Building Regulations 2002

Technical Guidance Document L

Conservation of Fuel and Energy DWELLINGS

BAILE ÁTHA CLIATH
ARNA FHOILSIÚ AG OIFIG AN tSOLÁTHAIR

Le ceannach go díreach ón
OIFIG DHÍOLTA FOILSEACHÁIN RIALTAS,
TEACH SUN ALLIANCE, SRÁID THEACH LAIGHEAN, BAILE ÁTHA CLIATH 2.
nó tríd an bpost ó
FOILSEACHÁIN RIALTAIS, AN RANNOG POST-TRACHTA
51 FAICHE STIABHNA, BAILE ÁTHA CLIATH 2.
(Teil: 01-647 6000; Faics: 01-647 6843)
nó trí aon díoltóir leabhar

DUBLIN:
PUBLISHED BY THE STATIONERY OFFICE

To be purchased from the
GOVERNMENT PUBLICATIONS SALES OFFICE,
SUN ALLIANCE HOUSE, MOLESWORTH STREET, DUBLIN 2
or by mail order from
GOVERNMENT PUBLICATIONS, POSTAL TRADE SECTION,
51 ST. STEPHEN'S GREEN, DUBLIN 2
(Tel: 01-647 6000; Fax: 01-647 6843)
or through any bookseller

Price: €10.00

Printed on recycled paper containing a minimum of 75% post-consumer waste

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

Amendments issued since publication

Technical Guidance Document L - Conservation of Fuel and Energy-Dwellings (2002)

Amd. No.	***Text Affected***
L(i)	Table 2: Heading over Column 2 amended to read:- Maximum combined area of external doors, windows and roof lights (A_{ope}) as % of floor area (A_f)
L(ii)	Table 2: Note 1 amended to read:- 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 values: $A_{ope}/A_f = 0.4825/(U_{ope} - 0.27)$. This expression may also be used to calculate appropriate values outside the range covered by the table.
L(iii)	Table 6: Heading in the first column to read:- "Total thickness of insulation (mm)"
L(iv)	"Provision of adequate roof space ventilation" replace the Word "Ventilation" with "Condensation"
L(v)	Table 20: bottom section amended to read:- This table is derived for walls as in W3(a) above, except with 100 mm of insulation ($\lambda = 0.04$) between 100 mm studs and additional layer of insulation as specified in the Table across the studs
L(vi)	Dwelling - Assessment of Compliance on Basis of Heat Energy Rating Standard Calculation Worksheet "Total Basic Air Change Rate should read: (32)+(33)+(34) = [ ] (35)
L(vii)	Table 29: Note 7th line amended to read:- "where $N = 0.038F - 0.00005F^2$ (for $F \leq 300\ m^3$)

Amd. No.	*Text Affected*
L(viii)	Solar and Other Energy Gains; Paragraph C.17 "Table 33" Amended to read:- "Table 32"
L(ix)	Table 33: Note 1: 4th line amended to read: "$N = 0.038F - 0.00005F^2$ (for $F \leq 300m^3$)
L(x)	Table 33: Note 2: 3rd, 4th, 5th lines amended to read: 10W, 10W 25W respectively.
L(xi)	Example E1: Semi-Detached House: Door and Window Openings: Amended to read: (Including 1.8 m^2 rear door)
L(xii)	Example E1 - Heat Energy Rating Calculation: - Amended to read: "Gross Air Change Rate (35) + (43) = 0.98 (44)
L(xiii)	Example E1 - Heat Energy Rating Calculation: - Amended to read: "Total Other Gains (69) + (70) = 650.72 (71)
L(xiv)	Example E1 - Heat Energy Rating Calculation: - Amended to read: "Total Gains (68) + (71) = 1005.22 (72)
L(xv)	Example E1 - Heat Energy Rating Calculation: - Amended to read: "Gains / Loss Ratio (72) / (50) 5.50 (73)
L(xvi)	Example E1 - Heat Energy Rating Calculation: - Amended to read: "Base Temperature (K) (77) – (76) 12.85 (78)

Amd. No.	*Text Affected*
L(xvii)	Example E1 - Heat Energy Rating Calculation: - Amended to read: "Energy to meet Space Heat Demand 0.024 x (79) x (50) = kWh/yr 5931.11 (80)
L(xix)	Standards and Other References I.S. EN ISO 10211-2:2001 Thermal bridge in building construction - heat flows and surface temperature. Part 2 linear thermal bridges
L(xviii)	Section 3: Insulation of Hot Water Storage Vessels, Pipes and Ducts: Paragraph 3.4 - Amended to read: ......to the standard outlined in Paragraph 3.3 above,.......
L(xx)	Standards and Other References: Other Publications referred to:- Homebond : "Right on Site" Issue No. 28, Building Regulations 2002 - Conservation of Fuel and Energy - Dwellings 2002
L(xxi)	Standards and Other References: Other Publications referred to:- Architectural Heritage Protection Guidelines for Planning Authorities, Department of the Environment, Heritage and Local Government 2004.
L(xxii)	"All Table numbers corrected (other than Tables 1 - 4), including references to Tables in the text".

Contents

Building Regulations 2002
Technical Guidance Document L
Conservation of Fuel and Energy - DWELLINGS

Introduction
This document has been published by the Minister for the Environment 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 ***insofar as it relates to dwellings***. The document should be read in conjunction with the Building Regulations 1997, 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 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.

Pending updating Part L insofar as it relates to buildings other than dwellings, guidance in relation to those buildings can be found in Building Regulations 1997, Technical Guidance Document L

Transitional Arrangements
In general, this document applies to works, or buildings in which a material change of use takes place, where the work or the change of use commences or takes place, as the case may be, on or after 1 January 2003. Technical Guidance Document L - **Conservation of Fuel and Energy, dated 1997**, insofar as it relates to dwellings, also ceases to have effect from that date. However, the latter document may continue to be used in the case of dwellings:-

- where the work or the change of use commences or takes place, as the case may be, on or before 31 December 2002, or
- where planning approval or permission has been applied for on or before 31 December 2002, and substantial work has been completed by 31 December 2005, or a notice pursuant to Part 8 of the Planning and Development Regulations 2001 has been published on or before 31 December 2002, and substantial work has been completed by 31 December 2005.

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

In the case of the replacement of external doors, windows or rooflights, this document will apply to work which takes place on or after 1 July 2003.

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 disabled persons. 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 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.

Conservation of Fuel and Energy - DWELLINGS

Building Regulations - The Requirement

1. The requirements regarding conservation of fuel and energy are laid out in Part L of the Second Schedule to the Building Regulations 1997 (S.I. No. 497 of 1997).

2. The Second Schedule in relation to works relating to dwellings, is amended to read as follows:

Conservation of fuel and energy	L1	A building shall be so designed and constructed as to secure, insofar as is reasonably practicable, the conservation of fuel and energy. This shall be achieved by – (a) limiting the heat loss and, where appropriate, maximising the heat gains through the fabric of the building (b) controlling, as appropriate, the output of the space heating and hot water systems; and (c) limiting the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air.

GENERAL GUIDANCE

0.1 The philosophy underlying Part L of the First Schedule to the Building Regulations is that occupants can achieve adequate levels of thermal comfort while minimising the use of scarce energy resources. Buildings should be designed and constructed to achieve this aim as far as is practicable. This requires, as a minimum, the provision of energy efficient measures which –

(a) limit the heat loss and, where appropriate, maximise the heat gains through the fabric of the building,

(b) control as appropriate the output of the space heating and hot water systems;

and

(c) limit the heat loss from pipes, ducts and vessels used for the transport or storage of heated water or air.

This Technical Guidance Document provides guidance on how to satisfy the requirement in these three areas for ***dwellings.*** The existing Technical Guidance Document "Building Regulations 1997, Technical Guidance Document – L, Conservation of Fuel and Energy" continues to apply to ***buildings other than dwellings.***

A range of issues related to performance assessment, calculation methods and applicability of Part L are dealt with initially in the following paragraphs.

0.2 Paragraph 1.4 and Appendix C of this document present a system of energy rating as a possible method of demonstrating compliance of new housing with the energy conservation requirements of the Building Regulations. The use of the system and the provision of standardised information derived from it will be promoted by the Department of Communications Marine and Natural Resources and the Sustainable Energy Authority of Ireland with a view to increasing awareness of the importance of energy efficiency in housing. To encourage greater use of this system, the authority will update the user-friendly computer software, which it has previously made available. This will enable compliance with Part L to be assessed and facilitate the provision of energy performance information in relation to new housing in a standardised format. Such information may be used for marketing purposes or as a means of conveying to potential owners or occupants the energy efficiency advantages of buildings, which comply with the Building Regulations.

0.3 For small extensions, not exceeding 6.5m^2 in floor area, reasonable provision for the conservation of fuel and energy 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 for the conservation of fuel and energy.

0.4 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.

0.5 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.

TECHNICAL RISKS AND PRECAUTIONS

General

0.6 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 from the incorporation of energy conservation measures is 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" (to be published shortly).

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

0.7 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 are required as secondary means of escape in accordance with Section 1.5 of TGD B, comply with the dimensional and other requirements for such windows as set out in paragraph. 1.5.6 of TGD B.

Ventilation

0.8 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. A new edition of Technical Guidance Document F is being published, simultaneously with this edition of TGD L which amends guidance in relation to ventilation of bathrooms, kitchens and ulitity 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 the Sustainable Energy Authority of Ireland.

THERMAL CONDUCTIVITY AND THERMAL TRANSMITTANCE

0.9 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).

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). In this Part, U-values specified as maximum elemental U-values, or used to derive average U-values, relate 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 space 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 occupied and 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 the overall transmission heat loss.

0.10 U-values and λ-values are dependant on a number of factors and, for particular materials, products or components, measured values, certified by an approved body or certified laboratory (see TGD D), should be used, where available. Measurements of thermal conductivity should be made in accordance with I.S. EN 12664, I.S. EN 12667 or I.S. EN 12939 as appropriate. Measurements of thermal transmittance should be made in accordance with I.S. EN ISO 8990, or, in the case of windows and doors, I.S. EN ISO 12567-1. The phasing out of the use of HCFC as a blowing agent for foamed insulants will be completed by January 2004. Certified λ-values for these materials should take account of the blowing agent actually used.

0.11 In the absence of certified measured values, values of thermal conductivity given in Table 5 of Appendix A may be used. This Table contains l-values for some common building materials. These are primarily based on data contained in I.S. EN 12524 or in CIBSE Guide A, Section A3. The values provide a general indication of the thermal conductivity that may be expected for these materials. However, values for specific products may differ from these illustrative values. For thermal insulation materials, or other products or materials which contribute significantly to overall thermal transmittance, certified test data should be used in preference to the values given in Table 5.

0.12 In the absence of certified measured values, U-values may be derived by calculation. Methods of calculation are outlined in Appendix A, together with examples of their use.

0.13 The procedure for the calculation of U-values of elements adjacent to unheated space (previously referred to as semi-exposed elements) is described in I.S. EN ISO 6946 and I.S. EN ISO 13789.

- I.S. EN ISO 6946 gives a simplified procedure, where the unheated space is treated as if it was an additional homogeneous layer.
- I.S. EN ISO 13789 gives more precise procedures for the calculation of heat transfer from a building to the external environment via unheated spaces, and may be used when a more accurate result is required.

A simplified procedure which may be used for typical situations is given in Appendix A, paragraph A.4.1.

0.14 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 28 in Appendix B contains indicative U-values for external doors, windows and rooflights.

DIMENSIONS

0.15 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 and door openings should be taken between internal faces of appropriate cills, lintels and reveals. "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.

APPLICATION TO BUILDINGS OF ARCHITECTURAL AND HISTORIC INTEREST

0.16 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 structure 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 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 "Architectural Heritage Protection - Guidelines for Planning Authorities", have been published by the Department of the Environment, Heritage and Local Government.

Section 1: Limitations of Heat Loss through the Building Fabric

1.1 GENERAL

1.1.1 Any one of the following three 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 Elemental Heat Loss** method (Paragraph 1.2);

(b) **The Overall Heat Loss** method (Paragraph 1.3);

(c) **The Heat Energy Rating** method (Paragraph 1.4).

For each of the three methods, the guidance regarding the limitation of thermal bridging (Paragraphs 1.5.1, 1.5.2 and 1.5.3) and of uncontrolled air infiltration through the building fabric (Paragraph 1.6.1) should be followed.

Any part of a roof which has a pitch of 70° 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 which can be reasonably assumed to be heated should not be included (See paragraph 0.9). An example of the use of each of the three methods are given in Appendix E.

1.1.2 When assessing transmission loss through the building fabric unheated ancilliary area should generally be considered as external to the insulated fabric. Their effect may be allowed for using methods specified in I.S. EN 6946 or I.S. EN ISO 13789 (see paragraph 0.13 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 level specified, no particular requirement for insulation between the heated and unheated areas would arise.

1.1.3 An attached conservatory-style sunspace or the like should generally be treated as an integral part of the dwelling. However, where

- clearly intended for occasional or seasonal use;
- separated from the adjacent spaces within the dwelling by walls, doors and other opaque or glazed 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 dwelling;

it may be treated as an extension to the main dwelling for the purposes of assessment for compliance with the provisions of Part L (see Paragraphs 1.2.1 to 1.2.4 and Table 1 below). In this case, the main dwelling may be assessed separately for compliance by any of the three methods given below. 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 (see paragraph 1.2.3).

1.1.4 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/m^2K 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 ELEMENTAL HEAT LOSS

1.2.1 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 1.

1.2.2 The combined area of external door, window and rooflight openings should not exceed 25% of floor area, when the average U-value of such openings is 2.2 W/m^2K. 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 2. The area of openings should not be reduced below that required for adequate daylighting provision. BS 8206: Part 2 gives advice on adequate daylight provision.

Table 1 **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 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 1.2.2 and 1.2.3, and Table 2

1.2.3 In applying paragraph 1.2.2 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 assessing the maximum area of openings allowed for any particular U-value, 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, can be added to the area calculated in accordance with paragraph 1.2.2 above.

For extensions which

- are separated from the adjacent spaces within the dwelling by walls, doors and other opaque or glazed elements,
- are clearly intended for occasional or seasonal use, 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 dwelling.

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 are set out in Table 1.

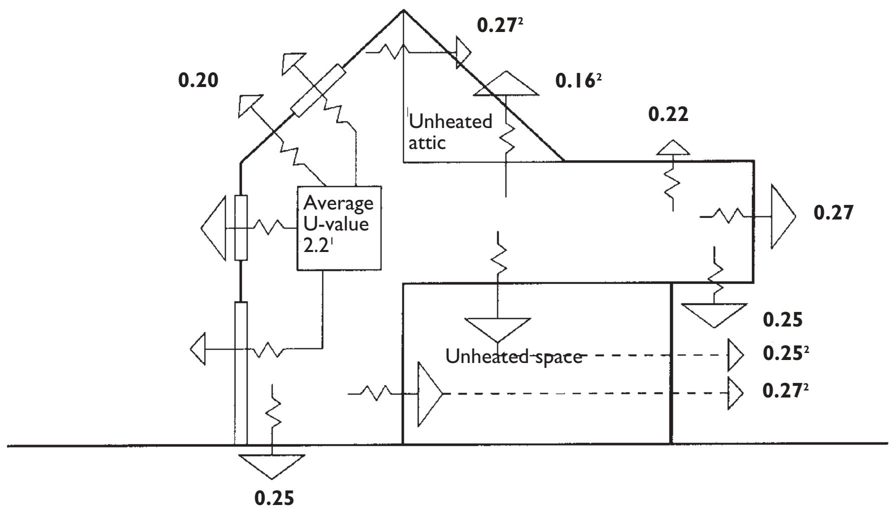
Table 2 **Permitted variation in combined areas and average U-values of external doors, windows and rooflights**

Average U-value of windows, doors and rooflights (U_{ope}) (W/m² K)	Maximum combined area of external doors, windows and rooflights (A_{ope}) 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: $A_{ope}/Af = 0.4825/(U_{ope} - 0.27)$. This expression may also be used to calculate appropriate values outside the range covered by the Table.

Diagram 1 *Par. 1.2*

Summary of elemental U-values



NOTES

1. Windows, doors and rooflights should have maximum U-value of 2.2 W/m^{2}K and maximum opening area as set out in Table B3. 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.

1.2.4 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 or I.S. EN ISO 10077-2, as appropriate (See Appendix A). Alternatively, the indicative U-values for these components given in Table 28 can be used (see Appendix B).

1.2.5 Diagram 1 summarises the fabric insulation standards and allowances applicable in the Elemental Heat Loss method.

1.1.3 OVERALL HEAT LOSS

1.3.1 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 3. The acceptable level of heat loss is expressed graphically in Diagram 2.

1.3.2 In addition to achieving the maximum average value set, average elemental U-values 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.

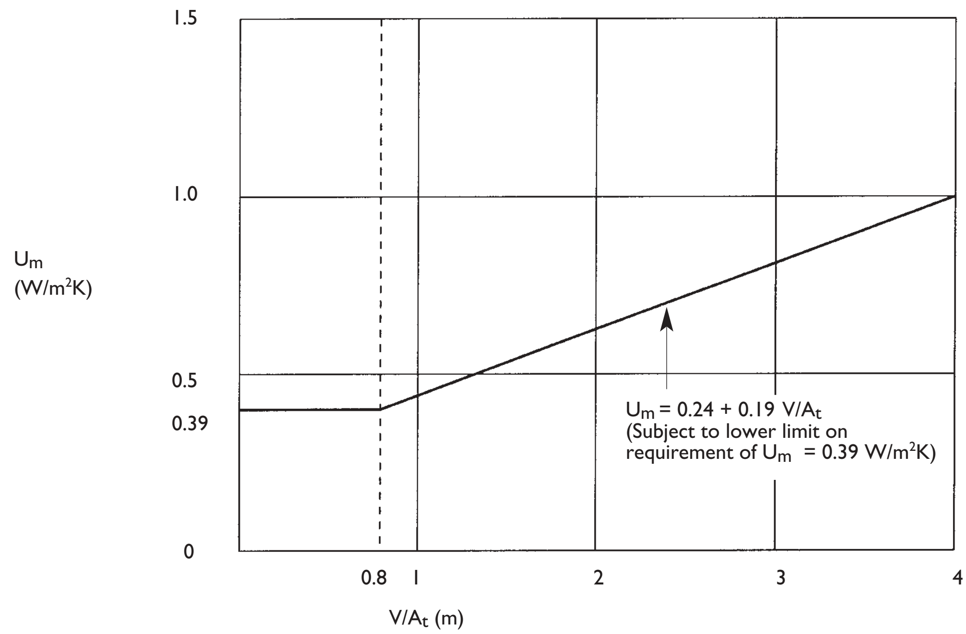
Table 3 **Maximum average U-value (U_m) as a function of building volume (V) and fabric heat-loss area (A_t)**

Area of Heat Loss Elements/ Building Volume (A_t/V) (m^{-1})	Maximum Average U Value (U_m) (W/m^{2}K)
1.3	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 0.3m^{-1}.

Diagram 2 *Par. 1.3*

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



1.4 HEAT ENERGY RATING

1.4.1 The Heat Energy Rating (HER) of a dwelling is a measure of the annual energy output from the appliance or appliances that provide space and water heating for the dwelling. The rating is calculated for standardised room temperatures, levels of hot water use and conditions of operation by the method specified in Appendix C. This involves the calculation of the energy required

(a) to offset transmission and air infiltration heat losses through the building fabric, including losses associated with thermal bridging (See Section 1.5 below)

(b) to offset heat losses associated with ventilation/air infiltration, and

(c) to provide for domestic hot water.

Solar gain and internal heat gains are taken into account in the calculation as are the type of heating system and its controls. The rating is specified in terms of energy output of the appliance or appliances per unit floor area per year (kWh/m²/yr).

1.4.2 Subject to paragraph 1.4.3 below, compliance with the requirements of Part L is demonstrated for dwellings when the calculated HER is less than the Maximum Permitted Heat Energy Rating (MPHER) specified in Table 4. This method allows some tradeoff between levels of insulation and other measures e.g. controlled air infiltration and ventilation, provision for solar gains, and space and water heating system controls.

Table 4 **Maximum Permitted Heat Energy Rating 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 Permitted Heat Energy Rating (MPHER) (kWh/m²/yr.)
1.25	102.5
1.2	101.4
1.1	99.2
1.0	99.0
0.9	94.8
0.8	92.6
0.7	90.4
0.6	88.2
0.5	86.0
0.4	83.8
0.3	81.6

NOTE 1: MPHER can be derived for intermediate values of A_t / V by interpolation in the above Table. Alternatively, it may be calculated from the expression MPHER $\leq 22A_t$ / V + 75.

1.4.3 In addition to achieving the target MPHER value set in Table 4, average elemental U-values should not exceed the following:

roofs	0.25 W/m²K
walls	0.37 W/m²K
ground floors	0.37 W/m²K

1.5 THERMAL BRIDGING

1.5.1 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 1.5.2 and 1.5.3 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.

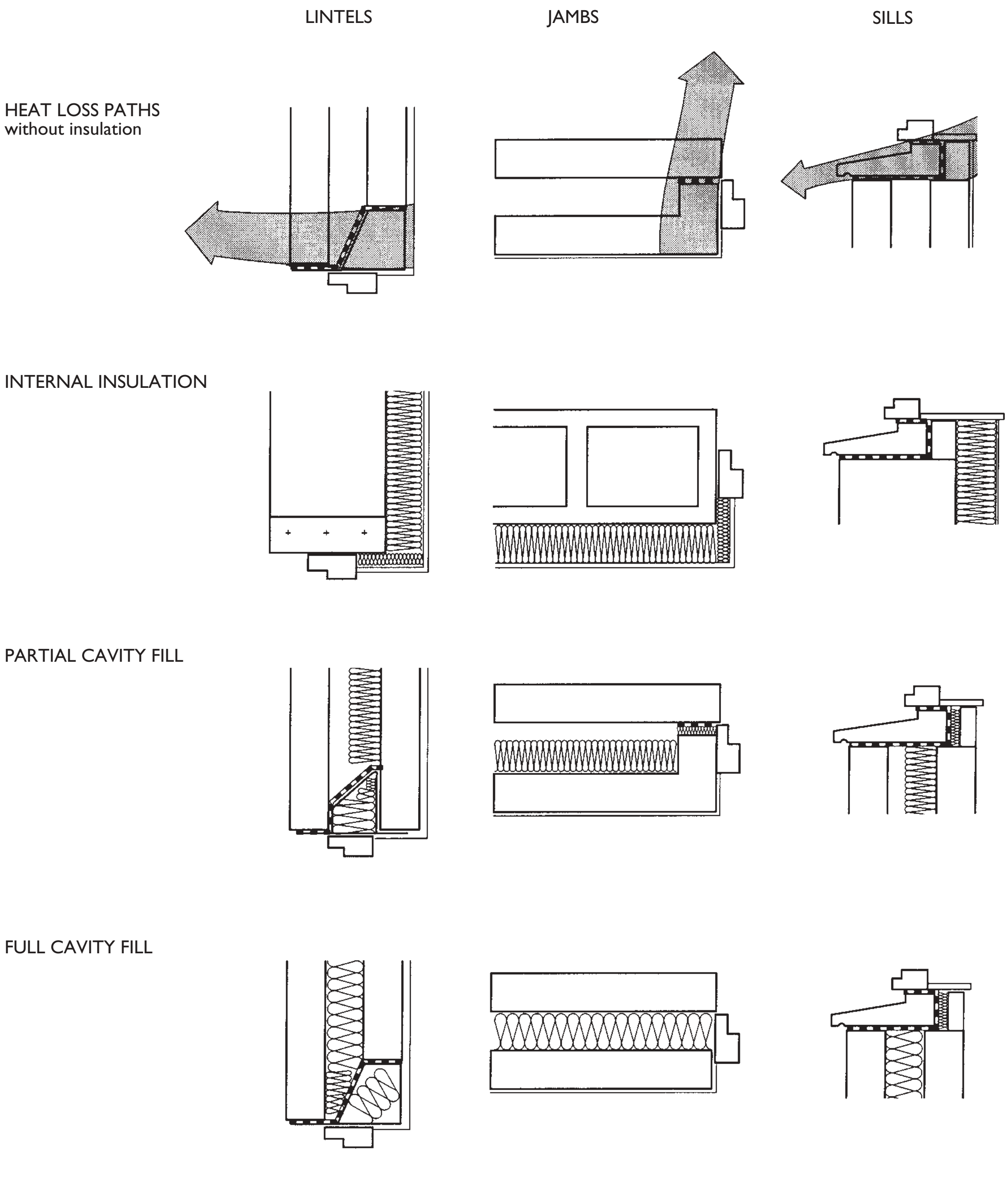
1.5.2 Use of sill, jamb, lintel and junction details set out in the HomeBond publication "Right on the Site No. 28", the publication "Limiting thermal bridging and air leakage: Robust construction details for dwellings and smaller buildings" (published by The Stationery Office, London), or other published 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 sill 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 sills generally a 15 mm thickness of insulation material having λ value of 0.04 W/mK (or equivalent) will generally be adequate.

1.5.3 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^2 K/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 *Par. 1.5*

Lintel, jamb and sill 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.

1.6 AIR INFILTRATION

1.6.1 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,

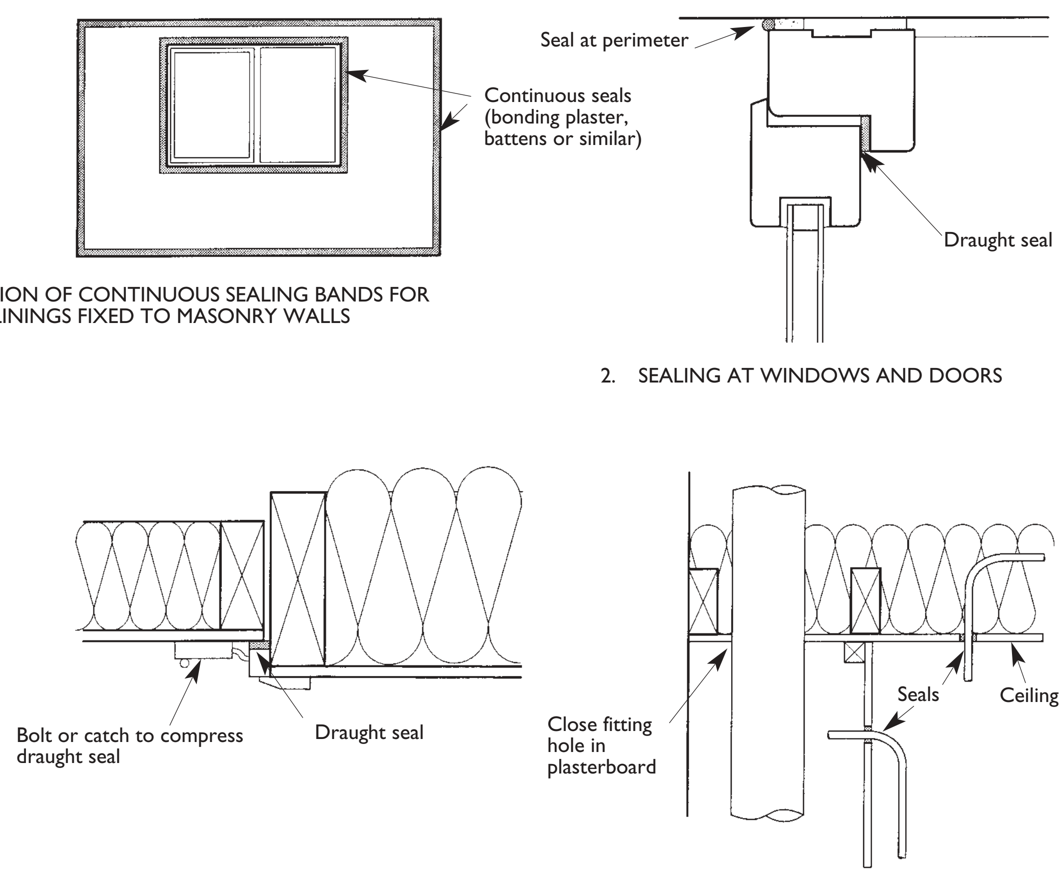
(e) ensuring boxing for concealed services is sealed at floor and ceiling levels and sealing piped services where they penetrate or project into hollow constructions or voids.

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 *Par. 1.6*

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

Section 2: Controls for Space Heating and Hot Water Supply System

2.1 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 2.2 to 2.5 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 the slumber load of the boiler through uncontrolled circulation to a radiator or hot water storage cylinder, or by other appropriate mechanism.

2.2 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.

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

2.4 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.

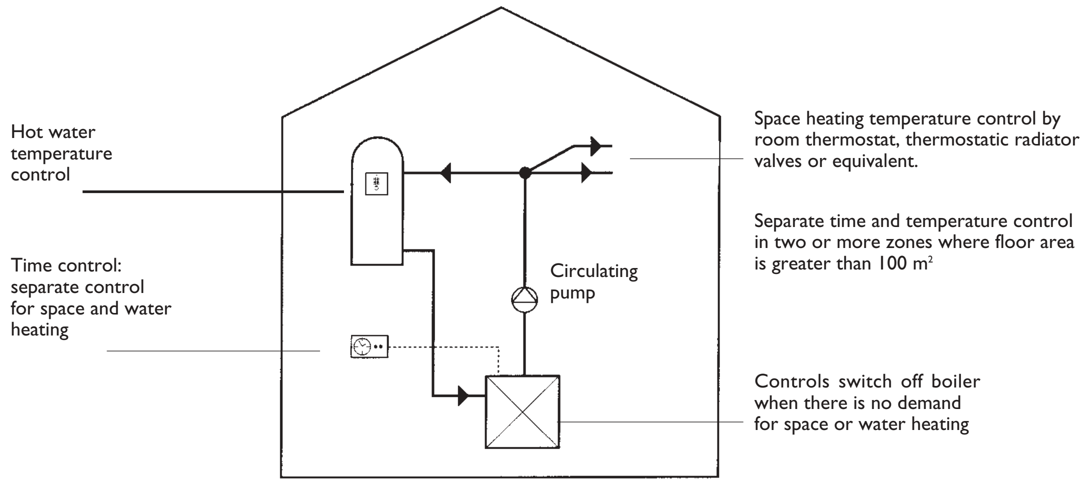
2.5 The operation of controls should be such that the boiler is switched off when no heat is required for either space or water heating. Systems controlled by thermostatic radiator valves should be fitted with flow control or other equivalent device to prevent unnecessary boiler cycling.

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

- BS 5449: 1990 Specification for forced circulation hot water central heating systems for domestic purposes;
- 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. 2.1*

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

Section 3:
Insulation of Hot Water Storage Vessels, Pipes and Ducts

3.1 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.

3.2 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 BS 1566, Part 1, 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/m^3 satisfies this criterion (see Diagram 6). Alternative insulation measures giving equivalent performance may also be used.

3.3 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):

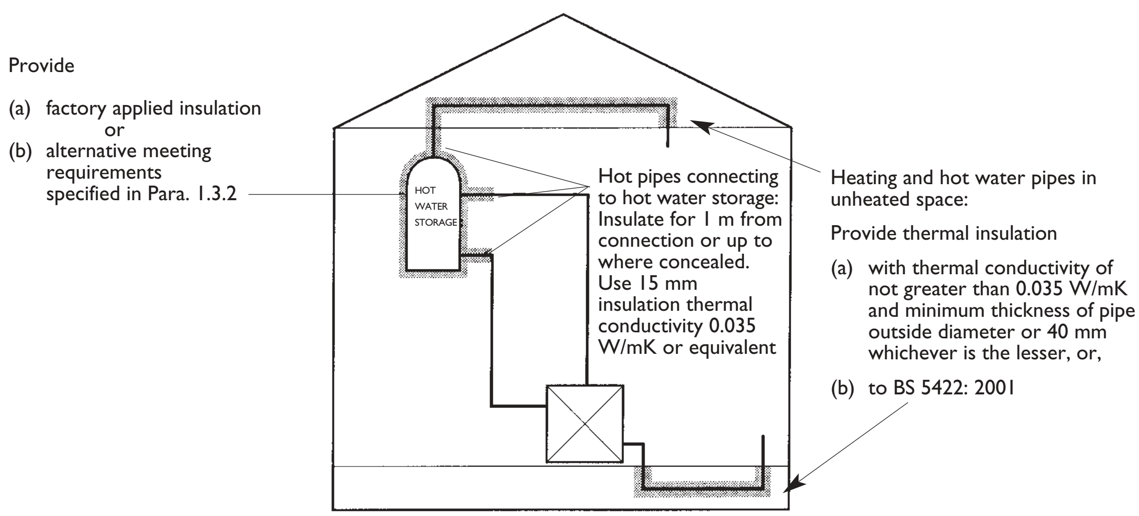
- pipe or duct insulation meeting the recommendations of BS 5422: 2001 Methods of specifying thermal insulating materials for pipes, ductwork and equipment (in the temperature range -40^{0}C to + 70^{0}C), or

- 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 40^{0}C 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.

3.4 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 3.3 above, for at least one metre from their point of connection or up to the point where they are concealed.

Diagram 6 *Para. 1.3.1*

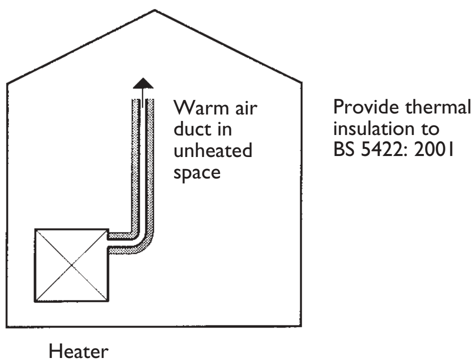
Insulation of hot water storage vessels and pipes



3.5 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 BRE Report 262, Thermal insulation: avoiding risks.

Diagram 7 *Para. 3.3*

Insulation of warm air ducts



Appendix A: Calculation of U-Values

GENERAL

A1.1 For building elements and components generally, the method of calculating U-values, is specified in I.S. EN ISO 6946. 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. U-values for windows, doors and shutters may be calculated using I.S. EN ISO 10077-1 or I.S. EN ISO 10077-2. A method for assessing U-values of light steel-framed constructions is given in BRE Digest 465. General Guidance on the Calculation of U-values is contained in BR 443 "Conventions for the Calculation of U-values". 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 soil thermal conductivity of 2.0 W/mK should be used, unless otherwise verified.

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 are given below. An example of the calculation of ground floor U-values using I.S. EN ISO 13370 is also given.

A1.4 Thermal conductivities of common building materials are given in Table 5. For the most part, these are taken from I.S. EN 12524: or CIBSE Guide A3.

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, 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.

Table 5 Thermal conductivity of some common building materials

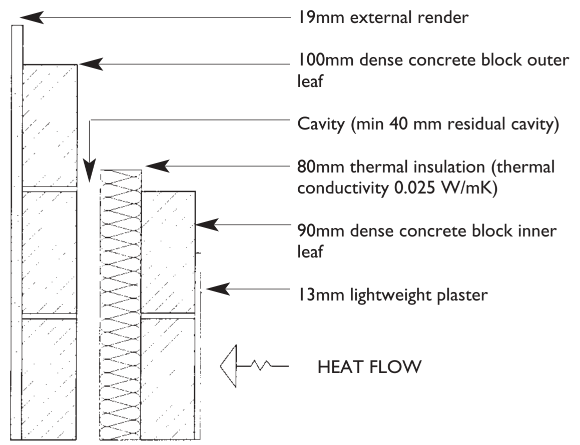
Material	Density (kg/m^3)	Thermal Conductivity (W/mK)
General Building Materials		
Clay Brickwork (outer leaf)	1,700	0.77
Clay Brickwork (inner leaf)	1,700	0.56
Concrete block (heavyweight)	2,000	1.33
Concrete block (medium weight)	1,400	0.57
Concrete block (autoclaved aerated)	600	0.18
Cast concrete, 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
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. Certified values, taking ageing into account, where appropriate, should be used in preference, if available. This applies particularly to insulation materials.

Example A1: Masonry cavity wall

Diagram 8 *Para. A.2.1*

Masonry Cavity wall



Layer/Surface	Thickness (m)	Conductivity (W/mK)	Resistanc (m²K/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			

I.S. EN 6946: provides for corrections to the calculated U-value. For this construction, 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 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.

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.

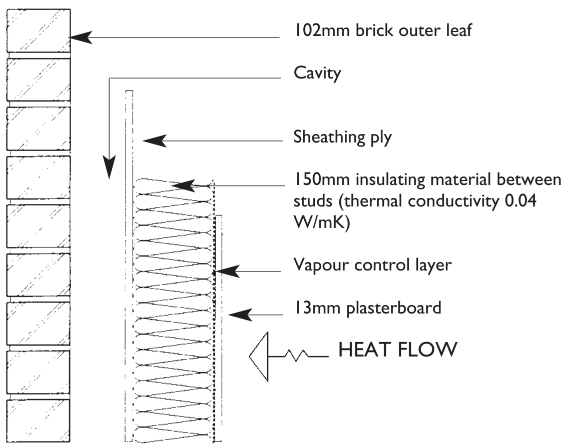
(a) the upper thermal resistance is based on the assumption that heat flows through the component in straight lines perpendicular to the element's surfaces. To calculate it, all possible heat flow paths are identified, for each path the resistance of all layers are combined in series to give the total 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 9 *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)	Resistanc (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 Ru 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/m²K (to 2 decimal places).

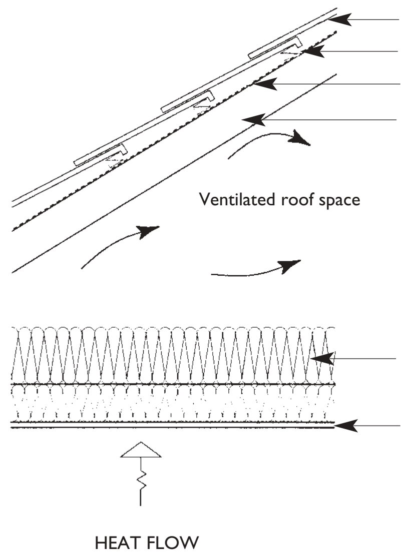
There is a potential correction for air gaps in the insulation layer. I.S. EN ISO 6946 gives a U-value correction of 0.0065 W/m²K for this construction. This is less than 3% of the calculated U-value and can be ignored.

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 10 *Para. A.2.2*

Domestic pitched roof



Layer/Surface	Thickness (m)	Conductivity (W/mK)	Resistanc (m²K/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 [m²K/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 $R_u = 1 / (0.92 / 6.642 + 0.08 / 4.911) = 6.460$ m² 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.

$R_b = 1 / (0.92 / 2.500 + 0.08 / 0.769) = 2.119$ m²K/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	0.100
Lower resistance (R_l)	**6.261**

Total resistance
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: 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: 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: also covers heat loss from basement floors and walls.

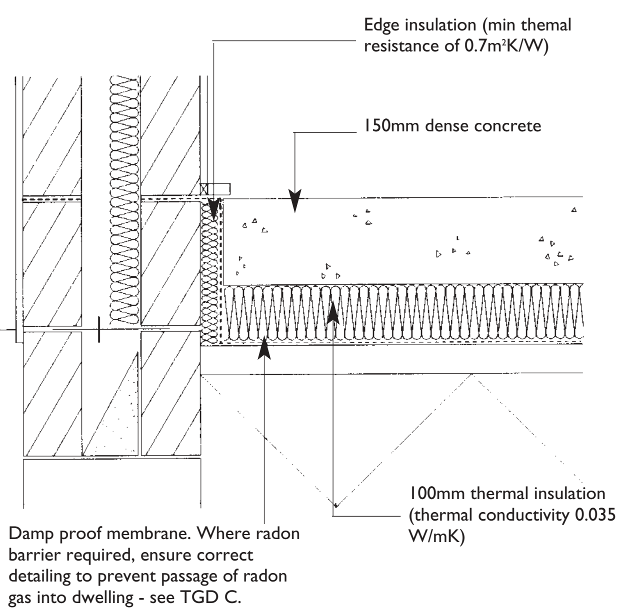
A3.2 In the case of semi-detached or terraced premises, blocks of flats and similar buildings, the floor dimensions can be taken as either those of the individual premises or those of the whole building. When considering extensions to existing buildings the floor dimensions can be taken as those of the 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 1.5.3, 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 11 *Para. A.3.1*
Concrete slab-on-ground floor



In accordance with I.S. EN ISO 13370, 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 m.
Also	B^1	=	2(8.75 x 7.25) / (8.75 + 7.25 + 7.25) = 5.457 m
Therefore	U	=	2.0 / ((0.457 x 5.457) + 6.434) = 0.22 W/m^2K.

The edge insulation to the slab is provided to prevent thermal bridging at the edge of the slab. I.S. EN ISO 13370 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 0.13, 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 and I.S. EN ISO 13789.

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.

$U_o = 1/(1/U - R_u)$ or

$U = 1/(1/U_o + R_u)$

Where: U – U-value of element adjacent to unheated space (W/m²K), taking the effect of the unheated space into account.

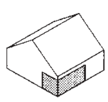
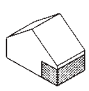
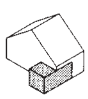
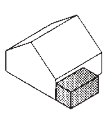
U_o – U-value of the element between heated and unheated spaces (W/m²K) calculated as if there was no unheated space adjacent to the element.

R_u – effective thermal resistance of unheated space inclusive of all external elements (m² K / W).

R_u for typical unheated structures (including garages, access corridors to flats, unheated conservatories and attic spaces) are given below.

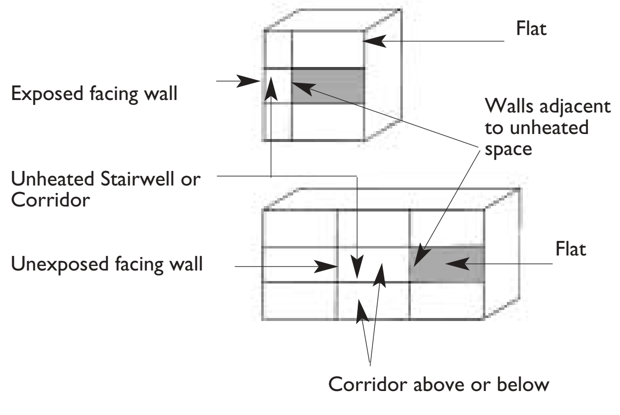
This procedure can be used when the precise details of the structure providing an unheated space are not available, or not crucial.

(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 $(0.5 \times R_u)$ for double garages when extra garage is not fully integral, and $(0.85 \times R_u)$ for fully integral double garages. Single garage means a garage for one car; double garage means a garage for two cars.

(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

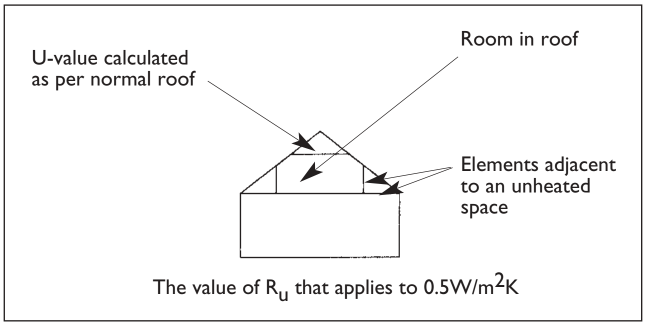
(c) **Conservatory-style sunroom**

This applies only where a conservatory – style Sunroom is not treated as a integral part of the dwelling i.e. is treated as an extension – see paragraph 1.1.2.

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

(d) **Small unheated attic spaces**

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.



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 12?

Diagram 12 *Para. B.2*
Partially filled cavity

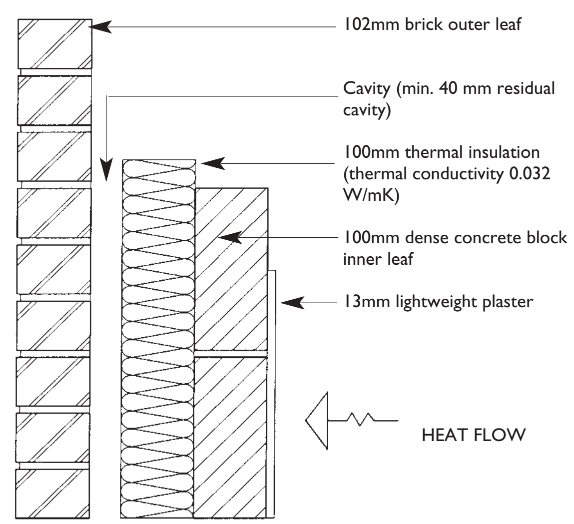
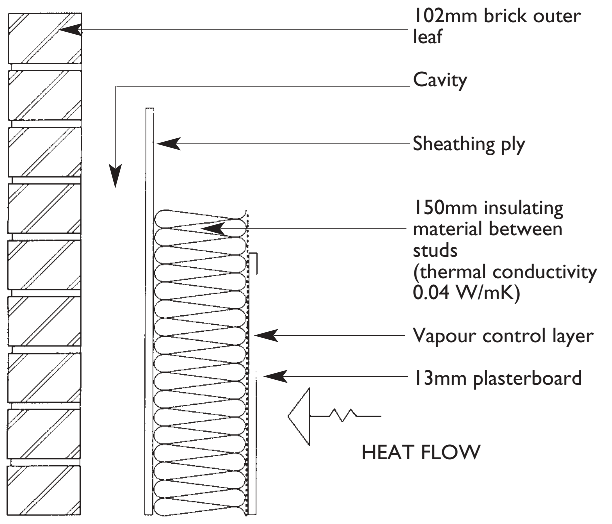


Table 14 gives U-values of 0.29 W/m^{2}K and 0.25 W/m^{2}K for 100 mm insulation of thermal conductivity of 0.035 W/mK and 0.030 W/mK respectively. By linear interpolation, the U-value of this construction, with 100 mm of insulation of thermal conductivity of 0.032 W/mK, is 0.27 W/m^{2}K.

Example B2: Timber frame wall

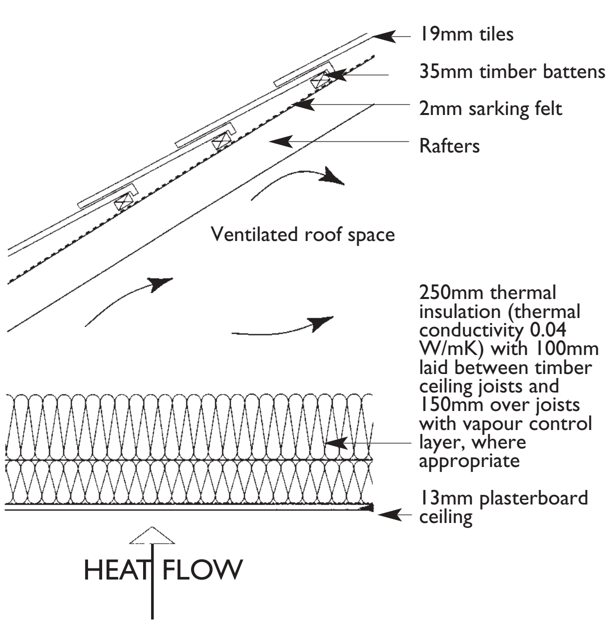
Diagram 13 *Para. B.2*
Timber frame wall



What is the U-value of this construction?
Table 19 gives the U-value for 150 mm of insulation of thermal conductivity of 0.04 W/mK as 0.27 W/m²K.

Example B3: Pitched roof

Diagram 14 *Para. B.2*
Pitched roof



What is the U-value of this construction?
Table 6 gives the U-value for 250 mm of insulation of thermal conductivity of 0.04 W/mK as 0.16 W/m² 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 15 *Para. B51.1*
Insulation between and over joists

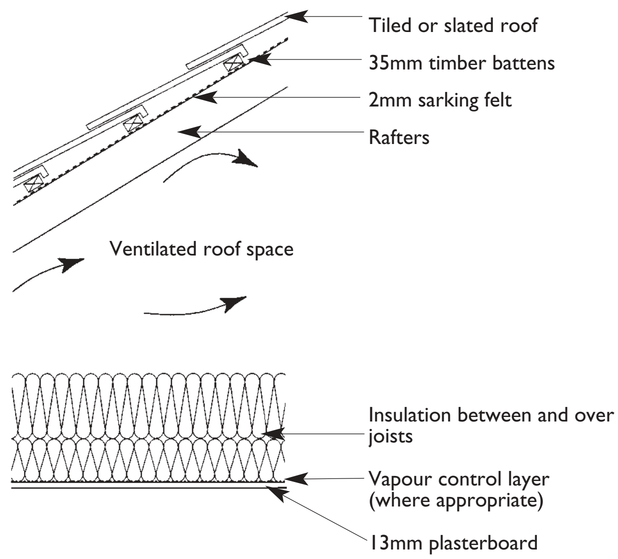


Table 6	**U-values for tiled or slated pitched roof, ventilated roof space, insulation placed between and over joists at ceiling level**				
Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
150	0.26	0.24	0.21	0.18	0.15
175	0.23	0.20	0.18	0.15	0.13
200	0.20	0.18	0.15	0.13	0.11
225	0.18	0.16	0.14	0.12	0.10
250	0.16	0.14	0.12	0.10	0.09
275	0.14	0.13	0.11	0.09	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 8%.

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

Provision of adequate roof space 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^{o}, 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 16 *Para. B.5.1.2*

Insulation between and below joists

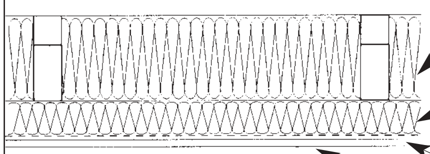


Table 7 **U-values for tiled or slated pitched roof, ventilated roof space, insulation placed between and below joists at ceiling level**

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	0.26	0.26	0.25	0.25	0.24
20	0.24	0.24	0.23	0.23	0.22
30	0.23	0.22	0.22	0.21	0.19
40	0.22	0.21	0.20	0.19	0.18
50	0.20	0.20	0.19	0.18	0.16
60	0.19	0.19	0.18	0.16	0.15
70	0.18	0.18	0.17	0.15	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	0.16	0.15	0.14	0.13	0.11
110	0.16	0.15	0.14	0.12	0.11
120	0.15	0.14	0.13	0.12	0.10

This table is derived for roofs as in Table 6 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 16).

(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 17 *Para. B.5.2.1*

Insulation between and below rafters

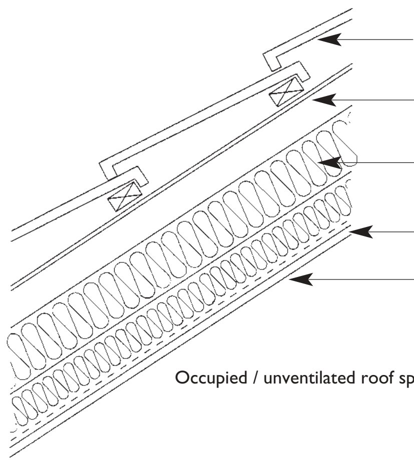


Table 8	**U-values for tiled or slated pitched roof, occupied or unventilated roof space, insulation placed between and below rafters**				
Total thickness of insulation below joists (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
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 17).
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 must be made for ventilation top and bottom of the 50mm ventilation gap on the cold side of the insulation.

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

The table above 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 18 *Para.5.2.2*
Insulation above and between rafters

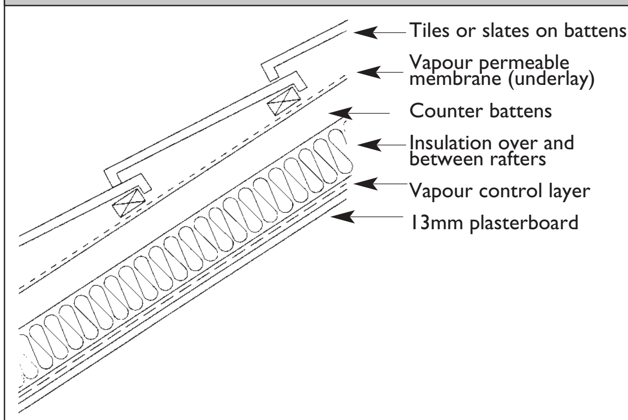


Table 9	**U-values for tiled or slated pitched roof, occupied or unventilated roof space, insulation placed between and above rafters.**				
Total thickness of insulation (mm)	Thermal conductivity of insulation (W/m K)				
	0.040	0.035	0.030	0.025	0.020
	U-Value of construction (W/m^{2}K)				
120	0.33	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:
Ties or slates, tiling battens, vapour permeable membrane (as underlay), counter battens, insulation layer over rafters, rafters with insulation of depth 100 mm 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 19 *Para. B.5.3.1*

Timber flat roof, insulation between joists

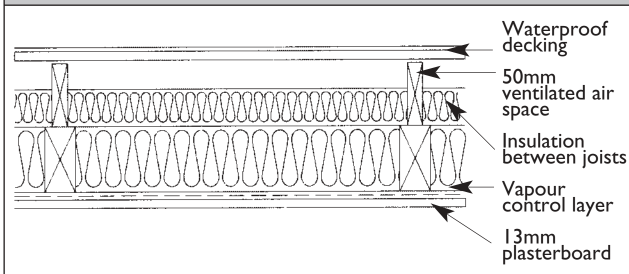


Table 10: **U-values for timber flat roof, insulation between joists, 50mm ventilated air gap between insulation and roof decking.**

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 19).
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 11: **U-values for timber flat roof, insulation between and below joists, 50mm 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 10 above, except with 100 mm of insulation of 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 20 *Para. B.5.4*

Sandwich warm deck flat roof above a concrete structure

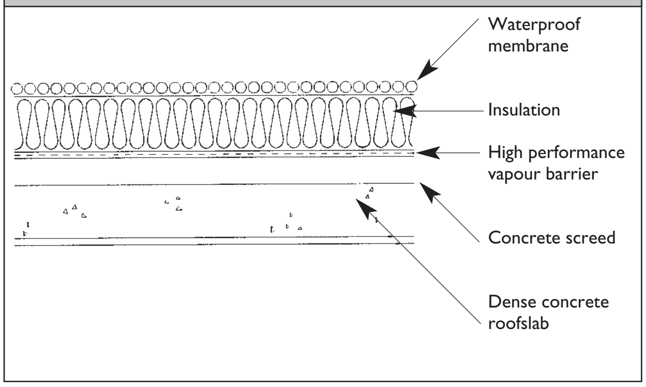


Table 12: **U-values for sandwich warm deck flat roof.**

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 20).

Installation guidelines and precautions

The insulation boards are laid over and normally fully bonded to a high performance vapour barrier complying with BS 747 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 21 *Para. B.5.5*

Inverted warm deck roof with concrete structure

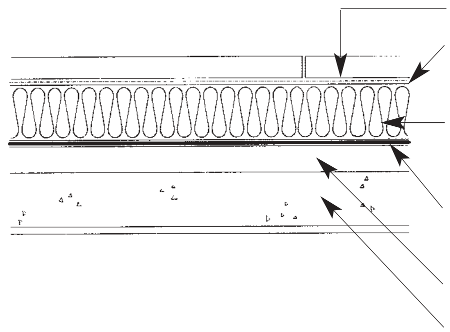


Table 13: **U-values for inverted warm deck flat roof.**

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	0.40	0.35	0.31	0.26	0.22
125	0.33	0.29	0.26	0.22	0.18
150	0.28	0.25	0.22	0.18	0.15
175	0.24	0.22	0.19	0.16	0.13
200	0.22	0.19	0.17	0.14	0.11
225	0.19	0.17	0.15	0.13	0.10
250	0.18	0.16	0.14	0.11	0.09
275	0.16	0.14	0.12	0.10	0.08
300	0.15	0.13	0.11	0.10	0.08

This table is derived for roofs with:
50 mm gravel ballast (λ = 2.0) over insulation over 10 mm mastic asphalt (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 thicknesses have been increased by 20% to balance loss of performance due to rain water flow. (See Diagram 21).

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 weatherproof 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.

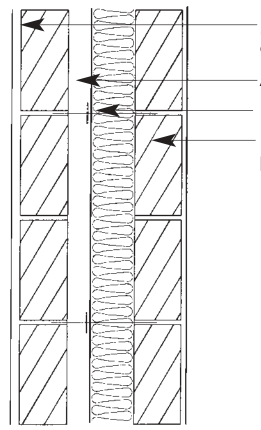
Thermal bridging at roof / wall junctions should be avoided.

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



The following tables deal with walls with maximum overall cavity width of 150mm, which is the greatest cavity width for which details of construction are given in I.S. 325. Where it is proposed to use wider cavity widths, full structural and thermal design will be necessary.

Table 14: **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 22). 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 15: **U-values for construction as Table 14 except for lightweight concrete block inner leaf.**

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	0.40	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 14, 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 1 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, tables 14 and 15 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 16 applies in this case.

Table 16: ***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 between 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)				
40	0.31	0.30	0.29	0.27	0.26
60	0.27	0.26	0.25	0.23	0.21

This table is derived for walls as in Table 14 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 8%, 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 23 *Para. B.6.2*

Cavity wall with full-fill insulation

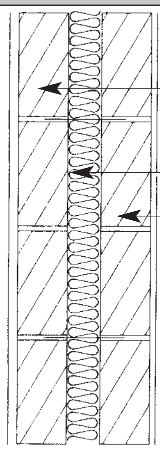


Table 17: **U-values for rendered dense concrete block external leaf, full-fill insulation dense concrete block inner leaf, plaster (or plasterboard) internal finish.**

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/m³, λ = 1.13), 13 mm dense plaster (λ = 0.57). The effects of wall ties are assumed to be negligible. (See Diagram 23).

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 18: **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 24 *Para. B.6.3.1*

Timber frame wall, insulation between framing timbers

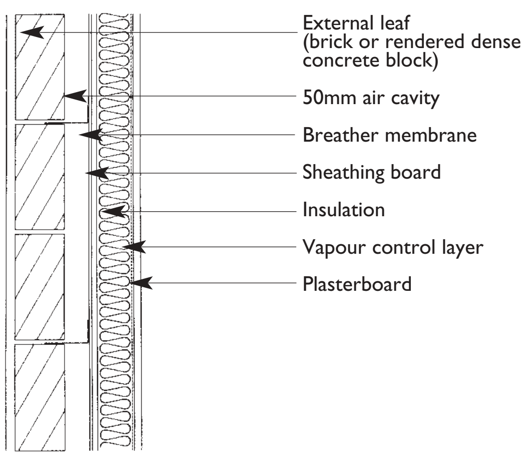


Table 19: **U-values for brick (or rendered dense concrete block) external leaf, timber frame inner leaf, insulation between timber studs, plasterboard internal finish.**

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	0.38	0.35	0.32	0.29	0.26
125	0.32	0.29	0.27	0.24	0.22
150	0.27	0.25	0.23	0.21	0.18
175	0.24	0.22	0.20	0.18	0.16

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 12%.

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 20: **U-values for brick (or rendered dense concrete block) external leaf, timber frame inner leaf, insulation between 100mm 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/m²K)				
20	0.31	0.31	0.30	0.29	0.27
40	0.27	0.26	0.25	0.23	0.21
60	0.24	0.23	0.21	0.20	0.17

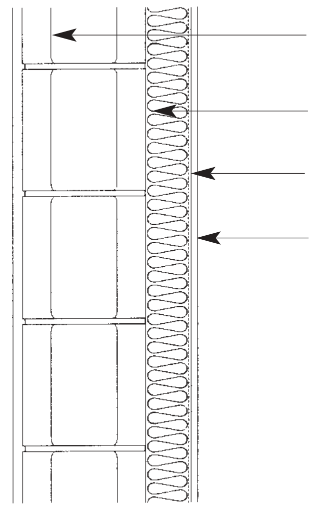
This table is derived for walls as in W3(a) above, except with 100 mm of insulation (λ = 0.04) between 100 mm studs and an additional layer of insulation as specified in the Table across the studs.

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 25 *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 21: **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)				
75	0.48	0.44	0.40	0.35	0.31
100	0.38	0.35	0.31	0.28	0.24
125	0.32	0.29	0.26	0.23	0.20
150	0.27	0.25	0.22	0.20	0.17
175	0.24	0.22	0.19	0.17	0.15

Table 21A: **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	0.61	0.56	0.51	0.45	0.38
50	0.53	0.49	0.44	0.38	0.32
60	0.47	0.43	0.38	0.33	0.28
70	0.42	0.38	0.34	0.29	0.24
80	0.38	0.34	0.30	0.26	0.22
90	0.35	0.31	0.28	0.24	0.19
100	0.32	0.29	0.25	0.22	0.18
110	0.30	0.27	0.23	0.20	0.16
120	0.28	0.25	0.22	0.18	0.15
130	0.26	0.23	0.20	0.17	0.14
140	0.24	0.22	0.19	0.16	0.13
150	0.23	0.20	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 25).
The calculations assume a fractional area of timber thermal bridging (or plaster dabs) 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.

Diagram 26 *Para. B.7.1*

Concrete slab-on-ground floor, insulation under slab

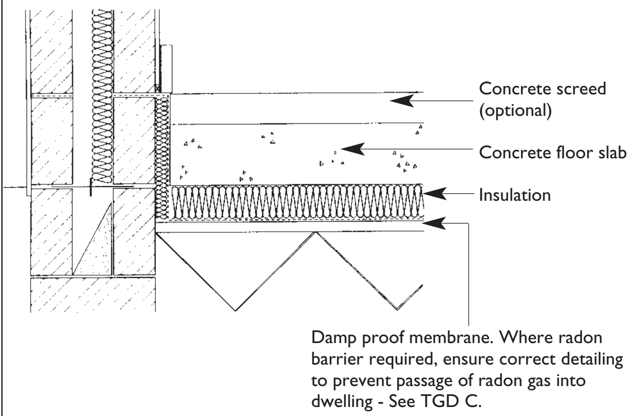
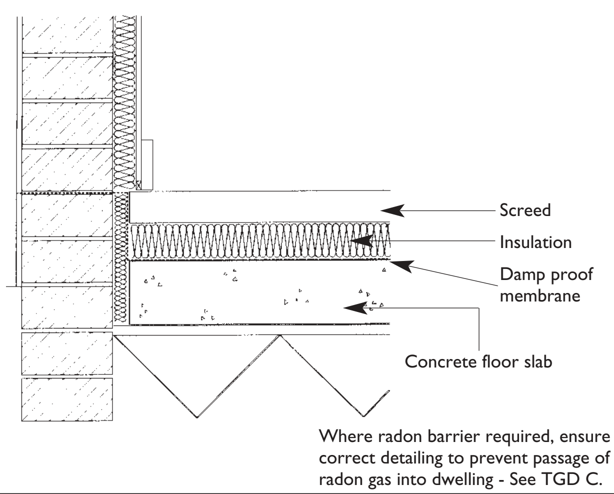


Diagram 27 *Para. B.7.1*

Concrete slab-on-ground floor, insulation under screed



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

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 22 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 23 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/m²K and full thickness of walls taken to be 0.3m.

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 22: **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 23: **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 (mm)				
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.

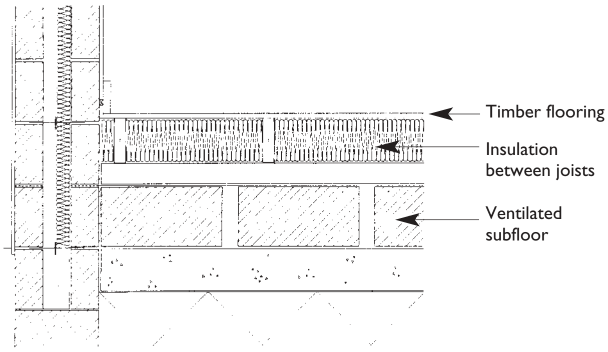
To minimise thermal bridging at floor-wall junctions, edge insulation of minimum thickness 25 mm should be placed vertically at the edge of the screed at the floor perimeter. With internally insulated external walls (including timber-frame), the floor perimeter insulation should meet the wall insulation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

Diagram 28 *Para. B.7.2*

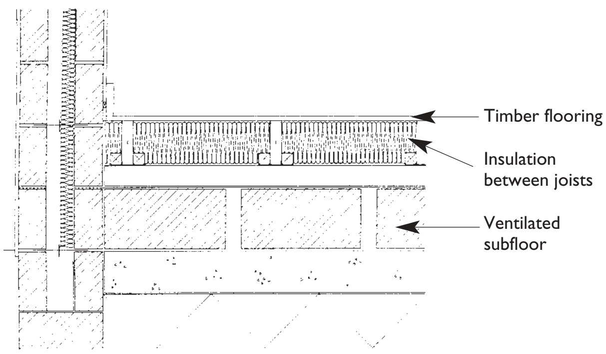
Suspended timber floor with quilt insulation



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

Diagram 29 *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 24: **Suspended timber ground floors: Insulation thickness required for U-value of 0.25 W/m^{2}K.**

P/A (m^{-1})	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	28	23
0.2	97	88	79	70	60
0.3	119	108	96	85	73
0.4	130	118	106	93	81
0.5	137	124	111	98	85
0.6	142	129	115	102	88
0.7	145	132	118	105	91
0.8	148	134	121	107	92
0.9	150	136	122	108	94
1.0	152	138	124	110	95

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 28 and 29).
A fractional area of timber thermal bridging of 12% 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 30 *Para. B.7.3*

Suspended reinforced concrete floor, internally insulated walls

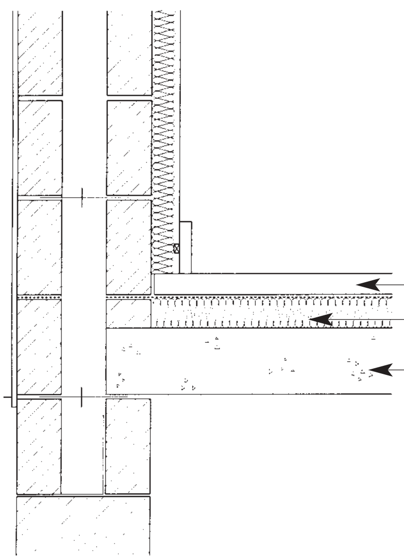


Diagram 31 *Para. B.7.3*

Suspended beam and block floor

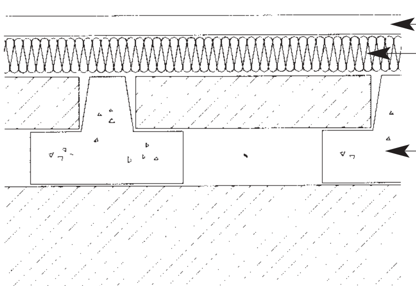


Table 25: **Suspended concrete ground floors: Insulation thickness required for U-value of 0.25 W/m²K.**

P/A (m^{-1})	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 30 and 31).
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 32 *Para. B.7.4*

Exposed timber floor, insulation between joists

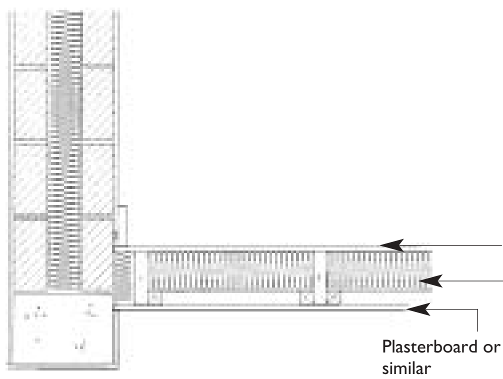


Table 26: **U-values for exposed timber floors, insulation between timber joists, plasterboard finish.**

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	0.42	0.38	0.35	0.32	0.28
120	0.36	0.33	0.30	0.27	0.24
140	0.31	0.29	0.26	0.24	0.21
160	0.28	0.26	0.23	0.21	0.19
180	0.25	0.23	0.21	0.19	0.17
200	0.23	0.21	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 12%. (See Diagram 32)

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 33 *Para. B.7.5*

Exposed concrete floor, external insulation

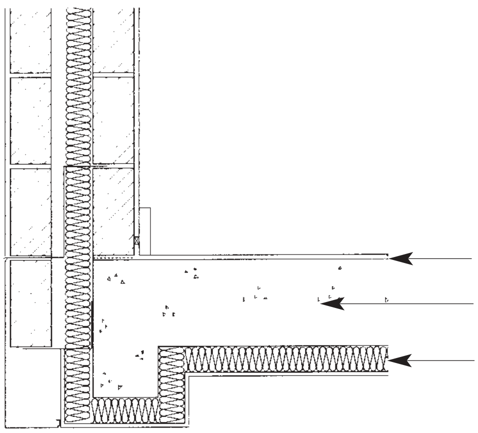


Table 27: **U-values for exposed concrete floors, external insulation, external render**

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 33).

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 33.

Table 28: **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	2.8	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	2.7	3.0	3.5
		12	2.1	2.4	2.9
		16	2.0	2.3	2.8
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	2.9	3.4
		12	2.1	2.4	2.9
		16	2.0	2.3	2.8
	0.1 (soft low-E glass)	6	2.4	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	2.0	2.5
	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	2.2	2.7
		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 a proportional basis. U-value is inverse of resistance.			

Appendix C Heat Energy Rating: Standard Calculation Method

GENERAL

C.1 This Appendix presents the procedure for the calculation of the Heat Energy Rating (HER) and Maximum Permissable Heat Energy Rating (MPHER) of a dwelling. The Heat Energy Rating is a measure of the annual energy requirements of the dwelling for space heating and domestic hot water for standardised conditions. It takes account of

- energy requirements associated with heat loss through the fabric, including loss at thermal bridges,
- energy requirements associated with air infiltration and ventilation,
- energy requirements associated with the provision of domestic hot water,
- energy inputs associated with solar gain,
- energy inputs associated with occupancy including the use of energy-using appliances,
- the heating system responsiveness to demand and it's degree of control.

The HER and MPHER are expressed in terms of energy requirements per unit floor area of the dwelling per annum (W/m^2/yr.).

C.2 The procedure is presented in the form of a worksheet accompanied by a number of Tables. This worksheet is appropriate for most situations. However, for particular situations such as buildings using active solar systems for space or water heating, some forms of passive solar systems or other systems making use of renewable energy sources, additional calculations may be necessary.

C.3 Boxes in which data in relation to the dwelling are to be entered are shown unshaded; boxes in which the results of calculations involving previously entered data are to be placed are shown shaded. Where there is no relevant data, boxes should be left blank.

OVERALL DWELLING DIMENSIONS

C.4 The dwelling is considered in terms of individual floors up to a maximum of three. For each floor, enter the floor area in Box (1), (2) and (3), as appropriate. For the ground or lowest floor, the average storey height is taken between floor surface and ceiling surface. For other floors, the average storey height is taken between the ceiling surface of the storey below and the the ceiling surface of the storey in question. The average storey height is entered in Box (4), (5) and (6) as appropriate. For any part of the building not included in the one, two or three storey categories, enter the total floor area in Box (10) and the total volume in Box (11). These Boxes may also be used to enter areas and/or volumes of small parts of the dwelling which may not be conveniently included in the calculation of floor area, average storey height and volume, e.g. bay windows, dormer windows and other protruding sections of varying height. Unheated areas and conservatories, other than those treated as integral to the building in accordance with Paragraph 1.1.3, should not be included.

C.5 The basis for calculating areas and volumes is as given in Paragraph 0.15.

C.6 Wall and roof areas are net areas excluding any windows, doors or rooflights. Window, door and rooflight areas are the total areas of the relevant openings, including frames.

RATE OF HEAT LOSS THROUGH THE BUILDING FABRIC

C.7 U-values are derived in accordance with Paragraphs 0.10 and 0.12 and Appendices A and B. In general, the Worksheet allows for two types of each element. Where there are more than two types, the Areas and Rate of Heat Loss of the additional elements may be calculated outside of the Worksheet, grossed up, and the combined results entered in the "Other" category.

Heat loss due to thermal bridging should be entered in Box 31. This may be derived by calculation as outlined in Appendix D. Alternatively, where standard details as described in Par. 1.5.2 and associated references are used, heat loss at thermal bridges should be taken as 15% of heat loss through fabric elements.

RATE OF HEAT LOSS DUE TO VENTILATION

C.8 The Effective Air Change Rate is made up of three parts - a basic air change rate associated with the particular type of construction, additional air

49

changes associated with particular elements such as chimneys, flues, vents, fans, lobbies, etc., and an allowance for occupant controlled ventilation based on the sum of the basic and additional air changes.

C.9 The Basic Air Change Rate represents air leakage through the building shell including all air infiltration through cracks and unsealed gaps and is expressed in terms of air changes per hour. It includes infiltration at opening sections of windows and doors and at any fully closeable vents provided. Specific permanent openings of various kinds are not included in these figures. The basic air change rate depends on the type of construction and is adjusted in relation to the number of stories and the type of ground floor provided. Good quality construction, including compliance with Paragraph 1.6, is assumed.

When considering "type of construction", traditional masonry construction should generally be classified as "standard construction". "Sealed Construction" should only be assumed where a continuous air infiltration barrier with sealed joints and specific measures to ensure sealing at all openings, penetrations by pipes, cables, etc. are incorporated in the construction.

C.10 Large Flue means a flue with a large diameter (200 mm or greater) and large opening at the base, e.g. flue serving solid fuel open fire with or without boiler or an open coal effect gas fire.

Small Flue includes all open flues serving closed appliances which draw air from the heated area, e.g. flues to closed solid fuel appliances, gas fires and oil or gas fired boilers within the heated area. Balanced flues are not included.

Permanent Vent means a ventilation opening not designed to be fully closeable. A typical traditional wall vent would be classified as "large". For vents that are partly closeable, the area referred to is the area of opening when closed as far as possible. Such vents will generally be classified as "small". No specific ventilation allowance is made for ventilation openings which are capable of being fully closed.

A Passive Vent, as described in BRE Information Paper IP13/94, is a near vertical duct running from a kitchen, utility room or bathroom ceiling to a terminal above the roof, designed to have a similar effect as an intermittently operated fan. Extract fans and cooker hoods should be included when deriving the number of fans. Any fans forming part of a whole-dwelling mechanical ventilation system should not be included in this category.

Houses with such systems must be treated separately. (See Paragraph C.14).

C.11 Where a fan pressurisation test on a dwelling is carried out, this provides a more accurate estimate of likely air change rates. The results of this test should be used with the air change rate estimated by dividing the infiltration rate at 50 Pascals by 20. The result should be entered in Box (35). The additional air changes due to flues, vents, fans etc. should be estimated as set out in the worksheet but including only those openings specifically sealed during the pressurisation test.

C.12 In deciding on the number of sides sheltered, account should be taken of existing buildings and planting and of proposed buildings in the same development as the dwelling in question. Proposed planting should be ignored.

A side should be considered sheltered if:

- the obstacle providing shelter is at least as high as the ceiling of the uppermost storey of the dwelling,
- the distance between the obstacle and the other dwelling is less than five times the height of the obstacle,
- the angle between the line of the obstacle and the side of the dwelling is not greater than 45^0 and
- the width of the obstacle is such that at least two-thirds of the side of the dwelling falls within the triangle created by the line of the obstacle and lines drawn from the end of the obstacle at 70^0 to the line of the obstacle.

Unless the location of the dwelling is sufficiently well defined that the number of sides sheltered {Box (45)} can be clearly specified, the following should be assumed:

- for dwellings in build-up areas or forming part of a larger development assume two sides sheltered (shading factor of 0.85);

- for dwellings in open countryside or distant from other buildings of similar or greater size, assume no side sheltered (shading factor of 1.00).

C.13 The Effective Air Change Rate allows for occupant controlled ventilation. The minimum effective air change rate is assumed to be 0.5 air changes per hour, while at air change rates above 1.0 air changes per hour, additional air changes due to occupants is assumed to be negligible.

C.14 Where full mechanical ventilation, with or without heat recovery, is installed, the rate of heat loss due to ventilation should be calculated separately based on the characteristics of the dwelling construction and the system installed. The value so derived should be entered in Box (49) and the calculations on which it is based provided on a separate sheet.

WATER HEATING

C.15 The estimate for the energy content of heated water is taken from Table 29 and is based on the floor area of the dwelling as entered in Box (12).

C.16 Three types of losses are considered - Distribution Losses, Storage Losses and Primary Circuit Losses. Values for each are given in Tables 29, 30 and 31 respectively. For stored water systems using an indirect cylinder, with water heated via a heating coil and primary circuit by a boiler at some distance from the cylinder, and with a number of hot water outlets served from the storage cylinder, all three types of losses apply. For stored water systems heated by an electric immersion heater or equivalent, there are no Primary Circuit Losses. For instantaneous water heating systems with a number of hot water outlets served from a single boiler, e.g. gas multipoint heater or combi boiler, only distribution losses apply. None of the three types of losses apply to single point heaters, without storage, located at point of use.

SOLAR AND OTHER ENERGY GAINS

C.17 The solar gain data given in Table 32 are typical figures for Ireland for the orientations given. The areas of windows and other glazed areas should be entered for each orientation when known. The areas entered should be inclusive of framing. Where the orientation of the dwelling is not fixed, the total area should be shared equally between East and West orientations. This approach may also be adopted where a number of identical dwellings are being constructed with varying orientations and it is wished to avoid doing separate calculations for each dwelling.

C.18 Gains from water heating are calculated based on the figures already derived for the energy content of heated water and the associated losses.

C.19 Gains from other energy uses are given in Table 33 as a function of floor area. These are typical figures.

C.20 The effectiveness of gains in contributing to the space heat requirements of the dwelling depends on the ratio of the rate of gross heat gains to that of heat losses - given as Specific Heat Loss [Box (50)]. This ratio is calculated and entered in Box (73). Based on this the appropriate utilisation factor is found in Table 34 and entered in Box (74). The total gains already calculated [Box (72)] are multiplied by the utilisation factor to give Useful Gains [Box (75)]. This is divided by the rate of heat loss to give the average temperature rise from gains [Box (76)].

SPACE HEATING

C.21 The mean internal temperature given in Table 35 is based on the heating requirements of a typical household with the dwelling heated morning and evening and with a higher temperature maintained in the living zone (assumed to be one-third of the floor area) than in the remainder of the dwelling. For dwellings insulated to the standards required by Part L, the main factors affecting average temperatures over the heating season are the responsiveness of the heating system and the type of heating system controls used. In Table 35 four types of heating systems in terms of responsiveness are identified and three levels of heating system control.

C.22 The mean internal temperature is achieved partly through heat input from solar and other gains and partly through heat input from the space heating system provided. The temperature rise from gains is subtracted from the mean internal temperature to give the Base Temperature which must be met by the space heating system [Box (78)].

C.23 Degree-days is a measure of the extent to which the external temperature falls below a specified base temperature taking account of both temperature and time aspects. Typical degree-days for Ireland are given in Table 36 for a range of base temperatures. The appropriate value is entered in Box (79).

C.24 The energy to meet space heating demand is calculated by multiplying degree-days [Box (79)] by the specific heat loss [Box (50)] and by a conversion factor which converts the result to kWh/yr. The result is entered in Box (80).

C.25 As with water heating there may also be losses associated with space heating. The majority of space heating systems do not involve storage and thus there are no equivalents of the storage and primary circuit losses which can occur in water heating. Further it is assumed that losses from distribution pipes and ducts contribute to the specified heat energy requirement when these pipes and ducts are located within the heated space. The main distribution losses are therefore those associated with pipe and ductwork located outside the heated space - generally in the void underneath a timber ground floor, embedded in a solid concrete ground floor or in the attic space. Table 37 gives typical annual losses as a function of the dwelling plan area. The appropriate figure should be entered in Box (81).

HEAT ENERGY RATING (HER)

C.26 The HER is specified in kWh/m^2/yr and is derived by dividing the energy for space and water heating for the dwelling [Box (84)] by the dwelling floor area [Box (12)]. Compliance is assessed by comparing the calculated HER with the Maximum Permitted Heat Energy Rating [MPHER] as set out in Table 4 of this TGD.

DWELLINGS - ASSESSMENT OF COMPLIANCE ON BASIS OF HEAT ENERGY RATING

STANDARD CALCULATION WORKSHEET

1. OVERALL DWELLING DIMENSIONS

	Floor Area (m^2)		Ave. Storey Height (m)		Volume (m^3)	
Ground Floor		(1) x		(4) =		(7)
First Floor		(2) x		(5) =		(8)
Second Floor		(3) x		(6) =		(9)

Additional Parts

Floor Area (m^2) (10)

Volume (m^3) (11)

FLOOR AREA (A_f) (1) + (2) + (3) + (10) = (12)

VOLUME (V) = (7) + (8) + (9) + (11) = (13)

2. RATE OF HEAT LOSS THROUGH THE BUILDING FABRIC

ELEMENTS	Area (A) (m^2)		U-value (U) (W/m^2K)		Rate of Heat Loss (A) x (U) (W/K)
Roof (type 1)		(14) x		=	(14a)
Roof (type 2)		(15) x		=	(15a)
Wall (type1)		(16) x		=	(16a)
Wall (type 2)		(17) x		=	(17a)
Ground Floor (type 1)		(18) x		=	(18a)
Ground Floor (Type 2)		(19) x		=	(19a)
Other Exposed Floor		(20) x		=	(20a)
Element adjacent to unheated area (Type 1)		(21) x		=	(21a)
Element adjacent to unheated area (Type 2)		(22) x		=	(22a)

ELEMENTS	Area (A) (m^2)		U-value (U) (W/m^2K)		Rate of Heat Loss (A) x (U) (W/K)
Rooflights		(23) x		=	(23a)
Window (Type 1)		(24) x		=	(24a)
Window (Type 2)		(25) x		=	(25a)
Door (Type 1)		(26) x		=	(26a)
Door (Type 2)		(27) x		=	(27a)
Other		(28) x		=	(28a)

Area of External Elements

Sum of (A) = (14) + (15) +.........+ (27) + (28) = (m^2) (29)

Rate of Heat Loss through the Fabric:

Sum of (A)x(U) = (14a) + (15a) + ...+ (27a) + (28a) = (W/K) (30)

Rate of Heat Loss due to Thermal Bridging:

15% of fabric loss: (30)x0.15 = (31)

(if calculated, use calculated value -insert in box (31)

3. RATE OF HEAT LOSS DUE TO VENTILATION

a) Basic Air Change Rate — Air changes per hour (ach)

i) effect of type of construction:- standard - 0.4ach; "sealed" - 0.3ach (32)

ii) effect of height:- ((no. of storeys-1) x 0.1) ach (33)

iii) suspended timber floor:- (0.1/ no. of storeys) ach (34)

Total Basic Air Change Rate (32) + (33) + (34) = (35)

b) Effect of, Flues, Vents, Fans, etc. — m^3 per hour

i) Number of large flues/chimneys x 40 = (36)

ii) Number of small flues x 20 = (37)

Number of permanent vents

iii) - large (opening > 5000 mm^2) x 15 = (38)

iv) - small (opening < 5000 mm^2) x 8 = (39)

v) Number of passive vents x 10 = (40)

vi) Number of fans x 10 = (41)

vii) Number of ext. doors without draught lobby x 10 = (42)

Total air change rate due to chimneys, flues, vents, fans, etc. (ach)

[(36) + (37) + (38) + (39) + (40) + (41) + (42)] / (13) = (43)

Gross Air Change Rate (35) +(43) = (44)

Adjustment for Degree of Shelter

No. of sides sheltered (45)

Shelter Factor 1 - ((44) x 0.075) (46)

Adjusted Air Change Rate (44) x (46) = (47)

Effective Air Change Rate (allowing for Occupant Controlled Ventilation)

For Adjusted Air Change Rate greater than 1: = (47)

For Adjusted Air Change Rate less than 1: = 0.5 + [$(47)^2$ x 0.5]

Air changes per hour (ach) (48)

Rate of Heat Loss due to Ventilation (48) x (13) x 0.33 = (W/K) (49)

Specific Heat Loss - Fabric and Infiltration (30) + (31) + (49) = (W/K) (50)

4. WATER HEATING

Energy content of heated water (kWh/yr) [ ] (51)
(See Table 29)

Allowance for losses

Distribution Losses (kWh/yr) [ ] (52)
(See Table 29)
(for all systems other than instantaneous water heating at point of use)

Storage Losses
(for all systems with a hot water tank or cylinder)

Tank Volume (litres) [ ] (53)
Tank Loss Factor (see Table 30) [ ] (54)
Tank Losses (kWh/yr) (53) x (54) = [ ] (55)

Primary Circuit losses (kWh/yr) (See Table 31) [ ] (56)

Total Losses (kWh/yr) (52) + (55) + (56) = [ ] (57)

Energy for Water Heating (kWh/yr) (51) + (57) = [ ] (58)

5. SOLAR AND OTHER ENERGY GAINS

a) Solar Gains

Orientation	Area (m^2)		Flux (W/m^2) (See Table 32)		Shading Correction Factor		Gains (W)	
North		x		x		=		(59)
Northeast		x		x		=		(60)
East		x		x		=		(61)
Southeast		x		x		=		(62)
South		x		x		=		(63)
Southwest		x		x		=		(64)
West		x		x		=		(65)
Northwest		x		x		=		(66)
Rooflights		x		x		=		(67)

Total Solar Gains (59) + (60) + ...+ (66) + (67) = [ ] (68)

b) Other Energy Gains

	Gains (W)	
i) Water Heating $0.114 \times (.8 \times (57) + .25 \times (51))$ =		(69)
ii) Lights, appliances, cooking, occupants, etc. (See Table 33)		(70)

Total Other Gains (69) + (70) = [ ] (71)

Total Gains (68) + (71) = [ ] (72)

Gains / Loss Ratio (72) / (50) = [ ] (73)

Utilisation Factor [ ] (74)
(See Table 34)

Useful Gains (72) x (74) = [ ] (75)

Temperature Rise from Gains (K) (75) / (50) = [ ] (76)

6. SPACE HEATING

Mean Internal Temperature (K) [ ] (77)
(see Table 35)
Base Temperature (K) (77) - (76) = [ ] (78)
Degree Days [ ] (79)
(See Table 36)

		kWh/yr	
Energy to meet Space Heat Demand	$0.024 \times (79) \times (50)$ =		(80)
Allowance for losses and equipment energy use			
Distribution Losses (kWh/yr)	(See Table 37)		(81)
Equipment Energy Use (kWh/yr)	(See Table 38)		(82)

Energy for Space Heating (kWh/yr) (80) + (81) + (82) = [ ] (83)

7. HEAT ENERGY RATING (HER)

Energy for Space and Water Heating (kWh/yr) (58) + (83) = [ ] (84)

Heat Energy Rating ($kWh/m^2/yr$) (84) / (12) = [ ] (85)

At / V (29) / (13) = [ ] (86)

Maximum Permitted Heat Energy Rating ($kWh/m^2/yr$) (See Table 4) [ ] (87)

Table 29: **Domestic hot water - Energy content and distribution losses**

Floor Area (m^2)	Hot Water Energy Use (kWh/yr)	Distribution Loss (kWh/yr)
30	695	116
40	842	140
50	984	164
60	1123	187
70	1256	209
80	1386	231
90	1511	252
100	1633	272
110	1749	292
120	1862	311
130	1970	329
140	2075	346
150	2174	363
160	2270	379
170	2361	394
180	2449	409
190	2531	422
200	2610	436

Note: The energy content of hot water used and distribution losses may be estimated by interpolation in the above Table. For Floor Areas outside the range given, they may be calculated as follows:

Hot water usage = 425N + 230 (kWh)
Distribution Loss = 71N + 38 (kWh)
where $N = 0.038F - 0.00005F^2$ (for $F \leq = 300\ m^2$)
$N = 7$ (for $F>300\ m^2$)
And F = floor area (m^2).

Table 30 **Hot water cylinder storage loss factor (kWh/yr/litre)**

Cylinder insulation		Dwelling Floor area (m^2)			
Type	Thickness (mm)	> 100 m^2	75 to 100 m^2	50 to 75m^2	< 50m^2
Foam	25	4.36	3.92	3.05	2.18
	38	2.89	2.60	2.02	1.45
	50	2.17	1.95	1.52	1.09
	80	1.36	1.22	0.95	0.68
	100	1.08	0.97	0.76	0.54
	150	0.72	0.65	0.50	0.36
Jacket	80	4.36	3.92	3.05	2.18
	100	3.50	3.15	2.45	1.75
	150	2.33	2.10	1.63	1.17

NOTE 1: See par. 1.8.2 for insulation of hot water cylinders.

NOTE 2: The factors given for floor areas greater than 100 m^2 should be used in all cases where the hot water system is not provided with separate time control.

Table 31 **Primary circuit losses (kWh/yr)**

Energy Source	Dwelling Floor area (m^2)			
	> 100 m^2	75 to 100 m^2	50 to 75m^2	< 50m^2
Electric Immersion heater	0	0	0	0
Boiler with uninsulated primary pipework	611	550	428	306
Boiler with insulated primary pipework	361	325	253	181

NOTE 1: See par. 3.3.1, for insulation of pipes carrying hot water.

NOTE 2: The factors given for floor areas greater than 100 m^2 should be used in all cases where the hot water system is not provided with separate time control.

Table 32 **Solar flux through glazing (W/m2)**

	Glazing Orientation					
Glazing Type	Horizontal	Vertical				
		North	NE/NW	E.W	SE/SW	South
Single glazed	34	10	12	20	29	34
Double glazed	28	8	9	16	24	28
Double glazed with low - E coating	25	7	9	14	22	25
Triple glazed	24	7	8	13	20	24

NOTE 1: For a rooflight in a roof with pitch 5° to 70°, use the value under "North" for orientations within 30° of north and the value under "Horizontal" for all other orientations.

For a pitch of less than 5°, treat as horizontal.

For a pitch of more than 10°, treat as vertical.

NOTE 2: The data above relates to an average degree of overshading. The following correction factors apply where the degree of overshading differs from this.

Overshading	% sky blocked by obstacles	Shading correction factor
Heavy	>80	0.4
Above average	60-80	0.7
Average	20-60	1.0
Very little	<20	1.3

Table 33	**Lighting, appliances, cooking and metabolic gains**		
Floor Area (m^2)	Gains (W)	Floor Area (m^2)	Gains (W)
30	198	120	602
40	246	130	643
50	293	140	684
60	340	150	723
70	385	160	762
80	430	170	800
90	474	180	838
100	518	190	874
110	560	200	910

NOTE 1: Lighting, appliances, cooking and metabolic gains may be estimated by interpolation in the above Table.

For Floor Areas outside the range given these may be calculated as follows:
Gains = 50 + 2.2F + 75N (W)
$N = 0.038F - 0.00005F^2$ (For $F \leq 300\ m^2$)
N = 7 (for F> $300m^2$) and F = floor area (m^2)

NOTE 2: When the following equipment is present, the associated gains should be added to those derived from the above Table:

central heating pump - 10W
warm air heating system fan - 10W
mechanical ventilation system - 25W

Table 34 **Utilisation factor as a function of Heat Gain/Loss Ratio (G/L)**

G/L	Utilisation factor	G/L	Utilisation factor
1	1.00	16	0.68
2	1.00	17	0.65
3	1.00	18	0.63
4	0.99	19	0.61
5	0.97	20	0.59
6	0.95	21	0.58
7	0.92	22	0.56
8	0.89	23	0.54
9	0.86	24	0.53
10	0.83	25	0.51
11	0.81	30	0.45
12	0.78	35	0.40
13	0.75	40	0.36
14	0.72	45	0.33
15	0.70	50	0.30

NOTE: Utilisation factors for intermediate Gain/Loss ratios may be estimated by interpolation in the above Table.
Alternatively, the utilisation factor may be calculated by the formula:
Utilisation factor = 1 - exp(-18/(G/L)).

Table 35 **Mean internal temperature of dwelling (K)**

Heating System Responsiveness	Control Category		
	1	2	3
1	18.45	18.07	17.81
2	18.90	18.52	18.26
3	19.35	18.97	18.71
4	19.80	19.41	19.15

Notes:

Responsiveness Categories

1. Standard gas or oil-fired fired radiator or warm-air systems; gas, oil or direct electric room heater systems.
2. Solid-fuel fired radiator based systems with boiler external to heated space; Electricaire or equivalent warm-air systems.
3. Solid-fuel based systems with boiler within heated space. Fan-assisted electric storage heaters.
4. Electric storage heater systems (other than fan-assisted); underfloor heating.

Control Categories

1. Basic control e.g. single room thermostat plus timer.
2. Thermostatic radiator valve control, or similar.
3. Full time and temperature zone control (at least two zones).

Table 36 **Degree-days as a function of base temperature**			
Base Temperature (°C)	Degree Days	Base Temperature (°C)	Degree Days
6	287	14	1583
7	394	15	1790
8	521	16	1999
9	665	17	2209
10	835	18	2420
11	998	19	2632
12	1185	20	2845
13	1381		

Note: Degree days for intermediate base temperatures may be estimated by interpolation in the above Table.

Table 37 **Space heating distribution losses (kWh/yr)**		
Ground Floor Area (m^2)	Distribution Loss (kWh/yr)	
	Pipe/Duct in floor void or attic	Pipe/Duct embedded in ground floor
40	220	110
50	240	120
75	290	145
100	330	165
125	370	185
150	410	205
175	440	220
200	470	235
250	530	265
300	580	290

Table 38 **Additional energy consumption associated with heating and ventilation equipment**	
Equipment	Energy Consumption (kWh/yr)
Central heating pump	120
Warm Air heating system fan	150
Mechanical ventilation	300

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 the heat losses.

The guidance is based on "BRE IP 17/01 Assessing the effects of thermal bridging at junctions and around openings" and can be used to demonstrate adequate provision to limit thermal bridging when the guidance in relation to appropriate detailing of sills, jambs, lintels, junctions between elements and other potential thermal bridges contained in Paragraphs 1.5.2 and 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 Parts 1 and 2. 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 either the Overall Heat Loss method or the Heat Energy Rating 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 or the Heat Energy Rating as the case may be.

D.5 Where the guidance given in Paragraphs 1.5.2 and 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 1.5.2 and 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	
Metal box lintel	0.30
Other lintel	0.21
Sills/jambs	0.06
Junctions with external element Ground floor, intermediatefloor, 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 *Limitation of Heat Loss through Building Fabric*

E.1 The following example illustrates the application of the three methods of demonstrating the efficient limitation of heat loss through the building fabric.

The example relates to a semi-detached house.

It is assumed that the construction details at thermal bridges are in accordance with those referred to in Par. 1.5.2. It is also assumed that the constructions comply with the guidance regarding thermal bridging at edges of floors (paragraph 1.5.3) and limitation of air infiltration (paragraph 1.6).

Example E.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).

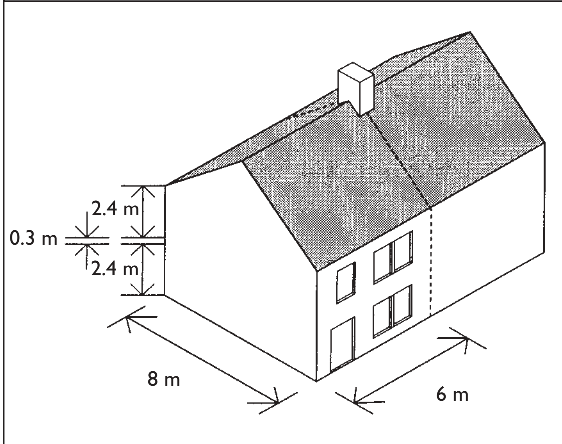
Construction:

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 34 *Para. F.2*
Semi-detached house



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 6 and 16, 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 23 and assuming an insulation thermal conductivity of 0.037 W/mK, the thickness of floor insulation required is 93 mm.

Table 2 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 (m²)	U-value	A x U
Doors	Solid Wooden	3.6	3.0	10.8
Windows	Softwood frame, Double glazed, 12mm 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 (emmissivity = 0.2) would not comply in this case.

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 3.

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 1.3.2., 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 1.3.2. 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 (m²)	U-value (W/m²K)	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) = 244.80m3

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

U_m (from Table 3) = 0.47 W/m2K.

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

HEAT ENERGY RATING METHOD

This method provides additional flexibility for the designer relative to the Overall Heat Loss method. The required calculation is described in Appendix C. The same requirement as for the Overall Heat Loss method applies in relation to the U-values of roofs, walls and ground floors.

The calculation of the Heat Energy Rating requires additional information regarding the house details as follows:

no. of chimneys/flues	1
no.of permanent vents (small)	6
no. of fans	2
draught lobbies to external doors	provide draught lobby to front
degree of shelter	2 sides sheltered
type of heating system	standard gas-fired radiator central heating system
heating system control	thermostatic radiator valves
water heating system	combined space and hot water system using 120 litre storage cylinder with 50mm factory applied foam insulation and uninsulated primary circuit and distribution pipes.

As standard construction details are used at locations of possible thermal bridges, the calculated Heat Energy Rating (HER) includes an estimate of heat loss at thermal bridges of 15% of the loss through the external fabric elements. The following assessment indicates the type of flexibility that can be achieved by this method. For this assessment, it is assumed that, in addition to providing draught lobby to front door, the window area is redistributed to provide 12.5 m^2 south facing and the remaining 6 m^2 north facing. The following construction is proposed:

- Roof U-value — 0.16 W/m^2K (250 mm insulation (thermal conductivity 0.04 W/mK) laid between and over joists (Table 6))
- Wall U-value — 0.33 W/m^2K (60mm insulation (thermal conductivity 0.025 W/mK) (Table 14))
- Floor U-value — 0.25 W/m^2K (93 mm insulation (thermal conductivity 0.037 W/mK) (Table 23))
- Window U-value — 2.30 W/m^2K (Double glazed, Low-E glass, 12mm gap, softwood frames (Table 28))
- Door U-value — 3.00 W/m^2K (solid timber doors (Table 28))

The calculation shows that the house has a HER of 91.70 kWh/m^2/yr. This is less than the calculated MPHER of 92.79 kWh/m^2/yr. The proposed construction is therefore acceptable.

Example E1 - HEAT ENERGY RATING CALCULATION

1. OVERALL DWELLING DIMENSIONS

	Floor Area (m^2)		Ave. Storey Height (m)		Volume (m^3)	
Ground Floor	48.00	(1) x	2.40	(4) =	115.20	(7)
First Floor	48.00	(2) x	2.70	(5) =	129.60	(8)
Second Floor		(3) x		(6) =	0.00	(9)
FLOOR AREA (A_f)	(1) +(2) +(3) + (10)			=	96.00	(12)
VOLUME (V) =	(7) + (8) + (9) + (11)			=	244.80	(13)

Additional Parts

Floor Area (m^2)	0.00	(10)
Volume (m^3)	0.00	(11)

2. RATE OF HEAT LOSS THROUGH THE BUILDING FABRIC

ELEMENTS	Area (A) (m^2)		U-value (U) (W/m^2K)		Rate of Heat Loss (A) x (U) (W/K)	
Roof (type 1)	48.00	(14) x	0.16	=	7.68	(14a)
Roof (type 2)	0.00	(15) x	0.00	=	0.00	(15a)
Wall (type1)	79.90	(16) x	0.33	=	26.37	(16a)
Wall (type 2)	0.00	(17) x	0.00	=	0.00	(17a)
Ground Floor (type 1)	48.00	(18) x	0.25	=	12.00	(18a)
Ground Floor (Type 2)	0.00	(19) x	0.00	=	0.00	(19a)
Other Exposed Floor	0.00	(20) x	0.00	=	0.00	(20a)
Semi-Exposed element (Type 1)		(21) x		=	0.00	(21a)
Semi-Exposed element (Type 2)		(22) x		=	0.00	(22a)

ELEMENTS	Area (A) (m^2)		U-value (U) (W/m^2K)		Rate of Heat Loss (A) x (U) (W/K)	
Rooflights	0.00	(23) x	0.00	=	0.00	(23a)
Window (Type 1)	18.50	(24) x	2.30	=	42.55	(24a)
Window (Type 2)	0.00	(25) x	0.00	=	0.00	(25a)
Door (Type 1)	3.60	(26) x	3.00	=	10.80	(26a)
Door (Type 2)		(27) x		=	0.00	(27a)
Other		(28) x		=	0.00	(28a)

Area of Exposed and Semi-exposed Elements (A_t): (m^2)
Sum of (A) = (14) + (15) +.........+ (27) + (28) = 198.00 (29)

Rate of Heat Loss through the Fabric:
Sum of (A)x(U) = (14a) + (15a) + ...+ (27a) + (28a) = 99.40 (W/K) (30)

Rate of Heat Loss due to Thermal Bridging:
15% of fabric loss: (30) x 0.15 = 14.91 (31)
(if calculated, use calculated value -insert in box (31)

3. RATE OF HEAT LOSS DUE TO VENTILATION

a) Basic Air Change Rate

i) effect of type of construction:- standard - 0.4 ach; "sealed" - 0.3 ach	0.40	(32)
ii) effect of height:- ((no. of storeys-1) x 0.1) ach	0.10	(33)
iii) suspended timber floor:- (0.1/ no. of storeys) ach	0.00	(34)
Total Basic Air Change Rate (32) + (33) + (34) =	0.50	(35)

b) Effect of, Flues, Vents, Fans, etc.

			m^3 per hour	
i) Number of large flues/chimneys	1.00	x 40 =	40.00	(36)
ii) Number of small flues	0.00	x 20 =	0.00	(37)
Number of permanent vents				
iii) - large (opening > 5000 mm^2)	0.00	x 15 =	0.00	(38)
iv) - small (opening < 5000 mm^2)	6.00	x 8 =	48.00	(39)
v) Number of passive vents	0.00	x 10 =	0.00	(40)
vi) Number of fans	2.00	x 10 =	20.00	(41)
vii) Number of ext. doors without draught lobby	1.00	x 10 =	10.00	(42)

Total air change rate due to chimneys, flues, vents, fans, etc. (ach)
[(36) + (37) + (38) + (39) + (40) + (41) + (42)] / (13) = 0.48 (43)

Gross Air Change Rate (35) + (43) = 0.98 (44)

Adjustment for Degree of Shelter

No. of sides sheltered	2.00	(45)
Shelter Factor 1 - ((44) x 0.075)	0.85	(46)
Adjusted Air Change Rate (44) x (46) =	0.83	(47)

Effective Air Change Rate (allowing for Occupant Controlled Ventilation)
For Adjusted Air Change Rate greater than 1: = (47)
For Adjusted Air Change Rate less than 1: = 0.5 + [(47)^2 x 0.5]

Air changes per hour (ach) 0.85 (48)

Rate of Heat Loss due to Ventilation (48) x (13) x 0.33 = 68.54 (W/K) (49)

Specific Heat Loss - Fabric and Infiltration (30) +(31) + (49) = 182.84 (W/K) (50)

4. WATER HEATING

Energy content of heated water (kWh/yr) (See Table 32) — 1584.00 (51)

Allowance for losses

Distribution Losses (kWh/yr) (See Table 32) (for all systems other than instantaneous water heating at point of use) — 264.00 (52)

Storage Losses (for all systems with a hot water tank or cylinder)

Tank Volume (litres)		120.00	(53)
Tank Loss Factor (See Table 33)		1.95	(54)
Tank Losses (kWh/yr)	(53) x (54) =	234.00	(55)
Primary Circuit losses (kWh/yr) (See Table 34)		550.00	(56)

Total Losses (kWh/yr) (52) + (55) + (56) = 1048.00 (57)

Energy for Water Heating (kWh/yr) (51) + (57) = 2632.00 (58)

5. SOLAR AND OTHER ENERGY GAINS

a) Solar Gains

Orientation	Area (m^2)		Flux (W/m^2) (See Table 35)		Shading Correction Factor		Gains (W)	
North	6.00	x	7.00	x	1.00	=	42.00	(59)
Northeast	0.00	x		x	1.00	=	0.00	(60)
East	0.00	x		x	1.00	=	0.00	(61)
Southeast	0.00	x		x	1.00	=	0.00	(62)
South	12.50	x	25.00	x	1.00	=	312.50	(63)
Southwest	0.00	x		x	1.00	=	0.00	(64)
West	0.00	x		x	1.00	=	0.00	(65)
Northwest	0.00	x		x	1.00	=	0.00	(66)
Rooflights	0.00	x		x	1.00	=	0.00	(67)

Total Solar Gains (59) + (60) + ...+ (66) + (67) = 354.50 (68)

b) Other Energy Gains

		Gains (W)	
i) Water Heating	0.114 x (.8 x (57) + .25 x (51)) =	140.72	(69)
ii) Lights, appliances, cooking, occupants, etc. (See Table 36)		510.00	(70)

Total Other Gains (69) + (70) = 650.72 (71)

Total Gains (68) + (71) = 1005.22 (72)

Gains/Loss Ratio (72) / (50) = 5.50 (73)

Utilisation Factor (See Table 37) — 0.95 (74)

Useful Gains (72) x (74) = 954.96 (75)

Temperature Rise from Gains (K) (75) / (50) = 5.22 (76)

6. SPACE HEATING

Mean Internal Temperature (K) (see Table 38) — 18.07 (77)

Base Temperature (K) (77) - (76) = 12.85 (78)

Degree Days (See Table 39) — 1351.60 (79)

Energy to meet Space Heat Demand 0.024 x (79) x (50) = 5931.11 (80) kWh/yr

Allowance for losses

Distribution Losses (kWh/yr) (See Table 40) — 120.00 (81)

Equipment Energy Use (kWh/yr) (See Table 41) — 120.00 (82)

Energy for Space Heating (kWh/yr) (80) + (81) + (82) = 6171 (83)

7. HEAT ENERGY RATING (HER)

Energy for Space and Water Heating (kWh/yr) (58) + (83) = 8803 (84)

Heat Energy Rating ($kWh/m^2/yr$) (84) / (12) = 91.70 (85)

Standards and Other References

Standards referred to:

I.S. 161: 1975 Copper direct cylinders for domestic purposes.

I.S. 325: 1986 Part 1: Structural use of unreinforced masonry.

I.S. EN 832: 1999 Thermal Performance of Buildings – Calculation of Energy Use for Heating – Residential Buildings.

I.S. EN ISO 6946: 1997 Building components and building elements –Thermal resistance and thermal transmittance – Calculation method (ISO 6946: 1996).

I.S. EN ISO 8990: 1997 Thermal insulation – Determination of steady-state thermal transmission properties – Calibrated hot box.

I.S. EN ISO 10077-1: 2000 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: simplified method (ISO 10077-1: 2000).

I.S. EN 10077-2: 2000 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: Numerical methods for frames (ISO 10077-2: 2000).

I.S. EN ISO 10211-1: 1996 Thermal bridges in building construction – heat flows and surface temperatures. Part 1 general calculation methods.

I.S. EN ISO 10211-1: 2001 Thermal bridges in building construction – heat flows and surface temperatures. Part 2 linear thermal bridges

I.S. EN IS0 10211-2:2001 Thermal bridge in building construction - heat flows and surface temperature. Part 2 linear thermal bridges

I.S. EN 12524: 2000 Building materials and products – Hygrothermal properties – Tabulated design values.

I.S. EN ISO 12567-1: 2001 Thermal performance of windows and doors – Determination of thermal transmittance by hot box method – Part 1: Complete windows and doors (ISO 12567-1: 2000).

I.S. EN 12664: 2001 Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meters method – Dry and moist products of low and medium thermal resistance.

I.S. EN 12667: 2000 Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meters method – Products of high and medium thermal resistance.

I.S. EN 12939: 2001 Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meters method – Thick products of high and medium thermal resistance.

I.S. EN ISO 13789: 2000 Thermal Performance of Buildings – Transmission Heat Loss Coefficient – Calculation Method (ISO 13789: 1999).

I.S. EN ISO 13370: 1999 Thermal performance of buildings – Heat transfer via the ground – Calculation methods (ISO 13370: 1998).

BS 747: 2000 Reinforced bitumen sheets for roofing – Specification.

BS 1566 Copper indirect cylinders for domestic purposes Part 1: 1984 Double feed indirect cylinders.

BS 5422 : 2001 Method for specifying thermal insulating materials on pipes, ductwork and equipment (in the temperature range - 400C to + 7000C).

BS 5449: 1990 Specification for forced circulation hot water central heating systems for domestic purposes.

BS 5864: 1989 Specification for installation in domestic premises of gas-fired ducted air-heaters of rated output not exceeding 60 kW.

BS 8206: Part 2: 1992 Lighting for buildings Part 2. Code of practice for daylighting.

Other Publications referred to:

BRE Report BR262, Thermal Insulation : avoiding risks, BRE 2001

CIBSE Guide, Volume A: Design Data - Section A3: Thermal Properties of Buildings and Components, 1999

HOMEBOND "Right on Site" Issue No. 28, Building Regulations 2002 - Conservation of Fuel and Energy - Dwellings.

Architectural Heritage Protection Guidelines for Planning Authorities, Department of the Environment , Heritage and Local Government 2004.

BRE Digest 465 U-values for light steel frame construction, BRE ,2002.

BRE Report 443, Conventions for the Calculation of U-values, BRE, 2002.

BRE Information Paper 17/01 Assessing the effects of thermal bridging at junctions and around openings, BRE, 2001.

Limiting thermal bridging and air leakage: Robust construction details for dwellings and similar buildings, DEFRA and DTLR, The Stationery Office, London, 2002.