U-VALUES: DEFINITION AND CALCULATION

U-VALUES

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What, Why, When, How, Extras

What is a U value?

A U value is a measure of heat loss in a building element such as a wall, floor or roof. It can also be referred to as an 'overall heat transfer co-efficient' and measures how well parts of a building transfer heat. This means that the higher the U value the worse the thermal performance of the building envelope. A low U value usually indicates high levels of insulation. They are useful as it is a way of predicting the composite behaviour of an entire building element rather than relying on the properties of individual materials.

Why use U values?

U values are important because they form the basis of any energy or carbon reduction standard. In practice, nearly every external building element has to comply with thermal standards that are expressed as a maximum U value. Knowledge of how to simply calculate U values at an early stage in the design process, avoids expensive re-working later on in a project. It allows the designer to test the feasibility of their project at an early stage to ensure it is fit for purpose and will comply with regulatory frameworks.

When to use U-values

U values are calculated at stages D onwards in the design process. A critical milestone in any building project is obtaining building regulation approval. For this a SAP calculation for housing or an SBEM procedure for non domestic work is obligatory. As part of this process, the build up of any external construction element must be specified and from this its U value can be derived.

How to use U values

Key points:

- To calculate the U value of a building element such as a wall, floor or roof, you need to know the build up of that element. Each building material should be positioned properly in sequence. The thickness of each building material also is required.

- The other key property you need to obtain is the conductivity of each building material. This is a measure of its inherent ability to facilitate the passage of heat. It is normally referred to as a ‘k value’ and values for materials can be found in publications such as the New Metric Handbook and the Architects’ Pocket Guide

- The properties of the internal and external faces of the constructional element under scrutiny need to be allowed for. These are called external resistances and are fixed values.

- The U value is defined as being reciprocal of all the resistances of the materials found in the building element.

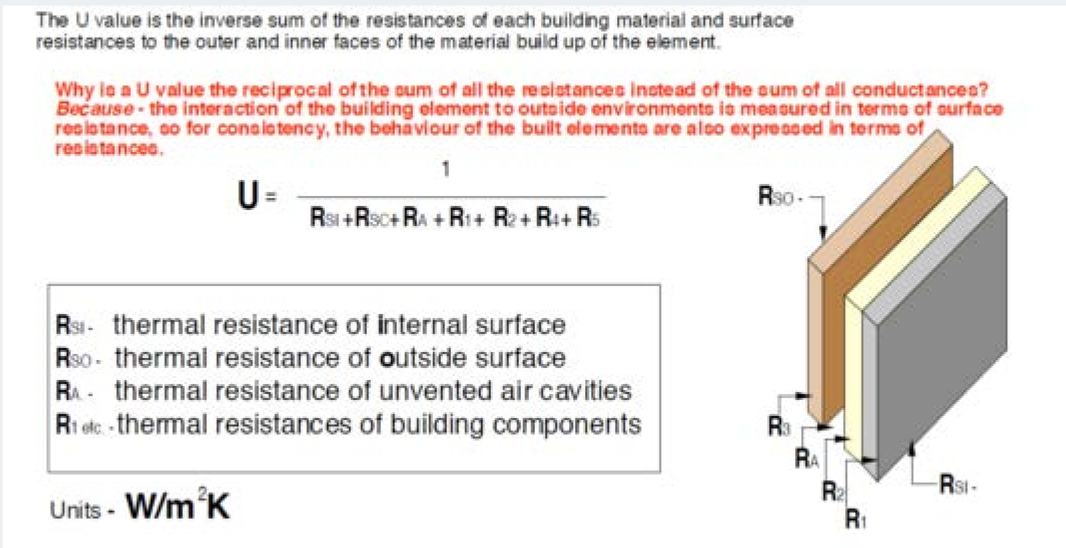
- The resistance of a building material is derived by the following formula:
  $R = (1/k) \times d$

- where k is the conductivity of the building material and d is the material thickness.

- The formula for the calculation of a U value is
  $U(element) = 1 / (R_{so} + R_{si} + R_1 + R_2 ...)$

- where Rso is the fixed external resistance

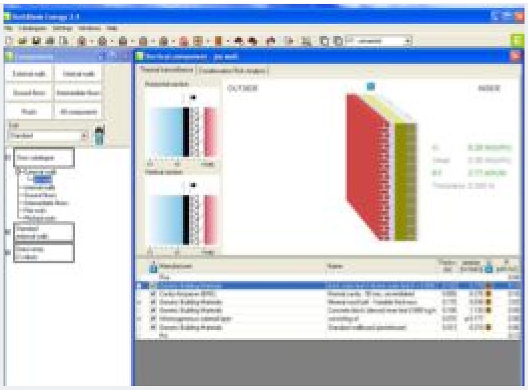
- where Rsi is the fixed internal resistance
- and R1… is the sum of all the resistances of the building materials in the constructional element.



U value calculations

Design Procedure:

- Most U value calculations are now undertaken with bespoke software such as the BRE's U value calculator, or packages produced by companies such as BuildDesk.



- Ensure you have drawn out your wall, roof or floor element and know the thickness and location of each constituent material.

- Do not bother trying to work out the U value of a window, element by element. This sometime is required in PassivHaus calculations but manufacturers and reference books tend to give fixed values for various glazing types.

- If you have a frame construction, then the conduction of heat through the frame element will be very different than through any intermediate insulating element. The key example is timber frame. Here, you need to take sepearate U values through the frame item and the insulating element and average them. Software packages usually have a module to cope with this.

- Remember to include internal and external resistances. Typically, the internal resistance for a wall is 0.13 m2K/W and the external resistance is 0.04 m2K/W . Again, information about this can be found in the New Metric Handbook or the Architects’ Pocket Book.

- You can now input data into a software package to derive the U value for the building element under investigation.

- Current limiting U values [area weighted] in England and Wales are 0.35 W/m2K for walls and 0.25 W/m2K for roofs.

Related strategies

Current legislation and targets

Take this further

Further Reading:

- Anderson. 2006 “Conventions for U value calculations : BRE 443” BRE Scotland (for further reading and full explanation of calculation methodologies)
- Baden-Powell 2001 “Architect’s Pocket Book” Architectural Press (for sample K values and internal + external resistances)
- Bougdah & Sharples. 2010 “Environment, Technology and Sustainability” Taylor & Francis (places concepts such as the U value in a wider perspective)

Web resources:

- Builddesk -a simple online calculator
- BRE online calculator where a validated result is required.

Notice:

The thermal insulation regulations were prepared and agreed upon by the ministers of electricity in the GCC members state in their meetings in Doha, Qatar in October, 1984. The proposed U-values are 0.74 $W/m^2\,^oC$ for walls and 0.75 $W/m^2\,^oC$ for roofs.

Table 1: Structures and thermal characteristics of walls used mostly in Saudi Arabian Residential buildings

Wall Type	Thickness of wall components (m)	Thermal conductivity of wall components W/mK	Wall Conductance U (W/m^2K)	Wall Resistance (m^2K/W)
Wall I External plaster Hollow bricks Internal plaster	0.02 0.20 0.03	1.20 0.90 1.20	2.25	0.44
Wall II External plaster Concrete Internal plaster	0.02 0.20 0.03	1.20 1.75 1.20	2.98	0.336
Wall III Stone Concrete Hollow bricks Plaster	0.20 0.07 0.20 0.03	1.70 1.75 0.90 1.20	2.28	0.438
Wall IV Stone Concrete Air gap Bricks Plaster	0.20 0.20 0.05 0.10 0.03	1.70 1.75 0.28 0.90 1.20	1.62	0.617

THERMAL CONDUCTANCE. Time rate of heat flow through a body (frequently per unit area) from one of its bounding surfaces to the other for a unit temperature difference between the two surfaces, under steady conditions (Btu/h · ft_2 · °F) [W/(m_2 · K)].

THERMAL RESISTANCE (*R*). The reciprocal of thermal conductance (h · ft_2 · °F/Btu) [(m_2 · K)/W].

THERMAL RESISTANCE, OVERALL (*R_o*). The reciprocal of overall thermal conductance (h · ft_2 · °F/Btu)[(m_2 · K)/W]. The overall thermal resistance of the gross area or individual component of the exterior building envelope (such as roof/ceiling, exterior wall,floor, crawl space wall, foundation, window, skylight, door, opaque wall, etc.), which includes the area weighted *R*-values of the specific component assemblies (such as air film,insulation, drywall, framing, glazing, etc.).

THERMAL TRANSMITTANCE (*U*). The coefficient of heat transmission (air to air). It is the time rate of heat flow per unit area and unit temperature difference between the warm-side and cold-side air films (Btu/h · ft_2 · °F) [W/(m_2 · K)]. The *U*-factor applies to combinations of different materials used in series along the heat flow path, single materials that comprise a building section, cavity airspaces and surface air films on both sides of a building element.

THERMAL TRANSMITTANCE, OVERALL (U_o). The overall (average) heat transmission of a gross area of the exterior building envelope (Btu/h · ft^2 · °F) [W/(m^2 · K)]. The U_o-factor applies to the combined effect of the time rate of heat flow through the various parallel paths, such as windows, doors and opaque construction areas, comprising the gross area of one or more exterior building components, such as walls, floors or roof/ceilings.

TABLE 2.2.2
DEGREE DAYS FOR METEOROLOGICAL STATIONS OF KINGDOM OF SAUDI ARABIA

S. No.	Station / City	DD*
1	TURAIF	1,800
2	ARAR	2,600
3	GURIAT	1,800
4	AL-JOUF	2,500
5	RAFHA	2,900
6	QAISUMAH	3,400
7	TABUK	2,300
8	HAFAR AL-BATIN	3,600
9	HAIL	2,600
10	WEJH	2,800
11	GASSIM	3,300
12	DHARHAN	3,500
13	AL-HASA	3,800
14	MADINAH	4,200
15	RIYADH	3,800
16	BISHA	3,500
17	KHAMIS MUSHAIT	1,200
18	JEDDAH-KFIA	3,900
19	TAIF	2,200
20	MAKKAH	4,900
21	YANBU	4,000
22	AL-BAHA	2,100
23	WADI-ALDAWASER	3,800
24	ABHA	1,000
25	NAJRAN	3,000
26	SHARORAH	4,000
27	GIZAN	4,600

* (Base 18°C) and DD values are rounded off to the nearest hundred.

TABLE 3.2.2.1.1
STANDARD DESIGN WALL ASSEMBLY *U*-FACTORS (U_W)

Degree Days[a]	U_w (air to air)[b] W/(m^2 · °K)
≥ 7,230	0.216
5,000 – 7,229	0.261
3,600 - 4,999	0.295
2,500 - 3,600	0.329
1,950 – 2,499	0.363
1,400 - 1,950	0.432
< 1400	0.483

a. From Table 2.2.1.
b. Including framing effects.

TABLE 3.2.2.1.2
STANDARD DESIGN FENESTRATION SYSTEM *U*-FACTORS (U_g OR U_F)

Degree Days[a]	U_g for Section 5.2.2.1.1 and U_f for Section 5.2.2.3.1 (air to air)[b] W(m^2 · °K)
≥ 7,230	1.42
5,000 - 7,229	1.48
3,610 – 4,999	1.59
2,500 - 3,600	1.70
1,950 – 2,499	2.33
1,400 - 1,950	2.50
400 - 1,399	2.67
< 400	4.20

a. From Table 2.2.1.
b. Entire assembly, including sash.

Interpreting the NFRC Label

A Visual Interpretation of the NFRC Ratings

U-factor measures the heat from INSIDE a room that can escape. The lower the number the lower the potential for wasted heating expenses.

Visible Transmittance measures how much natural light can come into a room -- a HIGH number means more natural light.

Solar Heat Gain Coefficient measures the amount of OUTDOOR heat that can enter a room. The lower the number, the lower the potential for wasted cooling expenses.

Air Leakage measures how much air will enter a room through the product. The lower the number, the lower the potential for draft through the product.

An Example of the NFRC Label You Should Look for and the Numbers You May See

U-factor U-factor ratings generally fall between 0.20 and 1.20. The lower the U-factor, the better a product is at keeping heat in. U-factor is particularly important during the winter heating season. This label displays U-factor in U.S. units. Labels on products sold in markets outside the United States may display U-factor in metric units.

Visible Transmittance (VT) is expressed as a number between 0 and 1. The higher the VT, the higher the potential for daylighting.

National Fenestration Rating Council®
CERTIFIED

World's Best Window Co.
Series "2000"
Casement
Vinyl Clad Wood Frame
Double Glazing • Argon Fill • Low E
ABC-X-1-00001-00001

ENERGY PERFORMANCE RATINGS	
U-Factor (U.S. / I-P)	Solar Heat Gain Coefficient
0.35	**0.32**
ADDITIONAL PERFORMANCE RATINGS	
Visible Transmittance	Air Leakage (U.S. / I-P)
0.51	**0.2**

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information.
www.nfrc.org

Solar Heat Gain Coefficient (SHGC) is expressed as a number between 0 and 1. The lower the SHGC, the better a product is at blocking unwanted heat gain. Blocking solar heat gain is particularly important during the summer cooling season.

Air Leakage (AL) rates typically fall in a range between 0.1 and 0.3. The lower the AL, the better a product is at keeping air out. AL is an optional rating, and manufacturers may choose not to include it on their labels. This label displays AL in U.S. units. Labels on products sold in markets outside the United States may display AL in metric units.

NFRC administers an independent, uniform rating and labeling system for the energy performance of fenestration products, including windows, curtain walls, doors, and skylights.

For more information on NFRC, please visit our Website at www.WindowRatings.org or contact NFRC directly at 301.589.1776.