Building Regulations, 1991

TECHNICAL GUIDANCE DOCUMENT L
CONSERVATION OF FUEL AND ENERGY

DEPARTMENT OF THE
ENVIRONMENT

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TECHNICAL GUIDANCE DOCUMENT L -

CONSERVATION OF FUEL AND ENERGY

INTRODUCTION

This document has been published by the Minister for the Environment under article 5 of the Building Regulations, 1991, for the purpose of providing guidance with regard to compliance with the requirements of Part L of the First Schedule to the Regulations. Where works are carried out in accordance with this guidance, this will, prima facie, indicate compliance with these requirements.

This document should he read in conjunction with the Regulations.

Guidance contained in this document with respect to the use of a particular material, method of construction, standard or other specification does not preclude the use of any other suitable material, method of construction, standard or specification.

TECHNICAL SPECIFICATIONS

Building Regulations are made for specific purposes - i.e. health, safety and welfare of persons, energy conservation and the special needs of disabled people. Technical Specifications (including Harmonised European Standards, European Technical Approvals, National Standards and Agrément Certificates) are relevant to the extent that they relate to these considerations. Technical Specifications may also address other aspects of performance not covered by the Regulations.

The references in this document to named Technical Specifications, or to materials and methods which are likely to be suitable for the purposes of the Regulations, are not exclusive and other materials and methods may be suitable in particular circumstances. A reference to a Technical Specification is to the latest edition (including any amendments, supplements or addenda) current at the date of publication of this Technical Guidance Document.

MATERIALS AND WORKMANSHIP

Under Part D of the First Schedule to the Regulations, building work must be carried out with proper materials and in a workmanlike manner. Relevant guidance is contained in Technical Guidance Document D.

Part D of the First Schedule to the Regulations defines "proper materials" as materials which are fit for the use for which they are intended and for the conditions in which they are to be used, and includes materials which:

(a) bear a CE Mark in accordance with the provisions of the Construction Products Directive (89/106/EEC); or

(b) comply with an appropriate harmonised standard, European technical approval or national technical specification as defined in article 4(2) of the Construction Products Directive (89/106/EEC); or

(c) comply with an appropriate Irish Standard or Irish Agrément Board Certificate or with an alternative national technical specification of any Member State of the European Community, which provides in use an equivalent level of safety and suitability.

CONSERVATION OF FUEL AND ENERGY

Building Regulations - The Requirement

Part L of the First Schedule to the Building Regulations, 1991 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.

This Technical Guidance Document is divided into three 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.

GENERAL

INTRODUCTION

0.1 The conservation of fuel and energy in a building requires the provision of energy efficient measures to:

(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.

This document describes measures appropriate to these three aspects of conservation.

SMALL EXTENSIONS

0.2 For extensions not exceeding 6.5m² in floor area, reasonable provision for the conservation of fuel and energy would be considered to have been made if the construction is similar to the existing construction.

ANCILLARY AREAS

0.3 Unheated ancillary areas such as conservatories, porches, garages and the like do not require specific provisions for the conservation of fuel and energy.

BUILDINGS WHICH HAVE ONLY A LOW LEVEL OF HEATING

0.4 Some commercial, industrial and storage buildings, because of the nature of their intended use, may only require a low level of heating (or even no heat at all) and insulation of the building fabric will 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. However, where the level of heating to be provided cannot be established because the use of the building when it is being constructed is not known, insulation of the building fabric will be necessary.

It should he noted that insulation of a building after construction (e.g. where insulation is required following a change of use) may be substantially more costly than initial insulation.

BUILDINGS REQUIRING HIGH HEATING LEVELS

0.5 The measures to achieve energy efficiency given in this document are applicable to heated buildings generally. In certain buildings requiring continuous high heating levels enhanced measures to conserve fuel and energy may be justified.

DESIGN DETAILS AND CONSTRUCTION PRACTICE

0.6 Accepted traditional building forms and practices are known to satisfy relevant performance requirements, generally with a considerable margin of safety. The addition of thermal insulation to these constructions will require reconsideration of the design details and specification, as well as the levels of workmanship and supervision, to ensure a trouble free building.

0.7 Research has shown that aspects which were not important for uninsulated constructions may become more significant when they are better insulated. For example, certain parts of the construction remain colder and create a greater risk of interstitial condensation, and changes to traditional forms of construction to improve the insulation could lead to damp penetration.

0.8 It is important to anticipate these effects and, by a better understanding of the physical principles involved, avoid the risk of building defects occurring. It is also important to ensure that the construction chosen is sufficiently robust having regard to the situation.

0.9 Guidance on avoiding risks which might arise from the application of energy conservation measures will be found in the relevant standards. Guidance on construction practice is contained in the publications **Insulation of External Walls in Housing**, An Foras Forbartha, 1987 (Ref CT322) and **Thermal Insulation: avoiding risks**; Building Research Establishment (Ref BR143). 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. Technical Guidance Document F : Ventilation, includes guidance on the provision of ventilation to reduce the risk of condensation.

CALCULATION OF U VALUE

0.10 " U value" means thermal transmittance coefficient, that is to say, the rate of heat transfer in watts through $1m^2$ of a structure when the temperature on each side of the structure differs by lK (expressed in W/m^2K).

Calculation of U values is dealt with in Appendix A. In calculations it will be acceptable to work to two decimal places.

When calculating U values the effects of timber joists or framing, wall ties, thin cavity closures, mortar bedding, damp-proof membranes, metal spacers and other thin discrete components may be ignored.

THERMAL CONDUCTIVITY

0.11 In the absence of manufacturers' certified test data, thermal conductivity values may be taken from Table 5 in Appendix A to this Technical Guidance Document, which is reproduced from Section A3 of the CIBSE Guide by permission of the Chartered Institution of Building Services Engineers. It provides a general indication of the thermal conductivities which may be expected for various types of material. However, values for particular products may differ from these illustrative values and certified test data should be used in preference.

BASIS FOR CALCULATING AREAS AND VOLUMES

0.12 Linear measurements for the calculation of wall, roof and floor areas and building volumes should be taken between internal faces of the appropriate 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 cills, lintels and reveals. "Volume" means the total volume enclosed by all enclosing elements and includes the volume of intermediate floors and associated floor space.

OPENINGS IN BUILDING FABRIC

0.13 When considering openings in the building fabric the following assumptions should apply:

a) 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, and

b) lintels, jambs and cills associated with window, rooflight and door openings may be counted as part of the window, rooflight and door opening area or as part of the roof, wall or floor in which the opening occurs. However, in no case should the U value of a lintel jamb or cill exceed 0.9 W/m²K.

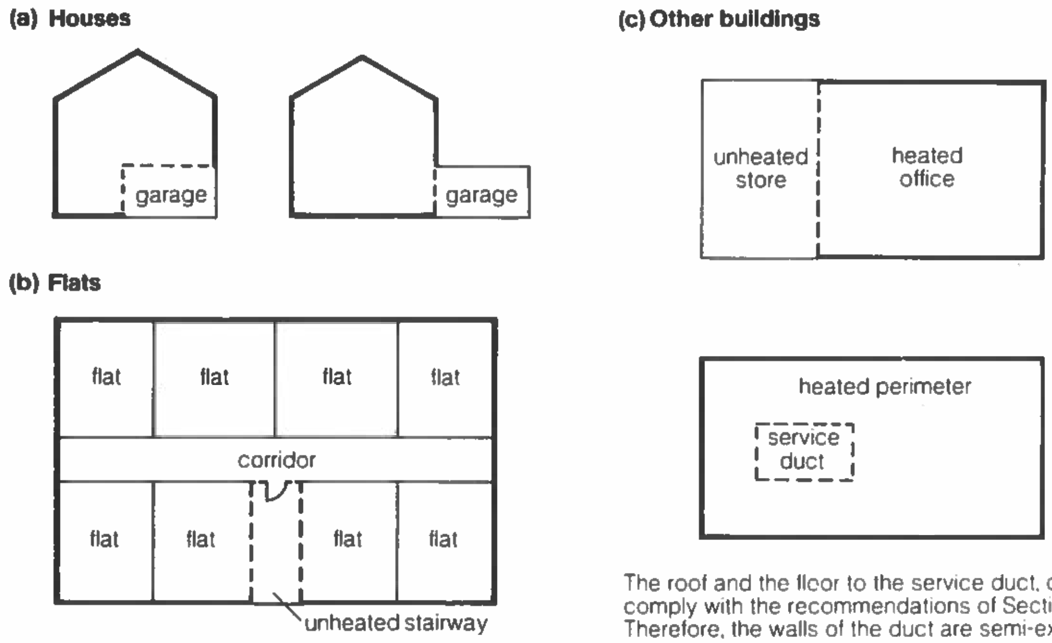
EXPOSED AND SEMI-EXPOSED ELEMENTS

0.14 In this document "exposed element" means an element exposed to the outside air; "semi-exposed element" means an element separating any part of a building (to which this Part applies) 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).

LARGE COMPLEX BUILDINGS

0.15 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.

Diagram 1 Examples of semi-exposed elements



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

The exposed wall to the unheated stairway has a substantial glazed area and does not comply with the recommendations in Section 1. Therefore the walls that face into the stairway are semi-exposed.

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

Exposed element of construction **which is insulated** to recommended level is shown ————

Semi-exposed element is shown - - - - - - -

Section 1

LIMITATION OF HEAT LOSS THROUGH THE BUILDING FABRIC

1.1.1 The method of calculating the maximum acceptable level of overall heat loss through the fabric of a building is set out in paragraph 1.2. The **Overall Heat Loss** method, which is set out in paragraph 1.2, provides for a limit on the average rate of heat loss of all exposed and semi-exposed fabric elements through the specification of a maximum average U value (U_m). The value specified is dependent on the ratio between the area of all heat loss elements and the building volume. This allows for the fact that, where buildings are relatively deep, the rate of heat loss per unit building volume through the building fabric is decreased and larger average U values can be accepted. In the case of dwellings specific elemental values must also be met.

1.1.2 As an alternative to using the calculation method set out in paragraph 1.2, two other approaches which could be used to meet the requirement in the case of certain simple forms of construction are dealt with. The **Elemental Heat Loss** method which is dealt with in paragraph 1.3, specifies maximum U values for each element of the building fabric, and limits on the extent of openings depending on the type of glazing. It is thus simpler to comply with but less flexible than the Overall Heat Loss method and does not allow for the effect of the building shape on the overall heat loss through the building fabric. It is considered suitable for use for dwellings, small buildings (less than 300 m² floor area) and for material alterations, extensions and change of use situations, where it is desired to avoid detailed calculations or where the Overall Heat Loss method may not be appropriate.

1.1.3 The **Net Heat Loss** method, which is dealt with in paragraph 1.4, provides a relatively simple method of allowing for solar gain through the building fabric in addition to heat loss. It is similar in concept to the Overall Heat Loss method but, since it involves a number of simplifying assumptions, it is suitable for use in the case of dwellings only. It provides a limit on the average rate of net heat loss (having allowed for solar gain through the windows). The limit specified is dependent on two ratios; that between the area of all heat loss elements and the building volume and that between the glazed area and the building volume.

U VALUES AND INSULATION THICKNESS

1.1.4 Appendix A demonstrates how to calculate the U value of a particular construction and the required thickness of insulation to meet a desired U value. It also provides Tables to aid the calculation of the thickness of insulation required to achieve specific U values in individual elements. Tables 6, 7 and 8 deal with walls, roofs and exposed floors and Tables 9 and 10 with ground floors. Table 11 gives standard and effective U values for single and double glazing. These tables can be used in lieu of full calculation and in the absence of certified data.

EXAMPLES OF COMPLIANCE

1.1.5 Examples of compliance using each of the three methods are given in Appendix B.

OVERALL HEAT LOSS

1.2 The maximum acceptable level of heat loss through the fabric of a building, set in terms of the maximum average U value of all exposed and semi-exposed elements, is specified in Table 1 in relation to the ratio of the total area of exposed and semi-exposed elements to the building volume. In calculating the average U value (U_m) notional U values equal to 0.75 times the actual U values should be used for semi-exposed elements. The requirement is expressed graphically in Diagram 2.

Where this approach is adopted in relation to a dwelling, the following maximum average elemental U values must be met in addition to meeting the overall value:

roofs	0.35 W/m²K
walls	0.55 W/m²K
ground floors	0.45 W/m²K.

Diagram 2	Maximum average U Value (U_m) in relation to building volume (V) and total area of heat loss elements (A_t)

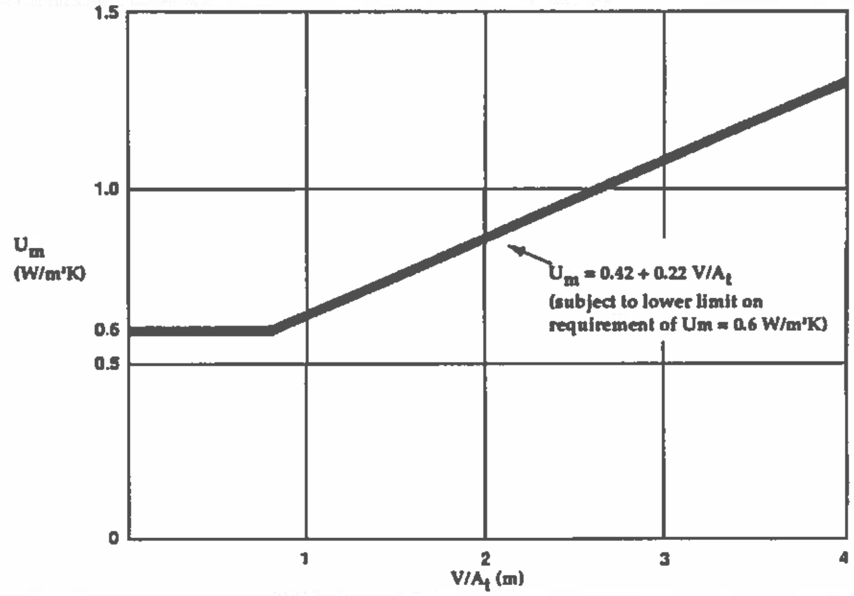


Table 1	Maximum average U value (U_m) as a function of building volume and fabric heat-loss area

Area of Exposed & Semi-Exposed Elements / Building Volume	(A_t) (m^{-1}) / V	Maximum Average U Value (U_m) (W/m²K)
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 $U_m \leq 0.42 + 0.22\ V/A_t$ can be used for intermediate values of A_t/V and for values below 0.3 m^{-1}.

NOTE 2: The area of shop display windows can be omitted when calculating the area of exposed and semi-exposed elements (A_t) and the average U value (U_m).

ELEMENTAL HEAT LOSS

1.3 For dwellings, small buildings (up to 300m² floor area) and for material alterations, material changes of use and extensions to existing buildings, the level of heat loss set in 1.2 above can be considered to have been achieved if each relevant element of construction has an average U value not exceeding that set out in Table 2. In addition, for new buildings, the total area of window, rooflight and door openings should not exceed 30% of the floor area.

Table 2	Maximum 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	No Requirement
Semi-exposed roofs	0.35	0.60
Semi-exposed walls	0.60	0.60
Semi-exposed floors	0.60	0.60

Table 3 Glazing requirement as a function of the total area of window, rooflight and door openings

Window, rooflight and door openings as a % of floor area (%)	Minimum proportion of total opening area to be double glazed or equivalent (U value < 3.6 W/m² K) (%)
≥20	100
18	75
16	50
14	25
≤12	No Requirement

NOTE 1: Solid panels and solid door leaves within an overall window, rooflight or door opening are considered equivalent to double glazing.

Where the total area of window, rooflight and door openings exceeds 20% of the building floor area, all windows, rooflights and doors should be double glazed (U value not exceeding 3.6 W/m²K). Where the area lies between 12% and 20% of the building floor area, the proportion of the total area of window, rooflight and door openings requiring to be double glazed (U value not exceeding 3.6 W/m²K) varies linearly between 0% at 12% of floor area and 100% at 20% of floor area. This requirement is presented in tabular form in Table 3.

In meeting the requirements regarding glazing, the area of shop display windows need not be taken into account.

NET HEAT LOSS

1.4 The Overall Heat Loss Method (Paragraph 1.2 above) does not take account of solar heat gains. Where there are no special measures to enhance solar heat gains, other than the location and orientation of glazing, these gains can be taken into account by using an analogous method based on some simplifying assumptions. This is based on the use of an "effective U value" for glazing i.e. one that takes account of the inward heat flow due to solar radiation in addition to the outward heat flow due to temperature difference. This "effective U value" varies with the orientation of the glazing. Average "effective U values" for the country and for the four cardinal directions for single and double glazing are given in Appendix A.

For average Irish conditions, the difference between the "effective U value" and the "standard U value" is 1.5 W/m²K on average - the difference being greater for southerly oriented glazing and less for northerly oriented glazing. Thus the net rate of heat loss (taking solar gain into account) from a building with glazing equally distributed on all four sides is less than the total heat loss by 1.5 W/m²K per square metre of glazing.

Appropriate maximum average effective U values (U_{me}) are given in Table 4. This is equivalent to Table 1 for equally distributed glazing and the values depend on the area of glazing in addition to the volume and fabric heat loss areas. Use of a greater proportion of southerly-oriented glazing gives a lower effective U value thus recognising the greater solar gain. This gives greater flexibility - allowing an easing of requirements for other elements or a greater proportion of glazing overall while meeting the target effective U value set.

Maximum U values for roofs, walls and ground floors as for the overall heat loss method apply.

Because of the simplifying assumptions involved, this method is considered suitable for housing only.

INSULATION OF SOLID SLAB-ON-GROUND FLOORS

1.5 In the case of slab-on-ground floors, the extent of floor insulation required to meet the appropriate average U value (U_m) or average effective U value (U_{me}) set out in Tables 1 and 4 respectively, or the value of 0.45 W/m²K required by the Elemental Heat Loss Method, depends on a number of factors including the shape and area of the floor and the nature of the soil. In the absence of information on soil thermal conductivity a value of 2.1 W/mK should be assumed. Houses and small buildings will generally require full floor insulation. Where full floor insulation is not used, slab-on-ground floors should be provided with edge insulation of minimum thermal resistance of 0.7 m²K/W (25mm of insulation with thermal conductivity of .035W/mK, or equivalent). The insulation should extend 1 metre vertically or horizontally and, where placed horizontally, the vertical edge of the slab above the insulation should also be insulated. Insulation materials used for floor insulation should have appropriate minimum compressive strength.

Table 4 **Maximum average effective U value (U_{me}) as a function of building volume (V) fabric heat loss area (A_t) and area of glazing (A_g)**

	A_g/V (m^{-1})						
$\frac{At}{V}$ (m^{-1})	.04	.05	.06	.07	.08	.09	.10
1.25	0.55	0.54	0.52	0.51	0.50	0.49	0.48
1.1	0.57	0.55	0.54	0.52	0.51	0.50	0.48
1.0	0.58	0.57	0.55	0.54	0.52	0.51	0.49
0.9	0.60	0.58	0.56	0.55	0.53	0.51	0.50
0.8	0.62	0.60	0.58	0.56	0.55	0.53	0.51
0.7	0.65	0.63	0.61	0.58	0.56	0.54	0.52
0.6	0.69	0.66	0.64	0.61	0.59	0.56	0.54
0.5	0.74	0.71	0.68	0.65	0.62	0.59	0.56

NOTE 1: The formula $U_{me} \leq 0.42 + 0.22\, V/At - 1.5\, Ag/At$ can be used for intermediate values of $\frac{At}{V}$ and $\frac{Ag}{V}$ and for values outside the range covered in the Table.

Section 2

CONTROLS FOR SPACE HEATING AND HOT WATER SUPPLY SYSTEMS

COMMERCIAL AND INDUSTRIAL INSTALLATIONS

2.1 This section is not intended to apply to control systems for commercial and industrial processes.

HEATING CONTROLS IN DWELLINGS

2.2 For dwellings heated from a central appliance capable of on-off operation the space heating output should be controlled by the provision of a room thermostat or thermostatic radiator valves or any other equivalent form of sensing device to control the output from the heating system. Such systems should also be provided with a clock control to allow intermittent operation.

Diagram 3 Elemental U values and glazing areas (dwellings and other small buildings < 300 m²)

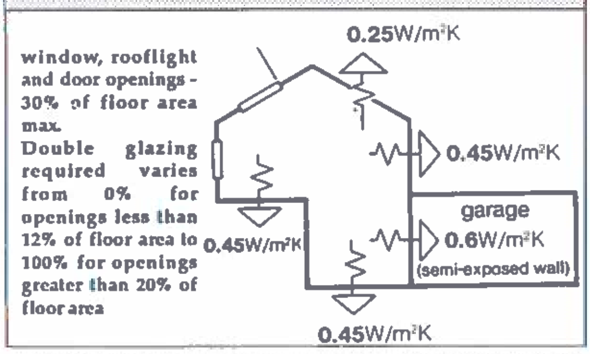
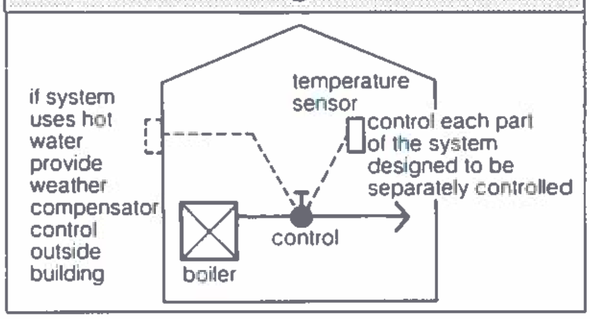


Diagram 4 Room temperature control (Buildings other than dwellings)



HEATING CONTROLS IN OTHER BUILDINGS

2.3 For buildings other than dwellings the space heating output should be controlled by the provision of:

(a) thermostats or thermostatic radiator valves, or any other equivalent form of temperature sensing, for each part of the space heating system designed to be separately controlled;

(b) where the space heating system uses hot water, an external temperature sensing device (weather compensating control) to regulate the temperature of the water flowing in the heating circuit: (see Diagram 4);

(c) intermittent heating controls to maintain the required temperature only when the building is normally occupied. The following provision should be made;

- for space heating with an output of 100 kW or less, a clock control which can be manually set to give start and stop times, and

- for space heating with an output more than 100kW a control arrangement giving start times for the heating system based on the rate at which the building will react when the heating is shut off and re-started (optimising control).

In addition, controls may be provided which will allow sufficient heating to prevent damage to the building structure, services or contents, by frost, excessive humidity or condensation; (see Diagram 5);

(d) boiler controls to achieve efficient operation where two or more gas or oil-fired boilers with a total load more than 100 kW, supply the same heat demand. Boilers run most efficiently at, or near, full output and control should be provided in a form which can detect variations in the need for heat in the building and so start, stop or modulate the boilers as needed (sequence control). Care is needed in the hydraulic design to ensure stable control. (See Diagram 6).

CONTROL FOR HOT WATER STORAGE VESSELS

2.4 For all buildings, other than dwellings where the hot water is provided by a solid fuel fired appliance, hot water energy use should be controlled by the provision of:

(a) a thermostat to keep the water at required temperature for all hot water storage vessels; and

(b) where the hot water storage vessel has a capacity of more than150 litres, and water is not heated by off-peak electricity, a time switch which will shut off the supply of heat when there is no hot water demand. (see Diagram 7).

Diagram 5 Intermittent heat control (Buildings other than dwellings)

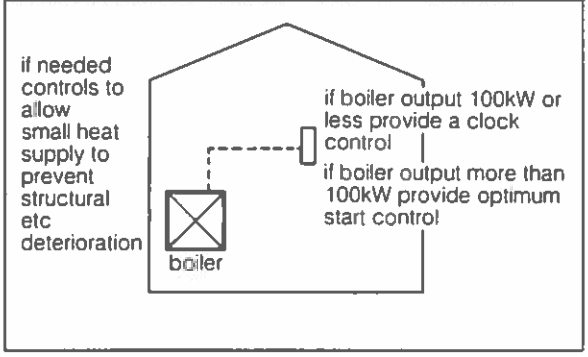


Diagram 6 Boiler control (Buildings other than dwellings)

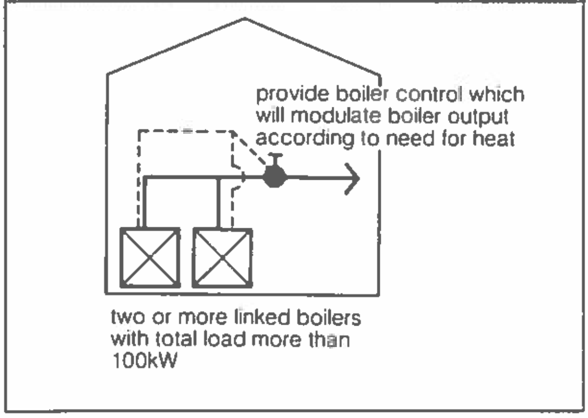
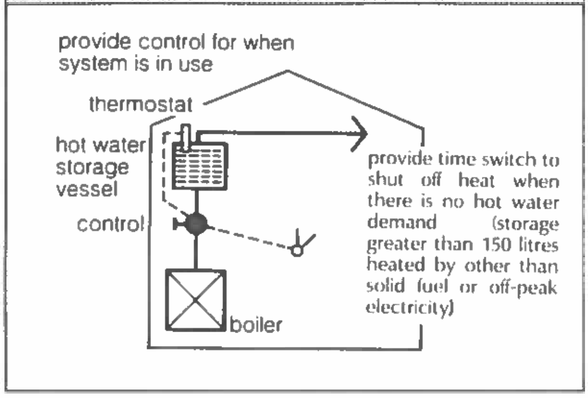


Diagram 7 Hot water storage control (All buildings)



Section 3

INSULATION OF HOT WATER STORAGE VESSELS, PIPES AND DUCTS

COMMERCIAL AND INDUSTRIAL INSTALLATIONS

3.1 This Section is not intended to apply to storage and piping systems for commercial and industrial processes.

INSULATION OF HOT WATER STORAGE VESSELS

3.2 Hot water storage vessels should be insulated so as to limit in use the heat loss to 90W/m² of surface area of the vessel. For factory insulated cylinders this can be achieved by the storage vessel complying with the relevant requirements of:

BS 699 : 1984 Copper direct cylinders for domestic purposes

BS 1566 Copper indirect cylinders for domestic purposes, Parts 1 and 2:1984, or

BS 3198 : 1981 Copper hot water storage combination units for domestic purposes.

For other cylinders it can be achieved by the use of an insulating jacket complying with the requirements of

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

Where an insulating jacket is used the segments of the jacket should be taped together so as to provide an unbroken insulation cover for the storage vessel. (see Diagram 8).

INSULATION OF PIPES AND DUCTS

3.3 Unless the heat loss from a pipe or duct contributes to the useful heat requirement of a room or space, the pipe or duct should be insulated so that:

(a) for pipes, the insulation material should have a thermal conductivity not greater than 0.045 W/mK and a thickness equal to the outside diameter of the pipe for pipes up to 40 mm diameter and a minimum of 40 mm for larger pipes (see Diagram 9).

(b) Alternatively for pipes, and in the case of ducts, insulation should meet the recommendations of BS 5422: 1990 Method of specifying thermal insulating materials for pipes, ductwork and equipment (in the temperature range - 40°C to + 700°C). (see Diagram 10).

Diagram 8 Hot water storage vessels

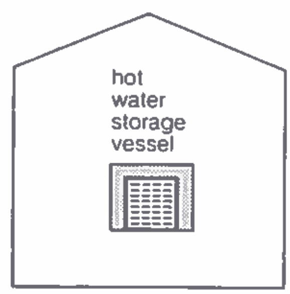
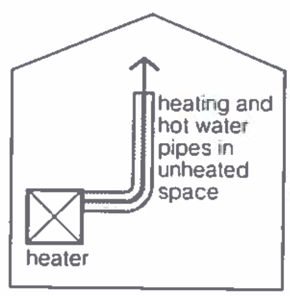


Diagram 9 Heating and hot water pipes



APPENDIX A

CALCULATION OF U VALUES

A1 The U value of an element of construction may be calculated by adding together the thermal resistance of the component parts of the construction, and then taking the reciprocal.

Table 5 Thermal Conductivity of some common building materials

Material	Density (kg/m³)	Thermal Conductivity (W/mK)
Walls (External and Internal)		
Asbestos cement sheet	700	0.35
Asbestos cement decking	1,500	0.36
Brickwork (outer leaf)	1,700	0.84
Brickwork (inner leaf)	1,700	0.62
Cast concrete (dense)	2,100	1.40
Cast concrete (lightweight)	1,200	0.38
Concrete block (heavyweight)	2,300	1.63
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
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 woolslab	500	0.10
Floors		
Cast concrete	2,000	1.13
Metal tray	7,800	50.00
Screed	1,200	0.41
Timber flooring	650	0.14
Wood blocks	650	0.14
Insulation		
Expanded polystyrene (EPS) slab	25	0.035
Glass fibre quilt	12	0.040
Glass fibre slab	25	0.035
Mineral fibre slab	30	0.035
Phenolic foam	30	0.040
Polyurethane board	30	0.025
Urea formaldehyde (UF) foam	10	0.040

NOTES

Where the claimed thermal conductivity of a masonry material is lower than stated in the above Table, the claim should be supported by test certificates as required in Appendix 4 of the CIBSE Guide, A3, 1980.

A2 The thermal resistances of the component parts of an element are calculated as follows:

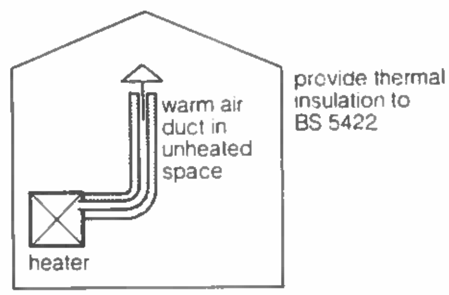
(a) in the case of a solid homogeneous material (such as concrete for instance) by dividing the thickness of the material (in metres) by its thermal conductivity (W/mK;) (Thermal conductivities of common building materials are given in Table 5);

(b) in the case of a non-homogeneous or bridged material (such as a hollow concrete block for instance) by calculation in accordance with the CIBSE Guide A3: 1980.

(c) in the case of an air space or surface, by using standard values for resistance such as:

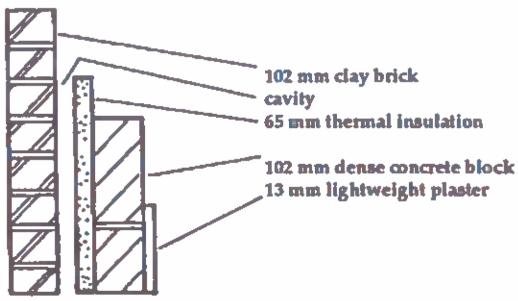
Exposed walls :	outside surface	= 0.06 m²K/W
	inside surface	= 0.12 m²K/W
	air space (cavity)	= 0.18 m²K/W
	air space with aluminium foil surface	= 0.35m²K/W
Roofs :	outside surface	= 0.04 m²K/W
	inside surface	= 0.10 m²K/W
	roof space (pitched)	= 0.18 m²K/W
	roof space (flat)	= 0.17 m²K/W
Exposed floors:	outside surface	= 0.04 m²K/W
	inside surface	= 0.14 m²K/W

Diagram 10 Warm air ducts



EXAMPLE A1 CALCULATION OF U VALUE OF EXTERNAL WALL

Diagram 11 Cavity wall



Component part of Wall	Thermal conductivity of Material (W/mK)	Thickness of material (m)	Thermal resistance (m^2K/W)
Outside Surface	-	-	0.06
Clay brick	0.84	0.102	0.12
Cavity -	-		0.18
Insulation	0.04	0.065	1.63
Concrete Block	1.63	0.102	0.06
Plaster (light weight)	0.16	0.013	0.08
Inside Surface	-	-	0.12

Total Resistance =2.25

U Value of construction = 1/2.25 = 0.44 W/m²K

A3 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 resistance of the component part 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.

EXAMPLE A2

Given the construction in Example 1 what thickness of insulation (thermal conductivity = 0.035 W/mK) is required to achieve a U value of 0.45 W/m²K.

(a) Sum of component resistances:
(0.06+0.12+0.18+0.06+0.08+0.12)
= 0.62 (m²K/W).

(b) Subtract from reciprocal of U value:
$\frac{1}{0.45} - 0.62 = 1.60$(m²K/W)

(c) Multiply by conductivity:
1.60 x 0.035 = 0.056(m)

Thickness required is 0.056 metres or 56mm.

A4 For typical roof, wall and exposed floor constructions, the required U value can be calculated approximately by the use of Tables 6, 7 and 8.

For a range of thermal conductivities, Table 6 gives the insulation thickness required to achieve specific U values when relying on the insulation material alone. By interpolation in this Table one can estimate the thickness of insulation required to achieve a chosen U value (no allowance being made for the basic uninsulated construction). Table 7 presents the U value of a range of common constructions used for roofs, walls and floors. This table also presents the thickness of insulation which would give the same U value on its own. The inclusion of insulation in a construction may create or remove a cavity, or significantly change the character of an existing cavity. Table 8 gives the equivalent thickness of insulation of a range of common cavity types. Tables 7 and 8 cover the same range of thermal conductivities as Table 6.

Thus, for any of these constructions, the actual thickness of insulation required can be estimated in the following manner:

(a) Select the basic construction, U value required and type of insulation to be used. Establish the thickness of insulation equivalent to the basic construction from Table 7.

(b) Check whether the insulated construction involves the creation, removal or significant alteration of an existing cavity when compared with the basic construction. If so, add or subtract the appropriate insulation thickness from Table 8 to give an adjusted equivalent insulation thickness for the construction.

(c) Establish the thickness of insulation alone required to give the desired U value using Table 6.

(d) Subtract the equivalent thickness of the basic construction, adjusted as outlined in (b) where necessary, from the thickness of insulation alone. This is the required insulation thickness.

Similarily the U value of a construction can be derived by adding the equivalent thickness of insulation (Table 7), adjusted for changes in cavity (Table 8), to the actual thickness and estimating the element U value equivalent to this total thickness from Table 6.

EXAMPLE A3:

Determine the U value of the construction shown.

EQUIVALENT THICKNESS OF INSULATION (THERMAL CONDUCTIVITY 0.035 W/mK)

Basic Construction	-	22mm (Table 7, ItemW2)
Insulation Provided	-	50mm
Total equivalent thickness	-	72mm
U value of construction	-	**0.49 W/m²K**

(by interpolation fromTable 6 e.g. 70mm of insulant gives a U value of 0.50W/m²K; 78mm gives a U value of 0.45 W/m²K)

EXAMPLE A3a:

What thickness of insulation (thermal conductivity 0.035 W/mK) is required to achieve a U value of 0.45 W/m²K.

Thickness of insulation alone	-	78mm (Table 6)
Equivalent thickness of basic construction	-	22mm (Table 7, Item W2)
Thickness required	-	**56mm**

EXAMPLE A4

Determine the U value of this construction

Diagram 12 Partially filled cavity

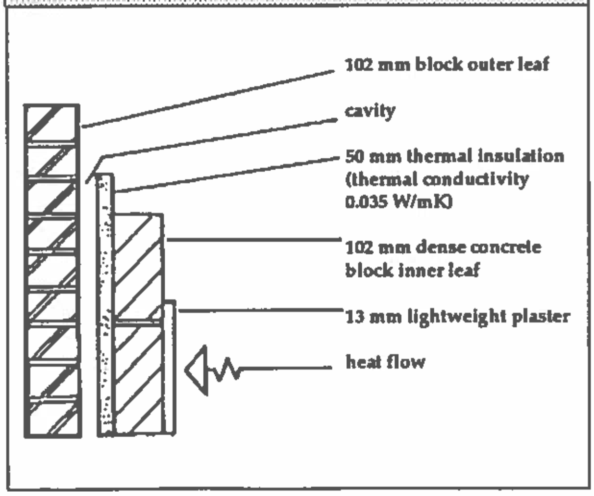
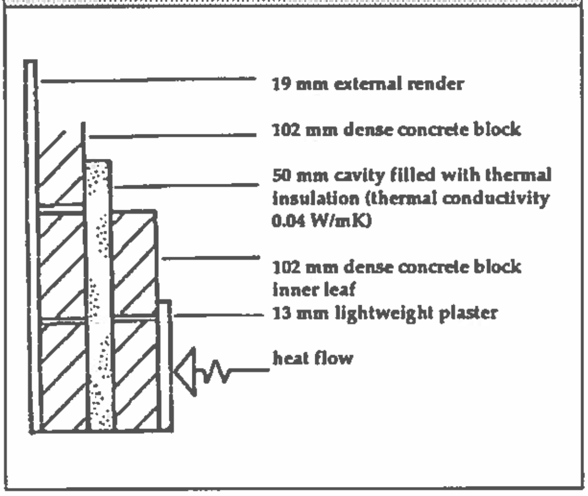


Diagram 13 Filled cavity



EQUIVALENT THICKNESS OF INSULATION (THERMAL CONDUCTIVITY 0.04 W/mK)

Basic Construction	-	23mm (Table 7, Item W1)
Deduct cavity (not retained)	-	7mm (Table 8)
		16mm
Insulation Thickness	-	50mm
Total equivalent thickness	-	66mm

U value of construction - 0.60 W/m²K

Table 6 e.g. 67mm of insulant gives a U value of 0.60 W/m²K

EXAMPLE A4a:

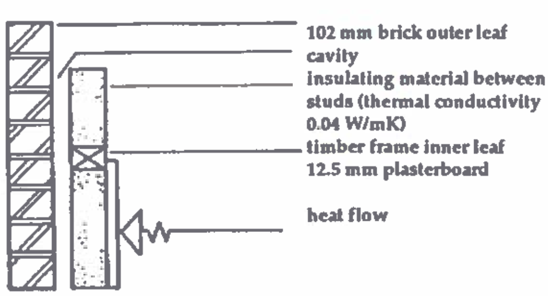
What thickness of insulation (thermal conductivity 0.04 W/mK) is required to achieve a U value of 0.45 W/m²K.

Thickness of insulation alone	-	89mm (Table 6)
Equivalent thickness of basic construction	-	23mm (Table 7)
less cavity (not retained)	-	7mm (Table 8)
Net equivalent thickness		**16mm**
Thickness required		73mm

EXAMPLE A5

Determine U value of the construction shown.

Diagram 14 Timber frame wall



EQUIVALENT THICKNESS OF INSULATION (THERMAL CONDUCTIVITY 0.04 W/m²K)

Basic Construction	-	30mm (Table 7, Item W7)
Deduct Cavity (not retained)	-	7mm (Table 8)
		23mm
Insulation thickness provided	-	100mm
Total equivalent thickness	-	123mm

U value of construction = 0.33 W/m²K

Table 6 e.g. by interpolation between 114mm for U value of 0.35 W/m²K and 133mm for U value of 0.30 W/m²K.

EXAMPLE A5a

What thickness of insulation (thermal conductivity 0.04 W/mK) is required to achieve a U value of 0.45 W/m²K.

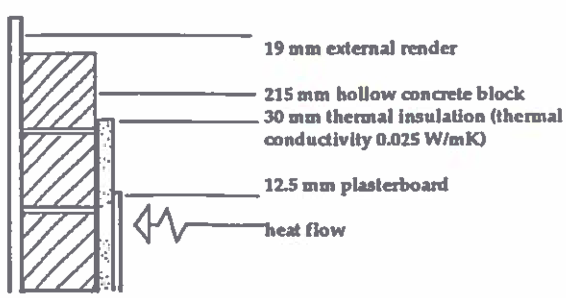
Thickness of insulation alone	-	89mm (Table 6)
Equivalent thickness of basic construction	-	30mm (Table 7)
Thickness required	-	**59mm**

NOTE: As required insulation thickness is less than the cavity formed by the framing, a cavity greater than 25mm wide is retained, and, therefore, there is no deduction from basic construction.

EXAMPLE A6

Determine U value of this construction

Diagram 15 Hollow block wall



EQUIVALENT THICKNESS OF INSULATION (THERMAL CONDUCTIVITY 0.025 WmK)

Basic Construction	-	14mm (Table 7, Item W6)
Deduct cavity (5-25mm) not retained	-	2mm (Table 8)
Net equivalent thickness	-	12mm
Insulation thickness	-	30mm
Total equivalent thickness	-	42mm
U value of construction	-	**0.60 W/m²K (Table 6)**

EXAMPLE A6a

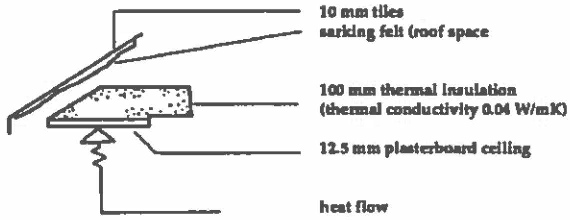
What thickness of insulation (thermal conductivity 0.025 W/mK) is required to achieve a U value of 0.45 W/m²K.

Thickness of insulation alone	-	56mm (Table 6)
Equivalent thickness of basic construction	-	14mm (Table 7)
less cavity (5-25mm) (not retained)	-	2mm (Table 8)
Net equivalent thickness	-	12mm
Thickness required		**44mm**

EXAMPLE A7:

Determine U value of this construction

Diagram 16 Pitched roof



EQUIVALENT THICKNESS OF INSULATION (THERMAL CONDUCTIVITY 0.04 W/mK)

Basic Construction	-	21mm (Table 7, Item R1)
Insulation Thickness	-	100mm
Total Equivalent Thickness	-	121mm
U value of construction	=	**0.33 W/m²K.**

Table 6 by interpolation between 114mm for U value of 0.35 W/mK and 133mm for U value of 0.30 W/m²K

Table 6 Thickness of Insulation required to achieve a given U value (mm)

U Value (W/m²K)	Insulant thermal conductivity (W/mK)				
	.04	.035	.03	.025	.02
.60	67	58	50	42	33
.55	73	64	55	45	36
.50	80	70	60	50	40
.45	89	78	67	56	44
.40	100	88	75	63	50
.35	114	100	86	71	57
.30	133	117	100	83	67
.25	160	140	120	100	80
.20	200	175	150	125	100

Note: No allowance included for surface resistance.

Table 7 Equivalent insulation thicknesses for common construction

CONSTRUCTION		Basic U-Value (W/m^2K)	Equivalent thickness of insulant (mm)				
				Insulant	Thermal	Conductivity	(W/mK)
			.04	.035	.03	.025	.02
	Roofs						
R1	Domestic tiled pitched roof, ventilated roofspace, 12.5mm plaster board ceiling.	1.93	21	18	16	13	10
R2	Flat concrete roof, screed to falls (average thickness 40mm) on 150mm dense concrete with light-weight plaster finish.	2.15	19	16	14	12	9
	Walls						
W1	2 x 102mm concrete block leaves, cavity, 19mm external render, 13mm lightweight plaster.	1.72	23	20	17	15	12
W2	As W1 but with brick external leaf (no external render).	1.62	25	22	19	15	12
W3	As W1 but with 12.5mm plasterboard on dabs or battens (no lightweight plaster).	1.48	27	24	20	17	14
W4	As W2 but with 12.5mm plasterboard on dabs or battens (no lightweight plaster).	1.39	29	25	22	18	14
W5	215mm hollow concrete block, 19mm external render, 13mm light-weight plaster.	2.16	19	16	14	12	9
W6	As W5 but with 12.5mm plasterboard on dabs or battens (no lightweight plaster).	1.78	22	20	17	14	11
W7	100mm timber frame, cavity, and brick or rendered concrete block external leaf with 12.5mm plaster-board and polythene vapour barrier.	1.35	30	26	22	19	15
W8	As W7 but with foil backed plaster-board lining internally	1.10	36	32	27	23	18
	Exposed Floors						
F1	22mm softwood boarding on joists, with 6mm insulating board	1.69	24	21	18	15	12
F2	50mm screed on 150mm dense concrete slab fair-faced.	2.45	16	14	12	10	8

Table 8 Equivalent insulation thickness for different cavity types (mm)

Type of Cavity	Thermal Conductivity of Insulant (W/mK)				
	0.04	.035	.03	.025	.02
5-25mm wide	4	3	3	2	2
5-25mm with aluminium foil surface	7	6	5	4	4
Greater than 25mm wide	7	6	5	4	4
Greater than 25mm wide with aluminium foil surface	14	13	11	9	7

EXAMPLE A7a

What thickness of insulation (thermal conductivity 0.04 W/mK) is required to achieve a U value of 0.25 W/m^2K.

Thickness of insulation alone	-	160mm (Table 6)
Equivalent thickness of basic construction	-	21mm (Table 7)
Thickness required	-	**139mm**

A5 For slab-on-ground and suspended ground floors the rate of heat loss and the level of insulation required to achieve a particular average U value depend on a number of factors including floor shape and dimensions, soil characteristic and, in the case of suspended floors, ventilation rate in the floor space. A method of calculation is presented in the CIBSE Guide, Section A3, 1980, which can be used to calculate floor U values using appropriate values of these variables, where known.

As an alternative to this calculation, Tables 9 and 10 give thickness of insulation which will achieve a floor U value of 0.45 W/m^2K for rectangular slab-on-ground floors and suspended floors respectively. The Tables are designed to be generally applicable and assume a soil thermal conductivity of 2.1 W/mK. Full calculation may show that lesser thicknesses are sufficient in particular situations. The data is presented graphically in Diagrams 17 and 18.

Tables 9 and 10 and Diagrams 17 and 18 relate to rectangular floors with four exposed edges. They can be applied to other rectangular floors on the following basis:

(a) Floor with one unexposed side:

Treat as floor with four exposed edges with the following dimensions: unexposed side x twice side perpendicular to unexposed side.

Example: Semi-detached house 5.5m x 8m with 8m side unexposed. Treat as floor 8m x 11m with four exposed sides.

To achieve U value = 0.45 W/m^2K
(Insulation thermal conductivity 0.035W/mK)

Slab-on-ground floor:	50mm of insulation (Table 9)
Suspended floor:	50mm of insulation (Table 10)

Diagram 17 Rectangular slab-on-ground floor - Dimensions and insulation requirements

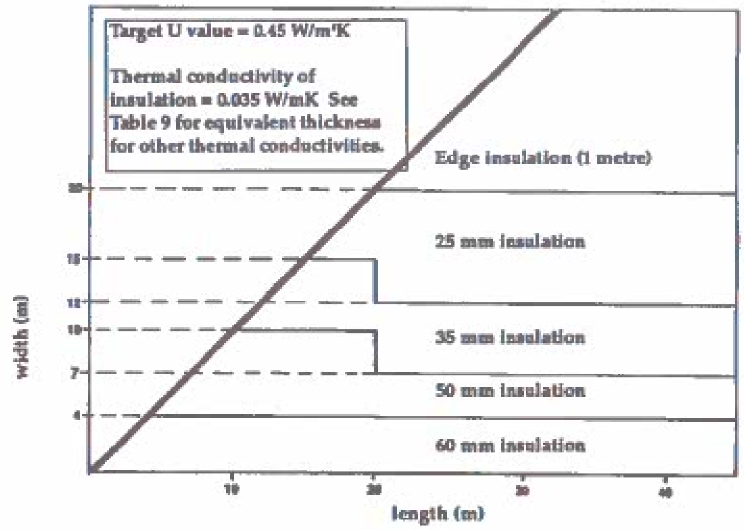


Diagram 18 Rectangular suspended floor - Dimensions and insulation requirements

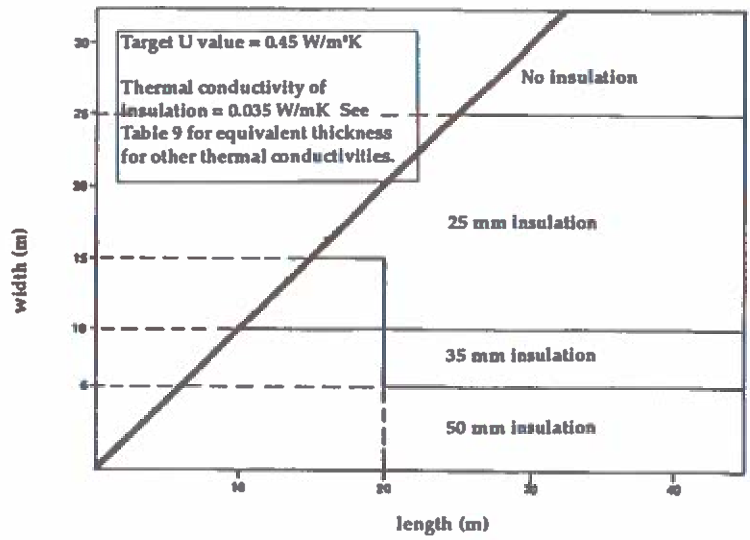


Table 9 Thickness of insulation to achieve U value less than 0.45 W/m²K for rectangular slab-on ground floors with four exposed edges (mm)

Dimension		Thermal conductivity of insulant (W/mK)					
Long side (m)	Short Side (m)	0.45	0.04	0.035	0.03	0.025	0.02
up to 20m	up to 4	77	69	60	51	43	34
	4 to 10	64	57	50	43	36	29
	10 to 15	45	40	35	30	25	20
	15 to 20	32	29	25	21	18	14
greater than 20	up to 4	77	69	60	51	43	34
	4 to 7	64	57	50	43	36	29
	7 to 12	45	40	35	30	25	20
	12 to 20	32	29	25	21	18	14
	above 20	edge insul-ation	edge insul-ation	edge insul-ation	edge insul-ation	edge insul-ation	edge insul-ation

NOTE: Thickness for insulation materials with different thermal conductivities can be calculated on a pro rata basis or by interpolation.

Table 10 Thickness of insulation to achieve U value less than 0.45 W/m²K for rectangular suspended floors with four exposed edges (mm)

Dimensions		Thermal conductivity of insulant (W/mK)					
Long Side (m)	Short Side (m)	0.45	0.04	0.035	0.03	0.025	0.02
Up to 20m	up to 10	64	57	50	43	36	29
	10 to 15	45	40	35	30	25	20
	15 to 20	32	29	25	21	18	14
greater than 20	up to 6	64	57	50	43	36	29
	6 to 10	45	40	35	30	25	20
	10 to 25	32	29	25	21	18	14
	above 25	no insul-ation reqd.	no insul-ation reqd.	no insul-ation reqd.	no insul-ation reqd.	no insul-ation reqd.	no insul-ation reqd.

NOTE: Thickness for insulation materials with different thermal conductivities can be calculated on a pro rata basis or by interpolation.

(b) **Floor with two parallel sides unexposed:**

Treat as floor with four exposed edges with the following dimensions: unexposed side x 20m.

Example: Mid-terrace house 5.5m x 8m with 8m side unexposed. Treat as floor 8m x 20m+ with four exposed edges.

To achieve U value = 0.45 W/m^2K, (Insulation thermal conductivity 0.04 W/mK)

Slab-on-ground floor:	40mm of insulation (Table 9)
Suspended floor:	40mm of insulation (Table 10)

(c) **Floor with two perpendicular sides unexposed:**

Treat as floor with four exposed edges with dimensions double actual dimensions.

Example: Corner flat 6m x 9m. Treat as floor 12m x 18m.

To achieve U value = 0.45W/m^2K. (Insulation thermal conductivity 0.04 W/mK)

Slab-on ground floor:	40mm of insulation (Table 9)
Suspended floor :	40mm of insulation (Table 10)

(d) **Floor with three sides unexposed. Treat as floor with four exposed edges and the following dimensions: twice parallel unexposed sides x 20m**

Example: Central ground floor flat 6m x 9m with 9m side exposed. Treat as floor 12m x 20m

To achieve U value = 0.45W/m^2K, (Insulation thermal conductivity 0.035W/mK)

Slab-on-ground floor:	35mm of insulation (Table 9)
Suspended floor :	25mm of insulation (Table 10)

It should be borne in mind that ground floor insulation may have to carry significant loads. The insulant chosen should have sufficient compressive strength to support this loading without excessive deformation.

A6 The calculation of window U values is complex with the value dependent not only on the glazing characteristics but also on frame type and window construction. Table 11 gives standard and effective U values for typical commonly used window types. These can be used where certified values are not available from the manufacturer.

Table 11 Standard and effective U value of glazed elements (W/m^2K)

Type of Glazing	Standard U value (W/m^2K)	Effective U value (W/m^2K) Orientation		
		North	South	East/West
Single glazing				
-metal frame	5.7	4.8	2.8	4.1
-wood/PVC frame	5.0	4.2	2.4	3.6
Double Glazing				
-metal frame	3.3	2.5	0.9	2.0
-wood/PVC frame	2.9	2.2	0.8	1.7

APPENDIX B

LIMITATION OF HEAT LOSS THROUGH BUILDING FABRIC

BI The following examples illustrate the application of the three methods of demonstrating the efficient limitation of heat loss through the building fabric which were presented in Section 1. Example BI relates to semi-detached houses and the application of all three methods is demonstrated. Examples B2 and B3 relate to commercial and industrial constructions respectively, types of buildings to which the overall heat loss method only applies.

EXAMPLE BI SEMI-DETACHED HOUSE

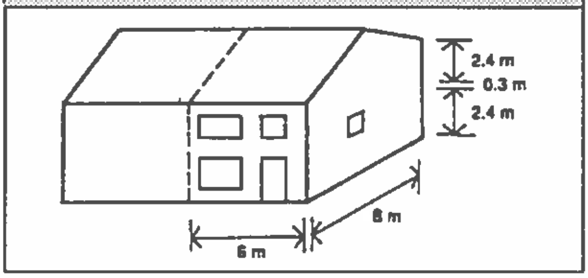
It is proposed to construct a semi-detached two storey house with the following dimensional and construction characteristics.

Dimensions (internal)	Width	-	6 m
	Depth	-	8 m (one side only exposed, adjoining house attached on other side)
	Height	-	5.1 m (2.4 metres floor to ceiling height, 300 mm first floor zone).
Door and Window Openings:	Front	-	8.5m² (including 1.7m² solid timber front door)
	Rear	-	6.7m² (including 1.7m² solid timber rear door)
	Side	-	1.0m²
	Total	-	16.2m² (17% of floor area).
Construction:	Roof:		Pitched tiled roof, 150mm glass fibre insulation laid on attic floor.
	Walls:		Cavity wall (dense concrete blocks) rendered externally, plastered internally with 50mm polystrene in the cavity and 50mm cavity retained.
	Floor:		Concrete slab-on-ground floor with edge insulation (25mm polystrene, 1 metre wide).
	Windows:		Single glazed, wooden frame.

This construction gives the following elemental U values.

Roof	0.23 W/m²K
Wall	0.50 W/m²K
Floor	0.75 W/m²K
Windows	5.0 W/m²K
Doors	2.9 W/m²K

Diagram 19 Semi-detached house



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

1. OVERALL HEAT LOSS METHOD

This is the basic method proposed and is generally applicable to all buildings. It provides greater flexibility than the elemental heat loss method. Use of the 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_m). The calculation of U_m 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. For the house under consideration the following calculation is required.

Heat loss element	Area (m²)	U value (W/m²K)	Area x U value (W/K)
Roof	48.00	0.23	11.04
Wall	85.80	0.50	42.90
Floor	48.00	0.75	36.00
Windows (single glazed, wood frame)	12.80	5.00	64.00
Doors (solid wood)	3.40	2.90	9.86

Total Area (A_t)(m²) = 198.00 Total AU (W/K) = 163.80

$U_m = \frac{\text{Total AU}}{A_t} = \frac{163.80}{198.00} = 0.83 W/m^2K$

Maximum Allowable Um

Building Volume (V) = 244.80m³

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

Maximum allowable Um (from Table 1) = 0.69 W/m²K.

The proposed construction is not acceptable. It is therefore necessary to improve the insulation characteristics of specific elements in order to reduce U_m to 0.69 W/m^2K or less. Specifically, the floor U value must be reduced to 0.45 W/m^2K. The proposals made below to satisfy the elemental heat loss method are, of course, satisfactory giving a value of U_m of 0.65 W/m^2K.

Compliance can also be achieved by a number of other methods including the following:

a) Double glazing (metal frame) front windows (6.8m²) and 50mm full floor insulation to ground floors. This gives a value of U_m of 0.68 W/m^2 which is acceptable.

b) Double glazed (metal frame) all windows, 50mm full floor insulation to ground floor and reduction of attic insulation to 100mm glass fibre (U = 0.35W/m²K). This gives a value of U_m of 0.67 W/m^2K which is acceptable.

2. ELEMENTAL HEAT LOSS METHOD

This is the easiest method to apply but provides little flexibility. Table 2 gives the required U values. Both wall and floor constructions are not acceptable. The acceptability of single glazing must also be checked.

a) Walls: The thickness of insulation (thermal conductivity =.035 W/mK) required to give U value = 0.45 W/m^2K can be established using Tables 6 and 7.

Thickness of insulation alone.	78mm (Table 6)
Equivalent thickness of basic construction	20mm (Table 7, Item W1)
Required thickness	58mm

Assume 60mm insulation used. This gives a U value of 0.44W/m²K (By interpolation in Table 6).

b) Floor: The floor has one unexposed side (8m side). To use Table 9, therefore, the floor should be treated as one with four exposed edges having dimensions 8mx12m. For this floor, assuming the insulation thermal conductivity is 0.035W/mK, Table 9 requires the use of 50mm insulation over the whole floor.

c) Openings: For opening area equal to 17% of floor area, Table 3 gives the minimum proportion of double glazing or equivalent as 62%. The total area of openings is 16.2m². Thus the area of double glazing or equivalent required is 10.1m². The area provided is 3.4m² (solid doors being treated as the equivalent of double glazing). Therefore, a further 6.7 m² of glazing must be double glazed. For example this could be achieved by double glazing all windows on the front of the house (6.8m²).

Compliance could also be achieved by reducing total openings area to 13.4m² and retaining single glazing. This would reduce glazing to 14% of floor area and the proportion of double glazing required to 25%. This would be provided by solid doors alone.

To comply with the requirements of the elemental heat loss method it is necessary:

a) to increase wall insulation to 58mm (probably use 60mm);

b) provide 50mm full floor insulation;

c) provide at least 6.7m² double glazing (or reduce overall opening area to 13.4m²).

3. NET HEAT LOSS METHOD

This method allows for solar gain through windows by using an effective U value for windows depending on their orientation. The calculation procedure is similar to that used for the overall heat loss method except that effective U values are used for glazing and an average effective U value (U_{me}) calculated.

Assuming the house is facing East/West, the following calculation applies:

Heat Loss Element		Area (m^2)	U value (W/m^2K)	Area x U value (W/K)
Roof		48.00	0.23	11.04
Wall		85.80	0.50	42.90
Floor		48.00	0.75	36.00
Windows	- Front (East/West)	6.80	3.6	24.48
	- Rear(East/West)	5.00	3.6	18.00
	- Side (North)	1.00	4.2	4.20
Doors		3.40	2.9	9.86

Total Area (A_t) (m^2) = 198.00 Total AU(W/K) = 146.48

$$U_{me} = \frac{\text{Total AU}}{A_t} = \frac{146.48}{198.00} = 0.74\ W/m^2K$$

Maximum Allowable U_{me}

$$\frac{At}{V} = 0.81\ ; \quad \frac{Ag}{V} = \frac{12.80}{244.80} = 0.052$$

Maximum Allowable U_{me} (from Table 4) = 0.59 W/m^2K

The proposed construction is not acceptable. Again there are a number of options to achieve compliance.

The following show the effect of orientation.

a) Reorient the house to face south, transfer $2m^2$ glazing from back to front (giving $8.8m^2$ in front and $3m^2$ at rear), double glaze north facing glazing ($3m^2$) and provide 50mm full floor insulation. This gives a value of U_{me} of 0.58 W/m^2K which is acceptable.

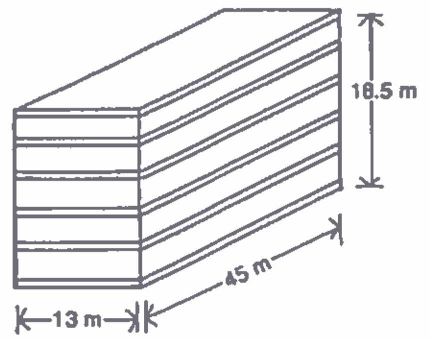
b) Reorient house to face south, with $8.8m^2$ glazing in front and $3.0m^2$ glazing at rear (as (a) above). All glazing to remain single glazed. Provide 60mm insulation in wall (giving a U value of 0.44 W/m^2K) and 50mm full floor insulation. This gives a value of U_{me} of 0.58 W/m^2K which is acceptable.

EXAMPLE B2 OFFICE BUILDING

A detached 5 storey shop and office building 45m x 13m in plan and 18.5m internal height is to be constructed. Shops are provided on the ground floor with 80% of the front facade being display windows. No glazing is provided to the side or rear on the ground floor. The upper four floors are provided with 60% double glazing (metal frames) 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/m²K and roof a U value of 0.60 W/m²K. The solid ground floor is edge-insulated.

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

Diagram 20 Office building



The following calculations give the total heat loss area (A_t), the average U value of heat loss elements (U_m) and building volume. The U_m value can then be compared with the maximum value set in Table 1.

Heat Loss Element	Area (m²)	U Value (W/m²K)	Area x U Value (W/K)
Roof	585	0.60	351.00
Wall	1210	0.50	605.00
Floor	585	0.44	257.40
Windows	810	3.3	2673.00
Doors	20	2.9	58.00
Total Area (A_t) (m²) =	3210	Total AU (W/K) =	3944.4

$$U_m = \frac{\text{Total AU}}{A_t} = \frac{3944.4}{3210} = 1.23 \text{ W/m}^2\text{K.}$$

Note: Display window area (126m²) not included in glazing area or in total area.

Maximum Allowable U_m

Building Volume (V) = 10,822.5 m³

$$\frac{A_t}{V} \quad \frac{3210}{10822.5} = 0.30$$

Maximum Allowable U_m (from expression $U_m = 0.42+0.22\ V/A_t$)

$= 1.16$ W/m²K.

The proposed construction is not acceptable. Among satisfactory solutions are:

a) Improve roof insulation to give a U value of 0.4 W/m²K and reduce office glazing to 57% of front and rear facades. This gives a value of U_m of 1.16 W/m²K.

b) Improve roof insulation to 0.4 W/m²K, reduce office glazing to 35% of front and rear facades and use PVC framed single glazing. This gives a value of U_m of 1.16 W/m²K.

EXAMPLE B3 INDUSTRIAL BUILDING

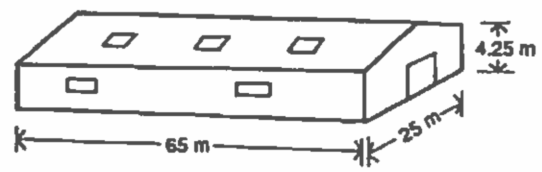
A single story industrial building 65 metres long, 25 metres wide and 4.25 metres high with a roof pitch of 10° is to be constructed. The roofs and walls are to have a U value of 0.60 W/m²K. Glazing is to be provided as follows:

15% of roof area - single glazed, metal frame
15% of wall area - single glazed, metal frame

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

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

Diagram 21 Industrial building



The following calculations give the total heat loss area (A_t), the average U_m value of heat loss elements (U_m) and the building volume (V). The U value can then be compared with the maximum value set in Table 1.

Heat Loss Element	Area (m²)	U value (W/m²K)	Area x U Value (W/K)
Roof (10° slope)	1403	0.60	841.80
Walls	657	0.60	394.20
Floor	1625	0.29	471.25
Windows - roof	247	5.70	1407.90
- wall	123	5.70	701.1
Doors (insulated)	40	1.50	60.00
Total Area (A_t) (m²) =	4095	Total AU (W/K) =	3876.25

$$U_m = \frac{\text{Total AU}}{\text{At}} = \frac{3876.25}{4095} = 0.95 \text{ W/m}^2\text{K}$$

Maximum allowable U_m

Building volume = 8697.07m³

$$\frac{A_t}{V} = \frac{4095}{8697.07} = 0.47$$

Maximum U_m (from Table 1) = 0.89W/m²K.

The proposed construction is not acceptable. One satisfactory solution would be to double glaze the roof glazing. This gives a value of U_m of 0.83 W/m²K.

Standards and other references

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BS 3958 Thermal insulating materials Part 3 : 1985 Metal mesh faced man-made mineral fibre mattresses.

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