warm surfaces – warm edges

Warm surfaces – warm edges
Insulated glass with thermally improved edge seal

New statutory requirements with respect to energy savings have had significant effects on the requirements of facade constructions, in particular the transfer from national standards to new and complex european standards – in particular the U-Value. These changes have led indirectly to more stringent requirements.

One of the most important changes refers to the effects of the warm bridges. In the old standards, warm bridges were mostly ignored but in the new regulations there are definite minimum requirements which need to be fulfilled.

What is a Warm bridge?

Warm bridges are determined as weak points in the envelope of a building. They lead to increased heat-loss and/or too low surface temperatures on the inner walls, thereby increasing the risk of condensation or mould build-up. Both effects are detailed with the help of new values in the fundamental standard EN 10211-1:

- Heat loss through the linear thermal transmission coefficient ψ (Psi-value),
- Risk of condensation by the dimensionless Temperature factor f

warm surfaces – warm edges

In principle it is possible to determine these values experimentally in a laboratory. It is simpler (no test specimens are required) to use the calculated values through a multi-dimensional thermal analysis. Also known as an „Isotherm calculation", this method is typically used in present day analyses. There are a number of special software programs available.

Effects for Windows

The insulation of windows and facades has been significantly improved in recent years. Highly effective thermally-insulating coatings and gas-filling of insulated glass units meant a technological quantum-leap. Frame construction has also been thermally improved. With this development, the installation of the glass in the frame and the edge seal of the insulated glass has come under closer scrutiny. The thermographic images (see Pic 1 and 2) of a facade clearly show the weak points of older windows being the interface between glass and frame. These window-integral warm bridges will be characterised in the future by the linear thermal-transmission coefficient ψ_{fg} or „ψ-value" for short, and encompassed in the calculation of the U-Value of the window.

In new European formulae to EN ISO 10077-1, the thermal transmission coefficient of a window is calculated from the U-values of the glass and frame together with the ψ-value and extent of glass as follows:

$$U = \frac{A_g \cdot U_g A_f \cdot U_f + l_{fg} \cdot \Psi_{fg} w}{A_g + A_f}$$

U_w Thermal transmission coefficient of the window in W/(m²K)(Index w for window)
A_g Glass area in m² (Index g for glass)
U_g Thermal transmission coefficient of the glass in W/(m²K)

warm surfaces – warm edges

A_f	Frame area in m² (Index f for Thermal transmission coefficient of frame in W/(m²K)
l_{fg}	perimeter of visible glass edge in m (Index fg for frame-glass)
ψ_{fg}	linear Thermal transmission coefficient in W/(mK)

Example:
Window 1,23 m x 1,48 m;Total area 1,82 m²
Frame with Uf = 1,4 W/(m²K) and Glass with Ug =1,1 W/(m²K)
Frame depth 0,11 m; gives Glass 1,01 m x 1,26 m with area 1,27 m² and perimeter 4,54 m
ψ-Wert 0,08 W(/mK) (typical glass application and edge seal with Aluminium spacer)

Calculation to DIN 4108:1981

$$k_F = \frac{1{,}27\ m^2 \cdot 1{,}1\ {}^{W}/_{m^2.K} + 0{,}55\ m^2 \cdot 1{,}4\ {}^{W}/_{m^2.K}}{1{,}82\ m^2} =$$

$$= (0{,}77+0{,}42)\,{}^{W}/_{m^2.K} = 1{,}2\ {}^{W}/_{m^2.K}$$

Calculation to DIN EN ISO 10077-1:2001

$$U_W = \frac{1{,}27\ m^2 \cdot 1{,}1\ {}^{W}/_{m^2.K} + 0{,}55\ m^2 \cdot 1{,}4\ {}^{W}/_{m^2.K} + 4{,}54\ m \cdot 0{,}08\ {}^{W}/_{mK}}{1{,}82\ m^2} =$$

$$= (0{,}77 + 0{,}42 + 0{,}20)\,{}^{W}/_{m^2.K} = 1{,}4\ {}^{W}/_{m^2.K}$$

The warm bridge between glass and frame, with the help of the ψ-value increases the calculated thermal transmission coefficient of a window with „conventional" insulated glass edge seals (spacer of Aluminium) by 0,2 W/m²K from 1,2 W/m²K to 1,4 W/m²K. This effect is, however, only obvious in windows with a well-insulated frame construction and with thermally insulating glass. Old windows, typically installed prior to 1990, are so poor that the weak edge is no longer obvious (Pic 2).

warm surfaces – warm edges

The „warm edge“

The Isotherm calculations show that conventional spacer bars (e.g. of Aluminium) are a significant reason for the warm bridge at the interface between glass and frame. Alternatives are simple to think of, but difficult to achieve, as they need to be mechanically stable and provide long-term performance in accordance with the requirements on insulated glass standards (moisture- and Gas diffusion).

Nevertheless, thermally improved spacer systems are nowadays available, and provide an improvement in the thermal transmission at the interface between glass and frame as well as increasing the inner surface temperatures.

Example: Window
1,23 m x 1,48 m; Total area 1,82 m²
Frame with U_f = 1,4 W/(m²K) and glass with U_g =1,1 W/(m²K)
Frame depth 0,11 m; gives Glass 1,01 m x 1,26 m with area 1,27 m² and perimeter 4,54 m
ψ-value 0,04 W/(mK) (thermally improved edge spacer)

$$U_W = \frac{1{,}27\ m^2 \cdot 1{,}1\ {}^{W}/_{m^2.K} + 0{,}55\ m^2 \cdot 1{,}4\ {}^{W}/_{m^2.K} + 4{,}54\ m \cdot 0{,}04\ {}^{W}/_{m.K}}{1{,}82\ m^2} =$$

$$= (0{,}77 + 0{,}42 + 0{,}10)\ {}^{W}/_{m^2.K} = 1{,}3\ {}^{W}/_{m^2.K}$$

With such a thermally improved edge seal, the edges of the inner glass surface are warmer (ergo „warm edge") and therefore significantly reduce the risk of condensation formation and mould build-up. The new Constant for this is the "f-Factor". DIN 4108-2: 2001 requires a minimum value of 0.70 to avoid mould build-up on the wall. This value applies particularly to warm bridges at walls and not for the interface between glass and frame in windows because these areas are less susceptible to mould occurence.

warm surfaces – warm edges

The „f-Factor" can also be useful as a guideline for these areas. Whilst a „conventional" edge seal with an Aluminium spacer achieves an „f-Factor" of approx. 0,50, an insulated unit with thermally improved edge seal will achieve a value almost 0,70, and triple glazing exceeds the value.

A thermally improved edge seal with the advantage of less heat loss and higher surface temperatures provides a sensible solution for modern windows and well-insulated glass units.

How do we get to the U_w-value?

The calculations for the window U-value U_w are more exact, but have also become more complicated, as one can see in Table 1. It is simple to find the respective areas A_g and A_f. From this it is possible to determine the perimeter of the visible glass edge l_{fg}. The U_g-value is, as previous, declared by the glass supplier. The U_f-value is dependent on the frame profile employed. The length-relative thermal transmission coefficient ψ_{fg} is dependent on a number of different factors. This is explained further in the Infobox. Important note: only after knowing all factors (type of glass edge seal, glass rebate, glass type, frame construction) is it possible to determine the ψ_{fg}-value of the window.

In order to make the process of determining U_w–value from input of frame size very simple, the Federal Glass Association of Troisdorf, Germany provides the software program WinU_w. This program can be obtained directly (www.bfflachglasverband.de). The WinU_w program allows the influences of window format, glass, frame and edge seal to be easily distinguished. In addition to this, Isotherm images and surface temperatures as well as heat waves are shown. The bases of this program are the current European standards and an extensive research project of the FGA carried out by ift. The concluding report contains the examples in the program.

warm surfaces – warm edges

This information has been established by the workshop „Warm edge" in the FGA e.V.

Literature reference: Forschungsvorhaben ift

Table 1
Terminology of the thermal transmission coefficients

Item	Currently valid	Old (DIN)	Unit
Glass	U_g (glass)	k_V (glass)	W/(m²K)
Frame	U_f (frame)	k_R (frame)	W/(m²K)
Glass edge	ψ_{fg} (or shorter ψ)	—	W/(mK)
Window	U_W (window)	k_F (window)	W/(m²K)
	$UW = \frac{A_g.U_g + A_f.U_f + l_{fg}.\Psi_{fg}}{A_g + A_f}$	$kF = \frac{A_V \cdot k_V + A_R \cdot k_R}{A_V + A_R}$	

warm surfaces – warm edges

INFOBOX

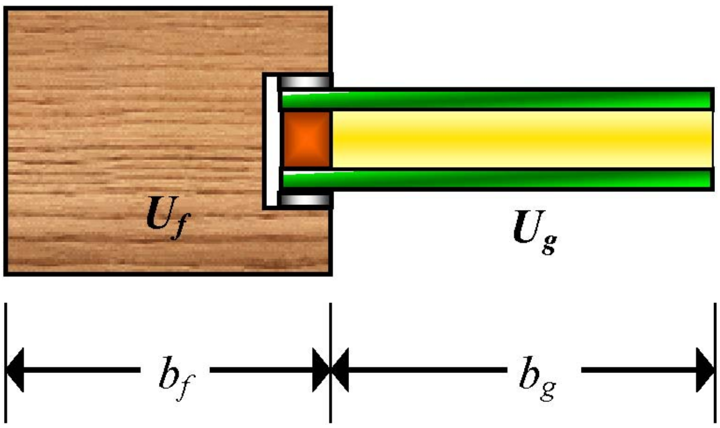
Effects of frame and glazing
The edge-length relative thermal transmission coefficient (Ψ-value)

The thermal transmission coefficient of an insulated unit describes the thermal transmission in the centre of the unit, the thermal transmission coefficient of a frame describes the thermal transmission through the frame without glazing. The edge-length relative thermal transmission coefficient (Ψ-value) describes the additional thermal transmittance which occurs as a result of the interaction of the frame profile and insulated glass edge seal including the edge spacer.

Because the measurements of the edge-length thermal transmission coefficients are very long-winded, calculations using programs for 2-dimensional analyses of thermal transmittance are preferred. The calculation method integrates the detailed cross-section of the frame profile including the glass and glass edge and the 2-dimensional thermal conductivity value is established. When the conductivity values of the frames and glass are deducted, the edge-length relative thermal transmission coefficients remain. The methodology is described in detail in DIN EN ISO10077-2.

As with the measurement, the exactness of the calculations and results are restricted due to unavoidable measurement and calculation tolerances. Thermal transmission coefficients are therefore rounded down to two digits. The edge-length relative thermal transmission coefficients (Ψ-Value) result from a difference between measured and calculated values and is therefore particularly sensitive. From experience it has been established that the calculation tolerance is approx. 0,005 W/(mK) so that differences in this amount are not significant.

warm surfaces – warm edges



$$\Psi_{fg} = L^{2D} - U_f \cdot b_f - U_g \cdot b_g$$

legend

Ψ_{fg} the edge-length relative thermal transmission coefficient (Ψ-Wert) in W/(m.K);

$L\Psi^{2D}$ the calculated 2-dimensional thermal conductivity value in W/(m.K)

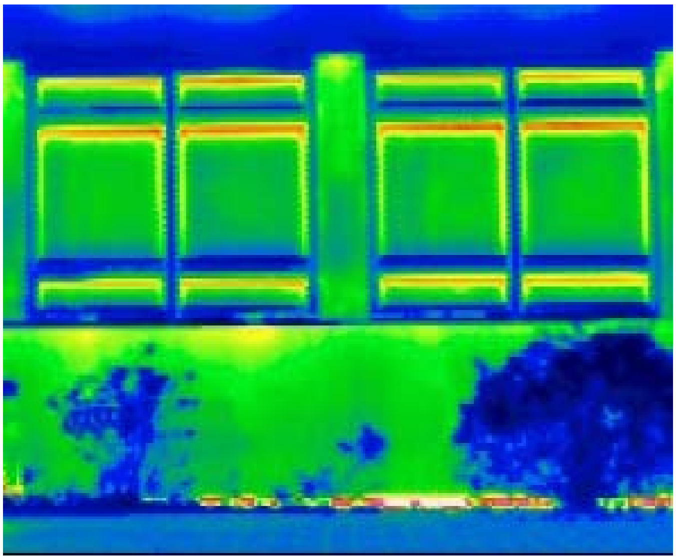
U_f the thermal transmission coefficient of the frame in W/(m^2.K);

U_g the thermal transmission coefficient of the Glass in W/(m^2.K);

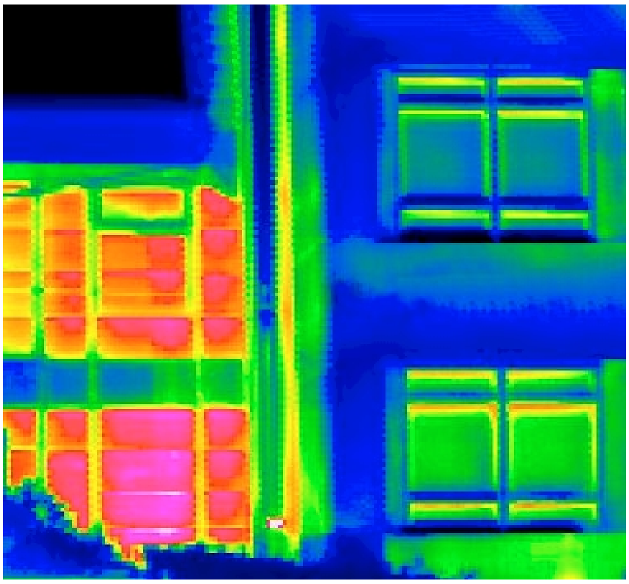
b_f the visible width of the frame in m;

b_g the visible width of the Glass in m.

warm surfaces – warm edges

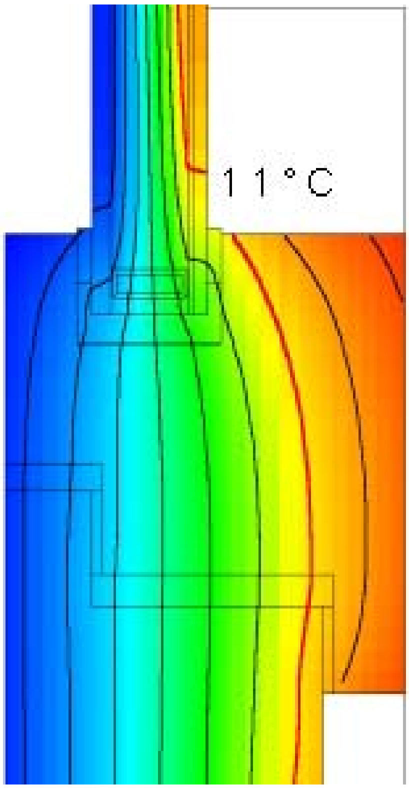


Window with thermal insulating glass and typical glass edge



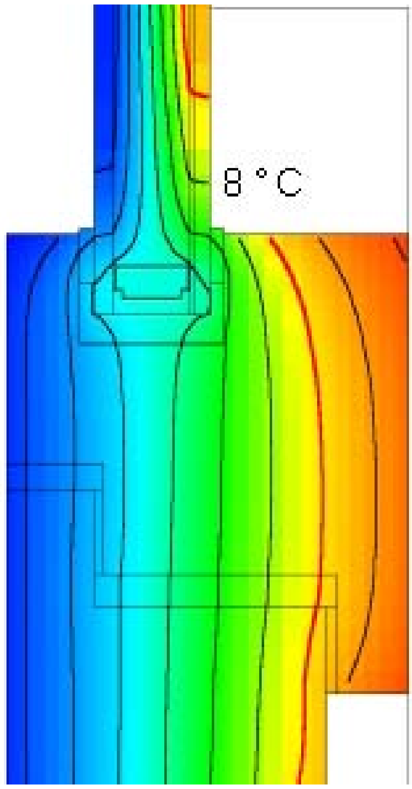
Old windows (about 1990)

warm surfaces – warm edges



CHROMATECH PLUS

Wood window with thermally insulated glass employing thermally improved edge seal (warm-edge)



Aluminium

Wood window with thermally insulated glass employing standard aluminium spacer