Building Regulations 1997

Technical Guidance Document L

Conservation of Fuel and Energy

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Building Regulations, 1997
Technical Guidance Document L
Conservation of Fuel and Energy

Introduction
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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.

Transitional Arrangements
In general, this document applies to works, or buildings in which a material change of use takes place, where the works or the change of use commence or takes place, as the case may be on or after 1 July, 1998. Technical Guidance Document L - **Conservation of Fuel and Energy,** dated 1991, also ceases to have effect from that date. However, the latter document may continue to be used in the case of works, or buildings in which a material change of use takes place -

- where the works or the change of use commence or takes place, as the case may be, before 1 July, 1998,

- in respect of which a Fire Safety Certificate under the Building Control Regulations, 1991 to 1994, has been granted, where the works or change of use commence or takes place, as the case may be, not later than 31 December, 2002.

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. 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 changes 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
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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 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.

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Conservation of Fuel and Energy

Building Regulations - The Requirement

Part L of the Second Schedule to the Building Regulations, 1997, provides 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.

0.1 This Technical Guidance Document is divided into four sections.

Section 1 relates to the limitation of heat loss through the building fabric.

Section 2 relates to controls for space heating and hot water supply systems.

Section 3 relates to the insulation of hot water storage vessels, pipes and ducts.

Section 4 presents a Heat Energy Rating method for dwellings which takes account of the issues dealt with in sections 1 to 3 and may be used as an alternative to those sections.

Energy Rating

0.2 The EU SAVE Directive (Council Directive 93/76/EEC) requires all Member States to draw-up and implement programmes for the energy certification of buildings. The introduction of a method of Heat Energy Rating in this Document is one of the measures being taken to implement this Directive in Ireland.

The Heat Energy Rating of a dwelling is a measure of the annual energy output for the appliance or appliances which provide space and water heating for standardised room temperatures, levels of hot water use and conditions of operation. The method is, on its own, the most integrated way of establishing that the requirements of Part L have been complied with. As such, it provides the best single indicator of overall thermal performance and the greatest scope for design flexibility. The use of the method will be promoted by the Department of Transport, Energy and Communications and the Irish Energy Centre, the latter will be making user-friendly software available for specifiers of new dwellings. This software will enable compliance with Part L to be assessed and also facilitate the provision of energy performance information in a standardised format. Such information may be used as a means of conveying to buyers the energy efficiency advantages of dwellings which comply with the Building Regulations and for marketing purposes.

General Issues

0.3 The philosophy underlying Part L of the Second Schedule to the Building Regulations is to ensure that occupants can achieve adequate levels of thermal comfort while minimising the use of scarce 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,

(c) limit the heat loss from hot water storage vessels, pipes and ducts.

0.4 For extensions not exceeding 6.5 m^2 in floor area to which the Regulations apply, 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.

0.5 Unheated ancillary areas such as conservatories, porches, garages and the like, to which the Regulations apply, do not require specific provisions for the conservation of fuel and energy provided such areas are separated from the main building by elements which satisfy the requirements of Part L.

Some conservatories may be provided with a heating facility for occasional use and for frost protection. Provided such conservatories

- are separated from the adjacent spaces by walls, doors and other opaque or glazed elements,
- are clearly intended for occupation on an occasional or seasonal basis,
- have provision for separate temperature and on/off control of the installed heating facility,
- the separating walls and floors are insulated to the level specified for semi-exposed walls and floors in the Elemental Heat Loss method (see Table 2),
- the separating windows and doors are insulated to the level specified for windows and doors in the Elemental Heat Loss method and meet the requirements regarding the limitation of air infiltration set out in par. 1.4,

no other specific provisions for conservation of fuel and energy are required.

Other conservatories and ancilliary areas should be treated as an integral part of the building and assessed for compliance with Part L on this basis.

0.6 Some commercial, industrial and storage buildings, because of the nature of their intended use, may only require a low level of space and water heating (or even no heat at all). In such buildings, specific measures for the conservation of fuel and energy may be unnecessary. As a general guide, buildings can be considered as requiring a low level of heating where the output of the space heating system does not exceed 25 watts per square metre of floor area.

Certain buildings, e.g. buildings used exclusively as holiday homes, may have limited occupancy during periods requiring space heating. A reduced level of provision for conservation of fuel and energy may be appropriate in these situations, particularly where the form of construction renders full provision difficult or costly.

Where the occupancy level or level of heating required when in use cannot be established at construction stage, the building should be treated as requiring to be fully heated and the provisions of Part L applied accordingly. It should also 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.

0.7 The measures to achieve energy efficiency given in this Document are applicable to heated buildings generally. In certain buildings requiring continuous high heating levels, e.g. nursing homes, enhanced measures to conserve fuel and energy may be appropriate.

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

0.9 The incorporation of thermal insulation in particular constructions may increase the risk of certain types of defects, such as rain penetration and condensation. Guidance on avoiding such risks will be found in relevant standards. Guidance on good design and construction practice pertaining to thermal insulation generally is contained in the publication “Thermal insulation: avoiding risks; Building Research Establishment” (Ref BR 262). Technical Guidance Document F - Ventilation, includes guidance on the provision of ventilation to reduce the risk of condensation. The guidance given in these documents is not exhaustive and designers and builders may have well established details using other materials which are equally suitable.

0.10 Thermal conductivity (i.e. λ-value) relates to a material or substance and is a measure of the rate at which that material or substance allows heat to pass through it. It is expressed in units of Watts per metre per degree (W/mK). Thermal transmittance (i.e. U-value) relates to a building component or structure and is a measure of the rate at which heat passes through the component or structure when a difference in air temperature is maintained between one side and the other. It is expressed in units of Watts per square metre per degree of air temperature difference (W/m^{2}K). U-values and λ-values are dependent on a number of factors and certified test results for particular materials, products or components should be used, where available. In the absence of such information, values may be taken from reference tables in this Document or, in the case of U-values, may be calculated.

0.11 Calculation of U-values is dealt with in Appendix A. Calculations should be carried out to a minimum of two decimal places. 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 0.1m^{2}K/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.

Table 5 in Appendix A contains λ-values for some common building materials. This table is primarily based on data in Section A3 of the CIBSE Guide. It provides a general indication of the thermal conductivities which may be expected for these materials. However, values for particular products may differ from these illustrative values and certified test data should be used in preference.

0.12 Appendix B contains tables and examples of their use which, for some common constructions, 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 thermal bridging where appropriate. Table 20 in Appendix B contains indicative U-values for windows, doors and rooflights.

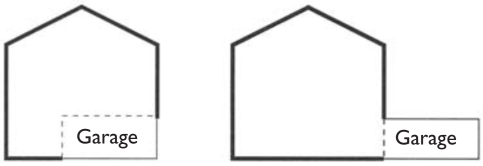
0.13 Linear measurements for the calculation of wall, roof and floor areas and building volumes should be taken between the finished internal faces of the appropriate external building elements and, in the case of roofs, in the plane of the insulation. Linear measurements for the calculation of the areas of window, rooflight and door openings should be taken between internal faces of appropriate sills, 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. Similarly, "floor area" means the gross floor area including the area represented by such non-useable space.

0.14 In this Document

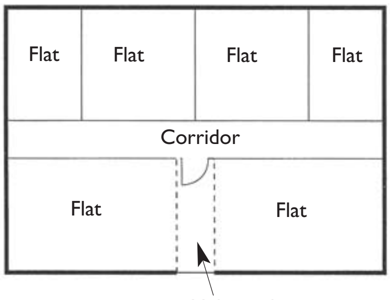
Exposed element means an element exposed to the outside air (including a suspended floor over a ventilated or unventilated void), or an element in contact with the ground.

Semi-exposed element means an element separating a heated space from an enclosed unheated space which has exposed elements which do not meet the recommendations for the limitations of heat loss through the building fabric set out in Section 1 (see Diagram 1) .

Diagram 1 **Examples of semi-exposed elements** *Par. 0.14*



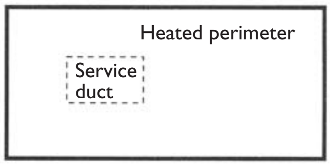
1. HOUSES



2. FLATS

Where the exposed walls at the ends of the corridor are insulated and glazed so as to comply with the recommendations of Section 1, the walls that face into the corridor have no insulation requirements.

Where the exposed wall to the unheated stairway does not comply with the recommendations in Section 1, the walls that face into the stairway are semi-exposed.



3. OTHER BUILDINGS

Where the roof and the floor to the service duct do not comply with the recommendations of Section 1, the walls of the duct are semi-exposed.

KEY

Exposed element

Semi-exposed element

Section 1
Limitation of Heat Loss through the Building Fabric

1.1 The limitation of heat loss through the building fabric requires the limitation of both direct transmission heat loss and heat loss associated with air infiltration. Two possible methods of demonstrating an acceptable level of transmission heat loss are given in this Section:

(a) The **Overall Heat Loss** method which is applicable to all buildings;

(b) The **Elemental Heat Loss** method. While it may be used for any building, it is considered suitable for dwellings, small buildings (less than 300 m^2 floor area), small sections of large complex buildings, for material alterations, extensions and change of use situations, where it is desired to avoid detailed calculations or where other methods may not be appropriate.

For both methods, the provisions to limit thermal bridging set out in pars. 1.3.1 and 1.3.2 should also be met. When assessing transmission loss through the building fabric, fabric elements separating the main building from ancilliary areas not treated as integral parts of the building (see par. 0.5) are taken into account. Examples of the use of both methods are given in Appendix E.

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.

This Section also provides guidance regarding the limitation of uncontrolled air infiltration through the building fabric.

Overall Heat Loss

1.2.1 This method sets a maximum acceptable level of transmission heat loss through the fabric of a building in terms of the maximum average U-value (U_m) of all exposed and semi-exposed elements. The level depends on the ratio of the total area of exposed and semi-exposed elements (A_t) to the building volume (V) and is specified in Table 1. In calculating the average U-value (U_{av}), notional U-values, equal to 0.75 times the actual U-values, should be used for semi-exposed elements. The acceptable level of heat loss is expressed graphically in Diagram 2.

1.2.2 For dwellings, in addition to achieving the maximum average value set, average elemental U-values should not exceed the following:

Roofs	0.35 W/m^2K
Walls	0.55 W/m^2K
Ground floors	0.45 W/m^2K.

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

Area of Exposed & Semi-Exposed Elements/Building Volume (A_t/V) (m^{-1})	Maximum Average U-value (U_m) (W/m^2K)
≥1.25	0.60
1.1	0.62
1.0	0.64
0.9	0.66
0.8	0.69
0.7	0.73
0.6	0.79
0.5	0.86
0.4	0.97
0.3	1.15

NOTE 1: The expression $U_m = 0.42 + 0.22\ V/A_t$ can be used to establish U_m for intermediate values of A_t/V and for values below $0.3m^{-1}$.
NOTE 2: Shop access doors and display windows at the access level can be omitted when calculating the area of exposed and semi-exposed elements (A_t) and the average U-value (U_{av}).

Elemental Heat Loss

1.2.3 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 2.

1.2.4 In the case of new buildings and extensions to existing buildings, the combined area of exposed window, rooflight and personnel door openings should not exceed 22.5% of floor area. For extensions to existing buildings, this limitation may be applied to the openings and floor area of the extension alone, or to the openings and floor area of the whole building, including the extension.

Diagram 2	**Maximum average U-value (U_m) in relation to building volume (V) and total area of heat loss elements (A_t)**	*Par. 1.2.1*

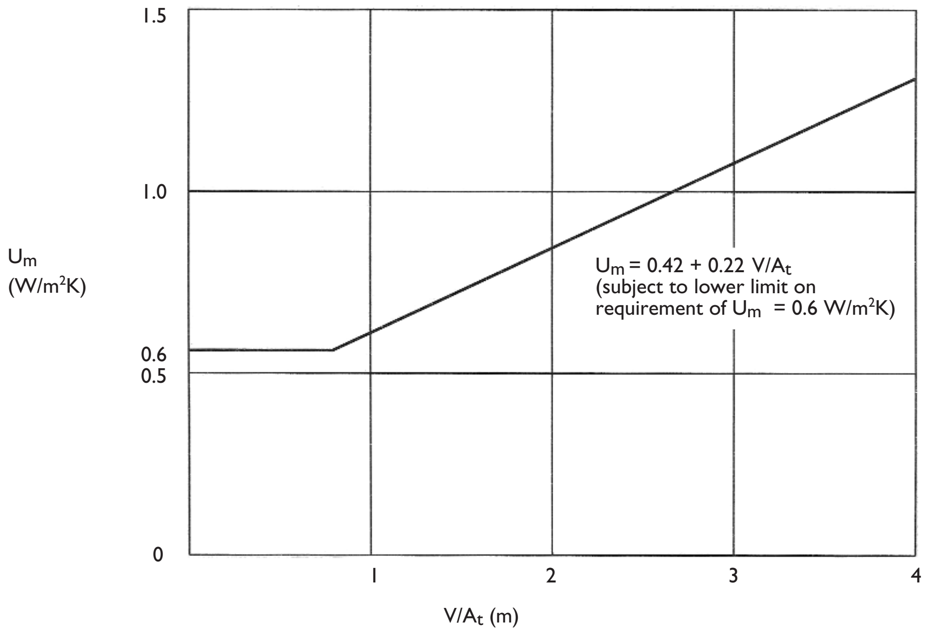


Table 2 **Maximum average elemental U-values (W/m²K)**

	New Buildings & Extensions to Existing Buildings	Material Alterations to, or Material Changes of Use of, Existing Buildings
Exposed Roofs	0.25	0.35
Exposed Walls	0.45	0.60
Exposed Floors	0.45	0.60
Ground Floors	0.45	----
Semi-exposed roofs	0.35	0.60
Semi-exposed walls	0.60	0.60
Semi-exposed floors	0.60	0.60
Exposed Windows, personnel doors and rooflights	3.30[1]	3.30
Vehicle access door	0.70	0.70

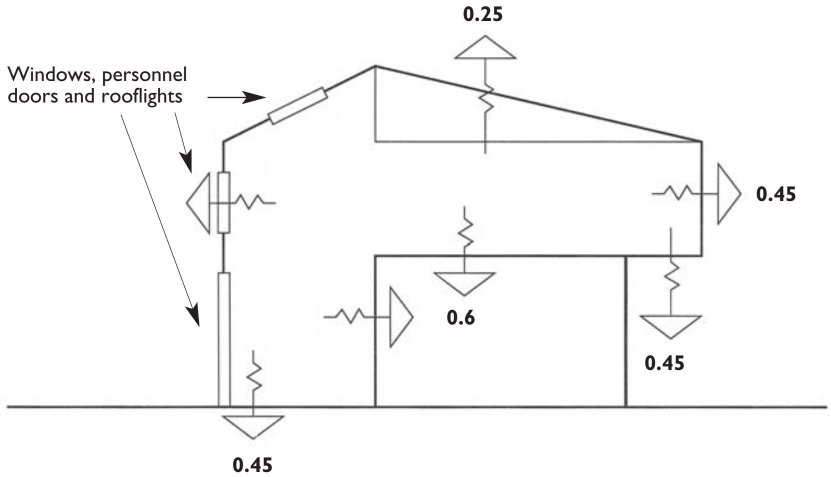
NOTE 1: Permitted average U-value of windows, personnel doors and rooflights may vary as described in par. 1.2.5 and Table 3.

Table 3 **Permitted variation in combined areas of exposed windows, personnel doors and rooflights**

Average U-value (W/m²K)	Maximum combined area of exposed windows, personnel doors and rooflights as % of floor area
2.0	41.5
2.1	39.0
2.2	36.5
2.3	34.5
2.4	33.0
2.5	31.5
2.6	30.0
2.7	28.5
2.8	27.5
2.9	26.0
3.0	25.0
3.1	24.0
3.2	23.5
3.3	22.5
3.4	21.5
3.5	21.0
3.6	20.5
3.7	19.5
3.9	18.5
4.1	17.5
4.3	16.5
4.6	15.5
4.9	14.5
5.2	13.5
5.6	12.5

NOTE 1: In meeting the requirements regarding glazing, the area of shop access doors and display windows at the access level need not be taken into account.

Diagram 3 | **Summary of elemental U-values** | *Par. 1.2.7*



NOTE

Windows, personnel doors and rooflights should have a maximum U-value of 3.3 and a maximum combined area of 22.5% of floor area. However areas and U-values can vary as set out in Table 3 and paragraph 1.2.5.

1.2.5 The levels set for the allowable average U-value of window, rooflight and personnel door openings and the combined area of these elements may be varied, provided the overall heat loss does not exceed that calculated for the maximum area and U-value specified. Table 3 indicates the variations in average U-value and area of openings that are permissible within this constraint.

1.2.6 There is a wide range of possible designs for windows, doors and rooflights. Certified U-values should be used where available. In the absence of certified data, the indicative U-values for these components given in Table 20 can be used.

1.2.7 Diagram 3 summarises the fabric insulation standards and allowances for windows, personnel doors and rooflights applicable in the Elemental Heat Loss method.

Thermal Bridging

1.3.1 Provision should be made to limit the thermal bridging which can occur around windows, doors and other wall openings in order to avoid excessive heat losses and local condensation problems. Appendix D gives information on calculation procedures which can be used to demonstrate compliance. Lintel, jamb and sill designs similar to those shown in Diagram 4 would be satisfactory and heat losses due to thermal bridging can be ignored if such designs are adopted.

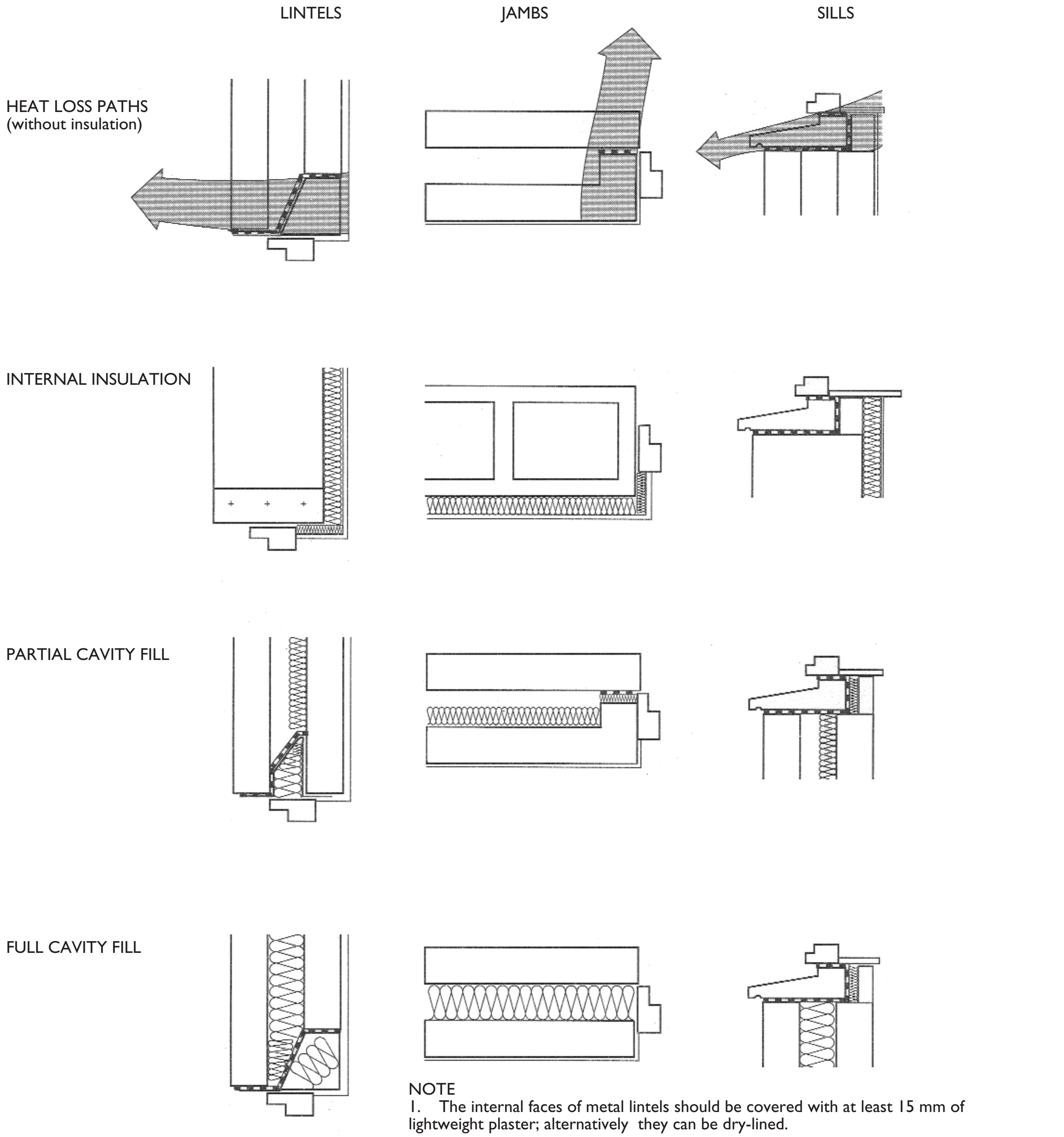
1.3.2 Care should be taken to control the risk of thermal bridging at the edges of floors. As a minimum, all slab-on-ground floors should be provided with edge insulation of minimum thermal resistance of 0.7 m^2K/W (25 mm of insulation with thermal conductivity of 0.035 W/mK, or equivalent). The vertical edge of the slab should be insulated and, in addition, the insulation should extend at least 0.5 m vertically or 1.0 m horizontally. For large floors this may be sufficient to achieve a U-value of 0.45 W/m^2K without the provision of additional insulation.

Air Infiltration

1.4 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),

Diagram 4	**Reducing thermal bridging around openings**	*Par. 1.3.1*



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.

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

Diagram 5 **Limiting air infiltration in dwellings** *Par. 1.4*

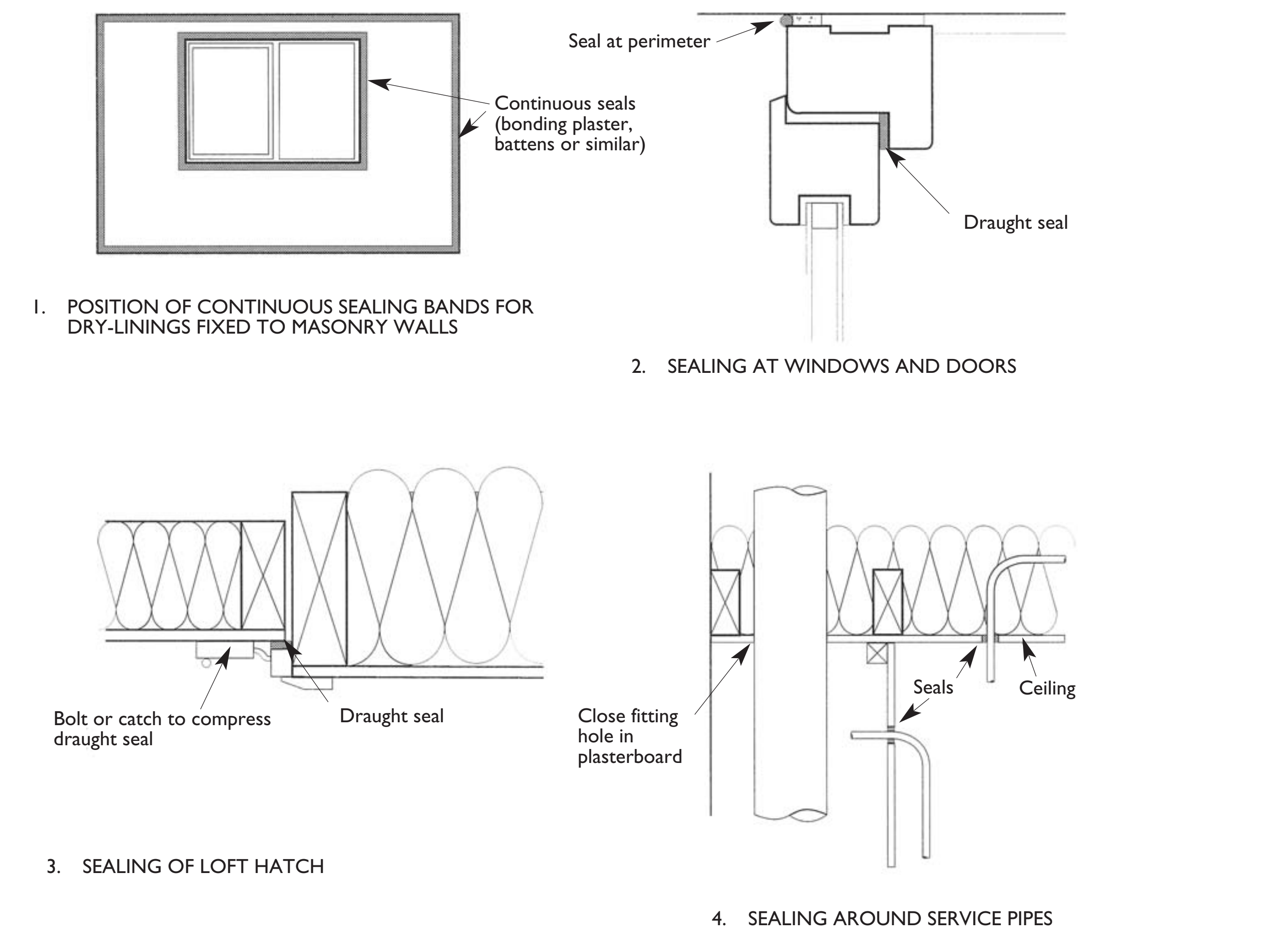


Diagram 5 illustrates some of these measures.

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

Section 2
Controls for Space Heating and Hot Water Supply Systems

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

2.1.2 The guidance in this Section covers provisions which are appropriate to the more common types of space and water heating systems. Systems not specifically referred to should achieve an equivalent level of control, where practicable. Guidance is given for dwellings and for other buildings.

Space and Water Heating Controls in Dwellings

2.2.1 Where practicable, provision should be made to control space heat emission on the basis of room temperature, e.g. by the use of room thermostats, thermostatic radiator valves, integral appliance controls or other equivalent forms of sensing devices. For larger dwellings, e.g. floor area greater than 100 m^2, with central heating systems for which zone control is appropriate, e.g. oil fired or gas fired hot water central heating systems, provision should be made for independent control in zones requiring different temperatures, e.g. sleeping areas and living areas (see Diagram 6).

2.2.2 For central heating systems capable of on-off control, provision should be made for time control to control the period when the heating systems operate.

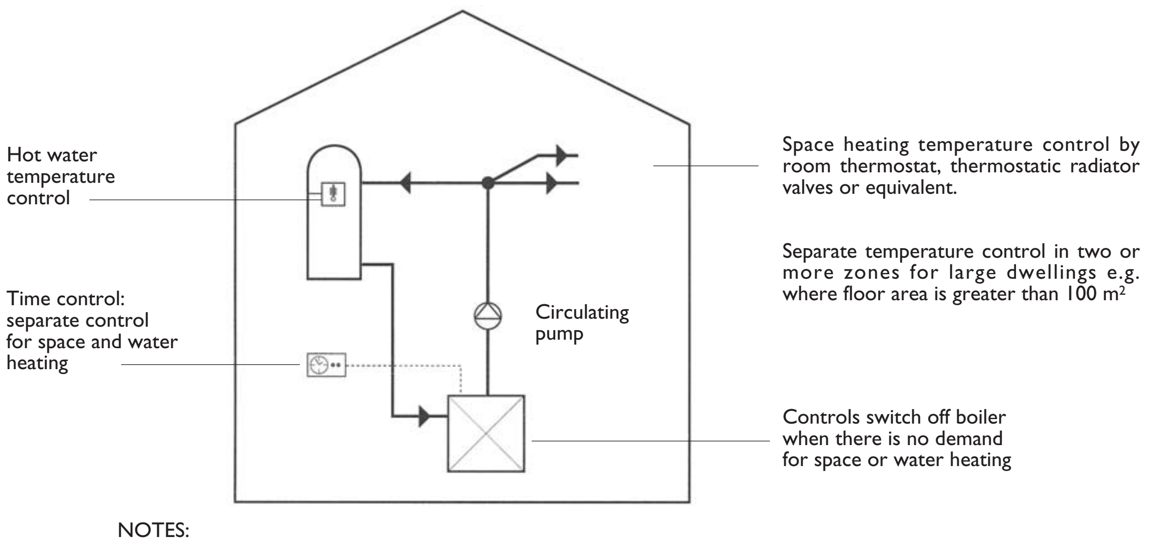
2.2.3 Hot water storage vessels, other than those providing the slumber load for solid fuel fired boilers, should be fitted with thermostatic controls which shut off the supply of heat when the desired storage temperature is reached. Time control should also be provided either as part of the central heating system or as a local device which enables the supply of heat to be shut off when water heating is not required.

2.2.4 The control of gas and oil fired hot water central heating systems 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 a flow control or other equivalent device to prevent unnecessary boiler cycling.

Space and Water Heating Controls in Other Buildings

2.3.1 Thermostats, thermostatic radiator valves, or other equivalent forms of room temperature based control should be provided for each zone of the space heating system designed to be separately controlled. Where the space heating system uses hot water, an external temperature sensing device and weather compensator controller which regulates the

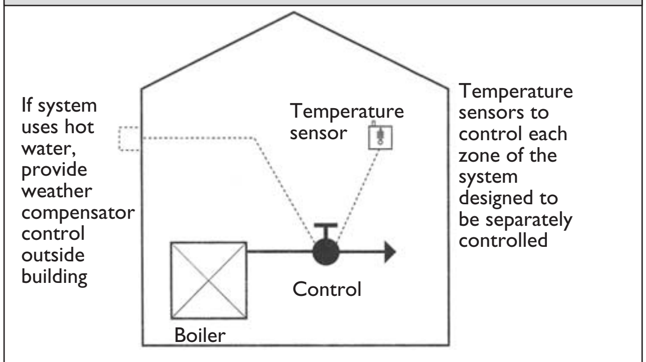
Diagram 6 **Controls for space and water heating in dwellings** *Par. 2.2.1*



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.

temperature of the water flowing in the heating system should also be provided (see Diagram 7).

Diagram 7 **Room temperature control (buildings other than dwellings)** *Par. 2.3.1*



2.3.2 Provision should be made for space heating time controls capable of limiting to specific periods heat input from the heating system to each part of the building designed to be separately controlled, e.g. the period necessary to give desired temperatures when the building is normally occupied. The following provision should suffice;

- for space heating systems with an output of 100 kW or less, clock controls which enables start and stop times to be manually set and adjusted, and

- for space heating systems with an output of more than 100kW, optimising controllers which set the start time for individual space heating systems based on the rate at which the building cools down and heats up when the heating is shut-off for a period and then re-started.

In addition, controls may be provided which allow sufficient heating, when the heating system would otherwise be switched off, to prevent damage to the building structure, services or contents, by frost, excessive humidity or condensation (see Diagram 8).

2.3.3 Where two or more gas or oil-fired boilers supply the same heat demand, a sequence controller should be provided when the total load exceeds 100 kW. This control should detect variations in heating demand and start, stop or modulate the boilers in combinations which ensure efficient operation (see Diagram 9).

Diagram 8 **Intermittent heat control (buildings other than dwellings)** *Par. 2.3.2*

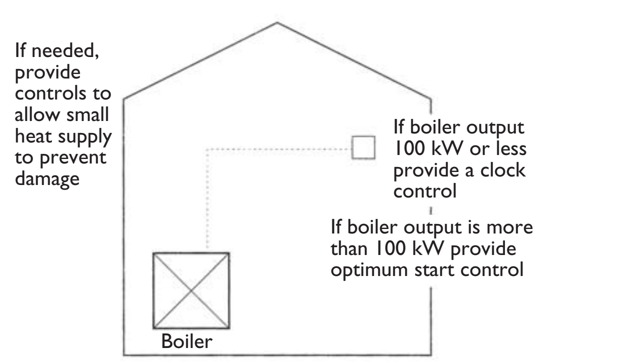
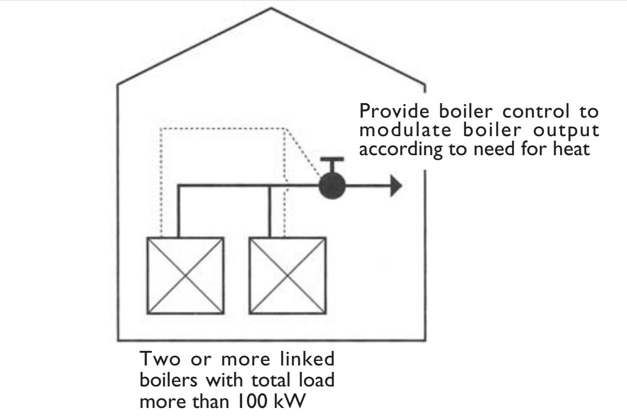


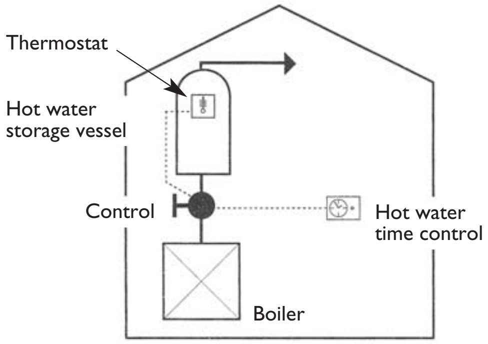
Diagram 9 **Boiler control (buildings other than dwellings)** *Par. 2.3.3*



2.3.4 Hot water storage vessels, other than those providing the slumber load for solid fuel fired boilers, should be fitted with thermostatic controls which shut off the supply of heat when the desired storage temperature is reached. Time control should also be provided either as part of the central heating system or as a local device which enables the supply of heat to be shut-off when water heating is not required (see Diagram 10).

2.3.5 The control of gas and oil fired hot water central heating systems 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 a flow control or other equivalent device to prevent unnecessary boiler cycling.

Diagram 10	**Hot water storage control(buildings other than dwellings)**	Para. 2.3.4



Alternative Methods

2.4 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;

- BS 6880 : 1988 Code of practice for low temperature hot water heating systems of output greater than 45 kW;

- CIBSE Applications Manual AM1: 1985 Automatic controls and their implications for system design.

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

3.1.1 All hot water storage vessels, pipes and ducts associated with the provision of heating and hot water in a building should be insulated to prevent heat loss except for hot water pipes and ducts within the normally heated area of the building which contribute to the heat requirement of the building. This Section does not deal with insulation requirements to protect against frost damage of vessels, pipes and ducts generally, nor does it apply to storage and piping systems for commercial and industrial processes.

Insulation of Hot Water Storage Vessels

3.2 Adequate insulation of hot water storage vessels can be achieved in one of the following ways or by alternative insulation measures giving equivalent performance:

- 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 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 should satisfy this criterion.

- In dwellings, use of an insulating jacket of such characteristics that, when tested on a 120 litre cylinder complying with I.S. 161 using the method specified in BS 5615 : 1985 Specification for insulating jackets for domestic hot water storage cylinders, standing heat losses are restricted to 2.5 kWh per 24 hours. The jacket must be installed with the segments tied together so as to provide an unbroken insulation cover for the storage vessel.

- In buildings other than dwellings, use of 50 mm thickness of insulating material having a thermal conductivity of 0.045 W/mK, or other material in a thickness giving an equivalent performance, with an outer casing to protect the insulating material.

Insulation of Pipes and Ducts

3.3.1 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:

- pipe or duct insulation meeting the recommendations of BS 5422 : 1990 Methods of specifying thermal insulating materials for pipes, ductwork and equipment (in the temperature range -40°C to + 700°C), or

- for pipes, insulation with material of such thickness as gives an equivalent reduction in heat loss as that achieved using material having a thermal conductivity of 0.045 W/mK and a thickness equal to the outside diameter of the pipe, or 40 mm, whichever is the lesser (see Diagrams 11 and 12).

3.3.2 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 for at least one metre from their point of connection or up to the point where they are concealed. The insulation should comprise 15 mm of a material having a thermal conductivity of 0.045 W/mK or other material applied in a thickness giving an equivalent performance.

3.3.3 It should be noted that water-carrying pipes in unheated areas may need increased insulation thickness for the purpose of protection against freezing. Guidance on suitable protection measures is given in BRE Report 262 Thermal insulation: avoiding risks.

Diagram 11 **Insulation of hot water storage vessels and pipes** *Par. 3.3.1*

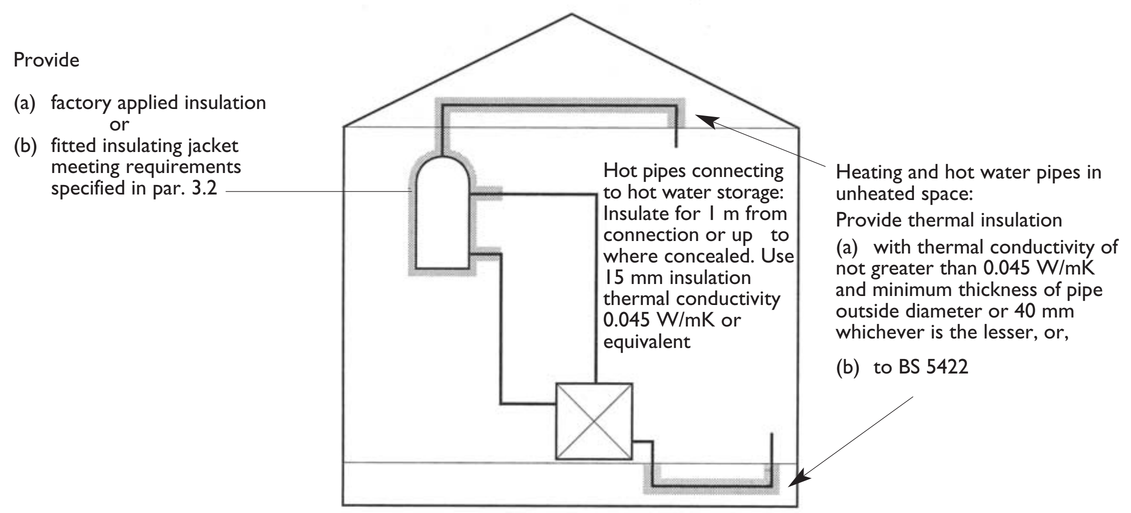
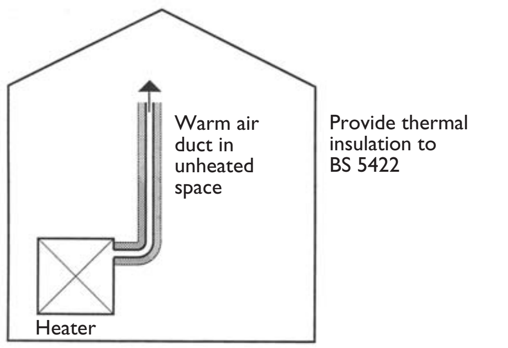


Diagram 12 **Insulation of warm air ducts** *Par. 3.3.1*



Section 4
Heat Energy Rating of Dwellings

4.1 The Heat Energy Rating (HER) of a dwelling is a measure of the annual energy output from the appliance or appliances which 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, which involves the calculation of the energy required to:

(a) offset transmission and air infiltration heat losses through the building fabric,

(b) offset heat losses associated with ventilation, and

(c) provide for domestic hot water.

Solar gain and internal heat gains are taken account of in the calculation as are the type of heating system and its controls. The rating is specified in terms of energy output per unit floor area (kWh/m^2/yr). User-friendly software for the performance of the necessary calculations will be made available by the Irish Energy Centre.

4.2 Subject to par. 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 trade-off between levels of insulation and other measures, e.g. controlled air infiltration and ventilation, provision for solar gains, space and water heating system controls.

4.3 In addition to achieving the target MPHER value set in Table 4, the following should also be satisfied:

(a) average elemental U-values should not exceed the following:

roofs	0.35 W/m^{2}K
walls	0.55 W/m^{2}K
ground floors	0.45 W/m^{2}K

(b) the provisions regarding thermal bridging specified in pars. 1.3.1 and 1.3.2;

(c) the provisions regarding air infiltration specified in par. 1.4;

(d) the provisions regarding controls for space and water heating systems specified in pars. 2.2.1 to 2.2.4;

(e) the provisions regarding the insulation of hot water storage vessels specified in par. 3.2; and

(f) the provisions regarding the insulation of pipes and ducts specified in pars. 3.3.1 and 3.3.2.

Table 4 **Maximum permitted heat energy rating (MPHER) as a function of building volume (V) and fabric heat-loss area (A_t)**

Area of Exposed and Semi-Exposed Elements/Building Volume (A_t/V) (m^{-1})	Maximum Permitted Heat Energy Rating (MPHER) (kWh/m^2/yr.)
1.2	138.4
1.1	132.7
1.0	127.0
0.9	121.3
0.8	115.6
0.7	109.9
0.6	104.2
0.5	98.5
0.4	92.8
0.3	87.1

NOTE: The expression MPHER = 57 A_t/V + 70 can be used to establish MPHER for intermediate values of A_t/V and for values outside the range given in this Table.

Appendix A
Calculation of U-values

General

A1.1 In general, U-values are calculated in accordance with the methods described in CIBSE Guide A3: Thermal Properties of Building Structures. Examples of the application of the calculation method to simple structures without thermal bridging and to structures with repeating thermal bridging are given below.

A1.2 U-values of ground floors and basement floors and walls in contact with the ground may be calculated by the methods described in BRE Information Papers 3/90, 7/93 and 14/94 but using a soil thermal conductivity of 2.0 W/mK, unless otherwise verified. Further details and examples of the calculation of ground floor U-values are given below.

A1.3 Thermal conductivities of common building materials are given in Table 5. For the most part, these are taken from CIBSE Guide A3.

A1.4 In the absence of specific information regarding appropriate values, the following standard values for thermal resistance of air spaces and surfaces can be used in the calculation of U-values:

Exposed walls:	outside surface	=	0.06 m^2K/W
	inside surface	=	0.12 m^2K/W
	air space (cavity)	=	0.18 m^2K/W
	air space with aluminium foil surface	=	0.35 m^2K/W
Roofs:	outside surface	=	0.04 m^2K/W
	inside surface	=	0.10 m^2K/W
	roof space (pitched)	=	0.18 m^2K/W
	roof space (flat)	=	0.17 m^2K/W
Exposed floors:	outside surface	=	0.04 m^2K/W
	inside surface	=	0.14 m^2K/W

A1.5 Thermal resistances of solid homogeneous materials (such as concrete) are calculated by dividing the thickness of the material (m) by its thermal conductivity (W/mK). Thermal resistances of masonry components with a pattern of filled or unfilled rectangular voids, e.g. hollow concrete blocks, can be calculated using the Combined Method specified in CIBSE Guide A3: 1986.

Simple Structures Without Thermal Bridging

A2.1 The U-value of an element of construction which does not contain significant thermal bridging, may be calculated by adding together the thermal resistance of the component parts of the construction, and then taking the reciprocal.

A2.2 Where the thickness of insulation required to achieve a specified U-value is sought and the conductivity of the insulation is known, the thickness is calculated as follows:

(a) Add together the thermal resistances of the component parts of the construction (exclusive of the insulation).

(b) Deduct the sum calculated from the reciprocal of the desired U-value.

(c) Multiply the answer by the thermal conductivity of the insulation material.

This is the insulation thickness required in metres.

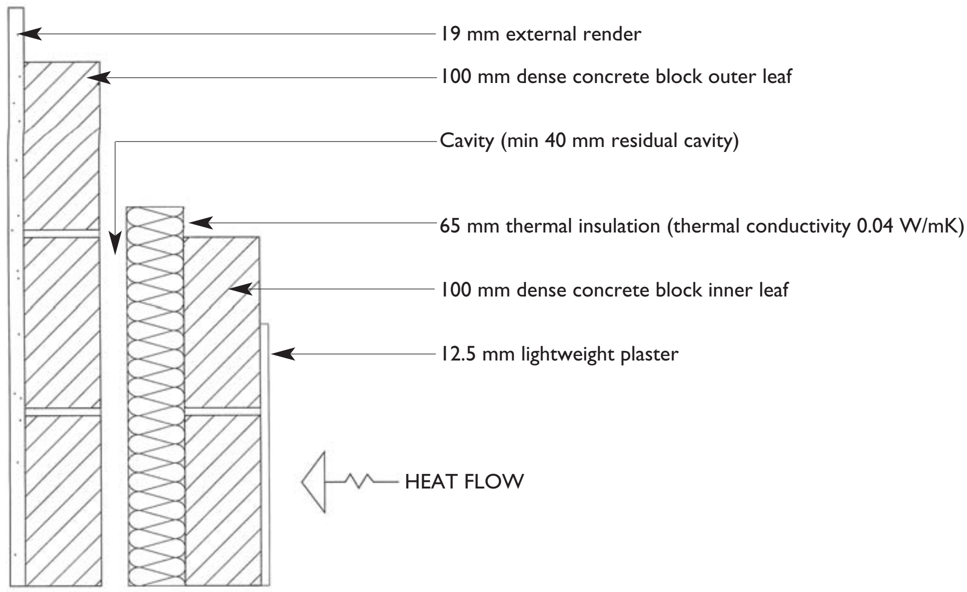
Table 5 Thermal conductivity of some common building materials

Material	Density (kg/m^3)	Thermal Conductivity (W/mK)
Walls (External and Internal)		
Fibrous cement sheet	700	0.35
Clay Brickwork (outer leaf)	1,700	0.84
Clay Brickwork (inner leaf)	1,700	0.62
Concrete Brickwork (outer leaf)	2,000	1.24
Concrete Brickwork (inner leaf)	2,000	1.13
Cast concrete (dense)	2,100	1.40
Cast concrete (lightweight)	1,200	0.38
Concrete block (heavyweight)	2,000	1.13
Concrete block (medium weight)	1,400	0.51
Concrete block (lightweight)	600	0.19
Fibreboard	300	0.06
Plasterboard	950	0.16
Tile hanging	1,900	0.84
Timber	650	0.14
Normal mortar	1,750	0.80
Surface Finishes		
External Rendering	1,300	0.50
Plaster (dense)	1,300	0.50
Plaster (lightweight)	600	0.16
Roofs		
Aerated concrete slab	500	0.16
Asphalt	1,700	0.50
Felt bitumen layers	1,700	0.50
Screed	1,200	0.41
Stone chippings	1,800	0.96
Tile	1,900	0.84
Wood wool slab	500	0.10
Floors		
Cast concrete	2,000	1.13
Screed	1,200	0.41
Timber flooring	650	0.14
Wood blocks	650	0.14
Insulation		
Expanded polystyrene (EPS) slab (HD)	25	0.035
Expanded polystyrene (EPS) slab (SD)	15	0.037
Extruded polystyrene	30	0.025
Glass fibre quilt	12	0.040
Glass fibre slab	25	0.035
Minerla fibre slab	30	0.035
Phenolic foam	30	0.040
Polyurethane board	30	0.025

NOTE 1: These values are indicative only. Certified values should be used in preference, if available.

Example 1: Calculation of U-value of External Wall

Diagram 13 **Cavity wall** *Par. A2.2*



Component part of Wall	**Thickness of Material (mm)**	**Thermal conductivity of material (W/mK)**	**Thermal Resistance (m^2K/W)**
Outside Surface	-	-	0.06
External Render	19	0.50	0.04
Concrete Block	100	1.13	0.09
Cavity	-	-	0.18
Insulation	65	0.04	1.63
Concrete Block	100	1.13	0.09
Plaster (light weight)	12.5	0.16	0.08
Inside Surface	-	-	0.12
Total Resistance	-	-	2.29

U-value of construction = 1/2.29 = 0.44 W/m^2K

Example 2: Calculation of Required Insulation Thickness

Given the construction in Example 1, what thickness of insulation (thermal conductivity = 0.037 W/mK) is required to achieve a U-value of 0.45 W/m^{2}K.

(a) Sum of component resistances:

(0.06+0.04+0.09+0.18+0.09+0.08+0.12)
= 0.66 (m^{2}K/W).

(b) Subtract from reciprocal of U value:

(1/0.45) - 0.66 = 1.56 (m^{2}K/W)

(c) Multiply by conductivity:

1.56 x 0.037 = 0.058 (m)

Thickness required is 0.058 metres or 58 mm.

Structures Containing Repeating Thermal Bridging

A3.1 The U-value of elements of construction containing discrete thermal bridges can be calculated using the proportional area method detailed in CIBSE Guide A3. Many commonly used construction elements contain repeating discrete thermal bridges. Examples 3 and 4 illustrate the method as applied to frequently encountered designs.

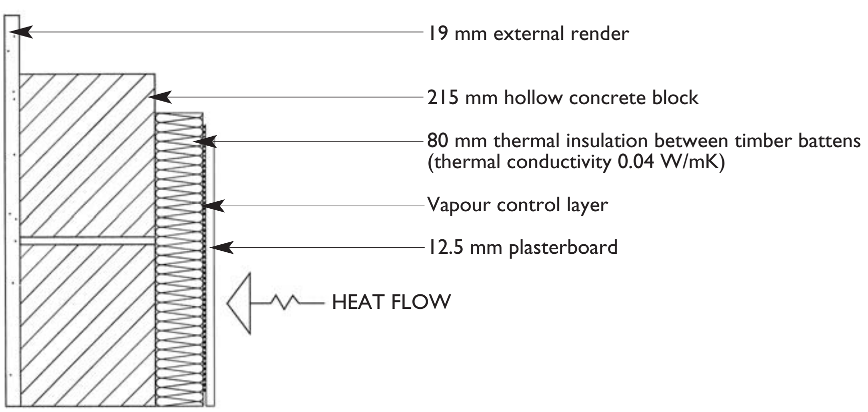
A3.2 If the element design contains a continuous cavity, or cavities, perpendicular to the direction of heat flow, the section should be divided along the centre of the cavity and the parts analysed separately. Half the cavity resistance should be assigned to each adjacent part. The calculated thermal resistances of each part are added together to get the thermal resistance of the element as a whole. Where the element design does not include such a cavity, all the element layers must be analysed together.

A3.3 Where insulation is placed between components such as timber joists in floors or roofs, and these components project freely beyond the surface of the insulation, the calculations should take the depths of the components to be the same as the depth of insulation, ignoring the effect of the projections. Where similar components project totally beyond the surface of the insulation or other adjacent material, they should be ignored in the calculation.

Example 3: Hollow Block Wall With Internal Insulation Between Battens

The fixing battens for the plasterboard dry-lining act as a thermal bridge through the insulation and must be taken into account in the calculation. The difference in resistance between the mortar joints and the concrete of the hollow concrete block is less than 0.1 m^{2}K/W, therefore the mortar joint does not constitute a thermal bridge. The construction does not have a continuous cavity so all layers must be analysed together. The thermal resistance of two

Diagram 14 **Hollow block wall** *Par. A3.1*



sections , i.e. that through the timber batten and that through the insulation, must be calculated separately and the results used to calculate the overall thermal resistance of the element.

- ***Resistance through section containing timber batten:***

	Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
External surface resistance			0.06
External render	19	0.50	0.04
Hollow concrete blockwork	215		0.21
Timber batten	80	0.14	0.57
Plasterboard	12.5	0.16	0.08
Internal surface resistance			0.12
Total Resistance through section			1.08

Note 1: Resistance of standard hollow blockwork is calculated as 0.21 m^2K/W using the "combined method" specified in CIBSE Guide A3: 1986.

- ***Resistance through section containing insulation:***

	Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
External surface resistance			0.06
External render	19	0.50	0.04
Hollow concrete blockwork			0.21
Insulation	80	0.04	2.00
Plasterboard	12.5	0.16	0.08
Internal surface resistance			0.12
Total Resistance through section			2.51

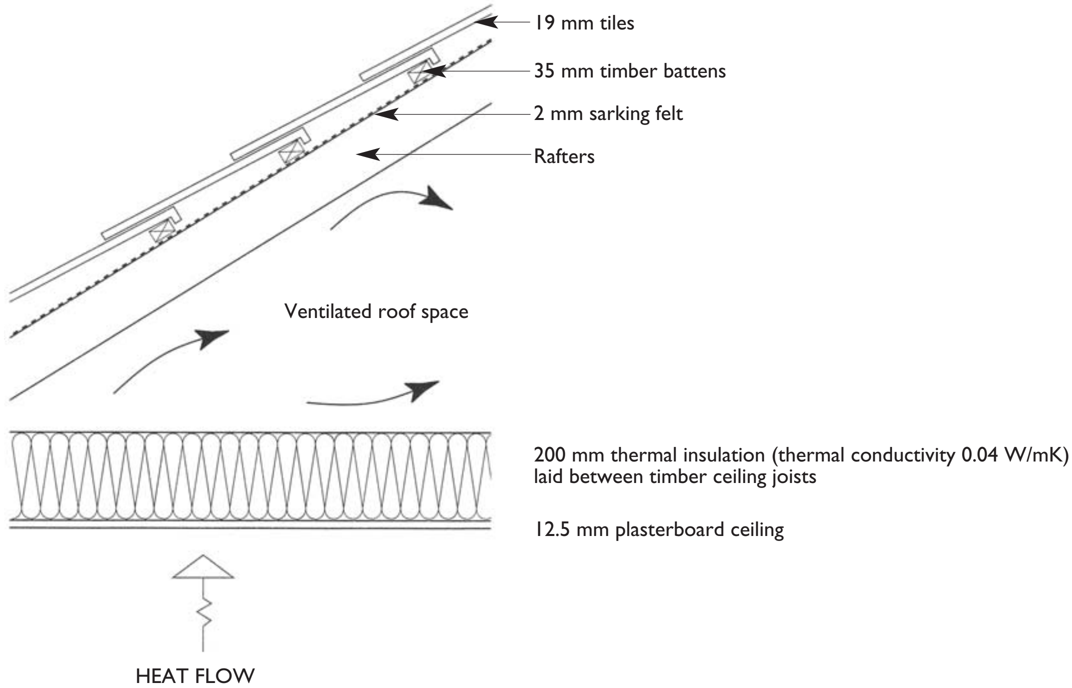
Fractional area of timber batten $= \frac{\text{thickness of batten}}{\text{batten centres}} = \frac{35}{600} = 0.058$

Fractional area of insulation $= 1 - 0.058 = 0.942$

U-value of element $= 0.058\,(1/1.08) + 0.942\,(1/2.51) = 0.43\ W/m^2K$

Example 4: Domestic pitched roof with insulation at ceiling level

Diagram 15 **Pitched roof** *Par. A3.1*



The timber joists at ceiling level act as thermal bridges through the insulation. The construction has a continuous cavity and should be considered in two parts for calculation purposes, i.e. a sloping part and a flat part. When summing the resistances of the two parts the resistance of the sloping part must be corrected by multiplying by the Cosine of the roof pitch. The roof pitch is 30°.

- **Resistance through sloping part:**

	Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
External surface resistance			0.04
Concrete tile/air gap			0.12[1]
2 mm sarking felt	2	0.2	0.01
Half cavity resistance			0.09
Total Resistance through section			**0.26**

Note 1: Standard resistance value for tiles with ventilated space between tiles and felt.

Corrected resistance = 0.26 X Cos 30° = 0.23 m^2K/W
(Roof slope = 30°)

- **Resistance through ceiling level:**

- **Resistance of section through timber joist:**

	Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
Half cavity resistance			0.09
Timber joist	100	0.14	0.71
Plasterboard	12.5	0.16	0.08
Internal Surface resistance			0.10
Total resistance through section			**0.98**

- **Resistance of section through insulation:**

	Thickness (mm)	Thermal Conductivity (W/mK)	Thermal Resistance (m^2K/W)
Half cavity resistance			0.09
Insulation	200	0.04	5.00
Plasterboard	12.5	0.16	0.08
Internal Surface resistance			0.10
Total resistance through section			**5.27**

Fractional area of timber joist $= \dfrac{\text{thickness of joist}}{\text{joist centres}} = \dfrac{34}{600} = 0.057$

Fractional area of insulation $= 1 - 0.057 = 0.943$

Resistance of ceiling level $= \dfrac{1}{\dfrac{0.057}{0.98} + \dfrac{0.943}{5.27}} = 4.22\ m^2K/W$

Total resistance of roof = corrected resistance of sloping part + resistance of ceiling level

$= 0.23 + 4.22 = 4.45\ m^2K/W$

U-value of roof $= \dfrac{1}{4.45} = 0.22\ W/m^2K$

Ground Floors

A4.1 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. Table 6, based on the method of determining ground floor U-values presented in BRE IP 3/90, gives the U-value of uninsulated ground floors of different sizes and shapes in relation to the ratio of the length of exposed perimeter to floor area. This Table can be applied to all shapes and types of uninsulated floors constructed next to the ground including slab-on-ground floors, concrete raft, suspended timber and beam-and-block floors. The Table takes account of the basic floor construction and assumes a ground thermal conductivity of 2.0 W/mK.

A4.2 In the case of semi-detached or terraced premises, blocks of flats and similar buildings, the floor dimensions can either be taken as 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.

A4.3 Table 7 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. When using this Table for suspended floors, where the resistance of the structural deck is greater than 0.2 m^2K/W, the resistance of the applied insulation should be increased by the amount by which the structural deck resistance exceeds 0.2 m^2K/W.

A4.4 For further information on floor U-values, see BRE IP 3/90. BRE IP 7/93 shows how the U-value of a floor is modified by edge insulation and BRE IP 14/94 gives procedures for basements.

A4.5 Slab-on-ground floors with minimum provision for edge insulation as specified in par. 1.3.2 achieve a U-value of 0.45 W/m^2K without extra insulation provided the ratio of exposed perimeter length to floor area is less than 0.22.

Table 6	**U-value of uninsulated ground floor as a function of floor area and exposed perimeter (U_0)**
Exposed Perimeter [P] (m) / Area [A] (m^2)	U-value [U_o] (W/m^2K)
0.1	0.30
0.2	0.51
0.3	0.70
0.4	0.88
0.5	1.04
0.6	1.18
0.7	1.30
0.8	1.41
0.9	1.50
1.0	1.57

NOTE 1: Intermediate values may be derived by linear interpolation or by use of the following equation $U_o = 0.07 + 2.36\ P/A - 0.86\ (P/A)^2$.

Table 7 **U-value of insulated ground floor as a function of floor area, exposed perimeter and thermal resistance of added insulation (U_{ins})**

Exposed Perimeter [P] / Area [A] (m^{-1})	Thermal Resistance of Added Insulation [R_{ins}] (m^2K/W)								
	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.10	0.26	0.24	0.23	0.22	0.21	0.20	0.19	0.18	0.17
0.20	0.40	0.37	0.34	0.31	0.29	0.27	0.25	0.24	0.22
0.30	0.52	0.46	0.41	0.37	0.34	0.31	0.29	0.27	0.25
0.40	0.61	0.53	0.47	0.42	0.38	0.35	0.32	0.29	0.27
0.50	0.68	0.58	0.51	0.45	0.41	0.37	0.34	0.31	0.29
0.60	0.74	0.62	0.54	0.48	0.43	0.38	0.35	0.32	0.30
0.70	0.79	0.66	0.57	0.50	0.44	0.40	0.36	0.33	0.31
0.80	0.83	0.68	0.58	0.51	0.45	0.41	0.37	0.34	0.31
0.90	0.86	0.71	0.60	0.52	0.46	0.41	0.37	0.34	0.32
1.00	0.88	0.72	0.61	0.53	0.47	0.42	0.38	0.35	0.32

NOTE 1: Intermediate values may be derived by linear interpolation or by use of the following equation $U_{ins} = 1/(1/U_o + R_{ins})$.

Appendix B
Tables of U-values of Common Constructions

B.1 For some 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.

B.2 These Tables have been derived using the proportional area method, taking into account the effects of thermal bridging where appropriate. 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.

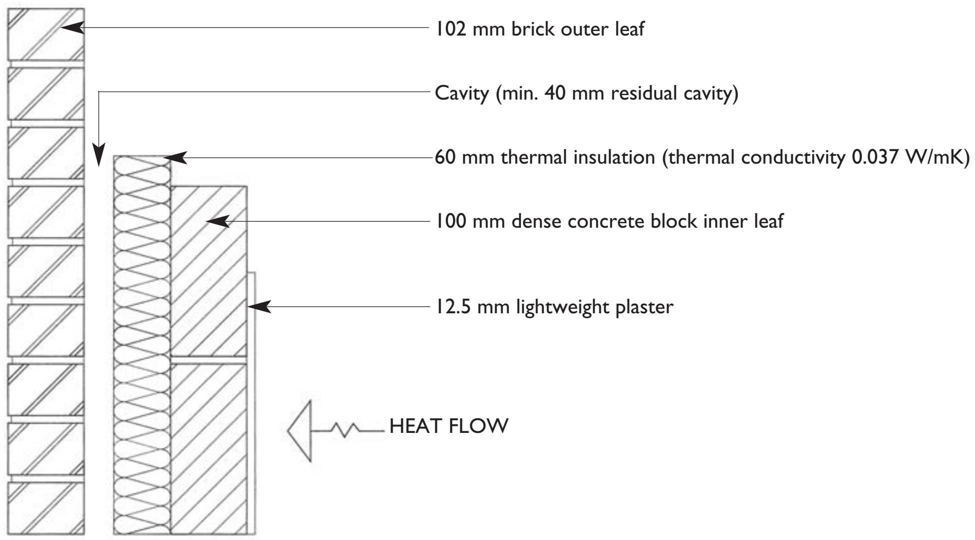
B.3 Intermediate U-values and values of required thickness of insulation can be obtained from the Tables by linear interpolation.

Example 5

Determine the U-value of the construction shown.

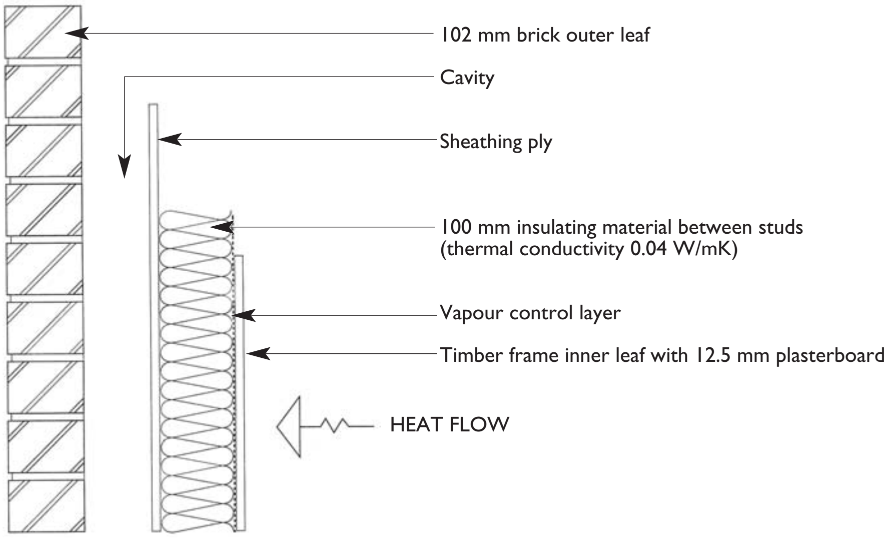
Table 14 gives U-values of 0.46 W/m^{2}K and 0.42 W/m^{2}K for 60 mm insulation of thermal conductivity of 0.04 W/mK and 0.035 W/mK respectively. By linear interpolation, the U-value of this construction, with 60 mm of insulation of thermal conductivity of 0.037 W/mK, is 0.44 W/m^{2}K.

Diagram 16 **Partially filled cavity** *Par. B.1*



Example 6

Diagram 17 **Timber frame wall** *Par. B.1*

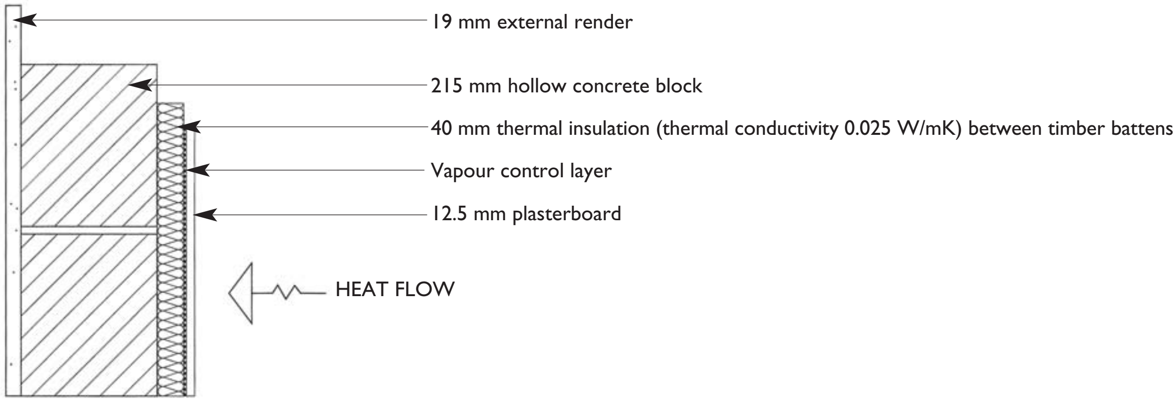


Determine the U-value of this construction.

Table 16 gives the U-value for 100 mm of insulation of thermal conductivity of 0.04 W/mK as 0.38 W/m^{2}K.

Example 7

Diagram 18 **Hollow block wall** *Par. B.1*



Determine the U-value of this construction.

Table 17 gives the U-value for 40 mm of insulation of thermal conductivity of 0.025 W/mK as 0.52 W/m^{2}K.

What thickness of insulation of this type is required to achieve a U-value of 0.45 W/m^{2}K?

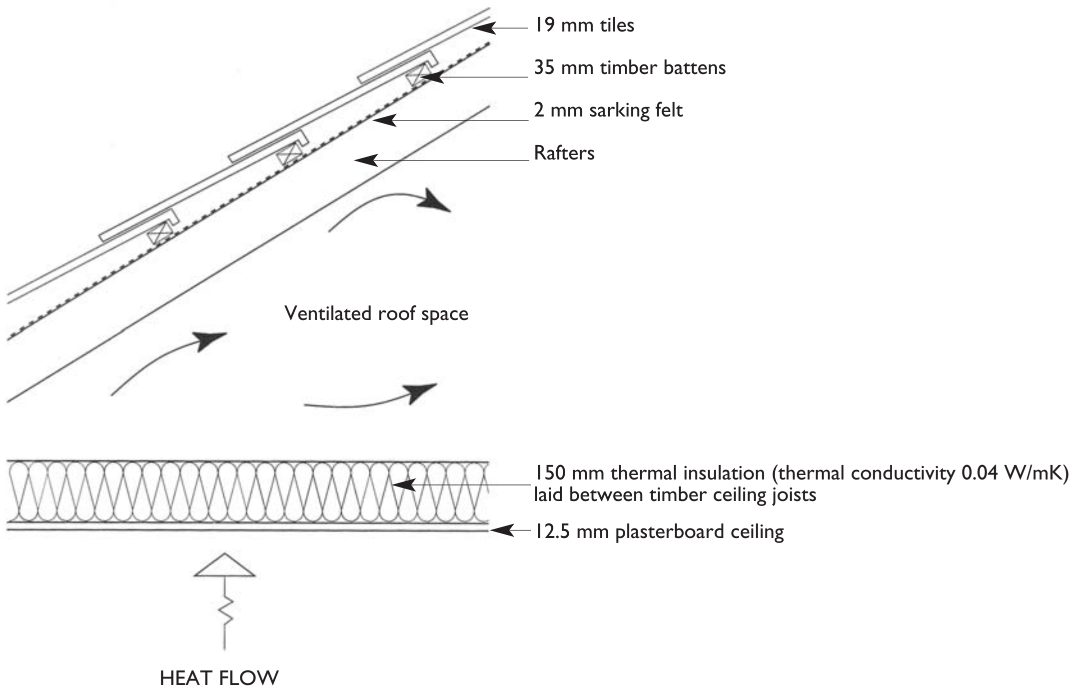
Table 17 gives U-values of 0.48 W/m^{2}K and 0.44 W/m^{2}K for thickness of insulation of thermal conductivity 0.025 W/mK of 45 mm and 50 mm respectively. By linear interpolation, the thickness required to give a U-value of 0.45 W/m^{2}K is 49 mm.

If insulation of thermal conductivity of 0.037 W/mK is used, what thickness is required to achieve a U-value of 0.45 W/m^{2}K?

Examination of Table 17 shows that the required thickness is likely to lie between 65 mm and 75 mm. By linear interpolation, the U-value of the construction with 70 mm of insulation of thermal conductivity of 0.037 W/mK is 0.45 W/m^{2}K.

Example 8

Diagram 19 **Pitched roof** *Par. B.1*



What is the U-value of this construction?

Table 8 gives the U-value for 150 mm of insulation of thermal conductivity of 0.04 W/mK as 0.28 W/m^{2}K.

What thickness of insulation of this type is required to achieve a U-value of 0.25 W/m^{2}K?

Table 8 shows that 175 mm of insulation of thermal conductivity 0.04 W/mK gives a U-value of 0.25 W/m^{2}K.

If the insulation is laid with 100 mm between the joists and the remainder over the joists, what thickness is required to achieve a U-value of 0.25 W/m^{2}K?

Table 9 shows that the total thickness of insulation required to achieve a U-value of 0.25 W/m^{2}K is 150 mm, when laid in this manner, i.e. 100 mm between the joists and 50 mm over the joists.

Roofs

Table 8 **Tiled or slated pitched roof, ventilated roof space, plasterboard ceiling, insulation between joists at ceiling level**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m²K)						
100	0.43	0.40	0.37	0.34	0.30	0.27	0.23
125	0.37	0.34	0.32	0.29	0.26	0.23	0.20
150	0.32	0.30	0.28	0.25	0.23	0.20	0.18
175	0.29	0.27	0.25	0.23	0.21	0.18	0.16
200	0.27	0.25	0.23	0.21	0.19	0.17	0.15
225	0.24	0.23	0.21	0.19	0.18	0.16	0.14
250	0.23	0.21	0.20	0.18	0.16	0.15	0.13
275	0.21	0.20	0.19	0.17	0.16	0.14	0.12
300	0.20	0.19	0.18	0.16	0.15	0.13	0.12

Table 9 **Tiled or slated pitched roof, ventilated roof space, plasterboard ceiling, 100 mm insulation between joists at ceiling level and additional insulation over joists**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m²K)						
100	0.43	0.40	0.37	0.33	0.30	0.26	0.23
125	0.35	0.32	0.29	0.26	0.23	0.20	0.17
150	0.30	0.27	0.25	0.22	0.19	0.16	0.13
175	0.26	0.24	0.21	0.19	0.17	0.14	0.11
200	0.23	0.21	0.19	0.17	0.14	0.12	0.10
225	0.21	0.19	0.17	0.15	0.13	0.11	0.09
250	0.19	0.17	0.15	0.13	0.12	0.10	0.08
275	0.17	0.15	0.14	0.12	0.11	0.09	0.07
300	0.16	0.14	0.13	0.11	0.10	0.08	0.07

Table 10 **Timber flat roof, insulation between joists, 50 mm air gap between insulation and roof decking**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m²K)						
50	0.68	0.64	0.60	0.55	0.50	0.45	0.39
60	0.60	0.57	0.53	0.49	0.44	0.39	0.34
70	0.55	0.51	0.47	0.44	0.39	0.35	0.30
80	0.50	0.47	0.43	0.40	0.36	0.32	0.27
90	0.46	0.43	0.40	0.36	0.33	0.29	0.25
100	0.42	0.40	0.37	0.33	0.30	0.27	0.23
110	0.39	0.37	0.34	0.31	0.28	0.25	0.21
120	0.37	0.34	0.32	0.29	0.26	0.23	0.20
130	0.35	0.32	0.30	0.27	0.24	0.22	0.19
140	0.33	0.30	0.28	0.26	0.23	0.20	0.18
150	0.31	0.29	0.27	0.24	0.22	0.19	0.17
160	0.29	0.27	0.25	0.23	0.21	0.18	0.16
170	0.28	0.26	0.24	0.22	0.20	0.17	0.15

Table 11	**Timber flat roof, insulation to falls over decking, unventilated air space, plasterboard ceiling**						
Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
50	0.62	0.58	0.54	0.49	0.44	0.39	0.33
60	0.55	0.52	0.48	0.44	0.39	0.34	0.29
70	0.50	0.47	0.43	0.39	0.35	0.31	0.26
80	0.46	0.43	0.39	0.35	0.32	0.28	0.23
90	0.42	0.39	0.36	0.33	0.29	0.25	0.21
100	0.39	0.36	0.33	0.30	0.27	0.23	0.20
110	0.36	0.34	0.31	0.28	0.25	0.22	0.18
120	0.34	0.32	0.29	0.26	0.23	0.20	0.17
130	0.32	0.30	0.27	0.25	0.22	0.19	0.16
140	0.31	0.28	0.26	0.23	0.21	0.18	0.16
150	0.29	0.27	0.25	0.22	0.20	0.17	0.15
160	0.28	0.26	0.23	0.21	0.19	0.17	0.14
170	0.26	0.24	0.22	0.20	0.18	0.16	0.14

Table 12	**Timber or slated pitched roof insulated on slope, insulation between rafters; 50 mm ventilated cavity between insulation and sarking felt**						
Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
50	0.67	0.63	0.59	0.54	0.48	0.43	0.37
60	0.60	0.56	0.52	0.47	0.42	0.37	0.32
70	0.54	0.50	0.46	0.42	0.38	0.33	0.28
80	0.49	0.45	0.42	0.38	0.34	0.30	0.25
90	0.45	0.42	0.38	0.35	0.31	0.27	0.23
100	0.41	0.38	0.35	0.32	0.29	0.25	0.21
110	0.38	0.36	0.33	0.30	0.26	0.23	0.20
120	0.36	0.33	0.30	0.28	0.25	0.21	0.18
130	0.34	0.31	0.29	0.26	0.23	0.20	0.17
140	0.32	0.29	0.27	0.24	0.22	0.19	0.16
150	0.30	0.28	0.25	0.23	0.20	0.18	0.15
160	0.28	0.26	0.24	0.22	0.19	0.17	0.14
170	0.27	0.25	0.23	0.21	0.18	0.16	0.14

Note: In this Table, the heated volume is assumed to extend to the sloped section of the roof. The U-value is calculated normal to the plane of this section.

Table 13 **Timber or slated pitched roof insulated on slope, 50 mm ventilated cavity between insulation and sarking felt, 50 mm insulation between rafters, remainder of insulation under rafters**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
50	0.67	0.63	0.59	0.54	0.48	0.43	0.37
60	0.59	0.55	0.51	0.46	0.41	0.36	0.30
70	0.53	0.49	0.45	0.41	0.36	0.31	0.26
80	0.48	0.44	0.40	0.37	0.32	0.28	0.23
90	0.44	0.40	0.37	0.33	0.29	0.25	0.21
100	0.40	0.37	0.34	0.30	0.27	0.23	0.19
110	0.37	0.34	0.31	0.28	0.24	0.21	0.17
120	0.35	0.32	0.29	0.26	0.23	0.19	0.16
130	0.32	0.30	0.27	0.24	0.21	0.18	0.15
140	0.30	0.28	0.25	0.22	0.20	0.17	0.14
150	0.29	0.26	0.24	0.21	0.18	0.16	0.13
160	0.27	0.25	0.22	0.20	0.17	0.15	0.12
170	0.26	0.23	0.21	0.19	0.16	0.14	0.11

Note: In this Table, the heated volume is assumed to extend to the sloped section of the roof. The U-value is calculated normal to the plane of this section.

Walls

Table 14 **Cavity wall: external leaf brick or rendered dense concrete blocks, partial fill insulation, internal leaf dense concrete block with lightweight plaster**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
40	0.69	0.65	0.61	0.56	0.50	0.44	0.38
45	0.64	0.61	0.56	0.52	0.46	0.41	0.34
50	0.61	0.57	0.53	0.48	0.43	0.38	0.32
55	0.57	0.53	0.49	0.45	0.40	0.35	0.29
60	0.54	0.50	0.46	0.42	0.38	0.33	0.27
65	0.51	0.48	0.44	0.40	0.35	0.31	0.26
70	0.49	0.45	0.42	0.38	0.34	0.29	0.24
75	0.46	0.43	0.40	0.36	0.32	0.27	0.23
80	0.44	0.41	0.38	0.34	0.30	0.26	0.21
90	0.41	0.38	0.34	0.31	0.27	0.24	0.19
100	0.38	0.35	0.32	0.29	0.25	0.21	0.18

Table 15 **Cavity wall: external leaf brick or rendered dense concrete block, full fill insulation, internal leaf dense concrete block with lightweight plaster**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
40	0.79	0.74	0.68	0.62	0.55	0.48	0.40
45	0.73	0.68	0.63	0.57	0.51	0.44	0.37
50	0.68	0.63	0.58	0.53	0.47	0.40	0.34
55	0.64	0.59	0.54	0.49	0.43	0.37	0.31
60	0.60	0.55	0.51	0.46	0.40	0.35	0.29
65	0.56	0.52	0.48	0.43	0.38	0.33	0.27
70	0.53	0.49	0.45	0.40	0.36	0.31	0.25
75	0.51	0.47	0.43	0.38	0.34	0.29	0.24
80	0.48	0.44	0.40	0.36	0.32	0.27	0.22
90	0.44	0.40	0.37	0.33	0.29	0.25	0.20
100	0.40	0.37	0.34	0.30	0.26	0.22	0.18

Table 16 **Timber frame construction: external leaf brick or rendered dense concrete block, internal leaf timber frame with plasterboard finish**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
90	0.46	0.44	0.41	0.38	0.35	0.31	0.28
100	0.43	0.40	0.38	0.35	0.32	0.29	0.26
110	0.40	0.38	0.35	0.33	0.30	0.27	0.24
120	0.38	0.35	0.33	0.30	0.28	0.25	0.22
130	0.35	0.33	0.31	0.29	0.26	0.24	0.21
140	0.33	0.31	0.29	0.27	0.25	0.22	0.20
150	0.32	0.30	0.28	0.26	0.23	0.21	0.19
160	0.30	0.28	0.26	0.24	0.22	0.20	0.18
170	0.29	0.27	0.25	0.23	0.21	0.19	0.17

Table 17 **Hollow block wall - rendered externally, plasterboard fixed to timber battens internally, insulation between battens**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
40	0.79	0.75	0.70	0.64	0.59	0.52	0.45
45	0.74	0.70	0.65	0.60	0.54	0.48	0.41
50	0.69	0.65	0.60	0.55	0.50	0.44	0.38
55	0.65	0.61	0.57	0.52	0.47	0.41	0.35
60	0.61	0.57	0.53	0.49	0.44	0.39	0.33
65	0.58	0.54	0.50	0.46	0.41	0.36	0.31
70	0.55	0.51	0.48	0.43	0.39	0.34	0.29
75	0.53	0.49	0.45	0.41	0.37	0.32	0.28
80	0.50	0.47	0.43	0.39	0.35	0.31	0.26
85	0.48	0.45	0.41	0.37	0.33	0.29	0.25
90	0.46	0.43	0.39	0.36	0.32	0.28	0.24
95	0.44	0.41	0.38	0.34	0.31	0.27	0.23
100	0.42	0.39	0.36	0.33	0.29	0.26	0.22

Table 18 **Hollow block wall - rendered externally, composite insulation and drylining board fixed with plaster dabs internally**

Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
40	0.71	0.67	0.62	0.57	0.52	0.45	0.38
45	0.67	0.62	0.58	0.53	0.48	0.42	0.35
50	0.62	0.58	0.54	0.49	0.44	0.38	0.32
55	0.59	0.55	0.51	0.46	0.41	0.36	0.30
60	0.55	0.52	0.48	0.43	0.38	0.33	0.28
65	0.53	0.49	0.45	0.41	0.36	0.31	0.26
70	0.50	0.46	0.43	0.38	0.34	0.29	0.24
75	0.48	0.44	0.40	0.36	0.32	0.28	0.23
80	0.45	0.42	0.38	0.35	0.31	0.26	0.22
85	0.43	0.40	0.37	0.33	0.29	0.25	0.21
90	0.42	0.38	0.35	0.32	0.28	0.24	0.20
95	0.40	0.37	0.34	0.30	0.27	0.23	0.19
100	0.38	0.35	0.32	0.29	0.25	0.22	0.18

Intermediate floors

Table 19	Intermediate timber floor - insulation between joists						
Thickness of Insulation (mm)	Thermal conductivity of insulation (W/mK)						
	0.05	0.045	0.04	0.035	0.03	0.025	0.02
	U-value of construction (W/m^{2}K)						
50	0.66	0.61	0.57	0.52	0.47	0.42	0.36
60	0.59	0.55	0.51	0.49	0.42	0.37	0.31
70	0.53	0.49	0.46	0.42	0.37	0.33	0.28
80	0.48	0.45	0.42	0.38	0.34	0.30	0.26
90	0.45	0.42	0.38	0.35	0.31	0.28	0.24
100	0.42	0.39	0.36	0.32	0.29	0.26	0.22
110	0.39	0.36	0.33	0.30	0.27	0.24	0.21
120	0.37	0.34	0.31	0.29	0.26	0.23	0.19
130	0.35	0.32	0.30	0.27	0.24	0.21	0.18
140	0.33	0.31	0.28	0.26	0.23	0.20	0.18
150	0.31	0.29	0.27	0.24	0.22	0.19	0.17
160	0.30	0.28	0.26	0.23	0.21	0.19	0.16
170	0.29	0.27	0.25	0.22	0.20	0.18	0.16

Windows, doors and rooflights

Table 20 **Indicative U-values (W/m²K) for windows, doors and rooflights**

Item	Type of frame							
	Wood		Metal		Thermal break		PVC-U	
Air gap in sealed unit (mm)	6	12	6	12	6	12	6	12
Window, double-glazed	3.3	3.0	4.2	3.8	3.6	3.3	3.3	3.0
Window, double-glazed, low-E	2.9	2.4	3.7	3.2	3.1	2.6	2.9	2.4
Window, double-glazed, Argon fill	3.1	2.9	4.0	3.7	3.4	3.2	3.1	2.9
Window, double-glazed, low-E, Argon fill	2.6	2.2	3.4	2.9	2.8	2.4	2.6	2.2
Window, triple-glazed	2.6	2.4	3.4	3.2	2.9	2.6	2.6	2.4
Door, half-double-glazed	3.1	3.0	3.6	3.4	3.3	3.2	3.1	3.0
Door, fully double-glazed	3.3	3.0	4.2	3.8	3.6	3.3	3.3	3.0
Rooflights, double-glazed at less than 70° from horizontal	3.6	3.4	4.6	4.4	4.0	3.8	3.6	3.4
Window or door, single-glazed	4.7		5.8		5.3		4.7	
Door, solid timber panel or similar	3.0		-		-		-	
Door, half single-glazed, half timber panel or similar	3.7		-		-		-	

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,
- 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 its degree of control.

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

C.2 The procedure is presented in the form of a Worksheet accompanied by a number of Tables included in this Appendix. 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 In the Worksheet, 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 Boxes (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 ceiling surface of the storey in question. The Average Storey Height is entered in Boxes (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 in Boxes (1) to (9), 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 par. 0.5, should not be included.

C.5 The basis for calculating areas and volumes is as given in par. 0.13. Floor area includes the area of any stairwell.

Rate of Heat Loss Through The Building Fabric

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.

C.7 U-values are derived in accordance with pars. 0.11 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 Box 28a. The figure entered in this box should include any increase in fabric heat loss to allow for thermal bridging at edges of openings (see Appendix D). For semi-exposed elements the U-value entered should be 0.75 times the actual U-value.

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 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 storeys and the type of ground floor provided. Good quality construction, including compliance with par. 1.4, is assumed.

When considering Type of Construction (Box (31)), 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 a large opening at the base, e.g. a flue serving a solid fuel open fire with or without a 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 IP 13/94, 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" (Box (40)). 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.

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 (34). 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 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°, 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° to the line of the obstacle.

Unless the location of the dwelling is sufficiently well defined that the number of sides sheltered (Box (44)) can be clearly specified, the following should be assumed:

- for dwellings in built-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 (48) 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 21 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 21, 22 and 23 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, 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 24 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. For glazed panels in doors or other components, the area entered should be the glass area increased by 20%. Doors or other components where the glazed area exceeds 70% of the total area should be treated as windows and the total area of the component entered. Where more than one glazing type exists for a given orientation, the gains for that orientation may be calculated externally and entered in the appropriate box. Alternatively an area-weighted average flux may be used.

Table 24 also provides shading correction factors associated with various degrees of overshading. The factors are based on the degree to which the view of the sky is obscured by obstacles. An average degree of overshading is applicable in most situations.

Where the orientation of the dwelling has not been determined, the total area should be shared equally between East and West orientations and an average level of overshading (shading correction factor = 1.0) assumed. 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.

Features that affect the shelter factor (par. C.12) are generally also relevant in assessing the degree of overshading.

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 25 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 total heat gains (Box (71)) to Specific Heat Loss (Box (49)). This ratio is calculated and entered in Box (72). Based on this, the appropriate utilisation factor is found in Table 26 and entered in Box (73). The total gains already calculated (Box (71)) are multiplied by the utilisation factor to give Useful Gains (Box (74)). This is divided by the Specific Heat Loss to give the average temperature rise from gains (Box (75)). This figure should be calculated to two decimal places.

Space Heating

C.21 The Mean Internal Temperature given in Table 27 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 27, four types of heating systems in terms of responsiveness and three levels of heating system control are identified. Where the heating system installed is based on a combination of heating methods with different responsiveness characteristics, an average responsiveness must be estimated. For example, a combination of electric storage heaters and direct electric room heaters may be represented by responsiveness category 2. In deciding on responsiveness and control categories, no account need be taken of appliances intended for occasional use only, e.g. an open fire in a centrally heated house.

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 (77)).

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 28 for a range of base temperatures. The appropriate value is entered in Box (78). When calculating degree-days by interpolation in Table 28, the calculation should be based on a base temperature given to two decimal places.

C.24 The Energy to meet Space Heating Demand is calculated by multiplying degree-days (Box (78)) by the specific heat loss (Box (49)) and by a conversion factor which converts the result to kWh/yr. The result is entered in Box (79).

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 29 gives typical annual losses as a function of the dwelling plan area. The appropriate figure should be entered in Box (80).

Table 30 gives estimated energy use of particular heating and ventilation equipment. Where such equipment exists, the appropriate value should be entered in Box (81).

C.26 Heat Energy Rating (HER) - 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 (83)) 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.

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)
FLOOR AREA (A_f)	(1) + (2) + (3) + (10)			=		(12)
VOLUME (V) =	(7) + (8) + (9) + (11)			=		(13)

Additional Parts

Floor Area (m^2)		(10)
Volume (m^3)		(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)		(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)
Semi-Exposed element (Type 1)		(21) x		=		(21a)
Semi-Exposed element (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 Exposed and Semi-exposed Elements (A_t):
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)

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		(31)
ii) effect of height:- ((no. of storeys-1) x 0.1) ach		(32)
iii) suspended timber floor:- (0.1/ no. of storeys) ach		(33)
Total Basic Air Change Rate (31) + (32) + (33) =		(34)

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

i) Number of large flues/chimneys		x 40 =		(35)
ii) Number of small flues		x 20 =		(36)
Number of permanent vents				
iii) - large (opening > 5000 mm^2)		x 15 =		(37)
iv) - small (opening < 5000 mm^2)		x 8 =		(38)
v) Number of passive vents		x 10 =		(39)
vi) Number of fans		x 10 =		(40)
vii) Number of ext. doors without draught lobby		x 10 =		(41)

Total air change rate due to chimneys, flues, vents, fans, etc. (ach)
[(35) + (36) + (37) + (38) + (39) + (40) + (41)] /(13) = (42)

Gross Air Change Rate (34) +(42) = (43)

Adjustment for Degree of Shelter
No. of sides sheltered (44)
Shelter Factor 1 - ((44) x 0.075) (45)
Adjusted Air Change Rate (43) x (45) = (46)

Effective Air Change Rate (allowing for Occupant Controlled Ventilation)
For Adjusted Air Change Rate greater than 1: = (46)
For Adjusted Air Change Rate less than 1: = 0.5 + [$(46)^2$ x 0.5]
Air changes per hour (ach) (47)

Rate of Heat Loss due to Ventilation (47) x (13) x 0.33 = (W/K) (48)

Specific Heat Loss - Fabric and Infiltration (30) + (48) = (W/K) (49)

4. WATER HEATING

Energy content of heated water (kWh/yr) [ ] (50)
(See Table 21)

Allowance for losses

Distribution Losses (kWh/yr) [ ] (51)
(See Table 21)
(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) [ ] (52)
Tank Loss Factor (see Table 22) [ ] (53)
Tank Losses (kWh/yr) (52) x (53) = [ ] (54)

Primary Circuit losses (kWh/yr) (See Table 23) [ ] (55)

Total Losses (kWh/yr) (51) + (54) + (55) = [ ] (56)

Energy for Water Heating (kWh/yr) (50) + (56) = [ ] (57)

5. SOLAR AND OTHER ENERGY GAINS

a) Solar Gains

Orientation	**Area (m²)**		**Flux (W/m²)** (See Table 24)		**Shading Correction Factor**		**Gains (W)**
North		x		x		=	(58)
Northeast		x		x		=	(59)
East		x		x		=	(60)
Southeast		x		x		=	(61)
South		x		x		=	(62)
Southwest		x		x		=	(63)
West		x		x		=	(64)
Northwest		x		x		=	(65)
Rooflights		x		x		=	(66)

Total Solar Gains (58) + (59) + ...+ (65) + (66) = [ ] (67)

b) Other Energy Gains **Gains (W)**

i) Water Heating
0.114 x (.8 x (56) + .25 x (50)) = [ ] (68)

ii) Lights, appliances, cooking, occupants, etc. [ ] (69)
(See Table 25)

Total Other Gains (68) + (69) = [ ] (70)

Total Gains (67) + (70) = [ ] (71)

Gains/Loss Ratio (71)/(49) = [ ] (72)

Utilisation Factor [ ] (73)
(See Table 26)

Useful Gains (71) x (73) = [ ] (74)

Temperature Rise from Gains (K) (74) / (49) = [ ] (75)

6. SPACE HEATING

Mean Internal Temperature (K) [ ] (76)
(see Table 27)

Base Temperature (K) (76) - (75) = [ ] (77)

Degree Days [ ] (78)
(See Table 28)

Energy to meet Space Heat Demand 0.024 x (78) x (49) = **kWh/yr** [ ] (79)

Allowance for losses and equipment energy use

Distribution Losses (kWh/yr) (See Table 29) [ ] (80)
Equipment Energy Use (kWh/yr) (See Table 30) [ ] (81)

Energy for Space Heating (kWh/yr) (79) + (80) + (81) = [ ] (82)

7. HEAT ENERGY RATING (HER)

Energy for Space and Water Heating (kWh/yr) (57) + (82) = [ ] (83)

Heat Energy Rating (kWh/m²/yr) (83) / (12) = [ ] (84)

At/V (29)/(13) = [ ] (85)

Maximum Permitted Heat Energy Rating
(kWh/m²/yr) (See Table 4) [ ] (86)

Table 21 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)
andF = floor area (m^2).

Table 22 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. 3.2 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 23 Primary circuit losses (kWh/yr)

Energy Source	Dwelling Floor area (m^2)			
	>100m^2	75 to 100m^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 24 Solar flux through glazing (W/m^2)

Glazing Type	Glazing Orientation					
	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 30^0 of north and the value under "Horizontal for all other orientations".
For a pitch of less than 5^0, treat as horizontal.
For a pitch of more than 70^0, 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
Very little	<20	1.3

Table 25 Lighting, appliances, cooking and metabolic gains

Floor Area (m²)	Gains (W)	Floor Area (m²)	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 $F \leq 300m^2$)
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 26 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 27	**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 28	**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 29	**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 30	**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 at Edges of Openings

D.1 This Appendix outlines a procedure for establishing whether:

- there is an unacceptable risk of condensation at the edges of openings, and/or
- the heat losses at the edges of openings are significant.

The procedure is described in "BRE IP 12/94 : Assessing condensation risk and heat loss at thermal bridges around openings". It can be used to demonstrate compliance with par. 1.3.1 which deals with thermal bridging at openings.

D.2 The procedure involves the assessment of the minimum thermal resistance between inside and outside surfaces at the edges of an opening and its comparison with satisfactory performance criteria which are set out in paragraphs D.4 and D.5 below. The minimum thermal resistance path through a thermal bridge is that path from internal surface to external surface which has the smallest thermal resistance, R_{min}. The minimum resistance path is often the shortest path but this is not necessarily so, and paths other than the shortest may need to be considered especially where the shortest path is through material of relatively low thermal conductivity.

D.3 For details containing thin layers, not exceeding 4 mm in thickness (such as metal lintels), satisfactory performance depends on both R_{min} and a modified calculation of minimum thermal resistance, R_{mod}. R_{mod} is calculated in the same manner as R_{min}, except that the effective thermal conductivity of the thin layer is taken as the larger of 0.1 W/mK or the largest of the thermal conductivities of the materials on either side of it.

D.4 The risk of surface condensation and mould growth at the edges of openings can be assumed to be negligible if:

- for edges containing thin layers of thickness not exceeding 4 mm:
  R_{min} is at least 0.10 m^2K/W; and
  R_{mod} is at least 0.45 m^2K/W; or
- for other edge designs:
  R_{min} is at least 0.20 m^2K/W.

Where the values of R_{min} or R_{mod} are less than the values indicated, the design should be modified unless a more rigourous analysis shows the risk to be negligible.

These criteria do not apply to cases where internal surface projections are used to avoid surface condensation, e.g. curtain walling.

D.5 The additional heat losses at the edges of openings may be ignored if:

- for edges containing thin layers of thickness not exceeding 4 mm:
  R_{mod} is at least 0.45 m^2K/W; or
- for other edge designs:
  R_{min} is at least 0.45 m^2K/W

Where the values of R_{min} or R_{mod} are less than the above, consideration should be given to modification of the design. Alternatively, provided the risk of condensation can be shown to be negligible, the additional heat losses can be taken into account as follows:

- measure or calculate the increased linear thermal transmittance of the thermal bridge (ψ'), i.e. the increased heat loss per degree temperature difference per unit length of the thermal bridge relative to that of a similar construction which just meets the specified resistance. As an alternative to measurement or calculation, ψ' can be taken as equal to 0.3 W/mK.
- use the OVERALL HEAT LOSS method, but allow for an increase in the average U-value (U_{av}) of the following amount

$$\frac{(\psi') \times \text{(total length of relevant thermal bridge)}}{\text{sum of exposed and semi-exposed surface areas}} \ (\mathrm{W/m^2K})$$

  or,
  use the HEAT ENERGY RATING method, but allow for an increase in the calculated heat loss through the building fabric of the following amount

$$(\psi') \times \text{(total length of relevant thermal bridge)} \ (\mathrm{W/K})$$

This amount should be included in the number entered in Box 28(a) of the Worksheet.

Appendix E
Limitation of Heat Loss through Building Fabric

E.1 The following examples illustrate the application of the two methods of demonstrating an acceptable level of heat loss through the building fabric, which are presented in Section 1. The use of the Heat Energy Rating method presented in Section 4 is also demonstrated for Example 9.

Example 9 relates to a semi-detached house. Examples 10 and 11 relate to commercial and industrial constructions respectively, and compliance is demonstrated using the Overall Heat Loss method. Although the Elemental Heat Loss method may be used for these examples, it is not considered particularly appropriate.

It is assumed that the requirement regarding thermal bridging at openings (par. 1.3.1) is satisfied without the need to allow for an increase in average U-value or heat loss (see Appendix D). It is also assumed that the requirements of pars. 1.3.2 and 1.4 are satisfied.

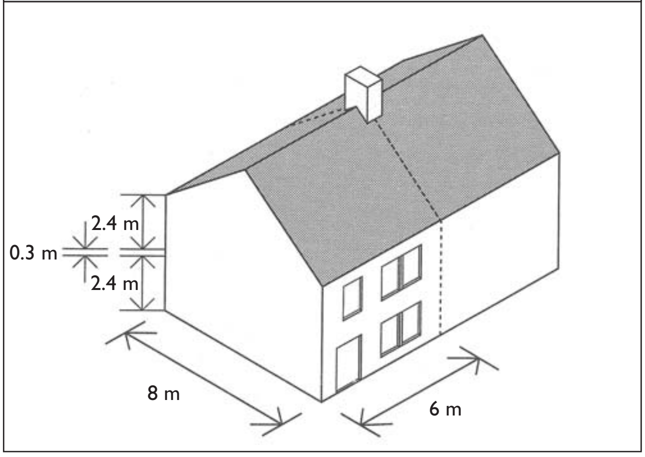
Example 9: Semi-Detached House

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 m floor to ceiling height, 300 mm first floor zone).
	Door and Window Openings:		
	Front	-	8.5 m^2 (including 1.7 m^2 front door)
	Rear	-	6.7 m^2 (including 1.7 m^2 rear door)
	Side	-	1.0 m^2
	Total	-	16.2 m^2 (17% of floor area).

Construction:	Roof:	Pitched tiled roof, glass fibre insulation laid on attic floor, between joists.
	Walls:	Cavity wall (dense concrete blocks) rendered externally, plastered internally with partial fill polystrene insulation in the cavity and 50 mm cavity retained.
	Floor:	Concrete slab-on-ground floor with polystyrene insulation.

Diagram 20 **Semi-detached house** *Par. E.1*



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

roof insulation	0.04 W/mK
wall insulation	0.037 W/mK
floor insulation	0.037 W/mK

Elemental Heat Loss Method

This is the easiest method to apply but provides little flexibility. Table 2 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 8 and 14, the required thicknesses of attic and wall insulation are 175 mm and 58 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 7, the resistance of the added insulation is estimated as 1.15 m^{2}K/W. Assuming insulation thermal conductivity of 0.037 W/mK, the thickness of floor insulation required is 43 mm.

Table 3 indicates that the required average U-value of windows, doors and rooflights (at 17% of floor area) is 4.2 W/m^{2}K. This can be achieved in a number of ways. For example, using data from Table 20, it can be shown that two doors, half single-glazed and half timber panel or similar, together with double-glazed windows, irrespective of frame type, will suffice.

Overall Heat Loss Method

This method provides greater flexibility for the designer allowing compensation for a reduction in insulation provision in one element by an increase in provision in another element. It also provides greater flexibility in relation to the areas and types of glazing provided.

Use of this method requires calculation of the total heat loss area (A_t), the building volume (V) and the average U-value of the heat loss elements (U_{av}). The calculation of U_{av} requires the multiplication of area and U-value for each element, summing the product calculated and dividing the sum by the total area of all heat loss elements. The calculated U_{av} is then compared to the maximum average U-value (U_m) for this building, which is specified in Table 1.

In addition, the U-values of roofs, walls and ground floors must not be greater than those set out in par. 1.2.2. The required thicknesses of insulation can be calculated as demonstrated above for the Elemental Method. For the insulation materials and locations specified, the minimum thicknesses of insulation work out as 110 mm, 44 mm and 43 mm for roof, wall and floor respectively.

For the house under consideration, the following calculation assesses compliance when the minimum acceptable level of insulation is provided in the roof and walls. To compensate for the reduction in roof and wall insulation, the windows are specified as double-glazed with a 12 mm gap and wood frames and the glazed parts of the external doors are similarly double-glazed.

Heat Loss Element	Area (m^2)	U-value (W/m^2K)	Area x U-value (W/K)
Roof	48.00	0.35	16.80
Wall	85.80	0.55	47.19
Floor	48.00	0.45	21.60
Windows (double glazed, 12 mm gap, wood frame)	12.80	3.00	38.40
Doors	3.40	3.00	10.20
	198.00		134.19

$$U_{av} = \frac{\text{Total AU}}{A_t} = \frac{134.19}{198.00} = 0.68\text{W/m}^2\text{K}$$

Building Volume (V) = 244.80m^3

$$\frac{A_t}{V} = \frac{198.00}{244.80} = 0.81\ (\text{m}^{-1})$$

U_m (from Table 1) = 0.69 W/m^2K.

The proposed construction is acceptable as U_{av} is less 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	no
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 80 mm cylinder jacket and uninsulated primary circuit and distribution pipes.

This assessment of compliance is for minimum levels of roof, wall and floor insulation, windows double-glazed with 12 mm gap and wood frames, and solid timber doors. The window area is increased to 16.8 m^2 with 10.8 m^2 South facing and the remaining 6 m^2 North facing.

The calculation shows that the house has a HER of 111.63 $kWh/m^2/yr$. This compares with a MPHER of 116.17 $kWh/m^2/yr$. The proposed construction is therefore acceptable.

Example 9 - Appendix E

DWELLINGS - ASSESSMENT OF COMPLIANCE ON BASIS OF HEAT ENERGY RATING

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	0.35	=	16.80	(14a)
Roof (type 2)	0.00	(15) x	0.00	=	0.00	(15a)
Wall (type1)	81.80	(16) x	0.55	=	44.99	(16a)
Wall (type 2)	0.00	(17) x	0.00	=	0.00	(17a)
Ground Floor (type 1)	48.00	(18) x	0.45	=	21.60	(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)	16.80	(24) x	3.00	=	50.40	(24a)
Window (Type 2)	0.00	(25) x	0.00	=	0.00	(25a)
Door (Type 1)	3.40	(26) x	3.00	=	10.20	(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: (W/K)
Sum of (A)x(U) = (14a) + (15a) + ...+ (27a) + (28a) = 143.99 (30)

3. RATE OF HEAT LOSS DUE TO VENTILATION

a) Basic Air Change Rate

i) effect of type of construction:-	standard - 0.4ach "sealed" - 0.3ach	0.40	(31)
ii) effect of height:- ((no. of storeys-1) x 0.1) ach		0.10	(32)
iii) suspended timber floor:- (0.1/ no. of storeys) ach		0.00	(33)
Total Basic Air Change Rate	(31) + (32) + (33) =	0.50	(34)

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

			m^3 per hour	
i) Number of large flues/chimneys	1.00	x 40 =	40.00	(35)
ii) Number of small flues	0.00	x 20 =	0.00	(36)
Number of permanent vents				
iii) - large (opening > 5000 mm^2)	0.00	x 15 =	0.00	(37)
iv) - small (opening < 5000 mm^2)	6.00	x 8 =	48.00	(38)
v) Number of passive vents	0.00	x 10 =	0.00	(39)
vi) Number of fans	2.00	x 10 =	20.00	(40)
vii) Number of ext. doors without draught lobby	2.00	x 10 =	20.00	(41)

Total air change rate due to chimneys, flues, vents, fans, etc. (ach)
[(35) + (36) + (37) + (38) + (39) + (40) + (41)]/(13) = 0.52 (42)

Gross Air Change Rate (34) +(42) = 1.02 (43)

Adjustment for Degree of Shelter

No. of sides sheltered		2.00	(44)
Shelter Factor 1 - ((44) x 0.075)		0.85	(45)
Adjusted Air Change Rate	(43) x (45) =	0.87	(46)

Effective Air Change Rate (allowing for Occupant Controlled Ventilation)
For Adjusted Air Change Rate greater than 1: = (46)
For Adjusted Air Change Rate less than 1: = 0.5 + [$(46)^2$ x 0.5]

Air changes per hour (ach): 0.88 (47)

Rate of Heat Loss due to Ventilation (47) x (13) x 0.33 = 71.09 (W/K) (48)

Specific Heat Loss - Fabric and Infiltration (30) + (48) = 215.08 (W/K) (49)

4. WATER HEATING

Energy content of heated water (kWh/yr) 1584 (50)
(See Table 21)

Allowance for losses

Distribution Losses (kWh/yr) 264 (51)
(See Table 21)
(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)		120.00	(52)
Tank Loss Factor (See Table 22)		3.92	(53)
Tank Losses (kWh/yr)	(52) x (53) =	470	(54)
Primary Circuit losses (kWh/yr) (See Table 23)		550	(55)

Total Losses (kWh/yr) (51) + (54) + (55) = 1284 (56)

Energy for Water Heating (kWh/yr) (50 + (56) = 2868 (57)

5. SOLAR AND OTHER ENERGY GAINS

a) Solar Gains

Orientation	Area (m^2)		Flux (W/m^2) (See Table 24)		Shading Correction Factor		Gains (W)	
North	6.00	x	8.00	x	1.00	=	48.00	(58)
Northeast	0.00	x		x	1.00	=	0.00	(59)
East	0.00	x		x	1.00	=	0.00	(60)
Southeast	0.00	x		x	1.00	=	0.00	(61)
South	10.80	x	28.00	x	1.00	=	302.40	(62)
Southwest	0.00	x		x	1.00	=	0.00	(63)
West	0.00	x		x	1.00	=	0.00	(64)
Northwest	0.00	x		x	1.00	=	0.00	(65)
Rooflights	0.00	x		x	1.00	=	0.00	(66)

Total Solar Gains (58) + (59) + ...+ (65) + (66) = 350.40 (67)

b) Other Energy Gains

	Gains (W)	
i) Water Heating 0.114 x (.8 x (56) + .25 x (50)) =	162.24	(68)
ii) Lights, appliances, cooking, occupants, etc. (See Table 25)	510.00	(69)

Total Other Gains (68) + (69) = 672.24 (70)

Total Gains (67) + (70) = 1022.64 (71)

Gains/Loss Ratio (71)/(49) = 4.75 (72)

Utilisation Factor (See Table 26) 0.97 (73)

Useful Gains (71) x (73) = 991.96 (74)

Temperature Rise from Gains (K) (74) / (49) = 4.61 (75)

6. SPACE HEATING

Mean Internal Temperature (K) (see Table 27) 18.07 (76)

Base Temperature (K) (76) - (75) = 13.46 (77)

Degree Days (See Table 28) 1473.92 (78)

Energy to meet Space Heat Demand 0.024 x (78) x (49) = kWh/yr 7608 (79)

Allowance for losses

Distribution Losses (kWh/yr) (See Table 29) 120 (80)

Equipment Energy Use (kWh/yr) (See Table 30) 120 (81)

Energy for Space Heating (kWh/yr) (79) + (80) + (81) = 7848 (82)

7. HEAT ENERGY RATING (HER)

Energy for Space and Water Heating (kWh/yr) (57) + (82) = 10716 (83)

Heat Energy Rating ($kWh/m^2/yr$) (83) / (12) = 111.63 (84)

A/V = (29)/(13) 0.81 (85)

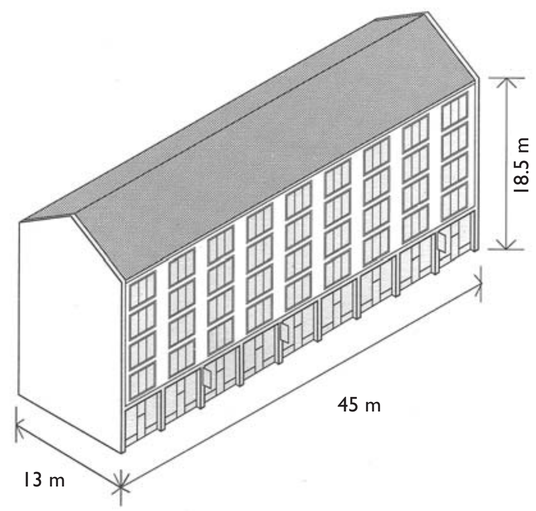
Maximum Permitted Heat Energy Rating ($kWh/m^2/yr$) (See Table 4) 116.17 (86)

Example 10: Office Building

A detached five storey shop and office building 45 m x 13 m in plan and 18.5 m internal height is to be constructed. Shops are provided on the ground floor with 80% of the front facade at access level being display windows and access doors. No glazing is provided to the side or rear on the ground floor. The upper four floors are provided with 55% double glazing (metal frames with thermal break, 12 mm air gap) on the front and rear facades with no glazing on end walls or roof. Exposed walls are to have a U-value of 0.5 W/m^{2}K and the roof is to have a U-value of 0.40 W/m^{2}K. The solid ground floor is edge-insulated.

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

Diagram 21 **Office building** *Par E.1*



The following calculations give the total heat loss area (A_t), the average U-value of heat loss elements (U_{av}) and building volume (V). The U_{av} value is then compared with U_m specified in Table 1 for the calculated volume and heat loss area.

Heat Loss Element	Area (m^2)	U-value (W/m^{2}K)	Area x U-value (W/K)
Roof	585	0.40	234.00
Wall	1277	0.50	638.50
Floor	585	0.40	234.00
Windows	743	3.30	2451.90
Doors	20	3.00	60.00
Totals	3210		3618.40

$$U_{av} = \frac{\text{Total AU}}{A_t} = \frac{3618.40}{3210} = 1.13\text{W/m}^2\text{K}$$

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

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

U_m (from Table 1) = 1.15 W/m^{2}K.

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

Example 11: Industrial Buildings

A single story industrial building 65 m long, 25 m wide and 4.25 m high with a roof pitch of 10° is to be constructed. The roofs and walls are to have a U-value of 0.60 W/m^{2}K. Glazing is to be provided as follows:

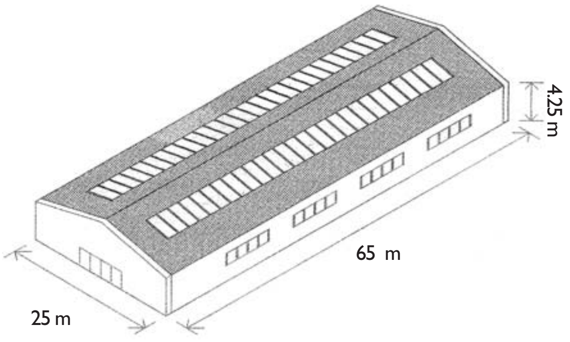
15% of roof area	-	double glazed, metal frame, 6 mm air gap.
15% of wall area	-	double glazed, metal frame, 6 mm air gap.

In addition, the building is provided with 10 m^2 personnel doors (U = 3.0 W/m^{2}K) and 30 m^2 of vehicle access doors (U = 0.70 W/m^{2}K).

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

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

Diagram 22	**Industrial building**	*Par. E.1*



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

Heat Loss Element	Area (m^2)	U-value (W/m^2K)	Area x U-value (W/K)
Roof (10° slope)	1403	0.60	841.80
Walls	657	0.60	394.20
Floor	1625	0.26	422.50
Windows - roof	247	4.60	1136.20
- wall	123	4.20	516.60
Doors - personnel	10	3.00	30.00
- vehicle access	30	0.70	21.00
Totals	4095		3362.30

$$U_{av} = \frac{\text{Total AU}}{A_t} = \frac{3362.30}{4095} = 0.82\ W/m^2K$$

Building volume = 8697.07 m^3

$$\frac{A_t}{V} = \frac{4095}{8697.07} = 0.47\ m^{-1}$$

U_m (from Table 1) = 0.89 W/m^2K.

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

Standards and other references

Standards referred to:

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

BS 853 : 1990 Specification for calorifiers and storage vessels for central heating and hot water supply

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

BS 1566 Copper indirect cylinders for domestic purposes Part 2: 1984 Specification for single feed indirect cylinders

BS 5422 : 1990 Method for specifying thermal insulating materials on pipes, ductwork and equipment (in the temperature range - 40°C to + 700°C)

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

BS 5615 : 1985 Specification for insulating jackets for domestic hot water storage cylinders

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

BS 6880 : 1988 Code of practice for low temperature hot water heating systems of output greater than 45 kW

Other Publications referred to:

BRE Report BR262, Thermal Insulation : avoiding risks, BRE 1994

BRE Information Paper 3/90 The U-value of ground floors: application to building regulations

BRE Information Paper 7/93 The U-value of solid ground floors with edge insulation

BRE Information Paper 12/94 Assessing condensation risk and heat loss at thermal bridges around openings

BRE Information Paper 14/94 U-values for basements

CIBSE Applications Manual AM1: 1985 Automatic controls and their implications for system design

CIBSE Guide, Volume A: Design Data - Section A3: Thermal Properties of Building Structures 1980. Reprinted 1988