Thermal transmission

Retaining heat energy within a building to reduce carbon emissions has become a very high priority over recent years, and this has led to increasing insulation thicknesses and some changes in the way that buildings are constructed, specifically to minimise heat loss through the fabric of the building.

This is not simply a key requirement of Building Regulations compliance. For building owners or tenants, it translates directly into a reduction in the running costs of the buildings due to increased energy efficiency.

In terms of heat retention, the energy efficiency of any element of a building is quantified by the U-value. This is a measure of the rate at which heat energy, measured in Watts, passes through a square metre of that element for every degree Kelvin difference in temperature from inside to outside, or outside to inside for refrigerated buildings. The U-value is usually expressed as W/m^2K.

The lower the U-value, the better the thermal performance.

THERMAL TRANSMISSION [U-value]

A measure of the flow of heat through an insulating or building material: the lower the U-value, the better the insulating ability.

Insulated rooflights

Improving the insulation performance of the key element of the building envelope that is designed to allow the important benefits of natural daylight into the building provides greater challenges than with any opaque part of the fabric. Rooflights, by their very nature, must allow the passage of the maximum amount of daylight whilst inhibiting the flow of heat.

Minimising the radiated heat component through the rooflight invariably reduces light transmission; therefore the most effective elements to be reduced are heat conduction and convection. Minimising the components or materials within a rooflight cavity helps to reduce heat conduction, and will have the benefit of improved light transmission.

For reasons of cost and practicality, in-plane rooflights for industrial metal clad buildings cannot be constructed with a vacuum, or filled with an inert gas, to reduce the convection of heat due to the nature of construction and installation. This leads to the simplest and most common of insulation methods being widely adopted; the inclusion of multiple layers of materials with high transparency.

This approach is reasonably effective for uses where moderately improved U-values are required, and a common technique would be to use multi-wall or structured polycarbonate sheet.

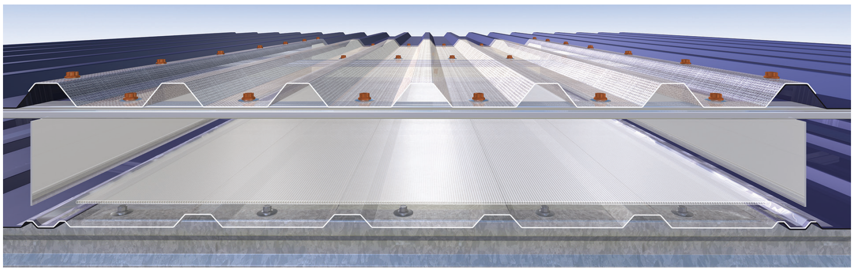
Still air pockets are created and conduction is minimised by using thin walled sections to inter-connect the walls or layers within the polycarbonate; for each layer that is added, there is a penalty in terms of light transmission due to the cumulative effect of the reflectance of light at each and every layer. As the number of layers increase, so does the absorption into the increasing mass within the rooflight cavity and the greater the re-radiation of heat through the rooflight as a secondary component of solar gain.

It follows, therefore, that due to the effect of diminishing returns, the optimum level of insulation that can be achieved by this layering method is soon reached as the thermal gain benefit is quickly outweighed by a corresponding decrease in light transmission level.

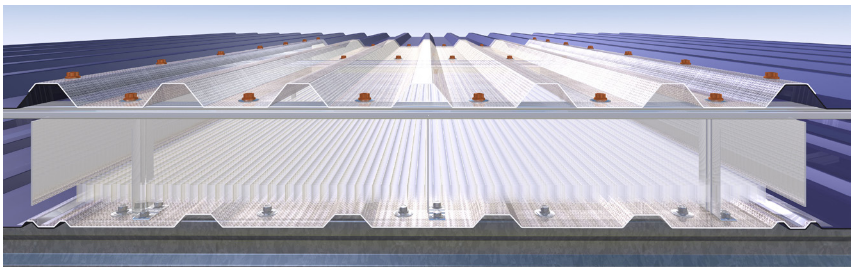
Zenon Insulator

To overcome the problem of achieving environmentally friendly, low U-value rooflights without significantly compromising the light transmission, Hambleside Danelaw developed the unique Zenon Insulator core system.

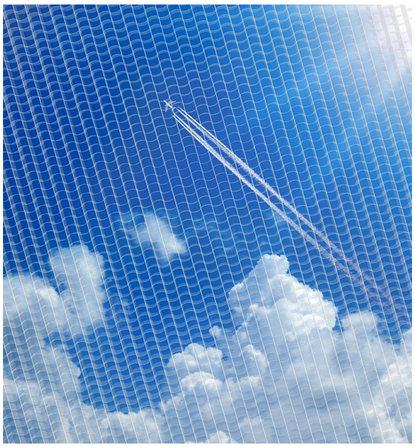
Made from cellulose acetate, a recycled wood pulp product and compostable at the end of its service, it provides much improved U-values without the penalties of creating multiple layers within the rooflight. It acheives this by trapping and containing the air in small pockets within the rooflight cavity thus significantly inhibiting the convection currents that carry the heat through the rooflight panels to the outside air.



Rooflight assembly using a multi-wall polycarbonate sheet insulation layer



Rooflight assembly using the Zenon Insulator insulation layer



Zenon Insulator

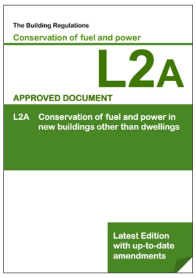
Polycarbonate

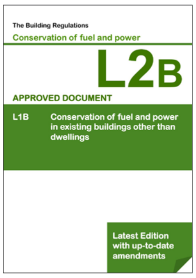
The honeycomb Zenon Insulator core comprises a lightweight, transparent cell structure that is perpendicular to the plane of the rooflight. This requires only a single thin clear film layer to encapsulate the air pockets and has minimal interference with the light transmission. The light entering the cell structure is channelled directly, or by reflectance, into the building creating a better, wider spread of diffused light irrespective of the angle of incidence of the light, and at the same time, minimises the absorptance and re-radiation of the light energy as heat energy.

Design considerations

There are now a wide range of insulation layer specifications for in-plane rooflights available, from simple Building Regulation compliant values of 1.8Wm²K, to very low U-values of around 0.8W/m²K that can still retain excellent levels of light transmission.

Independent research by De Montfort University, and published by the National Association of Rooflight Manufacturers (NARM), demonstrates the savings that can be made by the introduction of rooflights, and at larger areas than might previously have been considered optimum areas even with the most modest U-value performance.





Each building and building design should be considered on its own merits. However the energy consumed by artificial lighting where inefficient lighting systems are used, or where artificial lighting is turned on and left on irrespective of need, far exceeds the relatively small amounts of heat energy that is lost through increasing the rooflight area (a very small part of the whole building fabric). Generally, the amount of energy required to light a building is greater than the amount of energy required to heat it; it can be the greatest single energy use in operating the building.

While the gains that can be made in terms of reducing energy loss through rooflights can be quite significant by improving the U-values of the rooflights, the overall gains in reduced energy consumption of the building operation are relatively small if the light transmission of the rooflights is not designed to maximise the benefits of natural daylight in conjunction with artificial lighting using fully automated controls. Light and thermal transmission must be considered in tandem; too little daylight and the increased lighting energy requirement will far outweigh any savings on reduced heat loss.

In the shift towards zero carbon buildings, it will be necessary for the designer to maximise every opportunity and element of the building design, no matter how small, to achieve these goals, and heat loss through rooflights is just one consideration.

Rooflight insulation options

The standard thicknesses for insulation layers when using simple structured polycarbonate inserts for both site assembled rooflight applications for built-up cladding systems, or Factory Assembled Insulated Rooflights (FAIRS) for use with composite cladding systems, are 4mm twin-wall or 10mm four-wall panels.

Zenon Insulator is available for both site assembled rooflights or FAIRS. There are three standard thicknesses available, 20mm, 40mm and 80mm, depending upon thermal performance requirements. Unlike increasing the layers of polycarbonate, the high light transmission property of Zenon Insulator enables it to be used in multi-layer combinations where very low rooflight U-values are required without compromising light transmission into the building.

The thermal properties of any rooflight insulation layer should always be considered in conjunction with the U-value of the rooflight outer and liner sheets, and the type of assembly in which they are to be incorporated.

Condensation and surface temperature factor (ƒ-Factor)

In cold weather the internal surfaces of a building's external walls and roofs are generally colder than the internal air temperature, especially in areas of lower thermal insulation, allowing condensation to form.

Depending on the use of the building, the construction materials and finishes, this may be:

- a temporary nuisance in cold weather;
- a cause of water to drip onto equipment or processes within the building;
- a cause of mould growth that can damage internal finishes and have implications for the health of the occupants.

Surface condensation can be a consequence of thermal bridging as increased heat flow lowers the internal surface temperature. Surface temperature is expressed in terms of the Surface Temperature Factor or f-Factor, which is a property of the structure or fabric of the building and is not based on assumed internal and external temperatures.

The severity of the thermal bridge and therefore the risks of condensation are determined by the F-factor. This is calculated by modelling the building structure, and taking into account the local surface temperature of the particular component, together with the internal and external air temperatures.

Recommended f-Factors

BRE IP17/01 gives guidance on limiting the risk of surface condensation in buildings by providing the following table of minimum critical f-factors based on likely internal environments. The higher the f-Factor, the wider the scope for usage of the building. For example, a higher f-Factor would be required for a high humidity building such as a swimming pool.

Humidity class	Building type	Minimum f-factor
1	Storage buildings	0.30
2	Offices, retail premises	0.50
3	Dwellings with low occupancy	0.65
4	Sports halls, kitchens, canteens (buildings with un-flued gas heaters)	0.80
5	Buildings with high hummidity e.g. swimming pools, laundries, breweries	0.90

Determining the f-Factor

The minimum surface temperature factor (f_{min}) indicates the risk of surface condensation; the lower the value the greater the risk, and is calculated as follows:

$$f_{min} = \frac{(t_s - t_e)}{(t_i - t_e)}$$

Where

t_s = internal surface temperature

t_e = external temperature

t_i = internal temperature

For a well-insulated wall or roof t_s will be close to t_i therefore f will be close to 1. For a poorly insulated component or thermal bridge t_s will be lower therefore f may be 0.5 or less.

Rooflight f-Factors

Rooflights by their very nature are unable to achieve the generally very low U-values of the opaque roof areas and therefore will have a higher thermal transmittance.

The following table provides f-Factors calculated for different U-values of rooflight fixed in the horizontal position and with heat flow in an upwards direction. It should be noted that the calculation of the f-Factor assumes that the internal and external temperatures are constant and that the building fabric is not warming or cooling.

U-Value	f-Factor
1.8	0.82
1.6	0.84
1.4	0.86
1.2	0.88
1.0	0.90
0.8	0.92