# Rooflight Technical Bulletin '07

**This Technical Bulletin aims to give architects, engineers and building control officers comprehensive information on how rooflights can contribute to overall energy reductions in buildings and meet or beat the latest building regulations.**

*Inside* – detailed guidance on ensuring that quoted U-values are correct, accurate and sustainable.

# Optimising Energy Efficiency

## Reducing Energy with Rooflights

Taken at face value, the **Building Regulations Part L Approved Documents** (and other, similar national regulatory guidelines) approach rooflights purely from the perspective of limitation due to a lower insulation value than typical roof constructions. Generally, the area-weighted average U-value of all rooflights on a building must not exceed 2.2W/m$^2$K, whilst the U-value for any individual rooflight must not exceed 3.3W/m$^2$K and rooflights are limited to 20% of floor area. The regulations ignore rooflights as an effective light source in their own right, with substantial potential for reduction in energy used by artificial lighting. Clearly a more holistic approach is needed.

Various design guides—such as **BB 90 'Lighting Design for Schools'** already recognise that an extensive use of natural lighting can provide considerable energy savings. According to leading services engineer Max Fordham, horizontal rooflights provide two and a half times more light than vertical windows, so it is not surprising that a number of leading architects have been making extensive use of rooflighting in buildings aimed at 'zero carbon'. But comprehensive research is now available to quantify the energy savings that can be made.

## Comprehensive Research

Carried out by De Montfort University, the research brings together thermal effects with energy used for heating and illumination effects with energy used for artificial lighting, applied to a range of buildings. The findings proved conclusively that rooflights provide an overall energy benefit, with the level of that benefit depending on various factors, particularly the total area of rooflights, design illumination level, type of artificial lighting control used and the pattern of building use. Increasing the rooflight area reduces the need for artificial light, cuts the energy requirement of the building and reduces $CO_2$ emissions. It is therefore a straightforward means of meeting a building's target emission levels under the current Building Regulations.

By considering insulation values alone, it might be expected that heating requirements would grow as rooflight area increased. However, the research proves that for a building occupied primarily during the day this is not the case, as passive solar gain through the rooflights actually balances the insulation value. Therefore, heating requirements are barely affected and the most dominant effect by far is the decreasing requirement for artificial light as rooflight area is increased, as illustrated in the graph.

## Energy Benefits from Rooflights

In the case of a building occupied between 9am-5pm every day of the year, with a lighting requirement of 300 lux, some 23 kg $CO_2$/m$^2$—

Figure 1: Effect of Rooflight area on $CO_2$ emissions for first example building

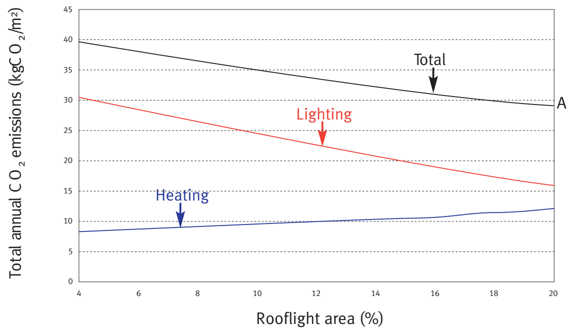
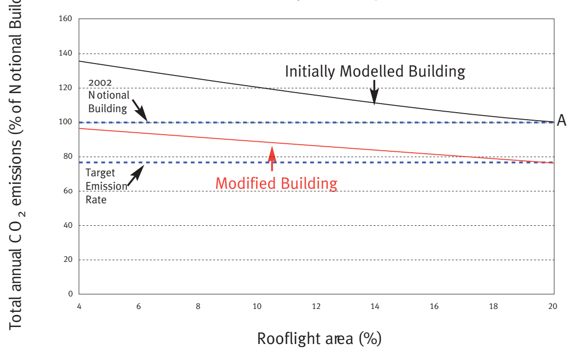



Figure 2: $CO_2$ emissions compared to notional building for first example building




*Effect of rooflight area on CO2 emissions (sample building from De Montfort University research)*

a massive 85%—saving in emissions will result from using 20% rooflights. For a building occupied 24 hours a day—the worst case scenario for rooflights, with no night-time benefits from natural light or passive solar gain—they still provide a very significant energy benefit. In almost all cases, a rooflight area of 15% - 20% will achieve almost all the available savings in overall energy use and $CO_2$ emissions.

To maximize these benefits, designers need to carefully consider interaction with artificial lighting, which will be essential during parts of the working day—particularly in the winter months—and specifically in working areas where light levels need to remain constant. Automatic controls will be needed to minimise the use of artificial lighting, so maximising energy savings from daylight. Better insulation of rooflights can offer further savings in $CO_2$ by reducing heating system energy—particularly with larger proportions of rooflight area. So, lower U-values for the complete rooflight will also help – but it is essential to have full confidence in the values offered by manufacturers, as discussed on the next page.



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Xtralite ROOFLIGHTS

# Accurate U-values for Responsible Specification

## Why Accuracy Matters

Historically, Building Regulations have been concerned primarily with safety of occupants, demanding accurate measurement and compliance to avoid deaths and injuries. Because buildings do not burn or collapse and users are not obviously injured by thermal performance, we really haven't put much effort into validating the various thermal calculation systems that we routinely use when designing. So, we could be fooling ourselves and buildings could just go on consuming more energy than predicted throughout their lives —an unacceptable situation with buildings using around 40% of the UK's total energy.

However, the current move towards 'zero carbon' buildings—driven by global warming and gaining impetus from both government and the population—makes it really important that we know what energy is being used to heat and cool our buildings. The high initial costs of many alternative energy systems demand that we know that the building fabric is performing as predicted. Zero carbon is very easily measured and we shall find out—for the first time—if our thermal performance specifications really work. In future, we need to use more sophisticated calculation methods routinely and validate those calculation methods by comparison with accurate measurements— just as the engineering industry has been doing for 50 years.

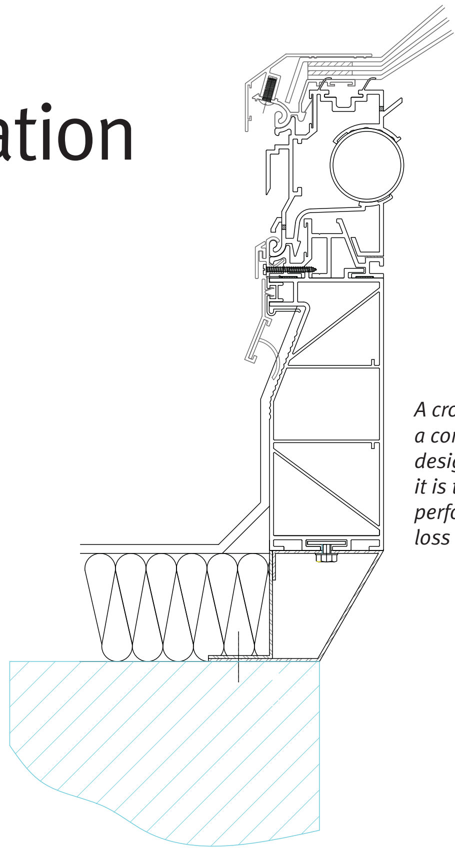
*'buildings could just go on consuming more energy than predicted'*

Today, simplified thermal calculations of complex products and building geometries are the norm and there has been almost no systematic validation of the various thermal calculation methods that we use. Interestingly, the exception is windows where there have been some projects to validate calculation standards against measurement. But, as we shall see, only testing to the appropriate standard gives accurate, reliable information for rooflights.

## What the Rules Say

National building regulations rely for their application on measurement rules. For example, the **Part L Approved Documents** clearly state that: 'U-values shall be determined in accordance with the methods and conventions as set out in **BR 443: Conventions for U-value calculations**.' The BRE's document **BR 443: 2006** considers a wide range of building components and takes the general view that: *'While calculated U-values are acceptable for Building Regulations and most other purposes, direct measurement of U-values is also possible and, indeed, test results should be preferred when available provided that the values have been obtained in accordance with the appropriate measurement standards.'*

For windows and rooflights, **BR 443: 2006** requires the U-value to be that of the complete unit, including the frame and upstand/kerb. U-values for windows and rooflights can be obtained either by testing or calculation. In either case, it is important that appropriate, independent organizations carry these out in order to satisfy building control officers (BCOs). In England and Wales, compliance of products or materials is covered by **'Regulation 7'** which describes some of the ways suitability for a specific purpose may be assessed by BCOs. Tests carried out by UKAS accredited organisations are considered reliable and should automatically be acceptable to BCOs.



*A cross section through a contemporary rooflight design shows how difficult it is to predict thermal performance using heat loss calculations*

*'test results should be preferred'*

For testing, **BR 443: 2006** specifically refers to measurement in a hot box according to **BS EN ISO 12567-1**. Xtralite rooflights are tested in this way by the UKAS accredited National Physical Laboratory (NPL), as described in the panel (see diagram and formula opposite).

Alternatively, numerical calculation may be applied using software conforming with **BS EN ISO 10077-2** although simplified calculations using the methods in **BS EN 673** and **BS EN ISO 10077-1** are also permissible, yielding more approximate results. However, even where UKAS accredited organisations are used to carry out calculations using these methods, there are real concerns about their accuracy.

## The Problems with Calculation

The NPL's Ray Williams explains: *'There are a number of calculation standards for determining the U-values of windows and doors but these may not be appropriate for many domed and barrel shaped skylights. To use these standards, the centre-of-glazing (COG) U-value of the insulated glazing units are calculated using the procedures specified in **BS EN 673** (or **ISO 10292**). Then, the U-values of the various frames are calculated using any suitable FEA or FDA software tool and following the procedures in **BS EN ISO 10077-2**. Finally, the glazing and frame U-values are combined to derive the overall window U-value using the procedures in **BS EN ISO 10077-1**.*

*'calculation standards may not be appropriate'*

*It is the COG calculation standard, **BS EN 673**, that is the most inappropriate for domed and barrel skylights, as it can only be used for "glazing with flat and parallel surfaces". And although the scope of **BS EN ISO 10077-1** does allow "the thermal transmittance of roof windows and other projecting products to be calculated, providing that the thermal transmittance of the frame sections is determined* *by measurement or numerical calculation", there are no examples of how this is to be achieved. Although the procedures in **BS EN ISO 10077-2** are for vertical window frames—and so could be used to calculate the U-values of for skylight upstands—it is a purely two dimensional method that does not take into account the thermal effects of the four corners of a square-based product.'*

## Taking Responsibility

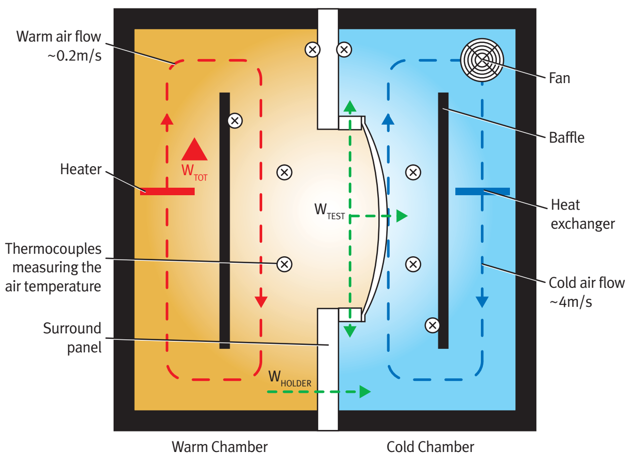
We can see from this expert's opinion how complex and potentially flawed calculation methods are for rooflight glazing. And just one look at the complex cross-section of a modern rooflight kerb shows how difficult it is to develop convincing heat-loss calculations. BCOs should therefore demand robust evidence supporting U-values for rooflights.

But is it really fair to rely just on local authority building control departments, which have to assess an increasingly complex array of performance criteria—ranging from disabled access to electrical installations, as well as thermal performance? Specifiers should also now take greater responsibility for the design and selection of rooflights, with far more rigorous investigations of U-values claimed by manufacturers. After all, there is more at stake than just meeting regulations.

# Hot Box Testing—Measuring U-values Accurately

The thermal transmittance or U-value of large, non-homogeneous structures is measured using a hot box apparatus, as shown here. Details of the general construction and operation of hot boxes are specified in **BS EN ISO 8990**. The operating principles of a hot box and procedure of how a U-value is calculated from the measured data are shown in the diagram. Many of the details of an actual hot box have been omitted for clarity.

For a number of reasons, the measurement standard **BS EN ISO 12567-1** for windows and doors is not appropriate for rooflights or any other products projecting out of the plane of the wall into the cold air stream. For these products. another measurement standard **BS EN ISO 12567-2** applies which is broadly similar to the very detailed window and door standard but with further details concerning the calibration measurements and installation details.




Measure $W_{TOT}$ and $W_{HOLDER}$ and derive $W_{TEST}$. $W_{TOT} - W_{HOLDER} = W_{TEST}$

Measure warm baffle, warm air, warm surround panel surface temperatures.

Measure cold baffle, cold air, cold surround panel surface temperatures.

Calculate the warm side "environmental" temperature ($Warm_{ENV}$) from the test and calibration data

Calculate the warm side "environmental" temperature ($Cold_{ENV}$) from the test and calibration data

Calculate the "environmental temperature difference"
$^{\Delta}T_{ENV} = Warm_{ENV} - Cold_{ENV}$

The area is the area of the aperture in the surround panel (A)

$$\text{U-value} = \frac{W_{TEST}}{^{\Delta}T_{ENV} \times A}$$

*The National Physical Laboratory hot box apparatus diagram and formula.*

*The National Physical Laboratory hot box apparatus provides an accurate method of measuring actual U-values for rooflights. It can be rotated into any orientation, enabling measurements to be carried out in the orientation that the product will be used.*

# Optimising Energy Efficiency with Xtralite

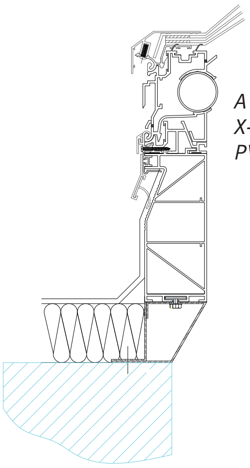
Some examples of different types of rooflight from the Xtralite range are illustrated here, with the U-values that apply and how these values were derived. The Xtralite Design Team can advise on how to obtain the best thermal efficiency from rooflights and also offers customers a free Daylight Consulting Service, where advanced computer modelling is used to predict the best location and size for rooflights and windows in a building project.

## X-One Modular Rooflight System

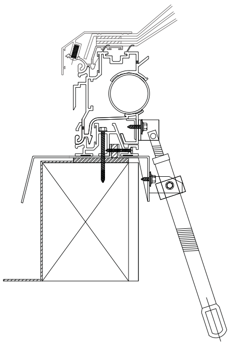
A rationalised system comprising polycarbonate glazing, accessory zone and roof attachment options, enabling a full range of functions with simple specification.

**U-value 1.32 W/m²K**

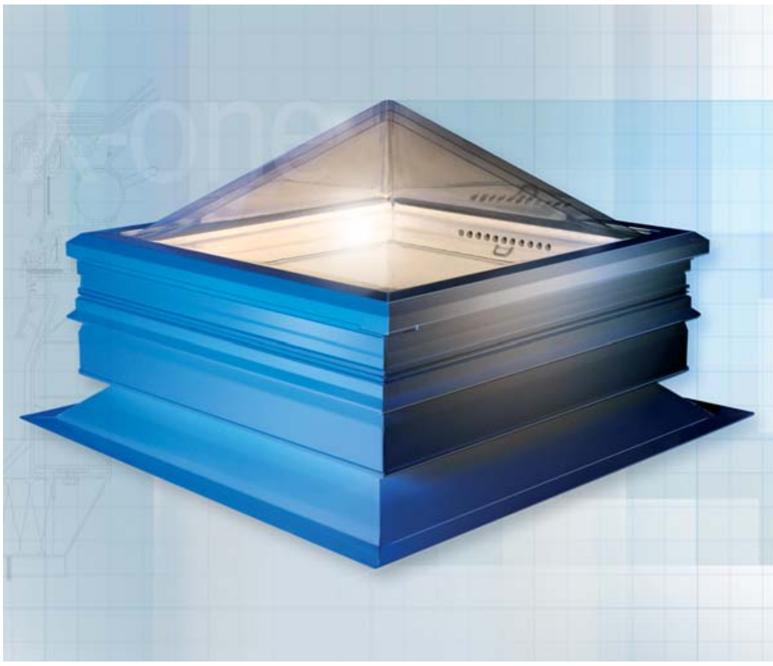
(with triple glazing) – measured with and without vents using hot box test



*A cross section through X-One rooflight using PVCu upstand*



*A cross section through X-One rooflight using adaptor kerb and worm gear opening*

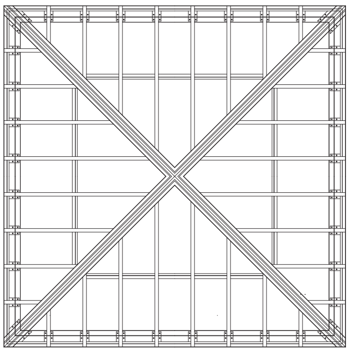


## Xspan Structural Rooflights

A universal structural package for bespoke designs, including semi-circular and low-profile barrel vaults, hipped and gable ended ridge-lights, self-supporting pyramids, pitched polygons and mono-pitched rooflights.

**U-value 1.0 – 2.0 W/m²K**

(with double glazing) – depending upon the nature of the project. As each bespoke project is unique, U-values are determined from the latest component test data.

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