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ENERGY LABELLING OF GLAZINGS AND WINDOWS IN DENMARK: CALCULATED AND MEASURED VALUES

KARSTEN DUER†, SVEND SVENDSEN, MORTEN MOLLER MOGENSEN and JACOB BIRCK LAUSTSEN
Department of Civil Engineering, Technical University of Denmark, Building 118, 2800 Kgs. Lyngby, Denmark

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Abstract—The influence of windows on the energy consumption in buildings is well known and in order to encourage the development and the appropriate use of high performance glazings and windows in Denmark, an Energy Labelling and Rating system is being developed. During this work a need for establishing a common and well-defined method to characterise the performance of glazings and windows on the Danish market has been recognised. This paper gives a short description of the Danish energy labelling and rating system for glazings and windows, which was put into operation during 2000. Furthermore, the results of a comparison between measured and calculated thermal transmittance for five different window types are given. The calculations on the glazing part have been performed in five different programmes (WIS, WINDOW, VISION, CALUMEN and GLAD99). The calculations on the frame part have been performed in three different programmes (FRAME, THERM and WinIso). The comparison indicates that all investigated programmes are qualified for calculating energy labelling data for glazings and windows. © 2002 Published by Elsevier Science Ltd.

1. INTRODUCTION

In order to stimulate the use of glazings and windows with better energy performance and to improve the competition on the energy performance of glazings and windows, an energy labelling and rating system for these products has been established and was being put into operation during the year 2000. In the following, the Danish energy labelling and rating system is briefly described. Furthermore, the paper gives the results of comparisons carried out between measured and calculated U-values for five Danish window designs.

2. ENERGY LABELLING AND RATING DATA FOR GLAZINGS AND WINDOWS

2.1. Energy labelling data

The energy performance of glazings and windows is based on the characteristic values shown in Table 1. Most of the data are traditionally used for characterising the energy performance of glazings and windows.

The data are defined in the listed standards and need no explanation here. However, the equivalent thermal conductivity of the edge construction of glazings, λ_k, is added in order to make it easy to compare this important detail of glazings. This is defined as the thermal conductivity of an imaginary solid material that is identical to the edge construction (spacer and seal) with respect to dimensions and heat flow.

The energy labelling data can be found by use of calculations or tests. In order to make it easy for manufacturers to document the characteristic data for their products, a number of detailed programs have been compared with tests of a number of typical Danish windows. The results are summarised in Sections 3 and 4. Based on this general validation the manufacturers are allowed to use the investigated programs for documenting the energy labelling data for glazings and windows without testing.

2.2. Energy rating data for glazings

In order to characterise the energy performance of glazings and windows it is necessary to include both U-value and g-value. Over the heating season and for a specified climate, the energy balance of a window can be described by the net energy gain, which is the solar heat transmitted in through the window, minus the heat loss transmitted out through the window during the heating

†Author to whom correspondence should be addressed. Tel.: +45-4525-1867; fax: +45-4593-4430; e-mail: kd@ibe.dtu.dk

season. Using the net energy gain makes it easy for private consumers to compare products to be used in heating-dominated houses.

By using typical climatic data for Denmark and by choosing a reference building, the relative areas for the main orientations of the windows can be used in calculating the net energy gain as a function of the U-value and the g-value of the glazing. The reference house used for the Danish energy rating system for glazings is a typical single-family house, which has the following distribution of the windows:

South:	41%
North:	26%
East/West:	33%

A shadow factor of 0.7 is used for the corrections for the effects of shadows.

The description of the method and the assumptions used to generalise the angular dependence of the total solar transmittance of glazings can be found in Nielsen *et al.*, (2000). Based on the Design Reference Year, DRY, the solar radiation on vertical surfaces corrected for the effects of varying incidence angles has been found for the heating season (24/9–13/5):

South:	431 kWh/m^2
North:	105 kWh/m^2
East/West:	232 kWh/m^2

Combining these with the distribution of the windows in the reference house and the shadow factor gives a weighted total solar radiation of 196.4 kWh/m^2 during the heating season. The heat loss is determined on the basis of the temperature difference between indoor and outdoor climate during the heating season. Based on DRY a total of 90.36 degree hours (kKh) is found. Thus the net energy gain, E_{ref}, during the heating season can be found for specific glazings from the equation:

$$E_{\mathrm{ref}} = 196.4 \times g - 90.36U \ (\mathrm{kWh/m^2}). \qquad (1)$$

Only glazings with positive net energy gain are given a rating based on the following classification: (A) net energy gain of more than 20 kWh/m^2; (B) net energy gain between 10 and 20 kWh/m^2; (C) net energy gain between 0 and 10 kWh/m^2.

The classification will of course depend on the climatic data and the reference house used and is only meant to give the private consumer an easy way to compare products. In the Danish energy rating and labelling system only glazings can be classified (A, B or C).

2.3. Information on the energy labelling and rating of products

The energy labelling and rating system is open to all manufacturers and has been accepted and notified by the European Commission. Hereby it is notified by the commission that the system does not distort trade competition. The European Commission does not have an energy rating system for glazings and windows for the present.

The manufacturers participating in the Danish energy rating and labelling system have to provide information on their products as follows.

The four energy labelling data for glazings, U_g, g_g, τ_g and λ_k, must be available on paper or electronically.
The energy rating class A, B or C (if any) for glazings must be given in the spacer profile. However, marking with the energy class is optional.
The three energy labelling data for the windows, U_w, g_w, τ_w, must be available for each window based on the actual dimensions on paper or electronically.

3. CALCULATED ENERGY LABELLING DATA

The calculations of energy labelling data for glazings and windows have been carried out by means of a number of relevant calculation programs. Distinctions are made between programs for determination of data for the glazing part and

Table 1. Energy labelling data for glazings and windows

	Data		Reference
Glazing	U_g	Thermal transmission coefficient, centre value	EN673
	τ_g	Light transmittance, centre value	EN410
	g_g	Total solar energy transmittance, centre value	EN410
	λ_k	Equivalent thermal conductivity of edge construction	
Windows	U_w	Thermal transmission coefficient based on total area	EN ISO10077-1 prEN ISO10077-2
	τ_w	Light transmittance based on total area	ISO DIS15099
	g_w	Total solar energy transmittance based on total area	ISO DIS15099

programs for determination of data for the frame part. The investigated programs are listed in Table 2.

3.1. Calculations of energy properties of glazings

The five calculation programs listed uppermost in Table 2 have been tested by means of calculations on a total of nine different glazings.

For each glazing the U-value, the total solar energy transmittance (g-value), and the light transmittance were calculated. Table 3 specifies the composition of glazing, gas type and width of space between the panes that were computed. Three types of coatings were investigated: hard low e-coating, soft low-e coating and solar protecting low e-coating — the latter always in position 2.

The glazings have been compiled in order to make demands on the accuracy of the calculation programs rather than to represent glazings that have typical applications. Therefore the glazings nos. 4–8 are equipped with two low-emittance coatings even though this would normally not be relevant in double glazed units.

The calculated light transmittances and total solar energy transmittances are shown in Tables 4 and 5. The calculated centre of glass U-values are shown in Table 6.

3.2. Discussion

There is in general a good consistency between the calculated results. It appears from the tables that the calculated light transmittances were independent of the calculation program and the calculated g-values were within ± 0.01 of mean values. Also the results of the calculated U-values show good consistency. It should be noted, however, that as to glazing no. 7 in Table 6 there is a significant deviation between the obtained results of the U-value. The deviations are due to the applied calculation models. The programs WIS, CALUMEN and GLAD99 apply a model corresponding to EN673, whereas the programs WINDOW4.1 and VISION4 apply a more detailed model. At present, analyses are in progress in the relevant ISO and CEN working groups, partly investigating the differences in the results of the different models and partly investigating which models best represent the actual conditions. Provisional results indicate that the EN673-model gives too low U-values compared with measurements for glass distances larger than 12 mm, and in fact this corresponds to the results in Table 6.

Table 3. Composition of glazings

Glazing no.	No. of glass panes	Coating position	Gas filling[a]	Width of space (mm)
1	2	3	1	12
2	2	3	1	12
3	2	2	1	12
4	2	2+3	2	12
5	2	2+3	1	6
6	2	2+3	1	12
7	2	2+3	1	18
8	2	2+3	3	12
9	3	2+5	1	12

[a] 1, Air/argon, 10/90%; 2, air, 100%; 3, air/krypton, 10/90%.

3.3. Description of the five test windows

Five different typical frame designs, of wood, aluminium covered wood, plastic, metal and mixed materials, have been selected. The designs of the five frame profiles are shown in Fig. 1 in Section 4. All the windows measure about 1.23 m×1.48 m (width×height) and are equipped with a double glazed unit composed of: 4 mm clear float glass — 10/90% air/argon-filled space — 4 mm glass with soft low emissivity coating in position 3. The glass pane distance varies from window to window, but glass types and gas filling are the same for all five windows.

3.3.1. Calculation of the window U-value. The calculations are divided up into three elements.

Table 2. Outline of programs for glazing and frame calculations

	Program	Calculated parameters	Distributor
Glazing	WIS	U_g, g_g, τ_g	TNO, The Netherlands
	WINDOW4.1	U_g, g_g, τ_g	Lawrence Berkeley National Laboratory, USA
	VISION4	U_g, g_g, τ_g	Enermodal Engineering, Canada
	CALUMEN	U_g, g_g, τ_g	Saint Gobain, France
	GLAD99	U_g, g_g, τ_g	EuroGlass, Switzerland
Frame	FRAME	U_f, Ψ	Enermodal Engineering, Canada
	THERM2.0	U_f, Ψ	Lawrence Berkeley National Laboratory, USA
	WinIso	U_f, Ψ	Sommer Informatik, Germany

Table 4. Comparison between calculated light transmittances, τ, for nine glazings

Glazing no.	1	2	3	4	5	6	7	8	9
WIS	0.74	0.78	0.62	0.60	0.60	0.60	0.60	0.60	0.54
WINDOW4.1	0.74	0.78	0.62	0.60	0.60	0.60	0.60	0.60	0.54
VISION4	0.74	0.78	0.62	0.60	0.60	0.60	0.60	0.60	0.54
CALUMEN	0.74	0.78	0.62	0.60	0.60	0.60	0.60	0.60	0.54
GLAD99	0.74	0.78	0.62	0.60	0.60	0.60	0.60	0.60	0.54
MEAN	0.74	0.78	0.62	0.60	0.60	0.60	0.60	0.60	0.54

Table 5. Comparison between calculated total solar energy transmittances, g, for nine glazings

Glazing no.	1	2	3	4	5	6	7	8	9
WIS	0.71	0.59	0.36	0.36	0.35	0.35	0.34	0.34	0.31
WINDOW4.1	0.71	0.60	0.37	0.36	0.37	0.35	0.35	0.35	0.32
VISION4	0.71	0.58	0.36	0.35	0.36	0.35	0.34	0.34	0.31
CALUMEN	0.71	0.59	0.36	0.35	0.36	0.35	0.34	0.34	0.31
GLAD99	0.71	0.59	0.35	0.35	0.35	0.34	0.33	0.33	0.30
MEAN	0.71	0.59	0.36	0.35	0.36	0.35	0.34	0.34	0.31

Table 6. Comparison between calculated centre of glass U-values for nine glazings (W/m^2 K)

Glazing no.	1	2	3	4	5	6	7	8	9
WIS	1.64	1.26	1.46	1.59	1.99	1.24	1.09	1.02	0.77
WINDOW4.1	1.65	1.29	1.48	1.58	2.00	1.27	1.21	1.08	0.77
VISION4	1.65	1.28	1.47	1.60	1.97	1.26	1.19	1.05	0.77
CALUMEN	1.64	1.26	1.47	1.59	1.99	1.24	1.14	1.02	0.77
GLAD99	1.68	1.28	1.50	1.60	2.00	1.26	1.08	1.04	0.78
MEAN	1.65	1.27	1.48	1.59	1.99	1.25	1.14	1.04	0.77

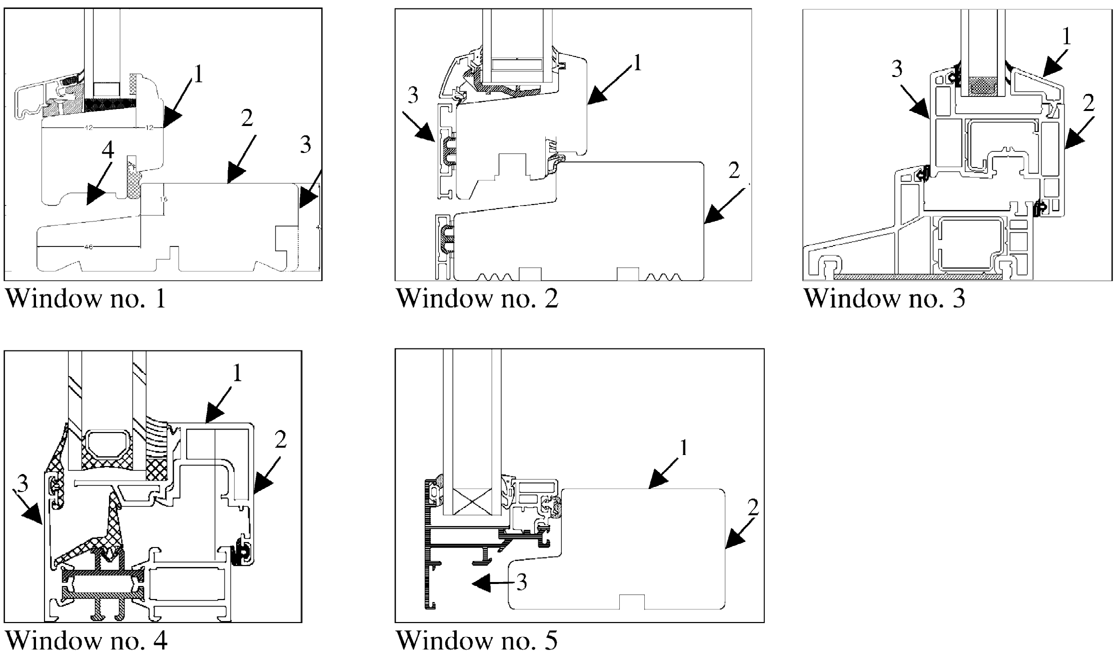

Fig. 1. Cross sections of frame profiles in windows 1–5 with locations of temperature sensors.

- Centre U-value for the glazing, U_g ($W/m^2 K$).
- The U-value of the frame, U_f ($W/m^2 K$).
- The linear thermal transmittance for the joint between the glazing and the frame, Ψ (W/m K).

The calculation of U_g has been carried out in accordance with EN673. The calculation of U_f and Ψ have been carried out in accordance with prEN10077-2. The method is described briefly in the following.

In accordance with prEN10077-2 the calculation of the thermal transmittance of the frame is based on the two-dimensional thermal coupling coefficient, L_r^{2D}, of a section consisting of the frame with an insulation panel inserted instead of the actual glazing. The thermal conductivity of the panel is 0.035 W/m K. The value of the thermal transmittance, U_f, of the frame is defined by:

$$U_f = \frac{L_f^{2D} - U_p b_p}{b_f} \quad (2)$$

where U_f is the thermal transmittance of the frame section ($W/m^2 K$); L_f^{2D} is the thermal conductance of frame and panel (W/m K); U_p is the thermal transmittance of the panel ($W/m^2 K$); b_f is the projected width of the frame section (m); b_p is the visible width of the panel (m).

The linear thermal transmittance, Ψ, describes the additional heat flow caused by the interaction of the frame and the glass edge, including the effects of the spacer. To determine Ψ, the frame section must, in accordance with prEN10077-2, be completed by the actual glazing used. The value of the linear thermal transmittance, Ψ, is defined by:

$$\Psi = L_{\Psi}^{2D} - U_f b_f - U_g b_g \quad (3)$$

where Ψ is the linear thermal transmittance (W/m K); L_{Ψ}^{2D} is the thermal conductance of frame and glazing (W/m K); U_g is the thermal transmittance of the glazing ($W/m^2 K$); b_g is the visible width of the glazing (m).

The boundary conditions used for the calculations are given in Table 7.

The results of the total window U-value calculations are shown in Table 8.

Table 8. Calculated total U-values for five windows. The frame part calculated with FRAME, THERM2.0 and WinIso, respectively. Glazing part calculated with GLAS98

Window no.	1	2	3	4	5	
FRAME	1.75	1.47	1.49	1.78	1.56	($W/m^2 K$)
THERM	1.73	1.46	1.46	1.76	1.56	($W/m^2 K$)
WinIso	1.74	1.47	1.49	1.74	1.56	($W/m^2 K$)
Mean	1.74	1.47	1.48	1.76	1.56	($W/m^2 K$)

As appears from Table 8, by and large the same total U-value is achieved for a specific window irrespective of which calculation program is chosen. The deviation from average is 1% at the maximum.

3.4. Measurements

Measurements of the total U-values for the five windows have been carried out in a guarded hot box consistent with the relevant draft standards (prEN12412-1 and ISO/DIS12567). (The two documents describe identical procedures.) Also the centre U-values of the glazings and selected temperatures of the frame profiles and the glazings have been measured.

The centre U-values of the glazings have been measured by mounting a window in the hot box and by attaching a sheet of polystyrene foam with a known thermal resistance on the glazing. The temperatures in the hot box were controlled so that the surface temperatures of the glazing came close to the surface temperatures that appeared during the U-value measurement of the current window. These temperatures also correspond to the boundary conditions demanded in EN673.

By measuring the temperature difference across the polystyrene sheet the heat flow through the glazing can be determined, and by measuring the temperature difference across the glazing the thermal resistance of the glazing, and with that the U-value of the glazing, can be determined under conditions corresponding to the total U-value measurement and also corresponding to the standard boundary conditions in EN673.

Table 7. Boundary conditions for the calculations

Surface resistances ($m^2 K/W$)	External	Internal
Normal (plane surface)	0.04	0.13
Reduced radiation/convection (in edges or junctions between two surfaces)	0.04	0.20
Temperatures (°C)	0	20

4. COMPARISONS BETWEEN CALCULATED AND MEASURED RESULTS FOR THE FIVE WINDOWS

By the comparison between measured and calculated total *U*-values the mean values of the calculated quantities given in Table 8 were used to represent the calculated window *U*-values.

Apart from the *U*-values, comparisons are also made on calculated and measured values of selected temperatures. Temperatures were calculated in THERM. A comparison between measured and calculated surface temperatures should be made with care, as there are not necessarily exactly the same boundary conditions in measurements as in calculations.

In the measurements a total surface heat resistance (inside + outside surface resistance) of ~0.17 m^2 K/W has been established and thus it is not taken into account how the surface resistance is divided inside and outside. Furthermore, there is a relatively large uncertainty in the total surface resistance during the measurements. The actual surface resistances during the measurements are of some significance to the measured surface temperatures, but the uncertainty in the resistance is not of great significance to the total measured *U*-value. For the calculations there are exact defined surface conditions with a known division between inside and outside surface resistance.

It should be noted that the uncertainty of the surface resistance during the measurements is included in the uncertainties that are given under the measured *U*-values.

During the measurements the environmental temperatures on the hot side and the cold side were about 19.7 and 0.5°C, respectively, whereas in the calculations the temperatures allowed for are 20 and 0°C on the hot side and the cold side, respectively.

In the present investigations a comparison between measured and calculated temperatures is therefore not expected to be carried out with an accuracy better than ±1°C. It is still estimated, however, that the comparisons of the temperatures will enable an evaluation of the validity of the calculated results.

In the following, a comparison has been made for each window between measured and calculated *U*-values and surface temperatures and in two cases the temperature of a slightly ventilated cavity. The results are shown in Table 9. The positions of temperature sensors are shown on a sketch for each window in Fig. 1. Surface temperatures on the warm side of the glazings were measured from the sash and 100 mm into the glazing. The results are given in Table 10. For all five windows the course of the temperature over the glazing agrees well, measured and calculated, and the discrepancy between measured and calculated temperatures were in all cases less than 1°C.

4.1. Window no. 1

The frames in window no. 1 are made from massive wood. As appears from Tables 9 and 10 there is a very good agreement between measured and calculated values for *U*-values as well as for surface temperatures.

4.2. Window no. 2

The frames in window no. 2 are made from aluminium cladded wood. Again there is a good agreement between measured and calculated window *U*-value as well as calculated and measured surface temperatures, see Tables 9 and 10. The glazing in window no. 2 has a glass spacing of 24 mm. Following the discussion in Section 3.2 a calculation of the centre *U*-value according to EN673 would lead to an underestimation of the centre *U*-value, and the biggest deviation between measured and calculated values is indeed found for this glazing. However, the calculated and measured centre *U*-values are within the expected

Table 9. Measured and calculated *U*-values and surface temperatures (see Fig. 1)

Window		*U* centre (W/m^2 K)	*U* total (W/m^2 K)	Temp. 1 (°C)	Temp. 2 (°C)	Temp. 3 (°C)	Temp. 4 (°C)
1	Measured	1.18±0.07	1.72±0.09	14.6	17.4	18.6	4.1
	Calculated	1.16	1.74	13.9	17.6	18.9	4.9
2	Measured	1.25±0.08	1.50±0.08	14.8	18.5	1.9	–
	Calculated	1.18	1.47	15.0	18.5	1.5	–
3	Measured	1.17±0.07	1.41±0.07	15.0	16.3	2.6	–
	Calculated	1.13	1.48	14.5	16.4	1.8	–
4	Measured	1.18±0.07	1.65±0.08	14.3	14.3	3.7	–
	Calculated	1.14	1.76	11.8	11.8	3.2	–
5	Measured	1.16±0.07	1.57±0.08	16.8	18.4	2.7	–
	Calculated	1.13	1.56	16.4	18.4	3.0	–

Table 10. Measured and calculated surface temperatures in (°C) in different distances from the frame

Window		Distance from the frame (mm)						
		10	20	30	40	60	80	100
1	Measured	13.3	14.4	15.1	15.6	16.2	16.4	16.5
	Calculated	13.0	14.4	15.5	16.0	16.7	17.0	17.1
2	Measured	13.5	14.7	15.6	15.9	16.4	16.5	16.5
	Calculated	12.5	14.3	15.3	16.0	16.6	16.9	17.0
3	Measured	14.3	15.2	15.7	16.1	16.4	16.6	16.7
	Calculated	13.3	14.6	15.6	16.2	16.8	17.0	17.1
4	Measured	14.4	15.2	15.6	16.0	16.5	16.7	16.8
	Calculated	13.7	14.8	15.7	16.2	16.8	17.0	17.1
5	Measured	11.9	13.5	14.7	15.4	16.2	16.5	16.8
	Calculated	11.4	13.3	14.8	15.7	16.6	16.9	17.1

tolerance of the measurement and more accurate measurements will have to be performed to investigate this matter.

4.3. Window no. 3

The frames in window no. 3 are made from plastic with two steel reinforcements. As appears from Tables 9 and 10 there is a good agreement between measured and calculated values for *U*-values as well as for surface temperatures.

4.4. Window no. 4

The frames in window no. 4 are made from aluminium with thermal break. For window no. 4 there is a discrepancy between measured and calculated total *U*-value which lies outside the uncertainty of the *U*-value measurement — see Table 9.

Apart from this there is a significant difference between the measured and the calculated surface temperatures on the hot side of the frame (temperatures 1 and 2). As there is a good agreement between measured and calculated centre *U*-value for the glazing and as the course of the temperature over the glazing agrees well with Table 10, measured and calculated, it indicates that there is an error in the calculated *U*-value of the frame part (U_r) and/or the linear thermal transmittance of the spacer profile of the glazing (Ψ).

Window no. 4 is built of aluminium profiles with thermal break of synthetic material. In the frame profile the heat transfer is depending on the thermal resistance of the thermal break and the air gap indicated in Fig. 2.

In the calculation of the *U*-value of the frame profile, the cavity to the left in Fig. 2 is calculated as one large cavity even though the cavity is partly divided at the upper arrow. The gap at the arrow is smaller than 10 mm and taking prEN10077-2 as a starting point, arguments can be put forward for dividing up the cavity into two parts as shown in Fig. 3.

By calculating the situation illustrated in Fig. 3, U_f is found at 3.1 W/m^2 K and ψ_g at 0.082 W/m K. (Calculations performed with THERM2.0. Equivalent values with one large cavity are 3.4 W/m^2 K and 0.093 W/m K.) The corresponding total window *U*-value and surface temperature are shown in Table 11.

As appears from Table 11 there is a better

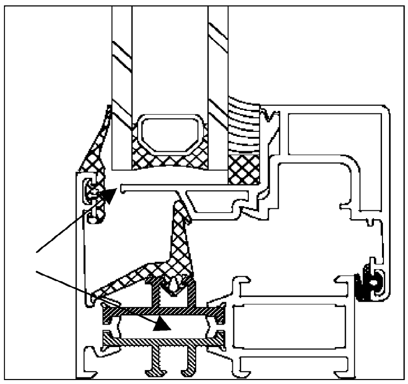

Fig. 2. Critical thermal resistance in window no. 4.

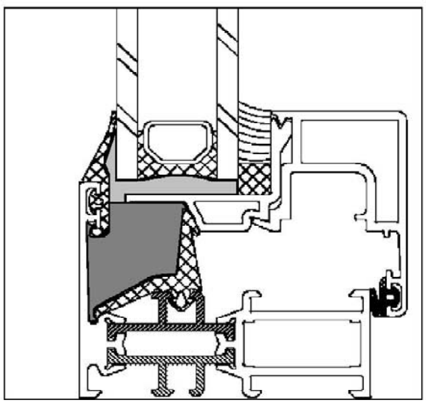

Fig. 3. Division of cavity of window no. 4 into two parts.

Table 11. Measured and calculated U-values and surface temperatures. Windows no. 4 and 5 with divided cavities

Window		U centre (W/m^2 K)	U total (W/m^2 K)	Temp. 1 (°C)	Temp. 2 (°C)	Temp. 3 (°C)
4	Measured	1.18±0.07	1.65±0.08	14.3	–	–
	Calculated	1.14	1.70	12.5	–	–
5	Measured	–	1.57±0.08	16.8	18.4	2.7
	Calculated	–	1.53	16.7	18.4	2.9

consistency between measured and calculated total U-value, but there is still a relatively large deviation between measured and calculated surface temperatures on the hot side of the frame. There are several possible reasons for this.

- In the calculations a firmly defined geometry is used corresponding to the sketches provided by the manufacturer. Even a small variation of the size of the critical air gap in Fig. 2 is of significance to the calculation result.
- In the calculation a perfect metal to metal contact is assumed between the window frame and the clipped on glazing supports. Experience from, e.g., metal absorbers in solar collectors has shown that a thermal contact resistance can occur between two metal parts that are clipped together. If a contact resistance is introduced into the calculations, the calculated U-value of the frame profile will fall and the calculated surface temperature on the hot side of the frame will rise. The contact resistance can be determined through detailed measurements, but this is not done in the present study.

It is concluded that especially for frame profiles of metal it is important to be careful even about small details.

4.5. Window no. 5

In window no. 5 the frame part is made from solid wood and the sash part is aluminium (outermost) and PVC (innermost). As appears from Tables 9 and 10 there is a good agreement between measured and calculated values for U-values as well as for surface temperatures.

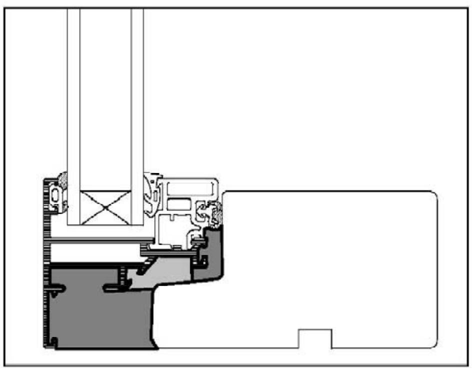

Fig. 4. Window no. 5 with divided cavity.

However, it is open to discussion whether the cavity between the aluminium profile and the frame should be divided into three cavities, cf. the discussion under window no. 4. According to the same argument as applied for window 4 the cavity for window 5 can be divided as stated in Fig. 4. The cavity indicated as point 3 in Fig. 4 is regarded as a slightly ventilated cavity as the gap between the aluminium sash and the surrounding wall is less than 10 mm.

By calculating the situation illustrated in Fig. 4 with THERM2.0, U_f is found at 2.8 W/m^2 K and Ψ at 0.051 W/m K. (Corresponding values with one large cavity are 3.0 W/m^2 K and 0.050 W/m K). Table 11 presents the values found.

The calculated total U-value will only be slightly affected by dividing the cavity in the calculation. This is due to the fact that the reduction of the U-value of the frame profile is by and large corresponding to the increase of the linear transmittance, Ψ_g. On the other hand it appears that the measured and calculated surface temperatures agree better with a calculation based on divided cavity. For both situations, however, the measured and calculated values clearly fall within the anticipated tolerances.

5. CONCLUSION

Investigations have been carried out for comparison of the results of different calculation programs, mutually and with measurements.

Following the discussion in Section 3.2 some discrepancy between calculated results for glazing U-value according to the EN673-model and more detailed models is observed for large glass spacing. Though this may be considered a second order effect it does call for further work in developing, investigating and harmonising the calculation models in the calculation standard.

The comparisons between calculated and measured thermal transmittance for especially the aluminium window (no. 4) show that care must be taken when modelling profiles with critical thermal resistances like thermal breaks and (air)gaps between highly conducting parts. It is recommended that unventilated and slightly ventilated cavities are subdivided according to the comments in Section 4.4.

A good consistency has been found between the calculated results irrespective of which calculation program was used and it may be concluded that all the investigated programs can be used for calculation of energy labelling data for glazings and windows.

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