind and low-e glass on the inner pane of the double pane unit. Is there likely to be a solar overheating problem?

(a) As the room is not more than 6 m deep, it should be considered as a single "perimeter zone" – there is no "interior zone"

(b) The calculation of the average solar cooling load (W) is set out in the following Table

Element / Orientation	Windows (SE)	Rooflight
Opening Area (m^2)	7.2	2.7
Frame correction	0.75	0.7
Glazing/blind correction (Table 40)	0.69	0.92
Average solar load per unit glazed area (W/m^2) (Table 7)	198	327
Average solar load (W)	738	569
Total Average Load (W)	1307	

(c) the total average solar cooling load per unit floor area (W/m^2) is derived by dividing the total average solar load by the zone floor area. In this case the floor area is 54 m^2 and the total average solar cooling load per unit floor area is 24.20 (W/m^2). As this is less than 25 W/m^2, there is not likely to be an overheating problem.

Example E2

E5 An office building has a floor to ceiling height of 2.8 m and curtain walling construction with a glazing ratio of 0.6. The long side of the office faces south and the short side faces west. On each floor, the main office area is open plan, but there is a 5 m by 3 m corner office, with the 5 m side facing South. It is proposed to use double glazing with the internal pane low-e glazing and the external pane absorbing glass, and with an internal blind.

For the open plan areas, the perimeter zone is defined by the 6 m depth rule, but for the corner office, it is defined by the partitions. The glazed area is taken as the nominal area less 10% for framing.
Three different situations must be considered

- the south facing open plan area;
- the west facing open plan area; and
- the corner office.

Open plan area

From Table 7, it can be seen that the solar loading for a West orientation (205 W/m^2) exceeds that for a South orientation (156 W/m^2). Thus, on the assumption that the same construction would be used on West and South facades, it is sufficient to check the West orientation for the open plan offices.

For a typical 5 m length of West facing office, the floor area of the perimeter zone is 30 m^2, and the area of glazing is 7.56 m^2, i.e. width (5 m) x height (2.8 m) x glazing ratio (0.6) x framing correction (0.9). The glazing/blind correction factor is 0.62 and the solar loading is 205 W/m^2. Thus the total average solar cooling load per unit floor area (W/m^2) is

$$(7.56 \times .62 \times 205)/30 = 32W/m^2.$$

As this is greater than the threshold of 25 W/m², it is necessary to decrease the glazing ratio or provide alternative or additional shading devices, e.g. a reduction in glazing ratio to 0.47 or provision of fixed shading devices which would provide a shading coefficient of 0.34 (giving a correction factor of 0.43), or a combination of these measures would reduce the risk of solar overheating to acceptable levels.

Corner Office

For the purpose of this example, it is assumed that it has been decided to reduce the glazing ratio of the building to 0.47. On this basis the average solar load for this office can be calculated as set out in the following table.

The office floor area is 15 m² and the total average solar cooling load per unit floor area (W/m²) is 68 W/m².

To achieve a total average solar cooling load per unit floor area (W/m²) of 25 W/m² would require a reduction in the total average solar load to 375 W. This can be achieved by a further reduction of glazing area, e.g. through the use of opaque panels so as to reduce the glazing ratio for the corner office to 17%. An alternative would be to use external shading devices to give a correction factor of 0.22. This implies fixed shading with a shading coefficient of 0.16. Such a shading coefficient is quite demanding to achieve in practice. Alternatively a more detailed calculation could be undertaken.

If the corner office was not partitioned from a general open floor area, it's solar load could be considered as part of the load of one of the facades it shares.

Element / Orientation	South Facade	West Facade
Nominal Glazed Area (m²)	6.8	3.95
Frame correction	0.9	0.9
Glazing/blind correction (Table 40)	0.62	0.62
Average solar load per unit glazed area (W/m²) (Table 7)	156	205
Average solar load (W)	573	452
Total Average Solar Load (W)	1025	

Appendix F: Limitation of Heat Loss through Building Fabric

F.1 This Appendix presents example calculations for the various methods of demonstrating compliance with the requirement to limit heat loss through the building fabric. It is assumed that the construction details at thermal bridges are in accordance with those referred to in Par. 1.2.4 and Par. 2.1.4, as appropriate. It is also assumed that the constructions comply with the guidance regarding limitation of air infiltration (paragraph 1.2.5 and 2.1.5, as appropriate).

DWELLINGS

F.2 Example F1 illustrates the application of the two methods of demonstrating the efficient limitation of heat loss through the building fabric for dwellings, as set out in Section 1.2 above.

Example F.1: Semi-Detached House

It is proposed to construct a semi-detached two storey house with the following dimensional and construction characteristics.

Dimensions:	Width	-	6 m (internal)
	Depth	-	8 m (one side only exposed, adjoining house attached on other side)
	Height	-	5.1 m (2.4 metres floor to ceiling height, 300 mm first Floor zone).

Door and Window Openings:

Front	-	11.0 m² (including 1.8 m² front door)
Rear	-	9.6 m² (including 1.8 m² rear door)
Side	-	1.5 m²
Total	-	22.1 m² (23% of floor area).

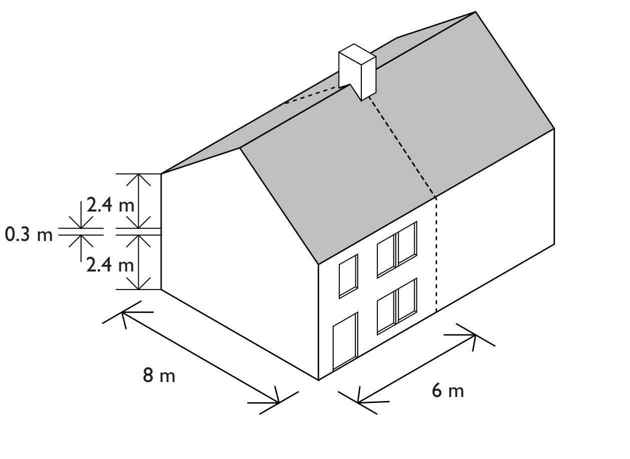
Construction:

Roof:	Pitched tiled roof, insulation laid on attic floor, part between joists and part over joists.
Walls:	Cavity wall (dense concrete blocks) rendered externally, dry-lined internally with partial fill insulation in the cavity and 50 mm cavity retained. Any additional insulation to be provided as internal lining between battens.
Floor:	Concrete slab-on-ground floor with insulation under slab.

The following are the assumed thermal conductivities of the insulation materials used:

roof insulation	0.04 W/m²K
wall insulation	0.037 W/m²K
floor insulation	0.037 W/m²K.

Diagram 39 *Para. F.2*
Semi-detached house



F.2.1 ELEMENTAL HEAT LOSS METHOD

This is the easiest method to apply but provides little flexibility. Table 1 gives the required U-values.

The required thickness of insulation for roof and walls may be calculated by the method specified in Appendix A, or estimated using the appropriate tables from Appendix B. Based on Tables 14 and 24, the required thickness of attic and wall insulation are 250 mm and 110 mm respectively. The required thickness of insulation in the ground floor depends on the ratio of exposed perimeter to floor area. This ratio is 20/48, or 0.42. Using Table 30 and assuming an insulation thermal conductivity of 0.037 W/mK, the thickness of floor insulation required is 93 mm.

Table 3 indicates that the required average U-value of windows, doors and rooflights (at 23% of floor area) is 2.37 W/m²K. The following table presents one combination that meets this requirement:

	Type	Area (m^2)	U-value	A x U
Doors	Solid Wooden	3.6	3.0	10.8
Windows	Softwood frame, Double glazed, 12 mm gap, Soft low-e glass	18.5	2.1	38.85
Totals		22.1	-	49.65
Average U-value	49.65/22.1	-	2.25	-

Other combinations can also be used to satisfy this requirement. However, it is important to check for compliance in relation to specific doors and windows proposed. Not all combinations comply. For example, a combination of two solid wooden external doors and double-glazed wood or PVC windows using a 12 mm gap and standard low-e glass (emissivity = 0.2) would not comply in this case.

F. 2.2 OVERALL HEAT LOSS METHOD

This method provides greater flexibility for the designer allowing compensation for a reduction in insulation provision in one element by an increase in provision in another element. It also provides greater flexibility in relation to the areas and types of glazing provided. Use of this method requires calculation of the total heat loss area (A_t), the building volume (V) and the average U-value of the heat loss elements (U_{av}). The calculation of U_{av} requires the multiplication of area and U-value for each element, summing the product calculated and dividing the sum by the total area of all heat loss elements. The calculated U_{av} is then compared to the maximum average U-value (U_m) for this building, which is specified in Table 1.

While the U-values of roofs, walls and ground floors can be relaxed (relative to the U-values specified or the Elemental method) to the values set out in Paragraph 1.1.3.2., it will generally be necessary to compensate for a reduction in insulation in one element by increased insulation elsewhere. It will rarely be possible to relax all U-values to the extent allowed by Paragraph 1.1.3.2. While some reduction in window area may facilitate trade-off, glazed areas should not be so small as to affect the adequacy of daylighting.

For the house under consideration, the construction may be varied by using 60 mm insulation with thermal conductivity of 0.025 W/mK in the cavity with no extra insulation behind the drylining. This gives a U-value of 0.33 W/m²K for the walls, which is acceptable provided the maximum average U-value (U_m) is not exceeded. To achieve this some increase in insulation elsewhere is required. For example, the attic insulation could be increased to 300 mm giving a U-value of 0.13 W/m²K, and the air gap in the glazing also increased to 16 mm giving a U-value for the windows of 2.0 W/m²K. In addition the use of half glazed wooden doors with double glazing using standard low-e glass and 12 mm gap between panes gives a door U-value of 2.65 W/m²K. Taking all these changes into account, U_{av} can be calculated as follows:

Heat loss Element	Area (m^2)	U-value (W/m^2K)	Area x U-value (W/K)
Roof	48.00	0.13	6.24
Wall	79.90	0.33	26.37
Floor	48.00	0.25	12.00
Windows (double glazed, soft low-E glass, 16 mm gap, wooden frame)	18.50	2.00	37.00
Doors	3.60	2.65	9.54
	198.00	**-**	91.15

U_{av} = Total AU / A_t = 91.15/198 = 0.46W/m²K

Building Volume (V) = 244.80 m³

A_t / V = 198.00/244.80 = 0.81 (m^{-1})

U_m (from Table 1) = 0.47 W/m²K.

The proposed construction is acceptable as U_{av} is not greater than U_m.

BUILDINGS OTHER THAN DWELLINGS

F.3 The following examples illustrates the application of the methods of demonstrating the efficient limitation of heat loss through the building fabric for buildings other than dwellings, as set out in Section 2.1 above.

F.3.1 OFFICE BUILDING

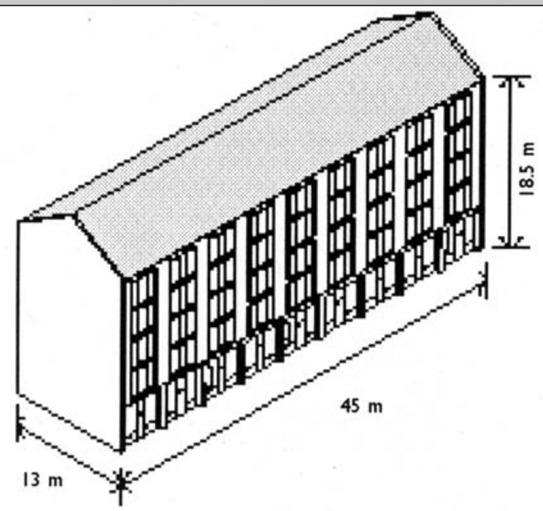
Example F2 relates to an office building.

Example F.2: Office Building

A detached 6 storey shop and office building 45 m x 13 m in plan and 18.5 m internal height is to be constructed. Shops are provided on the ground floor with 80% of the front facade being display windows. No glazing is provided to the side or rear on the ground floor. The upper four floors are provided with 55% double glazing (metal frames with thermal break, low-E glass, 12 mm air gap) on the front and rear facades with no glazing on end walls or roof. Exposed walls are to have a U-value of 0.43 W/m²K and roof a U-value of 0.30 W/m²K. The solid ground floor is edge-insulated.

Is this building satisfactory in terms of heat loss through the fabric?

Diagram 40 *Para F.3.1*
Office building



F.3.1.1 ELEMENTAL HEAT LOSS METHOD

As stated in Paragraph 2.1.1.1, this method is primarily appropriate for small buildings, small sections of large complex buildings, material alterations and material changes of use. It is not particularly appropriate for this type of building but may be used, if desired. This proposal clearly does not comply when assessed in accordance with this method. The U values of all of the main elements – roof, wall, floor, and windows exceed those specified in Table 5. The area of glazing as a % of exposed wall is acceptable when account is taken of the area of display glazing (see Table 6).

F.3.1.2 OVERALL HEAT LOSS METHOD

The following calculations give the total heat loss area (A_t), the average U-value of heat loss elements (U_{av}) and building volume (V). The U_{av} value is then compared with U_m specified in Table 4 for the calculated volume and heat loss area.

Heat Loss Element	Area (m²)	U-value (W/m²K)	Area x U- value (W/K)
Roof	585	0.30	175.50
Wall	1277	0.43	549.11
Floor	585	0.44	257.40
Windows	743	2.60	1931.80
Doors	20	3.00	60.00
Totals	3210		2973.81

$U_{av} = \frac{\text{Total AU}}{A_t} = \frac{2973.81}{3210} = 0.93$ W/m²K

Building Volume (V) = 10,822.5 m³

$\frac{A_t}{V} = \frac{3210}{10,822.5} = 0.30\ (m^{-1})$

U_m (from Table 4) = 0.88 W/m²K.

The proposed construction is not acceptable as U_{av} is greater than U_m.

A number of options are available which will ensure compliance. One such is to use soft low-E glazing. This gives a U-value for glazing of 2.4 W/m²K. The following sets out the revised calculation.

Heat Loss Element	Area (m^2)	U-value (W/m^2K)	Area x U-value (W/K)
Roof	585	0.30	175.50
Wall	1277	0.43	549.11
Floor	585	0.44	257.40
Windows	743	2.40	1783.20
Doors	20	3.00	60.00
Totals	3210		2825.21

$$U_{av} = \frac{\text{Total AU}}{A_t} = \frac{2825.21}{3210} = 0.88 \ W/m^2K$$

Building Volume (V) = 10,822.5 m^3

$$\frac{A_t}{V} = \frac{3210}{10,822.5} = 0.30 \ (m^{-1})$$

U_m (from Table 5) = 0.88 W/m^2K.

The proposed construction is now acceptable as U_{av} is greater than U_m.

F.3.2 INDUSTRIAL BUILDING

Example F.3: Industrial Building

A single story industrial building 65 metres long, 25 metres wide and 4.25 metres high with a roof pitch of 10^0 is to be constructed. Both roof and walls are designed to have a U-value of 0.35 W/m^2K. Glazing is to be provided as follows:

15 % of roof area - low-E glass, metal frame with thermal break,12 mm air gap.

15 % of wall area - low-E glass, metal frame with thermal break,12 mm air gap.

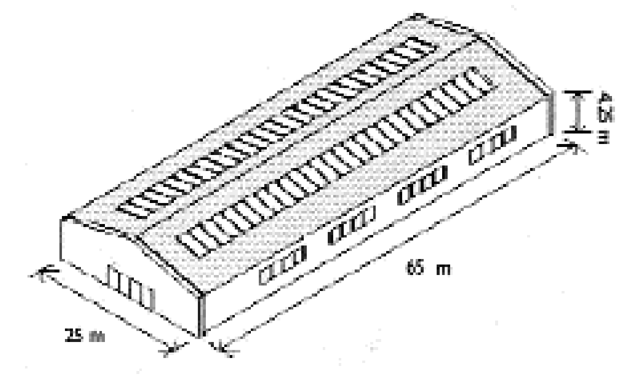
The building will also have 10 m^2 of personnel doors (U-value, 3.00 W/m^2K) and 30 m^2 vehicle doors (U-value, 0.70 W/m^2K)

The ground floor slab is to be provided with edge insulation.

Is this building satisfactory in terms of heat loss through the fabric?

Diagram 41 *Para F.3.2*

Industrial building



F.3.2.1 OVERALL HEAT LOSS METHOD

The appropriate method of assessment is the overall heat loss method. The following calculations give the total heat loss area (A_t), the average U-value of heat loss elements (U_{av}) and the building volume (V). The U_{av} value can then be compared with the U_m value specified.

Heat Loss Element	Area (m^2)	U-value (W/m^2K)	Area U-value (W/K)
Roof (10^0 slope)	1402.55	0.35	483.44
Walls	657.09	0.35	229.98
Floor	1625.00	0.26	422.50
Windows - roof	247.51	2.60	643.53
- wall	123.01	2.60	319.83
Doors - personnel	10.00	3.00	30.00
- vehicle	30.00	0.70	21.00
Totals	4095.16		2150.28

$$U_{av} = \frac{\text{Total AU}}{A_t} = \frac{2150.28}{4095.16} = 0.53 \ W/m^2K$$

Building Volume = 8697.07 m^3

$$\frac{A_t}{V} = \frac{4095.16}{8697.07} = 0.47 \ (m^{-1})$$

U_m (from Table 4) = 0.64 W/m^2K

The proposed construction is acceptable as U_{av} is greater than U_m.

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