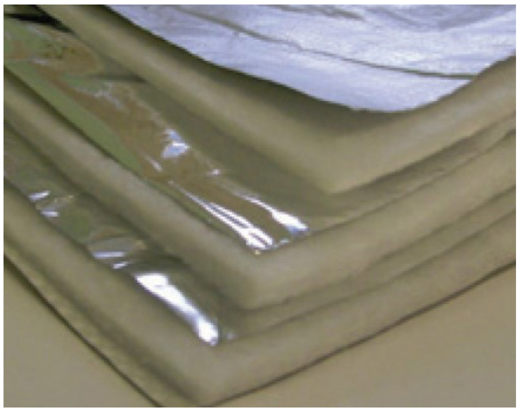
Reflective foil insulation – Conventions for U value calculations

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 layer 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 Information Sheet 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 Information Sheet 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 Information Sheet.

Conventions

Product Thickness (Uncompresssed)
As declared by the supplier. This is usually measured at a loading pressure in accordance with BS EN 16012.

Product Thickness (Compresssed)
When compressed betw een 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 recognised 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:

Cavity on both sides: 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.

Cavity on one side: 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 : 2017 *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.

All the example U value calculations in this Information Sheet 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: 2017. 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 air cavity resistance, the method described in BS EN ISO 6946: 2017, Annex B, (for ΔT < 5 K and with a mean cavity temperature of 10°C) was used.

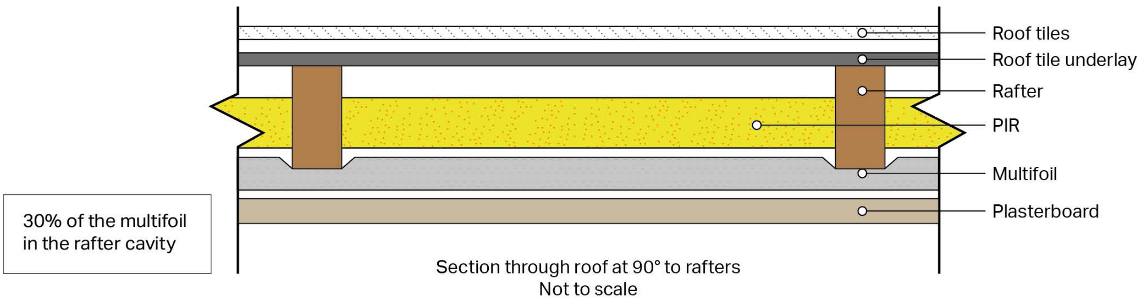
Using the set of conventions presented above, detailed U value calculations are provided for a roof construction utilising PIR or mineral wool and multifoil insulation and a timber-frame wall construction using glass wool and multifoil.

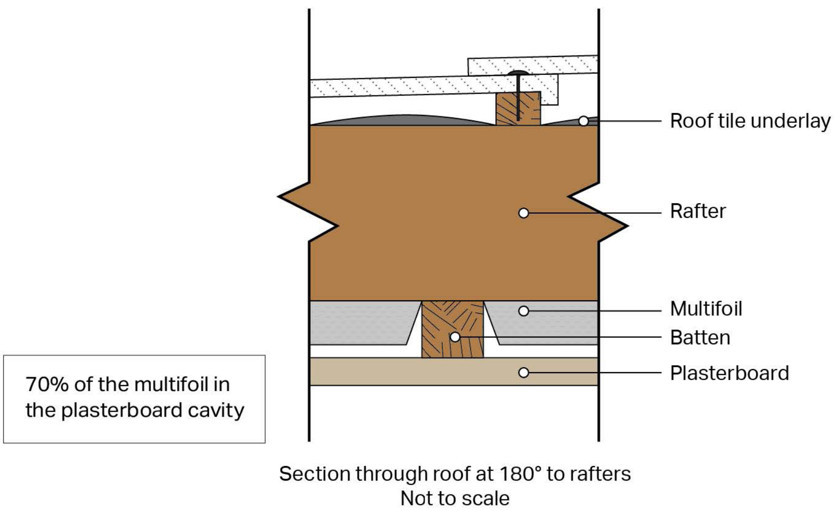
A roof construction with PIR between the rafters and reflective insulation under the rafters, one of the common configurations used in loft refurbishment, is shown in Figure 1.

The compression of the product due to battens being fixed against rafters 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, 9 mm will be considered as bridged with the rafters and the cavity and 21 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

Example roof construction. The rafters are 47 mm thick by 100 mm deep at 600 mm centres, giving a timber ercentage of 47/600 = 7.8%. Spacer battens 30 mm thick are used as well. The counter battens are 38 mm by 38 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 ($W{\cdot}m^{-1}{\cdot}K^{-1}$)	Thermal resistance ($m^2{\cdot}K{\cdot}W^{-1}$)
1	External surface			0.10(1)
2a	Air cavity	60		0.34(2)
2b	Rafter	60	0.13	0.462
3a	PIR(2)	90	0.022	4.091
3b	Rafter	90	0.13	0.692
4a	Air cavity	21		0.46
4b	Spacer battens	21	0.13	0.162
5a	Multifoil	9		0.273
5b	Spacer battens	9	0.13	0.069
6a	Counter battens	21	0.13	0.162
6b	Multifoil	21		0.636
7a	Counter battens	17	0.13	0.131
7b	Air cavity	17		0.45
8	Plasterboard	12.5	0.21	0.060
9	Internal surface			0.10

(1) The external surface resistance according to BS EN ISO 6946: 2017 is 0.04 $m^2{\cdot}K{\cdot}W^{-1}$ but, in this case, it can be taken as 0.10 $m^2{\cdot}K{\cdot}W^{-1}$ since the area under the tiles is well ventilated.

(2) This product is 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:

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

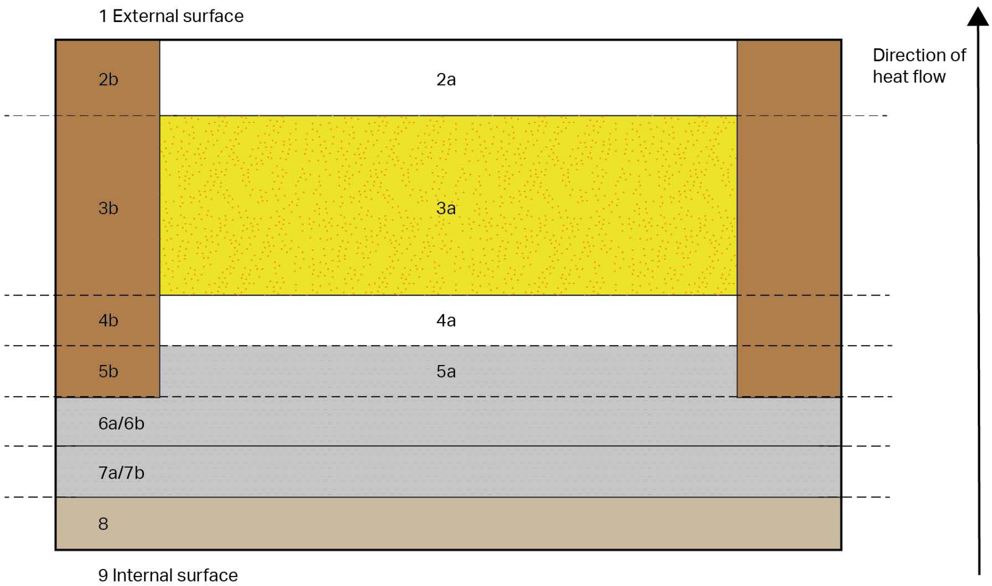
where:

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 $W{\cdot}m^{-2}{\cdot}K^{-1}$):

$$U = 1/R_T$$

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,

Path 1 - Counter-battens/Rafter
Path 2 - Multifoil/Rafter
Path 3 - Counter-batten/PIR
Path 4 - Multifoil/PIR

The fraction (F) for each heat flow path is as follows; and:

$F_1 = 0.078 \times 0.063 = 0.496\%$,
$F_2 = 0.078 \times (1\text{-}0.036) = 7.34\%$,
$F_3 = (1\text{-}0.0783) \times 0.063 = 5.84\%$
$F_4 = (1\text{-}0.0783) \times (1\text{-}0.0633) = 86.33\%$,

therefore:
$R_U = 5.805\ m^2{\cdot}K{\cdot}W^{-1}$

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: $R'_2 = \dfrac{1}{F_1/R_{2b} + F_2/R_{2b} + F_3/R_{2a} + F_4/R_{2a}}$

Where R_{2b} is the resistance of layer 2b etc.

for layer 6, $R'6 = \dfrac{1}{F_1/R_{6a} + F_2/R_{6b} + F_3/R_{6a} + F_4/R_{6b}}$

Similarly for layer 7.

Therefore: $R_L = 5.111\ m^2{\cdot}K{\cdot}W^{-1}$

The U value for this construction is: $U_T = 0.18\ W{\cdot}m^{-2}{\cdot}K^{-1}$.

Annex B
Example 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 140 mm and a timber fraction of 0.15 is assumed. Vertical counter battens 50 mm deep align with the studs. The product sits entirely in the plasterboard cavity as the stud cavity is completely filled with the glass wool insulation. 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.

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

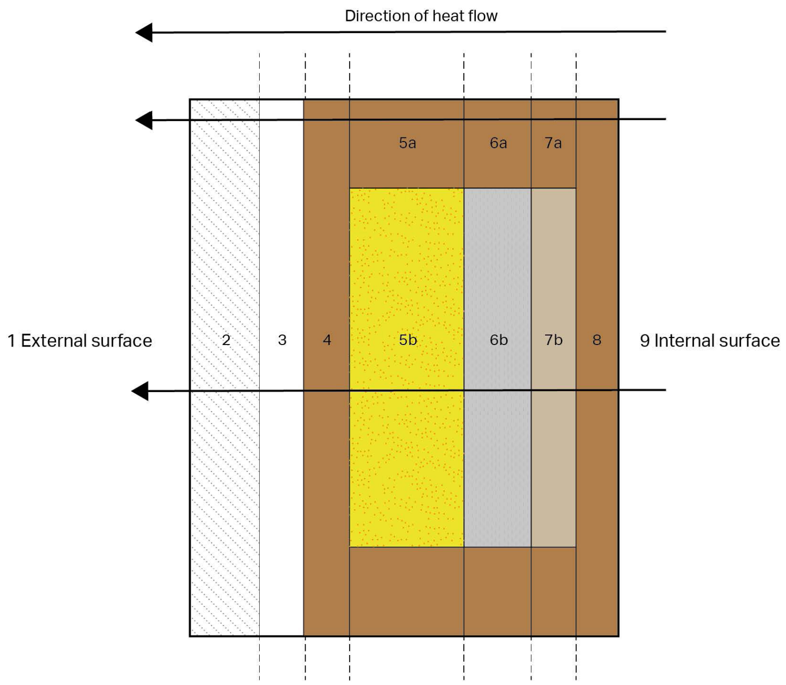


Table 2 List of materials used in the wall construction shown in Figure 3

Layer	Material	Thickness (mm)	Thermal conductivity ($W{\cdot}m^{-1}{\cdot}K^{-1}$)	Thermal resistance ($m^2{\cdot}K{\cdot}W^{-1}$)
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		0.91
7a	Timber battens	20	0.13	0.154
7b	Air cavity	20		0.67
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: $R'_5 = \frac{1}{F_1/R_{5b} + F_2/R_{5a}}$ and the fractional areas are as above.

The same applies for calculating the resistances R'_6 and R'_7. The upper resistance limit is 4.788 $m^2{\cdot}K{\cdot}W^{-1}$ and the lower resistance limit is 4.545 $m^2{\cdot}K{\cdot}W^{-1}$. The U value for this construction is: **$U_T = 0.21\ W{\cdot}m^{-2}{\cdot}K^{-1}$.**

