

## Reflective foil insulation – Conventions for U value calculations

### Introduction

Reflective foil insulation can be divided into products that typically comprise two or more layers of heat reflecting foil and internal layers of low density wadding insulation (also known as multifoils) and products where the inner surface is bubble sheet. The first type (see figures opposite) are soft and easily compressed by fixing battens and can expand in between battens.

Adopting different assumptions as to a product's thickness at these points and to what extent it intrudes into adjacent air cavities can have a small, but sometimes significant, effect on the result of a U value calculation. For both types of product, maintaining an air cavity on either side is preferable, as the low emissivity surface of the outer foil will increase the thermal resistance of the cavity, contributing towards achieving an overall lower U value for the specific construction.

This bulletin sets out some dimensional conventions to assist in the calculation of U values for elements incorporating reflective insulations. In the interest of consistency and simplification, the same conventions are applied to products with bubble sheet in the middle, even though these products are thinner and less compressible.

The conventions in this bulletin should be used and are a requirement for calculations carried out in accordance with the BBA/TIMSA *U value and condensation risk calculation competency scheme*. Example calculations are included in Annexes A and B of this bulletin.



### Conventions

- |                                  |   |
|----------------------------------|---|
| Product thickness (uncompressed) | As declared by the supplier. This is usually measured at a loading pressure of 50 Pa, to BS EN 823.   |
| Product thickness (compressed)   | When compressed between battens and rafters/studs, the thickness is taken as zero, unless the thickness and corresponding R value have been robustly determined under representative installed conditions. In the absence of a recognized standard to determine these parameters, testing the product under a pressure of 20 kPa would be sufficient to determine the compressed thickness value.   |
| Adjacent air cavity thickness    | Depending on the installation, a cavity could be created on either side of the product so the following two cases can be distinguished:<br><i>Cavity on both sides</i><br>When the product is installed above and/or below rafters in a roof construction, a ratio of 30/70 for the opening of the product is to be used accounting for the effect of gravity (see Figure 1). For a wall construction, a 50/50 opening is appropriate.<br><i>Cavity on one side</i><br>In a timber frame stud wall (studs fully filled with mineral wool) or in a roof (mineral wool completely filling the rafter cavity), the product sits entirely in the plasterboard cavity and flush with the face of the stud/joist/rafter to which it is fixed. |

The standard method of calculating air cavity resistances is that given in BS EN ISO 6946 : 2007 *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*. In this method the mean cavity temperature is 10°C and the temperature difference across the cavity is 5 K.

Another approach is to use ISO 15099 : 2003 *Thermal performance of windows, doors and shading devices — Detailed calculations* which provides a detailed iterative calculation using the relevant generic formulae for convective heat and can indicate slightly enhanced and perhaps more 'realistic' cavity R values. It is a construction specific calculation and the resulting cavity R value cannot be transferred to other constructions. This calculation is very complex and requires programming by an individual with good knowledge of U value calculations and it will not be included at this stage in the U value competency scheme developed jointly by the BBA and TIMSA. It is also now BBA policy not to make use of this calculation method in certificates where its usefulness is limited by its construction specific nature.

All the example U value calculations in this bulletin were performed using the principles and suggested thermal conductivity values given in BRE report (BR 443: 2006) *Conventions for U-value calculations* and BS EN ISO 6946: 2007. Also BS EN ISO 10456 : 2007 *Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values* was used for obtaining typical thermal conductivity values. To calculate the cavity air resistance, the method described in BS EN ISO 6946: 2007, Annex B, (for  $\Delta T \leq 5$  K and with a mean cavity temperature of 10°C) was used. The U value calculation method used in this bulletin is illustrated in Approved Document L (2002), Appendix B Calculating U values.

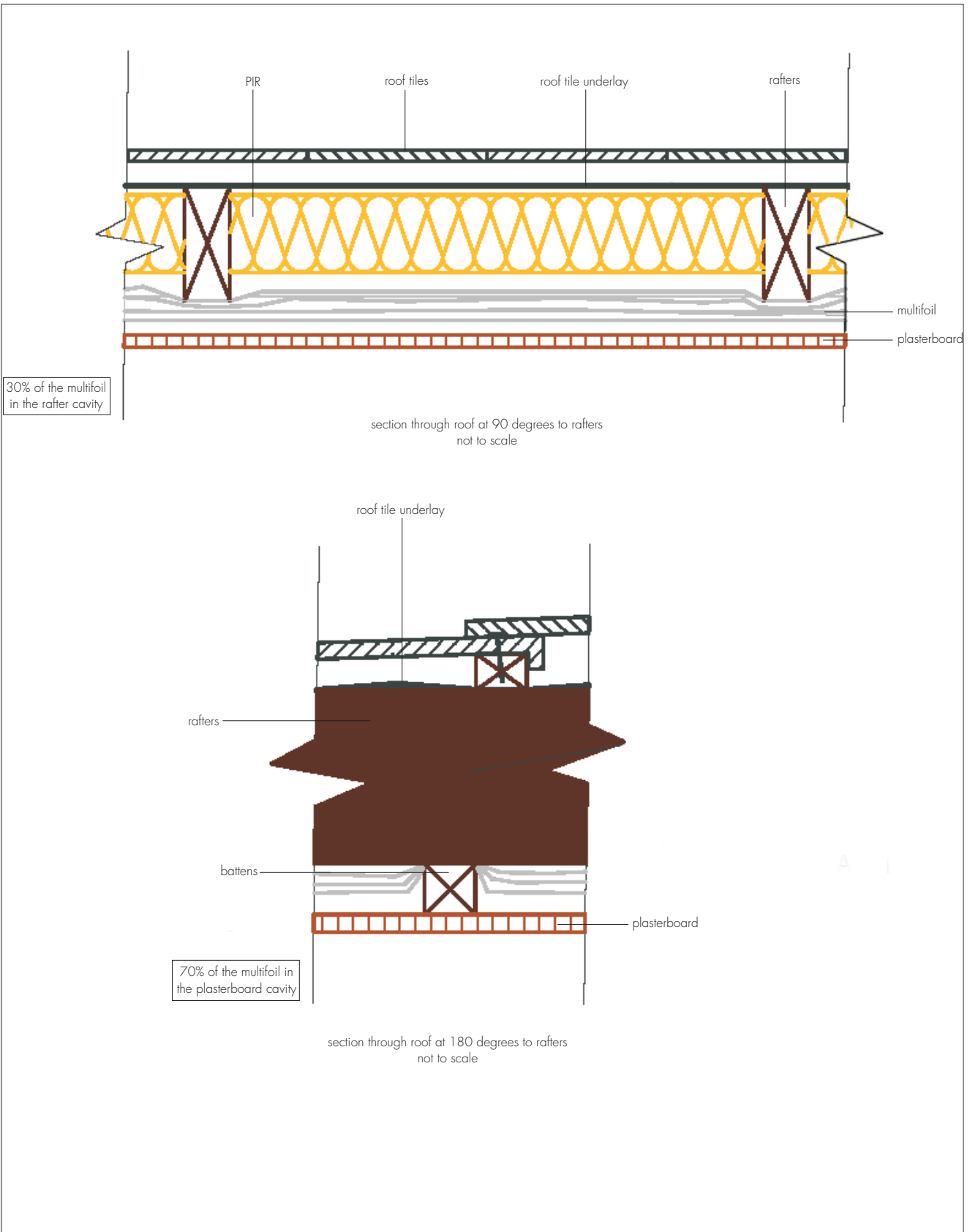
Using the set of conventions presented above, detailed U value calculations are provided for a roof construction utilising PIR or mineral wool and multifoil insulation and a timber-frame wall construction using glass wool and multifoil.

A roof construction with PIR between the rafters and reflective insulation under the rafters, one of the common configurations used in loft refurbishment, is shown in Figure 1 .

The compression of the product due to rafters pushing against the battens is also illustrated in Figure 1 , and the product can be seen 'draping' around the batten.

The convention used in this bulletin is that 30% of the multifoil will open up in the rafter cavity and 70% will be in the plasterboard cavity (created by the battens), taking the effect of gravity loosely into account. For example, for a 30 mm multifoil, 10 mm will be considered as bridged with the rafters and the cavity and 20 mm will be bridged with the battens and the cavity. This is assuming that the thickness of the product, when compressed between batten and rafters, would be zero.

Figure 1 Roof construction using reflective insulation and PIR



# Annex A

## Roof construction

The rafters are 47 mm thick by 100 mm deep at 600 mm centres, giving a timber percentage of  $47/600 = 7.8\%$ . Spacer battens 20 mm thick are used as well. The counter battens are 38 mm by 50 mm and at 600 mm centres, giving a timber percentage of  $38/600 = 6.3\%$ .

The multifoil is 30 mm thick and the outer layer emissivity of both surfaces is 0.05. The thickness of the multifoil, when compressed between battens, is assumed to be zero.

The  $R$  values used for the  $U$  value calculation and the different layers contributing to the upper and lower resistance limits calculation are given in Table 1.

*Table 1 List of materials used in the roof construction shown in Figure 2*

Layer	Material	Thickness (mm)	Thermal conductivity ( $\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ )	Thermal resistance ( $\text{m}^2\cdot\text{K}\cdot\text{W}^{-1}$ )
1	External surface			0.10 <sup>(1)</sup>
2a	Air cavity	20		0.34 <sup>(2)</sup>
2b	Rafter	20	0.13	0.154
3a	PIR <sup>(3)</sup>	80	0.022	3.636
3b	Rafter	80	0.13	0.615
4a	Air cavity	10		0.37
4b	Spacer battens	10	0.13	0.077
5a	Multifoil	10		0.30
5b	Spacer battens	10	0.13	0.077
6a	Counter battens	20	0.13	0.154
6b	Multifoil	20		0.61
7a	Counter battens	18	0.13	0.138
7b	Air cavity	18		0.46
8	Plasterboard <sup>(3)</sup>	12.5	0.21	0.059
9	Internal surface			0.10

(1) The external surface resistance according to BS EN ISO 6946: 2007 is  $0.04 \text{ m}^2\cdot\text{K}\cdot\text{W}^{-1}$  but in this case it can be taken as  $0.10 \text{ m}^2\cdot\text{K}\cdot\text{W}^{-1}$  since the area under the tiles is well ventilated.

(2) If the roof underlay is HR according to BS 5250: 2002, this cavity is considered ventilated. In this case the thermal resistance of the cavity and of the external surface would be  $0.17 \text{ m}^2\cdot\text{K}\cdot\text{W}^{-1}$ , as there is a low  $e$  surface of a PIR board on one side of the cavity.

(3) Both products are foil backed with outer layer emissivity of 0.20.

The different layers in the construction, with one well-defined layer in the rafter cavity (PIR, air cavities and multifoil) and two independent layers in the plasterboard cavity, between the timber battens, the air cavity and the multifoil, are shown in Figure 2. There are a total of four heat flow paths in this construction.

The total thermal resistance value is calculated using the equation:

$$R_T = \frac{R_U + R_L}{2}$$

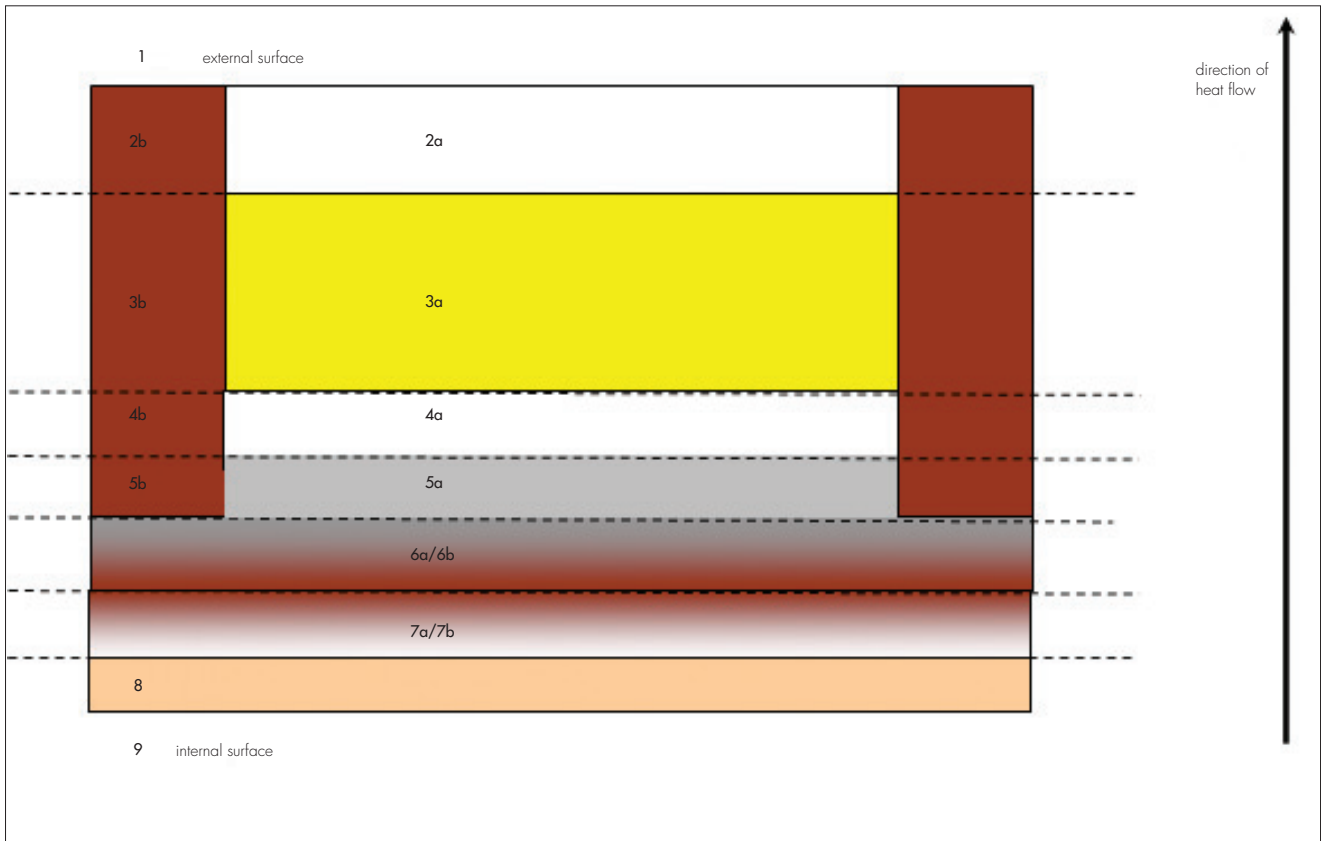
where:

$R_U$  is the upper limit resistance and  $R_L$  is the lower limit resistance. The upper limit resistance is calculated by combining in parallel the total resistance of all possible heat flow paths and the lower limit resistance by considering the heat flow paths of each layer separately.

The  $U$  value is then determined from the equation (units in  $\text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$ ):

$$U = 1/R_T$$

Figure 2 Schematic of roof construction (not to scale)



The upper limit resistance equals:

$$R_U = \frac{1}{\frac{F_1}{R_1} + \frac{F_2}{R_2} + \frac{F_3}{R_3} + \frac{F_4}{R_4}}$$

with:

$$R_1 = R_e + R_{2b} + R_{3b} + R_{4b} + R_{5b} + R_{6a} + R_{7a} + R_8 + R_i$$

$$R_2 = R_e + R_{2b} + R_{3b} + R_{4b} + R_{5b} + R_{6b} + R_{7b} + R_8 + R_i$$

$$R_3 = R_e + R_{2a} + R_{3a} + R_{4a} + R_{5a} + R_{6a} + R_{7a} + R_8 + R_i$$

$$R_4 = R_e + R_{2a} + R_{3a} + R_{4a} + R_{5a} + R_{6b} + R_{7b} + R_8 + R_i$$

where:  $R_e$  and  $R_i$  are the external and internal resistances respectively,

and:  $F_1 = 0.078 \times 0.937 = 7.34\%$ ,  $F_2 = 0.078 \times 0.063 = 0.49\%$ ,  $F_3 = 0.9217 \times 0.063 = 5.81\%$   
 $F_4 = 0.9217 \times 0.937 = 86.36\%$ , therefore:

$$R_U = 5.215 \text{ m}^2\cdot\text{K}\cdot\text{W}^{-1}$$

The lower limit resistance is calculated using:  $R_l = R_e + R'_2 + R'_3 + R'_4 + R'_5 + R'_6 + R'_7 + R'_8 + R_i$ .

where:  $R'_2 = \frac{1}{\frac{F_{2b}}{R_{2b}} + \frac{F_{2a}}{R_{2a}}}$

with fractional areas of  $F_{2b} = 7.8\%$  and  $F_{2a} = 92.17\%$ . The same  $F$  values are used for  $R'_3$ ,  $R'_4$  and  $R'_5$ , while  $F_{6b} = 6.3\%$  and  $F_{6a} = 93.7\%$  is used for calculating  $R'_6$  and  $R'_7$ .

Therefore:  $R_l = 4.638 \text{ m}^2\cdot\text{K}\cdot\text{W}^{-1}$

The U value for this construction is:  $U_T = 0.20 \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$ .

For a roof construction using mineral wool (typical thermal conductivity value of  $0.032 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ ) instead of PIR between the rafters, 130 mm of insulation will be needed to achieve a U value of  $0.20 \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$ . In that case there will be no air cavity between the mineral wool and the multifoil.

## Annex B

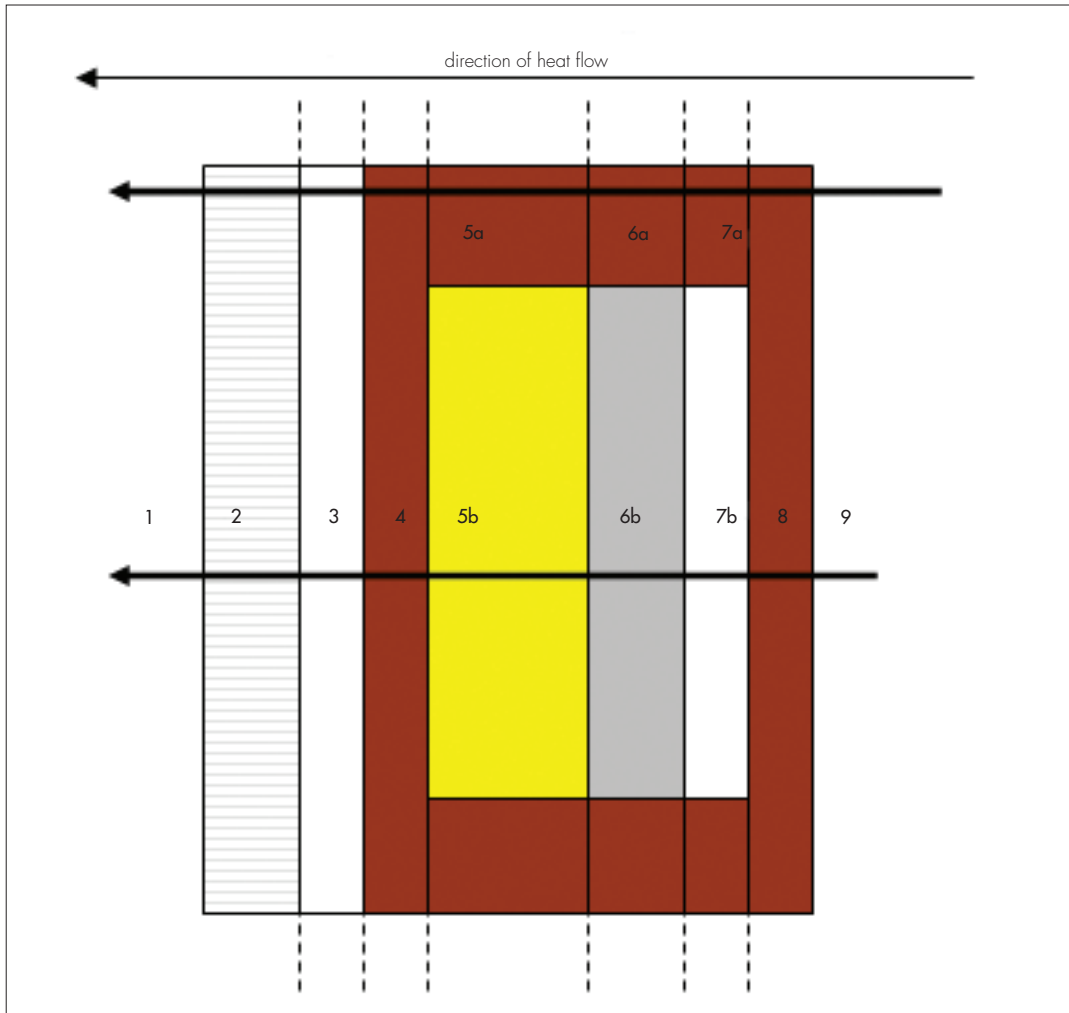
### Wall construction

The same method as in Annex A is used for calculating U values when using the multifoil in a timber frame wall or, most commonly, a dwarf wall in a loft.

A stud depth of 38 mm by 140 mm at 600 mm centres was used in this example. The percentage of timber to be used for the calculation is 15%, accounting for horizontal noggings and the effects of additional timbers at junctions and around openings.

The product sits entirely in the plasterboard cavity as the stud cavity is completely filled with the glass wool insulation.

Figure 3 Schematic of wall construction (not to scale) showing the two possible heat flow paths



The values used for the U value calculation and the different layers contributing to the upper and lower resistance limits calculation are given in Table 2.

Table 2 List of materials used in the wall construction shown in Figure 3

Layer	Material	Thickness (mm)	Thermal conductivity (W·m <sup>-1</sup> ·K <sup>-1</sup> )	Thermal resistance (m <sup>2</sup> ·K·W <sup>-1</sup> )
1	External surface			0.04
2	Brickwork	102.5	0.77	0.133
3	Air cavity	50		0.18
4	Sheathing	12	0.13	0.092
5a	Timber frame	140	0.13	1.077
5b	Glass wool	140	0.035	4.000
6a	Timber battens	30	0.13	0.231
6b	Multifoil	30		0.92
7a	Timber battens	8	0.13	0.061
7b	Air cavity	8		0.30
8	Plasterboard	12.5	0.25	0.050
9	Internal surface			0.13

The U value calculation is carried out as before using the upper and lower limit resistance where:

$$R_u = \frac{1}{\frac{F_1}{R_1} + \frac{F_2}{R_2}}$$

with:  $R_1 = R_e + R_2 + R_3 + R_4 + R_{5a} + R_{6a} + R_{7a} + R_8 + R_i$

$$R_2 = R_e + R_2 + R_3 + R_4 + R_{5b} + R_{6b} + R_{7b} + R_8 + R_i$$

and:  $F_1 = 85\%$  and  $F_2 = 15\%$ , as explained above.

The lower limit resistance will be calculated using:  $R_l = R_e + R_2 + R_3 + R_4 + R'_5 + R'_6 + R'_7 + R_8 + R_i$

where:  $R'_5 = \frac{1}{\frac{F_{5b}}{R_{5b}} + \frac{F_{5a}}{R_{5a}}}$  and the fractional areas are as above.

The same applies for calculating the resistances  $R'_6$  and  $R'_7$ .

The U value for this construction is:  $U_l = 0.23 \text{ W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$ .

