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Calculation procedure for determination of
the energy performance of windows with
large glass distance

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1 Introduction

This document describes a procedure for calculation of the energy performance for windows with large distance between the glass panes. The described method is valid for glass distances exceeding 25 mm. For glass distances below 25 mm the standard EN ISO 10077-2 must be used.

1.1 Problem definition

Due of the large gab the standard EN ISO 10077-2 cannot be used for calculation of the thermal transmittance, U_f for frames or mullions because an unequal distribution of the linear thermal transmittance, Ψ , and the U-value of the frame will occur.

According to EN ISO 10077-2, that only treats windows with small glass distances, an imaginary material with an equivalent thermal conductivity is placed between the glass panes. The problem with that method is that it will result in unrealistic temperatures between the glass panes close to the frame when used on windows with large gabs between the glass panes.

2 Calculation procedure

2.1 Method

The idea of this calculation method is to avoid the use of a material with equivalent thermal conductivity between the glass layers. Instead the resistance of the air layer is distributed on those surfaces immediately adjacent to the cavity.

A cross section of the window is modelled in e.g. Therm as shown in Figure 1. The used glass length in the model, l_g , must be 190 mm.

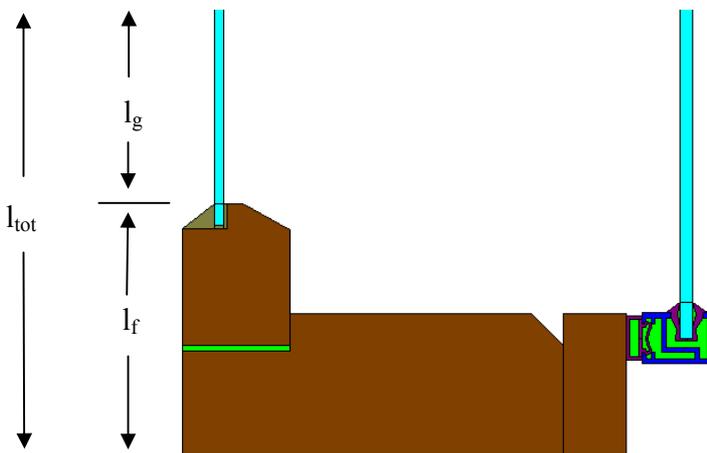


Figure 1. Frame profile with large distance between the glass panes.

When modelling windows where a sealed glazing unit is included e.g. “1 + 2” –windows the sealed glazing unit is still treated as described in EN ISO 10077-2 (see section 3)with a material with equivalent thermal conductivity inserted in the glazing unit but the large cavity must be treated as described in the following.

2.2 Material data for the glazing

The centre U-value of the glazing, U_g , the total solar energy transmittance, g , and the light transmittance, τ , shall be obtained from the glazing manufacturer or calculated in the program WIS.

2.3 Boundary conditions

In general the boundary conditions described in EN ISO 10077-2 are used in the model. These are:

$T_i = 20 \text{ }^\circ\text{C}$,	Temperature, internal
$T_e = 0 \text{ }^\circ\text{C}$,	Temperature, external
$h_e = 25.0 \text{ W/m}^2\text{K}$	Heat transfer coefficient, external
$h_i = 7.69 \text{ W/m}^2\text{K}$	Heat transfer coefficient, internal
$h_r = 5.0 \text{ W/m}^2\text{K}$	Heat transfer coefficient, reduced radiation
$q = 0$	Adiabats in top and bottom

These boundary conditions are applied to the internal and external surfaces of the model.

The lowermost part of the frame profile and the uppermost part of the glazing are applied adiabatic boundary conditions.

The boundary conditions of the large air cavity between the panes must be found on a basis of the equivalent thermal resistance, R_{eq} , of the air layer, which is derived from the centre U-value of the glazing, U_g .

R_{eq} , is given as

$$R_{eq} = \frac{1}{U_g} - \left(\frac{1}{h_i} + \frac{1}{h_e} + \frac{s_{g1}}{\lambda_{g1}} + \frac{s_{g2}}{\lambda_{g2}} \right)$$

Where

s_{g1} og s_{g2} :	Thickness of glass panes, m
λ_{g1} og λ_{g2} :	Thermal conductivity of the glass panes, W/mK

The equivalent thermal resistance of the cavity is separated equally on the two glass surfaces that are facing each other in the cavity. Consequently half the R_{eq} is added on each glass surface and also on the surface of the frame located inside the cavity. The thermal resistance is converted to a heat transfer coefficient, h_{cav} , which is the boundary condition that is applied to the surfaces in the cavity.

$$h_{cav} = \frac{1}{\frac{R_{eq}}{2}}$$

The boundary conditions for the two glass surfaces facing the air cavity are based on the temperature, T_{cav} , in the cavity. The temperature in the cavity, T_{cav} , is given as

$$T_{cav} = T_e + \left(\frac{h_e^{-1} + \frac{s_{g1}}{\lambda_{g1}} + \frac{R_{eq}}{2}}{U_g^{-1}} \right) \cdot (T_i - T_e)$$

This temperature will not be the final boundary condition but is used as a starting guess in the first calculation performed.

The boundary conditions h_{cav} and T_{cav} are applied on the three surfaces in the cavity: each glass surface and the surface of the frame located inside the cavity.

In Figure 2 the use of the boundary conditions are shown on a cross section model of the window.

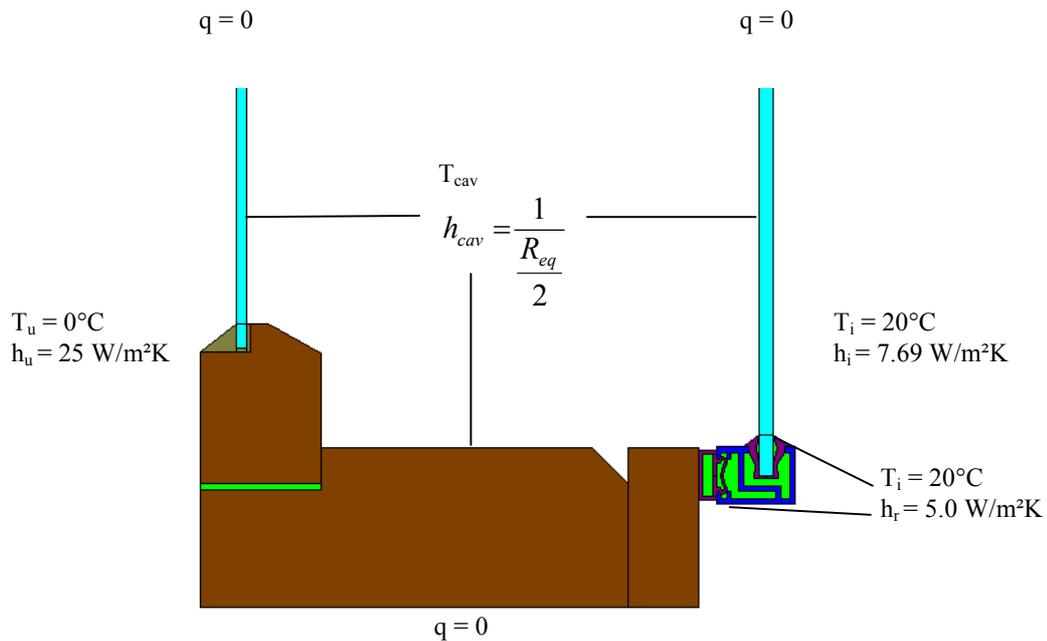


Figure 2 Boundary conditions on frame profile

The model is calculated in Therm which gives a result of the U-value of the cross section for the internal and the external surface respectively. These two results are most likely not the same as they should. Therefore it is necessary to change T_{cav} in the boundary conditions until the U-value for the internal and the external surface is very close to each other. When the difference is less than $0.05 \text{ W/m}^2\text{K}$ the average is used for the following calculations. In this way the value is found using an iterative process where the temperature in the cavity, T_{cav} , is changed until energy balance is obtained. See also “Therm guideline” for help when modelling the profile in Therm.

When the U-value of the internal and the external surface are identical the thermal transmittance, U_f can be determined as

$$U_f = \frac{U_{average} \cdot l_{tot} - U_g \cdot l_g}{l_r}$$

3 “1 + 2” windows

When modelling thick windows where a sealed glazing unit is included e.g. “1 + 2” or “2 + 1”– windows the sealed glazing unit must be modelled as described in EN ISO 10077-2 with a material with equivalent thermal conductivity inserted in the cavity in the glazing unit. The large cavity must still be treated as described in the previous chapters. The Excel spreadsheet “U-value calculation_Type 2 window_2007_ver1.xls” can be used for the calculations.

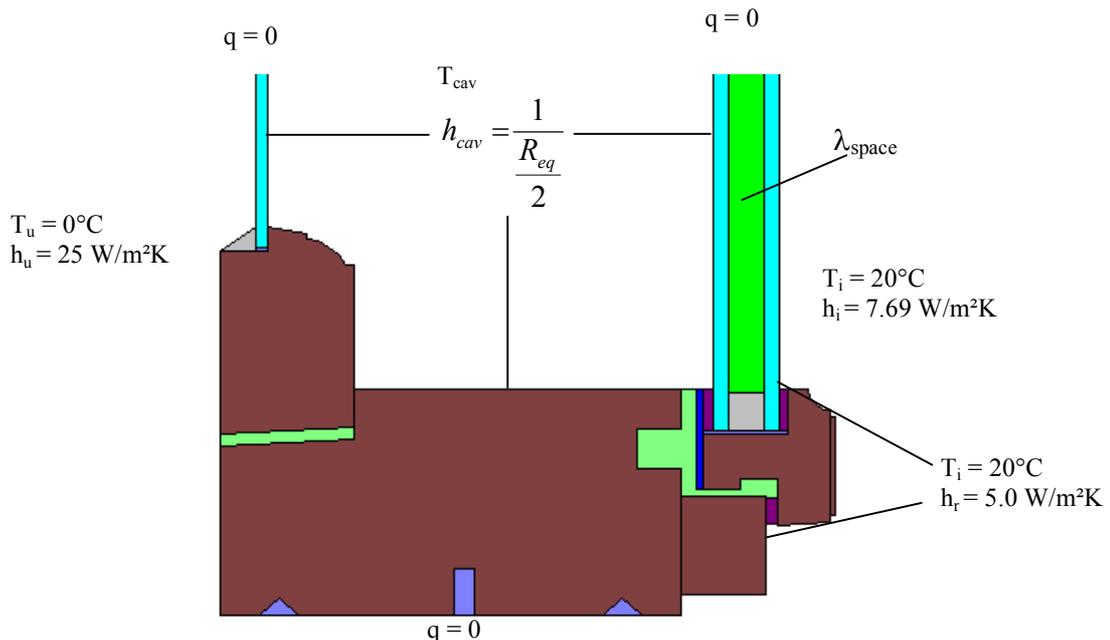


Figure 3. “1 + 2” window. Boundary conditions and equivalent conductivity of space in sealed glazing unit.

The equivalent thermal conductivity of the cavity, λ_{space} , depends on the U-value and the dimensions of the sealed glazing unit (see also “Therm guideline” p. 14). λ_{space} is given by

$$\lambda_{space} = \frac{d_{space}}{\frac{1}{U_{g,seal}} - \frac{1}{h_e} - \frac{1}{h_i} - 2R_{glass}} \quad [\text{W/mK}]$$

Where

- $U_{g,seal}$ is the centre U-value of the sealed glazing unit alone [W/m²K]
- d_{space} is the distance between the glass panes in the sealed glazing unit [m]
- R_{glass} is the resistance of each glass pane in the sealed glazing unit

The modelling of the large cavity in the glazing is treated the same way as described in chapter 2 but the formula for the equivalent thermal resistance, R_{eq} of the large cavity is slightly changed. The equivalent thermal resistance, R_{eq} , is given by

$$R_{eq} = \frac{1}{U_g} - \left(\frac{1}{h_i} + \frac{1}{h_e} + \frac{s_{g1} + s_{g2} + s_{g3}}{\lambda_g} + \frac{d_{space}}{\lambda_{space}} \right) \quad [\text{m}^2\text{K/W}]$$

Where

U_g is the centre U-value of the complete glazing [W/m²K]
 s_{g1} and s_{g2} and s_{g3} is the thickness of the three glass panes [m]
 λ_g is the thermal conductivity of the glass [W/mK]

4 Calculation of the overall U-value for arbitrary window configuration

The thermal transmittance U of the whole window of any size is calculated with the general formula:

$$U = \frac{A_g \cdot U_g + \sum A_f \cdot U_f}{A'}$$

Where

A_g area of the glazing [m^2]

U_g thermal transmittance of glazing (centre value) [W/m^2K]

A_f frame area [m^2]

U_f thermal transmittance of the frame [W/m^2K]

A' window area [m^2]

The light transmittance, τ , and the total solar energy transmittance, g , of the window are determined as the corresponding values for the glazing multiplied with the ratio between the glazing area and the total window area.

$$\tau = \frac{A_g \cdot \tau_g}{A'} \quad \text{og} \quad g = \frac{A_g \cdot g_g}{A'}$$