

**DTI 2001 – 2004 Thermal Programme
Project PT4.2**

**An investigation of measurement procedures
needed to determine thermal transmittance of
deep structures using both horizontal and
vertical heat flow**

**Ray Williams
Graham Ballard**

August 2004

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An investigation of measurement procedures needed to determine thermal transmittance of deep structures using both horizontal and vertical heat flow

**Ray Williams
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June 2004

ABSTRACT

This report contains the experimental results of measurements made in the NPL Rotatable Hot Box apparatus, to investigate measurement procedures that could be used to measure the U-value of test elements that project into the cold chamber, measured with both horizontal and vertically-upwards heat flow. The design and construction of the special surround panel built for these measurements is described and the details of the calibration measurements made following the procedures specified in EN ISO 12567-1 and prEN -ISO/DIS 12567-2 (the latter using both horizontal and vertically-upwards heat flow) are given. The detailed experimental results are then presented for measurements made on a “Ideal Skylight” made from expanded polystyrene and on a real skylight supplied by Xtralight. The results of the measurements made following the CEN methodology are compared with the results of measurements made using the straightforward methodology given in ISO 8990. The effect of air velocity and local heat transfer coefficients are highlighted. Some recommendations are given for changes to prEN/ISO-DIS 12567-2.

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Approved on behalf of Managing Director, NPL
by John Redgrove Head of Thermophysics,
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1 BACKGROUND

At the Kyoto Climate Change Conference in 1997, the UK agreed to cut the emissions of the six greenhouse gases by 12.5% and to cut its CO₂ emissions by 20% below 1990 levels by 2010. These commitments and those made by our European partners have stimulated a number of initiatives aimed specifically at reducing the energy used for space heating of buildings. In April 2002 new revisions to Parts L1 and L2 of the England and Wales Building Regulations (and Part J of the Scottish regulations) reduced still further the U-value criteria for walls, roofs, floors, windows and doors. Further reductions in those criteria are expected in the near future. The recent Government White Paper entitled "Our energy future - creating a low carbon economy" set out the stark reality that unless there are dramatic improvements in energy efficiency, the UK will not be able to meet those Kyoto commitments nor its commitment to obtain significant amounts of energy from renewable sources. After stating that improvements in energy efficiency can be expected to produce half the energy savings required, it goes on to state "we will raise standards [in our building regulations] over the next decade, learning lessons from the standards achieved in other comparable countries".

In parallel with these activities, the European Commission has published EC Directive 2002/91/EC dealing with the Energy Performance of Buildings. This states that by January 2006 all new buildings and all buildings at the point of re-sale will have to have a certificate of energy use. Furthermore, in parallel to the regulations concerned with energy use, the European regulatory system for ensuring an even playing field for construction products (the Construction Products Directive (CPD)) is only now coming into full effect, as the EU product standards for insulation and building materials and window and door systems are finally published. These product standards (including one for windows and doors) set out mandatory requirements for thermal property measurements to CEN standards to be carried out to achieve CE marking for those products.

Stimulated originally by the CPD, CEN TC89 Working Group 7 were mandated to produce a suite of standards for the measurement and calculation of window and door U-values. This task has almost been completed (see Section 3). That suite of standards had, however, a number of omissions, roof windows. At the demand of the industry to quickly rectify this omission so that they would be in a position to CE mark their products to (pr)EN 14351, TC89 WG7 produced a second part to the window hot box standard EN ISO 12567-1 that in essence explained how to modify the part 1 procedures when measuring the U-values of roof windows and projecting products. It was acknowledged in the introduction to the part 2 document that the lack of experience, knowledge and suitable equipment meant that this document was a pragmatic solution to a commercial problem and that measurements made on roof windows with horizontal heat flow (as allowed by prEN 12567-2) would produce values that were systematically in error. It was also appreciated that when a measurement produces systematic errors there will inevitably be occasions where good products cannot be discriminated from poorer products.

This report describes the first work carried out by NPL to generate some knowledge of these types of measurements that could later be used when producing a more precise measurement standard.

2 PROJECT OBJECTIVES AND ISSUES TO BE ADDRESSED

2.1 General objectives

With no previous experience in carrying out hot box measurements at different orientations and of test elements that project from the surround panel and that have significant depth, many of the important issues listed below have been identified during the project. The overall aim of the work was to identify, and where possible quantify, the importance of as wide a range of issues as possible. These included the issues listed below.

2.2 Sample size selection

Unlike windows, which are often “made-to-measure” to fit a particular size of opening, roof windows and skylights are usually only made in specific sizes which match rafter pitch and tile sizes. This puts an increased importance on the size of aperture(s) that are selected for the surround panel (see Section 6.1).

2.3 Mounting and fixing method selection

This is a particular problem as there are many different ways of mounting rooflights and skylights. For a given product, the mounting details may vary from application to application. The draft measurement standard prEN 12567-2 addresses some of these issues but has a different approach for Kerb mounting and surface mounting products. Where measurements were being carried out to compare products or to show compliance with a regulation then it is important to ensure the method of mounting and fixing have a neutral effect.

2.4 Definition of “skylight” in UK building regulations.

In the England and Wales Building Regulations Parts L1 and L2 the up-stand used with a skylight is considered part of the building. Therefore it is necessary to agree on how to correct for the heat loss that occurs through any upstand used.

2.5 Hot box design and operation

2.5.1 Warm air speed and direction

In most modern hot-box apparatus, the warm air flow is low (equivalent to natural convection) and constrained to be laminar and parallel to the surface of the surround panel. This is not necessarily the air flow that would be established in practice

2.5.2 Cold air speed and direction

In most modern hot-box apparatus, the cold air flow is around 2 to 6 m/s and constrained to be laminar (to start with) and parallel to the surface of the surround panel. This could be seen as reflecting the air flow conditions that will be found in practice.

2.5.3 Baffle positions

These ensure that the mean radiant temperature is quantifiable and help control the air flow nature, direction and speed. In the NPL rotatable hot box they can easily be moved back 420 mm from the surround panel face and with somewhat more difficulty back another

150 mm. The distance between the baffle and the specimen (in the cold box) will have a significant effect on air velocity and on the relative velocities across the sides and front face of any projecting specimen.

2.5.4 How to achieve desired external surface coefficients and air flow rates

prEN-ISO/DIS 12567-2 sets out target total surface resistance values when carrying out the calibration measurements and criteria for ensuring the air flow (in the cold box) is approximately the same when measuring projecting specimens. Can all those constraints be met?

2.6 How to calculate U-value

A number of issues need to be considered.

- What part of the baffle should be used as the radiant surface?
- Where should the warm air temperature be measured for a deep specimen?
- Does the warm surface temperature of the “self- seeing” specimen surfaces have to be included in the radiation exchange calculation?

2.7 Effect of specimen depth

How important is the change in cold air speed around a projecting specimen?

3 STANDARDS, SOFTWARE AND ACCREDITATION SCHEMES

3.1 Measurement standards

Below is a list of European and USA measurement standards that are (or could be) relevant to measuring the thermal performance of roof lights, skylights and projecting products.

EN ISO 8990:1996 Thermal insulation – Determination of steady-state thermal transmission properties – Calibrated and guarded hot box (ISO 8990:1994)

EN 1946-4:2000 Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 4: Measurements by hot box methods

EN ISO 12567-1:2000 Thermal performance of windows and doors – Part 1: Determination of thermal transmittance by hot box method

EN 12412-2:2003 Thermal performance of windows, doors and shutters – Determination of thermal transmittance by hot box method – Part 2: Frames

EN 12412-4:2003 Thermal performance of windows, doors and shutters – Determination of thermal transmittance by hot box method – Part 4: Roller-shutters boxes

prEN /ISODIS 12567-2 Thermal performance of windows and doors - Determination of thermal transmittance by hot box method – Part 2: Roof windows and other projecting windows

ASTM C1199-00 Standard Test Method for Measuring the Steady-State Thermal Transmittance of Fenestration Systems Using Hot Box Methods

ASTM C1363-97 Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus (new version in final draft form July 2004)

ASTM 1423-99 Standard Practice for Determining the Steady State Thermal Transmittance of Fenestration Systems

3.2 Calculation standards

Below is a list of European and USA calculation standards that are (or could be) relevant to measuring the thermal performance of roof lights, skylights and projecting products.

EN 673 1997: Glass in Building – Determination of thermal transmittance (U-value) – Calculation method.

EN ISO 10077-1:2000 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: Simplified method.

EN 10077-2: 2003 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames.

ISO/DIS 15099: 2003 Thermal performance of windows, doors and shading devices – Detailed calculations.

EN 10211-1:1996 Thermal bridges in building construction – Calculation of heat flows and surface temperatures. Part 1: General methods.

EN ISO 10211- 1:1995/AC:2002 Corrigendum to EN ISO 10211-1

EN 10211-2: 2001 Thermal bridges in building construction – Calculation of heat flows and surface temperatures. Part 2: Linear thermal bridges.

EN ISO 7345:1995 Thermal insulation – Physical quantities and definitions (ISO 7345:1987)

EN ISO 9288:1996 Thermal insulation – Heat transfer by radiation – Physical quantities and definitions (ISO 9288:1989)

EN ISO 6946:1996 Building components and building elements – Thermal resistance and thermal transmittance – Calculation method (ISO 6946:1996)

3.3 Product standards

prEN 14351 – Windows and external pedestrian doors – Product standard.

prEN 13830 – Curtain walling – Product standard

EN 13241 – Industrial, commercial and garage doors and gates – Product standard.

3.4 Software

There are a number of commercially available finite element and finite difference software tools that have been designed with the express objective of calculating heat transfer through building structures such as windows and doors. Some of these are listed below.

Lawrence Berkeley Laboratory – Windows and Daylighting Group

THERM 5.1 - 2D Finite Element Analysis tool for U-values of window frames

WINDOW 2.1 Calculation tool for centre of glass U-values of glazing units

Physibel

BISCO 2D Finite Difference Analysis tool for U-values of window frames

TRISCO 3D Finite Difference Analysis tool

SOLIDO

RADCON

3.5 Window rating schemes and Accreditation schemes

USA National Fenestration Rating Council (NFRC)

Canadian Canadian Rating Council

UK British Fenestration Rating Council

AWC Australasian Window Council

ISO ISO have a new work item (ISO TC163 WG2) is to produce a standard on Window Energy Rating

4 DETERMINING U-VALUE THE CEN WAY

4.1 Summary of CEN approach to calculating U-values of windows

All the CEN methods described below are based on a 2-D geometrical model, ie any corner effects are considered negligible.

The procedures for calculating window and door U-values specified in the European Standards require that the following parameters are derived:

- **U-value of the frame (U_f) with expanded polystyrene (EPS) substituted for the glazing unit.**
 - U_f can be measured using the procedures in EN 12412-2
 - U_f can be calculated using the tables and graphs in EN 10077-1 (Very simple – calculator only – very safe values)
 - U_f can be simulated using any finite element or finite difference software tool that meet the requirements of ISO 10211-1 and following the requirements of EN ISO 10077-2.
- **U-value of the centre of the glazing unit (U_g) – with no influence of the spacer bar system.**
 - Calculate using the procedures specified in EN 673. – Simple calculation (calculator only) method. There are also tables in EN 10077-1..

- **Heat transfer through the cold bridge formed by the glazing edge mounted in the frame. This is characterized by a term called the linear thermal transmittance (Ψ).**
 - This is simulated by deriving the U-value of the frame with EPS instead of the glazing unit, and then with the glazing unit. These two figures are used to calculate the heat transfer per metre length of glazing edge/frame interface.

Two simulations are done:

- (1) with the glazing in place;
- (2) with insulation ($\lambda = 0.035$) in place of the glazing.

In each of these simulations the model consists of a section of the frame plus glazing or insulation, extending to 190 mm from the edge of the frame. An adiabatic boundary is used at this point (190 mm from the edge of the frame). It is generally considered that this is sufficient distance for the heat flow to be unidirectional there. It is important that the adiabatic boundary is appropriately positioned, in order that the results can be scaled up to a full-size window: the assumption is that glazing beyond the 190 mm distance can adequately be represented by the centre-pane U-value calculated using the procedures in EN 673.

The U-value of the window is then given by

$$U = \frac{A_f U_f + A_g U_g + \ell \Psi}{A_f + A_g} \quad (1)$$

where

- A_f = (projected) area of frame
- U_f = U-value of frame (with EPS instead of glazing)
- A_g = whole area of glazing
- U_g = U-value of glazing (according to EN 673)
- ℓ = perimeter length (of boundary between glazing and frame)
- Ψ = linear thermal transmittance for specific frame/glazing junction

Note: U_g is taken as applying to the whole glazed area. Heat transfer into the glazing is higher near the edges of the glazing because of the influence of the spacer bar and the frame, but these effects are incorporated into the linear Ψ term.)

4.2 Summary of CEN approach to measuring U-values of windows

The thermal transmittance (U-value) of a structure is measured in a hot box apparatus. A brief description of the NPL Rotatable Hot Box is given in Section 5. The procedure for measuring a window or door in general is given in BS EN ISO 12567-1 and for a roof light in particular in prEN 12567-2. A summary of the main steps in those procedures is given below.

- The method requires the test laboratory to carry out a schedule of hot box measurements on two glazed calibration panels (GCP) - 20 mm and 60 mm thick, mounted in the surround panel that will be used to measure the window.

- These GCPs comprise a sheet of expanded polystyrene (EPS) sandwiched between 2 sheets of glass.
- The thermal conductivity of the EPS has to be measured
- The thickness of the panels has to be determined
- The thermal conductance of each panel is measured at three temperature differences in the hot box. In each case the warm air temperature is kept constant and the cold air temperature is varied.
- During these measurements, the standard air flow conditions are established in the cold box.
- From the results of those 6 measurements the following parameters are determined:
 - –Environmental temperatures
 - –Heat transfer through the holder panel
 - –A correction for the change in total surface difference that is the result of using a different heat flux during the window test to that used during the calibration

5 DESCRIPTION OF NPL ROTATABLE HOT BOX

The rotatable wall-guarded hot-box (RWGHB) apparatus has been designed and built at the NPL. The principle of this equipment is the same as the original wall-guarded hot-box (see NPL Report QU 91). It retains the advantages of a traditional guarded hot-box but with improved control over the operating environment yet it is more compact than the traditional calibrated hot-box.

The apparatus is designed to make measurements on insulation panels, window and door systems and wall and roof structures, over the conductance range 0.1 to $10 \text{ W/m}^2\text{.K}$. The maximum test element size that can be accommodated is $2.4 \text{ m} \times 2.4 \text{ m} \times 0.15 \text{ m}$. The cold-box air temperature can be set between $-20 \text{ }^\circ\text{C}$ and $+20 \text{ }^\circ\text{C}$ and the hot-box air temperature to a maximum of $35 \text{ }^\circ\text{C}$. The minimum hot-box temperature is limited by the requirement that the outer wall guard shall be approximately $3 \text{ }^\circ\text{C}$ above the laboratory air temperature, which is usually held at $18.5 \text{ }^\circ\text{C} \pm 1 \text{ }^\circ\text{C}$.

In the conventional guarded hot-box the objective of experimentally reducing to zero, the heat loss or gain from the apparatus, other than through the test element, is achieved by surrounding a "metering box" by a "guard box" and controlling the temperature and air flow conditions in the guard box to ensure such heat transfer is minimised. In the wall-guarded hot box, the two-box technique is dispensed with and the heat flow through the apparatus walls is reduced to negligible proportions by actively controlling the temperature of the outside surface of the apparatus to be equal to that of the corresponding zone of the inside wall. This design change has two main effects; firstly, a much larger test element can be accommodated for a given overall size of apparatus and secondly the specimen edges are now a source of heat loss or gain, as they are no longer in the "guard area". This unwanted heat transfer path is eliminated by using a linear-gradient edge-guard system to establish a temperature gradient across the edge of the specimen, which is closely matched to that in the body of the specimen.

This apparatus has been designed so that it can be fully rotated, enabling the apparatus to be set up at any orientation from cold-box horizontally positioned above the hot-box, through the vertical position, to the hot-box positioned horizontally above the cold box.

A schematic diagram of the apparatus and the associated control systems is shown in Figure 1 and a photograph is shown in Figure 2.

The wall-guard heater system comprises large, self-adhesive, silicone heater pads, fixed evenly to the surface of each of the 6 mm thick aluminium plates that make up the external wall guard. High precision temperature control is achieved by using a thermistor embedded in the top back plate, connected to a bridge circuit as the temperature sensor system. The bottom zone is controlled relative to the top zone by using a differential thermocouple between the top and bottom back plates. The heater system is built as different zones, with the power into each zone being separately controlled to enable their temperatures to be matched as required. The hot box walls have been lined with a purpose built heat-flow meter (HFM) system to measure the heat flow through them with high sensitivity and precision. This HFM consists of a uniform array of differential thermocouple junctions anchored to thin copper discs attached to the opposite faces of six 2 m x 1 m x 0.02 m panels of rigid insulating board. The HFM system is clamped to the inside surface of the hot box with fixings which incorporate a thermal break. The output of the heat flow meter system is $6524 \mu\text{V}/^\circ\text{C}$.

The edge-guard heater system is shown schematically in Figure 1. It consists of four heater plate assemblies, which form a frame around the edge of the entire specimen. They are made from 0.5 mm thick, stainless steel plate against which the specimen or its support panel rests. A strip heater, taped to the back face of the stainless steel plate close to the edge nearest the hot box, is used in conjunction with a 16-way differential thermocouple to raise the edge temperature to that of the face of the specimen or support panel. The opposite edge of this stainless steel plate is firmly clamped to a copper-cooling fin, which protrudes 75 mm into the cold box. The required temperature gradient for effective edge guarding is thus established. Thermocouples attached to the midpoints of the stainless steel plates enable their mean temperatures to be monitored.

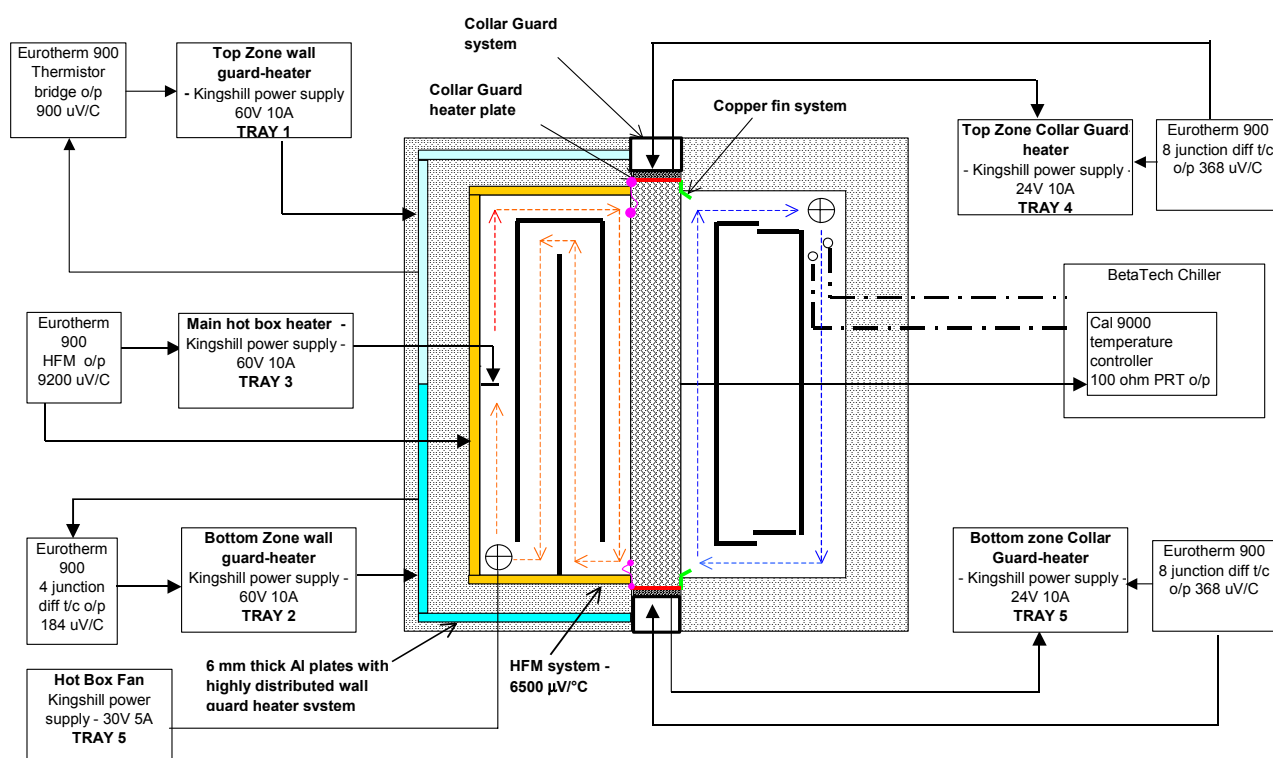


Figure 1 Schematic diagram of the Wall Guarded Hot Box

Figure 2 Photograph of the Rotatable Hot Box



6 DESIGN OF THE SPECIAL SURROUND PANEL (ROTHOLD3)

6.1 Aperture sizes

The surround panel was designed to be able to accommodate a number of different size specimens. This was achieved by building the surround panel with a large central aperture and a number of different inserts that are used to create the required aperture sizes.

The standard roof window sizes for Velux roof windows in the UK are:

55 cm x 78 cm, 55 cm x 98 cm, 66 cm x 118 cm, 78 cm x 98 cm, 78 cm x 118 cm, 78 cm x 140 cm, 94 cm x 160 cm, 114 cm x 118 cm.

After reviewing the possible sizes of standard roof windows available in the UK the following surround panel apertures were selected:

- 1.48 m x 1.23 m – standard window size and size of the glazed calibration panels
- 1.2 m x 1.2 m – large skylight
- 1.180 m x 1.140 m - standard roof window size
- 1.40 m x 1.14 m – standard roof window size

The surround panel was made so that these four apertures can be formed by using the correct inserts into the main aperture. These inserts are secured in position using the same method used to fix the samples in position.

6.2 Special design to allow mechanical fastenings

When heavy samples are tested in a vertical position, mounted inside the aperture, the weight of the sample is taken in compression by the EPS surround panel. When the sample is fixed to the cold face of the surround panel a special fixing method had to be devised that was strong enough to support the weight of the structure but that does not have a significant influence on the thermal performance of the sample. The method selected was as follows: The cold face of the surround panel was clad with 6 mm thick plywood tiles measuring approximately 200 mm x 200 mm. These tiles were glued to the EPS using PVA. The cladding could not be in one continuous sheet because the 150 mm thick surround panel bends when subjected to the temperature difference of 20 °C across its faces. A schematic diagram of the surround panel showing the plywood tiling and a set of typical insert panels is shown in Figure 3. Stainless steel plates with tapped 3 mm holes were rebated into the back face of the plywood tiles, at various points around the aperture to provide strong fixing points (see Figure 4)

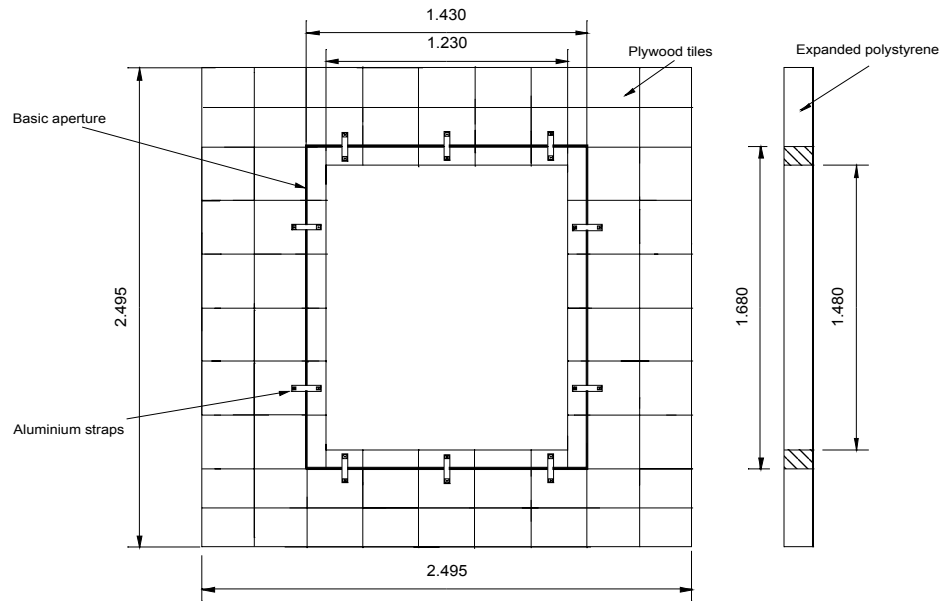
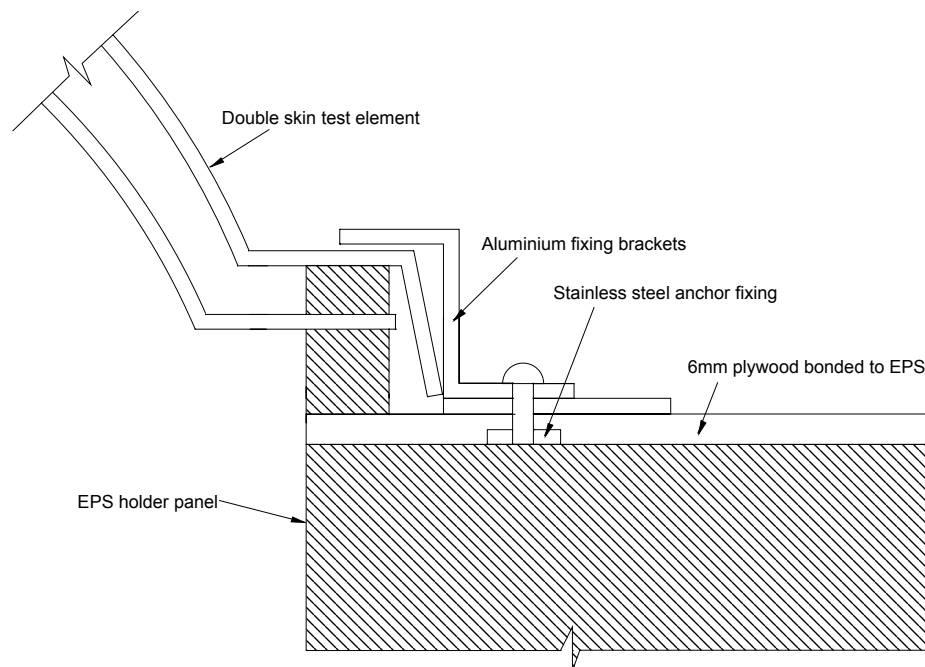
7 CALIBRATION OF ROTHOLD3 BS EN ISO 12567-1 & 2

7.1 Description of glazed calibration panels

The glazed calibration panels were made as specified in BS EN ISO 12567-1 Annex C. The thermal conductivity values of the expanded polystyrene used in the calibration panels were taken from NPL Test Reports PP21/E01090142 and PP21/E01090090. The thermal conductance values are taken from NPL Test Report PP31/E02020284.

7.2 Results of measurements to BS EN ISO 12567-1

The 21 mm thick glazed calibration panel was installed in the special surround panel (NPL ID – Rothold3), mounted 40 mm from the warm face of the holder panel as specified in BS EN ISO 12567-1. The thermal conductance of this panel was then measured in the hot box

Figure 3 Tiling system used with special surround panel Rothold3**Figure 4 Fixing system used with special surround panel Rothold3**

with a warm air temperature of 23.6°C and a cold air temperature of 2.7°C. The air speed in the cold box was adjusted to give a total surface resistance of $0.17 \pm 0.01 \text{ m}^2\text{K/W}$. The cold box air speed was then kept at this setting for the rest of the calibration measurements and indeed for all subsequent window measurements. The measurement schedule as specified in BS EN ISO 12567-1 was then carried out on the 21 mm and the 58 mm thick glazed calibration panels. The summary results for these six measurements are shown in Tables 1 to 6. The calculation procedures specified in BS EN ISO 12567-1 were then used to produce the data shown in EN 12567-1: Tables D1, D2, D3 and D4. These are shown in Tables 7, 8, 9 and 10. The three graphs required by the standard are shown in Figure 5.

Table 1 Data - 21 mm GCP - Rothold3 - EN 12567-1 @ 24 °C & 3 °C

R012A		Data entered by.....										Programme			ROT_LOG8.TXT		
TT206 in Rothold3		Data entry checked by.....										Hot fan volts			7		
		Service number....										Cold fan setting			48		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	
Date	time	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss	
		(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(W)		
					1.0105												
5 Nov 2003	02:18:56	1.822	0.03434	0.000	82.922	22.924	3.121	18.648	4.602	23.860	2.873	22.496	3.064	1.500	0.000	1.638	
5 Nov 2003	04:18:52	1.822	0.03434	0.000	82.782	22.944	3.177	18.673	4.655	23.871	2.929	22.517	3.129	4.700	0.000	1.635	
5 Nov 2003	06:18:56	1.822	0.03434	0.000	82.672	22.931	3.160	18.661	4.638	23.861	2.898	22.500	3.109	-0.300	0.000	1.636	
5 Nov 2003	08:18:52	1.822	0.03434	0.000	82.778	22.938	3.180	18.662	4.649	23.861	2.928	22.498	3.122	1.700	0.000	1.634	
5 Nov 2003	13:09:45	1.822	0.03434	0.000	82.964	22.920	3.173	18.645	4.649	23.842	2.939	22.487	3.121	-0.700	0.000	1.631	
Averages		1.8218	0.03434		82.824	22.931	3.162	18.658	4.639	23.859	2.913	22.500	3.109	1.4	0.000		

R012A																	
Area of specimen	1.8218	m²	Thick @ edge		21.02		mm		Mean temp		11.65		°C		Hr (c)		5.738
Area holder	3.966	m²	Holder thickness		0.15000		m		λ Holder		0.03434		W/m.K		Hr (h)		4.812
Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95				Spec. Emis. Hot		0.9				Tot Res		0.1705
			Baffle Emis. Cold		0.95				Spec. Emis. Cold		0.9						

Total power Corfor	Surround Surface	Hot	Power through Insert	Hot surface temp	Cold surface temp	Surface Temp diff	Air temperatures		Environmental temperatures		Baffle temperatures		Thermal Resistance				
HEM Off	Hot	Cold	(W)	(°C)	(°C)	(°C)	Hot	Cold	diff	Hot	diff	Hot	Cond	Trans	Hot	Cold	
(W)	(°C)	(°C)					(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(W/m².K)	(m².K/W)	(m².K/W)	
02:18:56	82.917	22.924	3.121	64.938	18.648	4.602	23.860	2.873	20.987	23.032	20.130	22.496	2.538	1.771	0.123	0.048	
04:18:52	82.765	22.944	3.177	64.819	18.673	4.655	23.871	2.929	20.943	23.050	20.090	22.517	2.538	1.771	0.123	0.048	
06:18:56	82.673	22.931	3.160	64.723	18.661	4.638	23.861	2.898	20.963	23.035	20.104	22.500	2.534	1.767	0.123	0.048	
08:18:52	82.771	22.938	3.180	64.833	18.662	4.649	23.861	2.928	20.934	23.035	20.078	22.498	2.540	1.772	0.123	0.048	
13:09:45	82.966	22.920	3.173	65.039	18.645	4.649	23.842	2.939	20.903	23.023	20.056	22.487	2.551	1.780	0.123	0.047	
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Av. Values	82.819	22.931	3.162	64.870	18.658	4.639	23.859	2.913	20.946	23.035	20.092	22.500	2.540	1.772	0.123	0.048	
Variation	0.35%	0.025	0.059	0.49%	0.028	0.053	0.029	0.066	0.40%	0.027	0.064	0.029	0.68%	0.72%	0.000	0.001	
Surround temp difference		19.769	°C	Atmospheric pressure		not measured		mb				Calc		2.446			
Surround mean temperature		13.047	°C									Error		3.8			

R012B	Rothold3
TT206 in Rothold3	

Service number...

Cold fan setting 48.8

R012B											
Area of specimen	1.8218	m ²	Thick @ edge	21.02	mm		Mean temp	7.22	°C	Hr (c)	5.665
Area holder	3.966	m ²	Holder thickness	0.15000	m		λ Holder	0.03401	W/m.K	Hr (h)	4.448
Boundary correction	0.000	Watts	Baffle Emis. Hot	0.95		Spec. Emis. Hot	Emissivity Factor	Hot	0.8593	Tot Res	0.1711
			Baffle Emis Cold	0.95		Spec. Emis. Cold	Emissivity Factor	Cold	0.8593		

	Total power Corfor HEM Off	Surround Surface		Power through Insert - BL%	Hot surface temp		Cold surface temp		Surface Temp diff	Air temperatures			Environmental temperatures			Baffle temperatures			Thermal			Surface Resistance		
		Hot	Cold		Hot	surface temp	Cold	Temp diff		Hot	Cold	diff	Hot	Cold	diff	Hot	Cold	diff	Hot	Cold	Cond	Trans	Hot	Cold
(W)	(°C)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m²·K)	(W/m²·K)	(m²·K/W)	(m²·K/W)		
17:06:10	111.390	22.428	-4.295	87.363	16.741	-2.307	19.048	23.712	-4.585	28.297	22.620	-4.552	27.172	21.882	-4.351	2.518	1.765	0.123	0.047					
15:06:05	110.927	22.435	-4.149	87.025	16.786	-2.178	18.964	23.707	-4.506	28.213	22.636	-4.468	27.104	21.910	-4.242	2.519	1.762	0.122	0.048					
13:06:07	111.325	22.432	-4.421	87.182	16.743	-2.424	19.167	23.690	-4.890	28.580	22.615	-4.842	27.457	21.890	-4.569	2.497	1.743	0.123	0.051					
11:06:04	111.267	22.453	-4.381	87.140	16.748	-2.391	19.140	23.726	-4.695	28.421	22.635	-4.661	27.296	21.905	-4.456	2.499	1.752	0.123	0.047					
09:06:08	111.092	22.457	-4.289	87.044	16.779	-2.300	19.079	23.719	-4.705	28.424	22.640	-4.662	27.302	21.913	-4.413	2.504	1.750	0.123	0.049					
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
Av. Values	111.20	22.441	-4.307	87.151	16.759	-2.320	19.080	23.711	-4.676	28.387	22.629	-4.637	27.266	21.900	-4.406	2.507	1.755	0.123	0.048					
Variation	0.42%	0.029	0.271	0.39%	0.044	0.246	1.07%	0.036	0.384	1.29%	0.025	0.373	1.29%	0.031	0.327	0.89%	1.25%	0.001	0.004					
Surround temp difference		26.748	°C							not measured	mb				Calc	2.402								
Surround mean temperature		9.067	°C												Error	4.4								

Table 4 Data - 57 mm GCP - Rothold3 - EN 12567-1 @ 24 °C & 5 °C

R019A

Rothold3

Glazed Calibration Panel TT207

RGW

Data entered by.....
Data entry checked by.....
Service number...

Programme ROT_LOG8.TXT
Hot fan volts 7
Cold fan setting 48.8

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Date	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air temp	Air temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss	Boundary loss	Boundary loss	
	(m ²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	used (W)			
8-Mar-04	00:29:00	1.82169	0.0344	38.074	23.121	4.703	22.033	4.990	23.848	4.481	23.269	4.578	3.3	0.000	0.647		Line1
8-Mar-04	02:29:40	1.82169	0.0344	38.066	23.126	4.701	22.038	4.983	23.858	4.444	23.281	4.562	2.2	0.000	0.648		Line2
8-Mar-04	04:29:39	1.82169	0.0344	38.007	23.119	4.699	22.026	4.982	23.852	4.443	23.271	4.560	-0.4	0.000	0.648		Line3
8-Mar-04	06:29:37	1.82169	0.0344	38.001	23.110	4.702	22.020	4.979	23.836	4.445	23.263	4.560	2.4	0.000	0.647		Line4
8-Mar-04	08:29:34	1.82169	0.0344	37.956	23.140	4.742	22.046	5.025	23.864	4.525	23.292	4.614	4.1	0.000	0.646		Line5
Averages		1.8217	0.03442	38.0206	23.123	4.709	22.033	4.992	23.852	4.467	23.275	4.575	2.3	0.0	0.647		

R019A	Area of specimen	1.8217	m ²	Thick @ edge	57.74	mm	Mean temp	13.51	°C	Hr (c)	5.861
	Area holder	3.966	m ²	Holder thickness	0.15000	m	λ Holder	0.03442	W/m.K	Hr (h)	4.861
	Boundary correction	0.000	Watts	Baffle Emis. Hot	0.95		Emissivity Factor Hot		0.8593	Tot Res	0.1688
				Baffle Emis Cold	0.95		Emissivity Factor Cold		0.8593		

	Total power Corfor HFM Off	Surround Surface		Power through Insert - BL%	Hot		Cold		Surface		Air temperatures		Environmental temperatures		Baffle temperatures		Thermal Resistances		Surface Resistance	
		Hot	Cold		surface temp	Hot surface temp	Cold surface temp	Temp diff	Hot	Cold	diff	Hot	Cold	diff	Hot	Cold	diff	Hot		Cold
(W)	(°C)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(W/m².K)	(m².K/W)
08/03/2004 00:29	38.062	23.121	4.703	21.300	22.033	4.990	17.043	23.848	4.481	19.367	23.486	4.490	18.995	23.269	4.578	0.686	0.616	0.124	0.043	
08/03/2004 02:29	38.058	23.126	4.701	21.291	22.038	4.983	17.055	23.858	4.444	19.414	23.496	4.457	19.039	23.281	4.562	0.685	0.614	0.125	0.045	
08/03/2004 04:29	38.008	23.119	4.699	21.246	22.026	4.982	17.044	23.852	4.443	19.409	23.486	4.455	19.031	23.271	4.560	0.684	0.613	0.125	0.045	
08/03/2004 06:29	37.992	23.110	4.702	21.240	22.020	4.979	17.042	23.836	4.445	19.391	23.476	4.457	19.019	23.263	4.560	0.684	0.613	0.125	0.045	
08/03/2004 08:29	37.941	23.140	4.742	21.198	22.046	5.025	17.021	23.864	4.525	19.339	23.503	4.533	18.970	23.292	4.614	0.684	0.613	0.125	0.042	
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Av. Values	38.012	23.123	4.709	21.255	22.033	4.992	17.041	23.852	4.467	19.384	23.489	4.478	19.011	23.275	4.575	0.685	0.614	0.125	0.044	
Variation	0.32%	0.030	0.043	0.48%	0.026	0.046	0.20%	0.028	0.082	0.38%	0.027	0.079	0.36%	0.029	0.054	0.35%	0.44%	0.001	0.003	
Surround temp difference		18.414	°C			Atmospheric pressure		not measured			mb				Calc	0.658				
Surround mean temperature		13.916	°C												Error%	4.1				

Table 5 Data - 57 mm GCP - Rothold3 - EN 12567-1 @ 24 °C & -4 °C

R019B Rothold3
Glazed Calibration Panel TT207

Data entered by....
 Data entry checked by....
 Service number...

RGW

Programme ROT_LOG8.TXT
 Hot fan volts 7
 Cold fan setting 48.8

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Date	time	Specimen area (m ²)	Holder Th Cond. (W/m.K)	Atm. pressure (mb)	Total power (W)	Holder Hot temp (°C)	Holder Cold temp (°C)	Specimen Hot surface (°C)	Specimen Cold surface (°C)	Air Hot temp (°C)	Air Cold temp (°C)	Baffle Hot temp (°C)	Baffle Cold temp (°C)	Diviny Offset (uV)	Boundary loss used (W)	Boundary loss actual (W)	
11/03/2004	07:00	1.82169	0.03403		54.331	22.702	-3.878	21.160	-3.466	23.751	-4.233	22.923	-4.087	2.9	0.000	0.934	Line1
11/03/2004	09:00	1.82169	0.03404		54.416	22.738	-3.840	21.195	-3.433	23.784	-4.200	22.953	-4.049	5	0.000	0.934	Line2
11/03/2004	10:59	1.82169	0.03403		54.477	22.726	-3.887	21.184	-3.480	23.772	-4.217	22.946	-4.086	1.5	0.000	0.934	Line3
11/03/2004	13:00	1.82169	0.03403		54.293	22.719	-3.879	21.170	-3.470	23.769	-4.197	22.935	-4.072	0.7	0.000	0.934	Line4
11/03/2004	15:00	1.82169	0.03403		54.580	22.709	-3.887	21.162	-3.483	23.754	-4.212	22.935	-4.083	0.4	0.000	0.934	Line5
Averages		1.8217	0.03403		54.4193	22.719	-3.874	21.174	-3.467	23.766	-4.212	22.939	-4.075	2.1	0.000	0.934	

R019B																	
Area of specimen	1.8217	m ²	Thick @ edge	57.74	mm												
Area holder	3.966	m ²	Holder thickness	0.15000	m												
Boundary correction	0.000	Watts	Baffle Emis. Hot	0.95		Spec. Emis. Hot		0.9		Mean temp	8.85	°C	Hr (c)	5.825			
			Baffle Emis. Cold	0.95		Spec. Emis. Cold		0.9		λ Holder	0.03403	W/m.K	Hr (h)	4.426			
										Emissivity Factor	Hot	0.8593	Tot Res	0.1679			
										Emissivity Factor	Cold	0.8593					
Total power Corfor HFM Off	Surround Surface		Power through Insert	Hot surface temp	Cold surface temp	Surface Temp diff	Air temperatures			Baffle temperatures			Environmental temperatures			Thermal Surface Resistance	
	Hot	Cold					Hot	Cold	diff	Hot	Cold	diff	Hot	Cold	Hot	Cold	Thermal Cond
(W)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m ² .K)	(m ² .K/W)	(m ² .K/W)
11/03/2004 07:00	54.321	22.702	-3.878	30.403	21.160	-3.466	23.751	-4.233	27.984	23.236	-4.219	27.455	22.923	-4.087	0.678	0.608	0.124
11/03/2004 09:00	54.398	22.738	-3.840	30.481	21.195	-3.433	23.784	-4.200	27.985	23.269	-4.186	27.455	22.953	-4.049	0.679	0.609	0.124
11/03/2004 10:59	54.471	22.726	-3.887	30.524	21.184	-3.480	23.772	-4.217	27.989	23.260	-4.205	27.465	22.946	-4.086	0.679	0.610	0.124
11/03/2004 13:00	54.290	22.719	-3.879	30.357	21.170	-3.470	23.769	-4.197	27.966	23.248	-4.185	27.434	22.935	-4.072	0.676	0.607	0.125
11/03/2004 15:00	54.579	22.709	-3.887	30.646	21.162	-3.483	23.754	-4.212	27.965	23.246	-4.200	27.446	22.935	-4.083	0.683	0.613	0.124
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Av. Values	54.412	22.719	-3.874	30.482	21.174	-3.467	23.766	-4.212	27.978	23.252	-4.199	27.451	22.939	-4.075	0.679	0.610	0.124
Variation	0.53%	0.036	0.047	0.95%	0.035	0.050	0.033	0.037	0.08%	0.033	0.034	0.11%	0.031	0.038	0.93%	0.90%	0.001
Surround temp difference	26.593 °C																
Surround mean temperature	9.422 °C																
						Atmospheric pressure	not measured			mb				Calc	0.647		
														Error	5.0		

Table 7 EN 12567-1 (Table D1) - Calibration data for Rothold3

BS EN ISO 12567-1:2000 - Calibration data - Horizontal heat flow - HOLDER = Rothold3								
Measured values			Thin panel TT206			Thick panel TT207		
d	overall thickness	m	0.02102			0.05774		
A	area of panel	m ²	1.8218			1.82169		
S _{sur}	area of surround panel	m ²	3.9658			3.96591		
A _t	hot box metering area	m ²	5.7876			5.7876		
L	perimeter length	m	5.42			5.42		
Test number			2	1	3	5	4	6
			R012B	R012A	R012C	R019B	R019A	R019C
Cold temperatures								
θ _{ce}	air	°C	-4.68	2.91	9.17	-4.21	4.47	10.65
θ _{se,b}	baffle	°C	-4.41	3.11	9.31	-4.08	4.57	10.71
θ _{se,cal}	calibration panel	°C	-2.32	4.64	10.40	-3.47	4.99	11.00
θ _{se,p}	reveal surface	°C	-4.06	3.37	9.50	-3.90	4.69	10.79
θ _{se,sur}	surround panel	°C	-4.31	3.16	9.33	-3.87	4.71	10.80
Warm temperatures								
θ _{ci}	air	°C	23.71	23.86	23.84	23.77	23.85	23.9052
θ _{si,b}	baffle	°C	21.90	22.50	22.87	22.94	23.28	23.4998
θ _{si,cal}	calibration panel	°C	16.76	18.66	20.14	21.17	22.03	22.6381
θ _{si,p}	reveal surface	°C	19.64	20.78	21.62	21.89	22.54	23.01
θ _{si,sur}	surround panel	°C	22.44	22.93	23.19	22.72	23.12	23.3997
φ _{in}	input power	W	111.20	82.82	58.24	54.41	38.01	26.1942
v _i	air flow warm side (down)	m/s	0.1	0.1	0.1	0.1	0.1	0.1
v _e	air flow cold side (up)	m/s	4.1	4.1	4.1	4.6	4.6	4.6

Table 8 EN 12567-1 (Table D2) - Calibration data for Rothold3

BS EN ISO 12567-1:2000 - Calibration data - Horizontal heat flow - HOLDER = Rothold3				
Values resulting from mounting instructions		Remarks	Thin panel TT206	Thick panel TT207
Total thickness of the calibration panel	mm	-	21.016	57.738
Total thickness of the surround panel	mm	-	150	150
Surround panel reveal depth - warm side	mm	-	40	40
Surround panel reveal depth - cold side	mm	-	88.98	52.26
Thermal conductivity of the surround panel	W/(m.K)	E0	0.0343	0.0344
Emissivity of the calibration panel			0.88	0.88
Emissivity of the reveal			0.92	0.92
Emissivity of the baffle			0.95	0.95
Ψ_{edge} for $\lambda = 0.0334$ (W/(m.K))	W/(m.K)	Table B.1	-	0.00636
Warm side	view factors	f_{cbi}	Table A.1	0.944
		f_{ppi}	Table A.1	0.0472
		f_{cpi}	equation (A.11)	0.056
		f_{bpi}	equation (A.11)	0.056
	radiant factors	f_{pbi}	equation (A.12)	0.4764
		α_{cbi}	equation (A.8)	0.7910
		α_{cpi}	equation (A.9)	0.04765
Cold side	view factors	f_{cbe}	Table A.1	0.8813
		f_{ppe}	Table A.1	0.0930
		f_{cpe}	equation (A.11)	0.1187
		f_{bpe}	equation (A.11)	0.0724
	radiant factors	f_{pbe}	equation (A.12)	0.4535
		α_{cbe}	equation (A.8)	0.7404
		α_{cpe}	equation (A.9)	0.10105

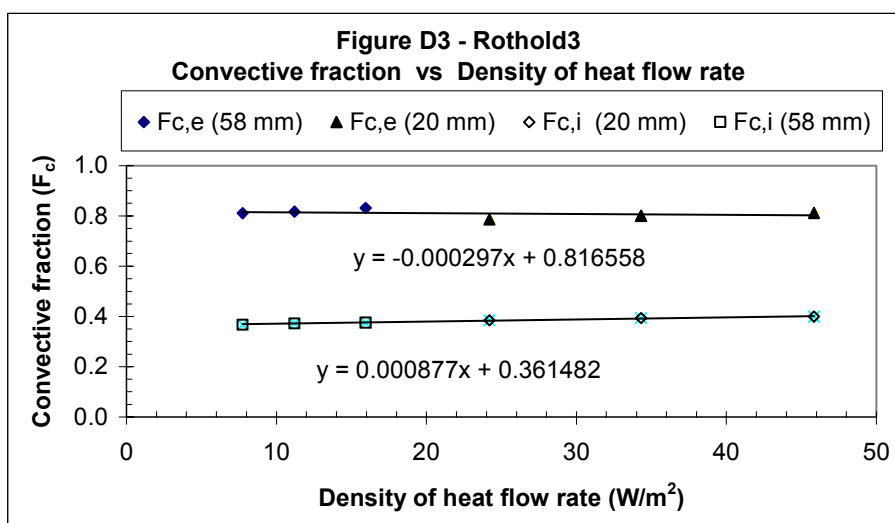
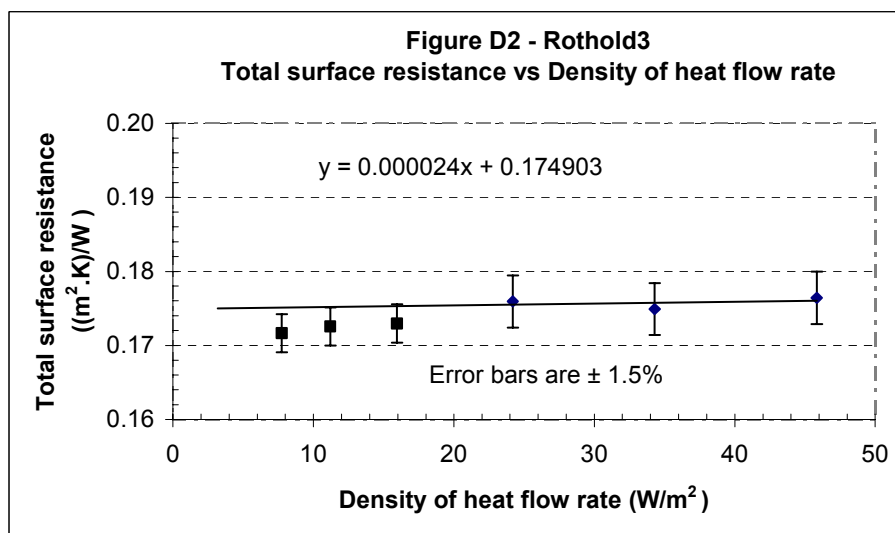
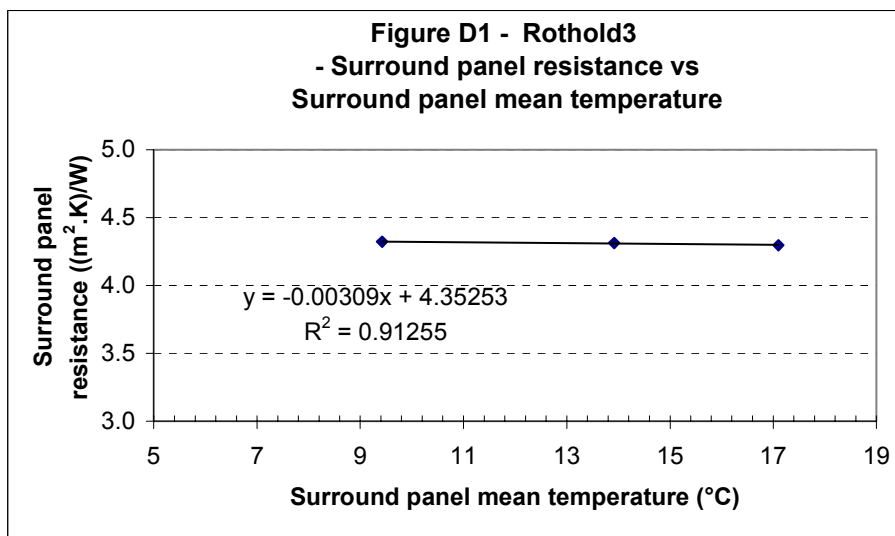
Table 9 EN 12567-1 (Table D3) - Calibration data for Rotahold3

BS EN ISO 12567-1:2000 Window Standard - Calibration data - Horizontal heat flow						
Data element			Remarks	Thick panel TT207		
Temperature difference air	$\Delta\theta_c$	K	-	27.978	19.384	13.259
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	-	26.593	18.414	12.602
Temperature mean surround	$\theta_{me,sur}$	°C	-	9.42	13.92	17.10
Heat flow rate into the box	Φ_{in}	W	-	54.412	38.012	26.194
Heat flow rate through the calibration panel	Φ_{cal}	W	equation 9	29.044	20.415	14.107
Heat flow rate around perimeter	Φ_{edge}	W	equation 10	0.9644	0.6682	0.4571
Power through surround panel ($\Phi_{in} - \Phi_{cal} - \Phi_{edge}$)	Φ_{sur}	W	-	24.404	16.929	11.63
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	equation 8	4.3216	4.3137	4.2972
Optional check with thermal conductivity data						
Temperature mean surround	$\theta_{me,sur}$	°C	610 HFM values	9.42	13.92	17.10
thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)		0.0340	0.0344	0.0347
Thickness of the holder panel	d_{sur}	m		0.1501	0.1501	0.1501
Thermal resistance of the surround panel	$R_{sur(check)}$	(m ² .K)/W		4.4093	4.36	4.3206
Difference in resistance				2.0	1.1	0.5

Table 10 EN 12567-1 (Table D4) - Calibration data for Rothold3

BS EN ISO 12567-1:2000 Window Standard - Calibration data - Horizontal heat flow										
Data element		Remarks	Thin panel TT206			Thick panel TT207				
			R012B	R012A	R012C	R019B	R019A	R019C		
Mean temperature cal panel		$\theta_{me,cal}$ °C	7.22	11.65	15.27	8.85	13.51	16.82		
Surface temp diff cal panel		$\Delta\theta_{s,cal}$ K	19.08	14.02	9.75	24.64094	17.041	11.6421		
Thermal resistance cal panel		R_{cal} m².K/W	0.4163	0.4088	0.4028	1.5455	1.5206	1.5034		
Density of heat flow rate thro' cal panel		q_{cal} W/m²	45.827	34.293	24.192	15.9432	11.2067	7.7439		
Warm blackbody radiant heat transfer coefficient baffle		$h_{cb,i}$ W/m².K	5.6750	5.7478	5.8024	5.8348	5.8703	5.8950		
Cold blackbody radiant heat transfer coefficient baffle		$h_{cb,e}$ W/m².K	4.4536	4.8217	5.1406	4.4334	4.8693	5.1954		
Warm blackbody radiant heat transfer coefficient reveal		$h_{cp,i}$ W/m².K	5.6092	5.6972	5.7655	5.8038	5.8485	5.8803		
Cold blackbody radiant heat transfer coefficient reveal		$h_{cp,e}$ W/m².K	4.4621	4.8284	5.1458	4.4376	4.8723	5.1975		
radiant heat transfer coefficient warm side		$h_{r,i}$ W/m².K	4.7560	4.8178	4.8642	4.8917	4.9219	4.9429		
radiant heat transfer coefficient cold side		$h_{r,e}$ W/m².K	3.7482	4.0577	4.3259	3.7215	4.0873	4.3610		
Mean radiant temperature warm side		$\theta_{r,i}$ °C	21.77	22.40	22.80	22.88	23.23	23.47		
Mean radiant temperature cold side		$\theta_{r,e}$ °C	-4.36	3.14	9.33	-4.06	4.58	10.72		
Warm side convective heat transfer coefficient		$h_{c,i}$ W/m².K	3.163	3.125	3.045	2.934	2.912	2.859		
Cold side convective heat transfer coefficient		$h_{c,e}$ W/m².K	16.197	16.352	15.876	18.417	18.187	18.645		
Warm side convective fraction		$F_{c,i}$ -	0.3994	0.3935	0.3850	0.3749	0.3717	0.3665		
Cold side convective fraction		$F_{c,e}$ -	0.8121	0.8012	0.7859	0.8319	0.8165	0.8104		
Warm side environmental temperature		$\theta_{ni,cal}$ °C	22.55	22.98	23.20	23.21	23.46	23.63		
Cold side environmental temperature		$\theta_{ne,cal}$ °C	-4.62	2.96	9.20	-4.19	4.49	10.66		
Environmental temperature difference		$\Delta\theta_{n,cal}$ K	27.16	20.02	14.00	27.40	18.97	12.97		
Warm side surface resistance		$R_{s,i}$ (m².K)/W	0.1263	0.1259	0.1264	0.1278	0.1277	0.1282		
Cold side surface resistance		$R_{s,e}$ (m².K)/W	0.0501	0.0490	0.0495	0.0452	0.0449	0.0435		
Total surface resistance		$R_{s,t}$ (m².K)/W	0.1764	0.1749	0.1759	0.1730	0.1725	0.1716		

Figure 5 EN 12567-1 (Figs D1, D2 & D3) - Calibration graphs - Rothold3



7.3 Background to prEN 12567-2 - the Roof window measurement standard.

The title of prEN 12567-2 is:

“Thermal performance of windows and doors — Determination of thermal transmittance by hot box method —Part 2: Roof windows and other projecting windows”

The idea behind the standard is well explained in its own Introduction, which states;-

*“This standard should be read together with ISO 12567-1:2000 **Thermal performance of windows and doors .Determination of thermal transmittance by hot box method . Part 1: Complete windows and doors.** Both standards are developed by ISO and CEN. It is designed to provide standardised thermal transmittance test values, which enable product comparison to be made. ISO 12567-1:2000 specifies standardised specimen sizes and applied test criteria.*

It is recognised, that the thermal performance of products will vary with heat flow direction and so it is preferable to test these products at the orientation in which they will be installed. However, as there are only a few hot boxes capable of carrying out such measurements, this measurement procedure specifies that it is acceptable to measure the thermal transmittance of roof windows mounted vertically to facilitate the fair comparison of products.”

To carry out measurements to prEN 12567-2 some additional calibration measurements must be carried out with the thin, glazed calibration panel. The calibration panel is mounted flush with the cold side of the surround panel and the three calibration measurements at different heat flow densities carried out. These measurements must be carried out at the different orientations that will be used. In this work they were carried out with the calibration panel mounted vertically and horizontally. In both cases the measurements carried out on the thick glazed calibration panel for BS EN ISO 12567-1 can be re-used.

7.4 Results of measurements to prEN ISO/DIS 12567-2 with horizontal heat flow

The 21 mm thick glazed calibration panel was installed in the special surround panel (NPL ID – Rothold3), mounted flush with the cold face of the surround panel as specified in prEN 12567-2. The thermal conductance of this panel was then measured in the hot box with a warm air temperature of 23.6°C and a cold air temperature of 2.7°C. The air speed in the cold box was adjusted to give a total surface resistance of $0.17 \pm 0.01 \text{ m}^2\text{.K/W}$. The cold box air speed was then kept at this setting for the rest of the calibration measurements and indeed for all subsequent window measurements. The measurement schedule as specified in BS EN ISO 12567-1 was then carried out on the 21 mm thick glazed calibration panels, with horizontal heat flow. The summary results for these three measurements are shown in Table 11, Table 12 and Table 13. The calculation procedures specified in prEN ISO 12567-2 were then used to produce the tables C1, C2, C3 and C4. These are shown in Table 14, Table 15, Table 16 and Table 17. The three graphs required by the standard are shown in Figure 6.

Table 11 Data - 21 mm GCP - Rothold3 -prEN 12567-2 @ 24 °C & 3 °C - Horizontal HF

R013A Rothold3
Horizontal Heat Flow
TT206 - Flush mount - Vertical mount

RGW
Data entered by....
Data entry checked by....
Service number...

Programme ROT_LOG8.TXT
Hot fan volts 7
Cold fan setting 48

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18
Date	time	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air temp Hot	Air temp Cold	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss
		(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(W)	
15-Nov-03	7:02	1.826	0.0343	0.000	85.202	22.892	2.823	18.467	4.232	23.661	2.528	22.392	2.772	0.500	0.000	3.196
15-Nov-03	9:03	1.826	0.0343	0.000	85.183	22.899	2.842	18.473	4.243	23.667	2.528	22.399	2.708	2.400	0.000	3.197
15-Nov-03	11:02	1.826	0.0343	0.000	85.280	22.893	2.845	18.458	4.246	23.662	2.534	22.390	2.668	3.700	0.000	3.195
15-Nov-03	13:03	1.826	0.0343	0.000	85.274	22.893	2.839	18.463	4.244	23.660	2.570	22.386	2.731	3.200	0.000	3.189
15-Nov-03	15:02	1.826	0.0343	0.000	85.437	22.859	2.790	18.437	4.197	23.634	2.499	22.367	2.689	1.200	0.000	3.196
Averages		1.8260	0.03432		85.2752	22.887	2.828	18.460	4.232	23.657	2.532	22.387	2.714	2.2	0.000	

R013A																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
Boundary correction	Area of specimen	1.8260	m ²	Thick @ edge		21.02		mm	Mean temp		11.35		°C	Hr (c)		5.730																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
	Area holder	3.962	m ²	Holder thickness		0.15000		m	λ Holder		0.03432		W / m.K	Hr (h)		4.794																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
	Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95			Spec. Emis. Hot		0.9			Emissivity Factor Hot		0.8593																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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Total power		Surround		Surface		Power		Hot surface		Cold surface		Temp diff		Surface		Air temperatures		Hot		Cold		diff		Baffle temperatures		Hot		Cold		Thermal		Cond		Trans		Hot		Cold		Surface Resistance																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
Confor		Hot		Cold		through Insert		temp		temp		diff		Temp diff		Temp diff		Hot		Cold		Hot		Cold		Hot		Cold		Thermal		Cond		Trans		Hot		Cold		Surface Resistance																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
HPM Off		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C		°C	

Table 12 Data - 21 mm GCP - Rothold3 - prEN 12567-2 @ 24 °C & 9 °C

R013B TT206 in Rothold3
Horizontal Heat Flow
TT206 - Flush mount - Vertical mount

RGW

Data entered by....
Data entry checked by....
Service number....

Programme ROT_LOG8.TXT
Hot fan volts 7
Cold fan setting 48

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Date	time	Specimen area (m ²)	Holder Th Cond. (W/m.K)	Atm. pressure (mb)	Total power (W)	Holder Hot temp (°C)	Specimen surface Hot temp (°C)	Specimen surface Cold temp (°C)	Air Hot temp (°C)	Air Cold temp (°C)	Baffle Hot temp (°C)	Baffle Cold temp (°C)	Diviny Offset (uV)	Boundary loss used (W)	Boundary loss		
19-Nov-03	0:37	1.826	0.0346	0.000	61.905	23.215	19.957	9.747	23.775	8.512	22.832	8.712	3.500	0.000	2.308		Line1
19-Nov-03	2:37	1.826	0.0346	0.000	61.948	23.227	19.961	9.754	23.779	8.513	22.841	8.660	0.400	0.000	2.308		Line2
19-Nov-03	4:37	1.826	0.0346	0.000	61.892	23.224	19.969	9.759	23.780	8.506	22.840	8.638	5.300	0.000	2.310		Line3
19-Nov-03	6:37	1.826	0.0346	0.000	61.916	23.244	19.983	9.777	23.802	8.553	22.862	8.730	3.300	0.000	2.306		Line4
19-Nov-03	8:37	1.826	0.0346	0.000	61.877	23.248	19.982	9.772	23.792	8.520	22.865	8.623	4.300	0.000	2.309		Line5
Averages		1.8260	0.03462		61.9075	23.232	19.970	9.762	22.848	8.521	22.848	8.672	3.4	0.000			

R013B																	
Area of specimen	1.8260	m ²	Thick @ edge	21.02	mm						Mean temp	14.87	°C			Hr (c)	5.787
Area holder	3.962	m ²	Holder thickness	0.15000	m						λ Holder	0.03462	W/m.K			Hr (h)	5.099
Boundary correction	0.000	Watts	Baffle Emis. Hot	0.95			Spec. Emis. Hot	0.9			Emissivity Factor Hot					Tot Res	0.1676
			Baffle Emis Cold	0.95			Spec. Emis. Cold	0.9			Emissivity Factor Cold						

Total power Corfor	Surround Surface Hot	Surround Surface Cold	Power through Insert	Hot surface temp	Hot surface temp diff	Cold surface temp	Cold surface temp diff	Air temperatures Hot	Air temperatures Cold	Air temperatures diff	Environmental temperatures Hot	Environmental temperatures Cold	Baffle temperatures Hot	Baffle temperatures Cold	Baffle temperatures diff	Thermal Surface Resistance Cond	Thermal Surface Resistance Trans	Thermal Surface Resistance Hot	Thermal Surface Resistance Cold
HFV Off	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m ² .K)	(W/m ² .K)	(m ² .K/W)	(m ² .K/W)
00:37:19	61.893	23.215	8.710	48.631	19.957	9.747	10.209	23.775	8.512	15.264	23.203	8.543	22.832	8.712	2.609	1.817	0.122	0.045	
02:37:13	61.946	23.227	8.724	48.686	19.961	9.754	10.208	23.779	8.513	15.266	23.210	8.536	22.841	8.660	2.612	1.817	0.122	0.046	
04:37:16	61.872	23.224	8.724	48.614	19.969	9.759	10.210	23.780	8.506	15.274	23.211	8.527	22.840	8.638	2.608	1.813	0.122	0.046	
06:37:18	61.904	23.244	8.746	48.648	19.983	9.777	10.206	23.802	8.553	15.249	23.232	8.581	22.862	8.730	2.610	1.818	0.122	0.045	
08:37:13	61.861	23.248	8.739	48.595	19.982	9.772	10.210	23.792	8.520	15.272	23.230	8.536	22.865	8.623	2.606	1.811	0.122	0.046	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Av. Values	61.895	23.232	8.728	48.635	19.970	9.762	10.209	23.786	8.521	15.265	23.217	8.545	22.848	8.672	2.609	1.815	0.122	0.046	
Variation	0.14%	0.033	0.036	0.19%	0.026	0.029	0.04%	0.027	0.048	0.16%	0.029	0.054	0.034	0.107	0.21%	0.40%	0.000	0.002	
Surround temp difference		14.503	°C			Atmospheric pressure		not measured		mb					Calc	2.478			
Surround mean temperature		15.980	°C												Error	5.3			

R013C

Rothrowd3

Horizontal Heat Flow

TT206 - Flush mount - Vertical mount

Data entered by:....

Data entry checked by:....

Service number:...

RGW

Programme

ROT_LOG8.TXT

Hot fan volts

Cold fan setting

1	Date	time	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18
		Specimen area	Holder Th	Cond.	Atm. pressure	Total power	Holder Hot temp	Cold temp	Specimen surface	Specimen surface	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss	
		(m²)	(W/m.K)	(mb)		(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(W)		
						1.0105												
	20-Nov-03	18:20	1.8260	0.0340	0.0000	112.8793	22.6416	-3.9763	16.8862	-2.1600	23.6449	-4.4401	21.9993	-8.7718	-1	0.0000	4.247	Line1
	21-Nov-03	2:20	1.8260	0.0340	0.0000	112.9945	22.6449	-4.0237	16.8739	-2.1983	23.6339	-4.4081	21.9946	-4.1735	5	0.0000	4.240	Line2
	20-Nov-03	22:20	1.8260	0.0340	0.0000	112.9559	22.6459	-3.9579	16.8898	-2.1284	23.6601	-4.3558	21.9968	-4.1052	0	0.0000	4.237	Line3
	21-Nov-03	0:20	1.8260	0.0340	0.0000	112.8004	22.6354	-4.0229	16.8662	-2.1943	23.6551	-4.4138	21.9852	-4.1782	1	0.0000	4.245	Line4
	21-Nov-03	2:20	1.8260	0.0340	0.0000	113.0584	22.6337	-4.0226	16.8829	-2.1853	23.6493	-4.4778	21.9808	-4.2137	7	0.0000	4.253	Line5
	Averages		1.8260	0.03403		112.9377	22.640	-4.001	16.880	-2.173	23.649	-4.419	21.991	-5.088	2.6	0.000		

R013C																			
Area of specimen	1.8260	m²	Thick @ edge																
Area holder	3.962	m²	Holder thickness		21.02	mm													
Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95		Spec. Emis. Hot		0.9										
			Baffle Emis. Cold		0.95		Spec. Emis. Cold		0.9										

Total power	Surround	Surface	Power	Hot surface	Hot surface temp	Cold surface temp	Surface Temp diff	Air temperatures	Hot	Cold	diff	Environmental temperatures	Hot	Cold	diff	Baffle temperatures	Hot	Cold	Thermal Surface Resistance	Hot	Cold
Confor																					
HFM Off	(W)	(°C)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(m².K/W)	(m².K/W)
18:20:14	112.881	22.642	-3.976	16.886	88.961	16.886	-2.160	19.046	23.645	-4.440	28.085	22.689	-5.247	27.937	21.999	-8.772	2.558	1.744	0.119	0.063	
02:20:20	112.975	22.645	-4.024	16.874	89.009	16.874	-2.198	19.072	23.634	-4.408	28.042	22.682	-4.377	27.059	21.995	-4.174	2.556	1.801	0.119	0.045	
22:20:13	112.955	22.646	-3.958	16.890	89.047	16.890	-2.128	19.018	23.660	-4.356	28.016	22.695	-4.323	27.018	21.997	-4.105	2.564	1.805	0.119	0.045	
00:20:17	112.796	22.635	-4.023	16.866	88.839	16.866	-2.194	19.060	23.655	-4.414	28.069	22.682	-4.383	27.065	21.985	-4.178	2.553	1.798	0.120	0.045	
02:20:20	113.033	22.634	-4.023	16.883	89.078	16.883	-2.185	19.068	23.649	-4.478	28.127	22.682	-4.442	27.124	21.981	-4.214	2.558	1.798	0.119	0.046	*
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Av. Values	112.928	22.640	-4.001	16.880	88.987	16.880	-2.173	19.053	23.649	-4.419	28.068	22.686	-4.554	27.241	21.991	-5.088	2.558	1.789	0.119	0.049	
Variation	0.21%	0.012	0.066	0.027%	0.024	0.024	0.070	0.28%	0.026	0.122	0.40%	0.013	0.925	3.37%	0.019	4.667	0.46%	3.41%	0.001	0.019	

Surround temp difference	26.641	°C	Atmospheric pressure		not measured		mb		Calc	2.403
Surround mean temperature	9.320	°C							Error	6.4

Table 14 prEN 12567-2 (Table C1) - Calibration data - Rothold3 - Horizontal HF

prEN 12567-2 Roof light calibration - Mounted flush with cold side - Horizontal heat flow								
Measured values			Thin panel TT206 Horizontal heat flow			Thick panel TT207 Horizontal heat flow		
d	overall thickness	m	0.02102			0.05774		
A	area of panel	m ²	1.8260			1.82169		
S _{sur}	area of surround panel	m ²	3.96159			3.96591		
A _t	hot box metering area	m ²	5.7876			5.7876		
L	perimeter length	m	5.42			5.42		
Test number			2	1	3	5	4	6
Cold temperatures			R013B	R013A	R013C	R019B	R019A	R019C
θ _{ce}	air	°C	8.52	2.53	-4.42	-4.21	4.47	10.65
θ _{se,b}	baffle	°C	8.67	2.71	-5.09	-4.08	4.57	10.71
θ _{se,cal}	calibration panel	°C	9.76	4.23	-2.17	-3.47	4.99	11.00
θ _{se,p}	reveal surface	°C	8.73	3.25	-3.53	-3.90	4.69	10.79
θ _{se,sur}	surround panel	°C	8.73	2.83	-4.00	-3.87	4.71	10.80
Warm temperatures								
θ _{ci}	air	°C	23.79	23.66	23.65	23.77	23.85	23.9052
θ _{si,b}	baffle	°C	22.85	22.39	21.99	22.94	23.28	23.4998
θ _{si,cal}	calibration panel	°C	19.97	18.46	16.88	21.17	22.03	22.6381
θ _{si,p}	reveal surface	°C	21.73	21.15	20.13	21.89	22.54	23.01
θ _{si,sur}	surround panel	°C	23.23	22.89	22.64	22.72	23.12	23.3997
φ _{in}	input power	W	61.90	85.27	112.93	54.41	38.01	26.1942
v _i	air flow warm side (down)	m/s	0.1	0.1	0.1	0.1	0.1	0.1
v _e	air flow cold side (up)	m/s	4.1	4.1	4.1	4.6	4.6	4.6

Table 15 prEN 12567-2 (Table C2) - Calibration data - Rothold3 - Horizontal HF

prEN 12567-2 Roof light calibration - Mounted flush with cold side - Horizontal heat flow				
Values resulting from mounting instructions		Remarks	Thin panel TT206 Horizontal heat flow	Thick panel TT207 - Results from EN 12567-1 calibration measurements
Total thickness of the calibration panel	mm	-	21.016	57.738
Total thickness of the surround panel	mm	-	149.67	149.67
Surround panel reveal depth - warm side	mm	-	128.65	40
Surround panel reveal depth - cold side	mm	-	0.00	51.93
Thermal conductivity of the surround panel	W/(m.K)	E0	0.0343	0.0344
Emissivity of the calibration panel			0.88	0.88
Emissivity of the reveal			0.92	0.92
Emissivity of the baffle			0.95	0.95
Ψ_{edge} for $\lambda = 0.0334$ (W/(m.K))	W/(m.K)		-	0.00636
Warm side view factors	f_{cbi}	Table A1	0.8338	0.944
	f_{ppi}	Table A1	0.12535	0.0472
	f_{cpi}	equation (A.11)	0.1662	0.056
	f_{bpi}	equation (A.11)	0.1662	0.056
	f_{pbi}	equation (A.12)	0.4373	0.4764
	α_{cbi}	equation (A.8)	0.7019	0.7910
radiant factors	α_{cpi}	equation (A.9)	0.1415	0.04765
Cold side view factors	f_{cbe}	Table A.1	1.0000	0.92757
	f_{ppe}	Table A.1	0.0000	0.06070
	f_{cpe}	equation (A.11)	0.0000	0.0724
	f_{bpe}	equation (A.11)	0.0000	0.0724
	f_{pbe}	equation (A.12)	0.5000	0.4697
	α_{cbe}	equation (A.8)	0.8360	0.7777
radiant factors	α_{cpe}	equation (A.9)	0.00000	0.06165

Table 16 prEN 12567-2 (Table C3) - Calibration data - Rothold3 - Horizontal HF

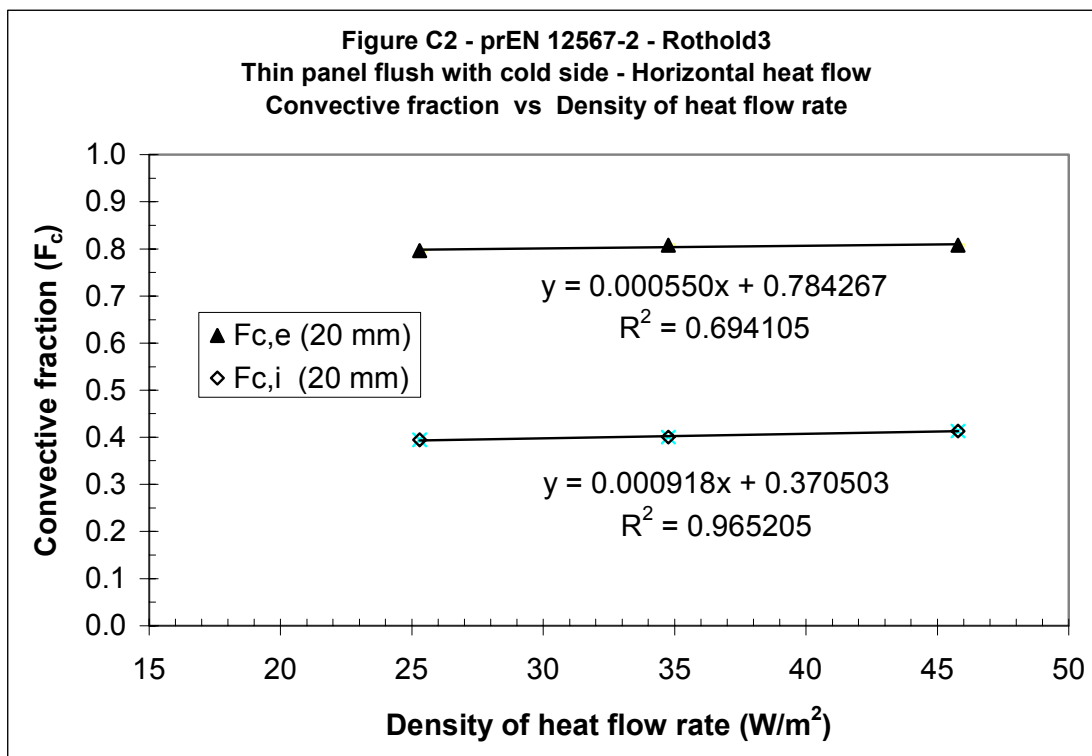
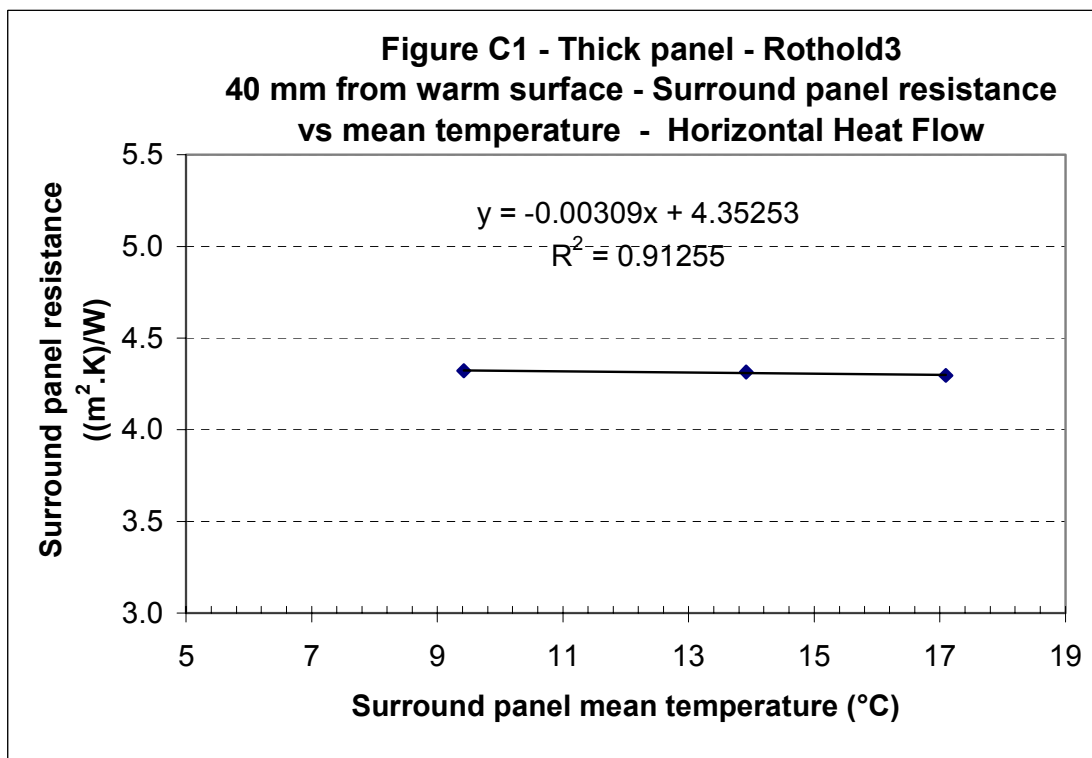
prEN 12567-2 Roof light calibration - Mounted flush with cold side - Horizontal heat flow						
Data element			Remarks	Thick panel TT207 - Results from EN 12567-1 calibration measurements		
Temperature difference air	$\Delta\theta_c$	K	-	27.97781	19.384	13.259
Temperature difference surface, surround	$\Delta\theta_{s,\text{sur}}$	K	-	26.59255	18.414	12.602
Temperature mean surround	$\theta_{\text{me},\text{sur}}$	°C	-	9.42	13.92	17.10
Heat flow rate into the box	Φ_{in}	W	-	54.41166	38.012	26.194
Heat flow rate through the calibration panel	Φ_{cal}	W	equation 9	29.04361	20.415	14.107
Heat flow rate around perimeter	Φ_{edge}	W	equation 10	0.964429	0.6682	0.4571
Power through surround panel ($\Phi_{\text{in}} - \Phi_{\text{cal}} - \Phi_{\text{edge}}$)	Φ_{sur}	W	-	24.40363	16.929	11.63
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	equation 8	4.321639	4.3137	4.2972
Optional check with thermal conductivity data						
Temperature mean surround	$\theta_{\text{me},\text{sur}}$	°C		9.42	13.92	17.10
thermal conductivity of surround @ $\theta_{\text{me},\text{sur}}$	λ_{sur}	W/(m.K)		0.0340	0.0344	0.0347
Thickness of the holder panel	d_{sur}	m		0.1501	0.1501	0.1501
Thermal resistance of the surround panel	$R_{\text{sur}(\text{check})}$	(m ² .K)/W		4.4093	4.3600	4.3206
Difference in resistance (%)				2.0	1.1	0.5

Table 17 prEN 12567-2 (Table C4) - Calibration data - Rothold3 - Horizontal HF

prEN 12567-2 Roof light calibration - Mounted flush with cold side - Horizontal heat flow									
Data element	Remarks	Thin panel TT206 Horizontal heat flow			Thick panel TT207 - Results from EN 12567-1 calibration measurements				
Mean temperature cal panel	$\theta_{me,cal}$ °C	14.87	11.35	7.35	8.85	13.51	16.82		
Surface temp diff cal panel	$\Delta\theta_{s,cal}$ K	10.21	14.23	19.05	24.64094	17.041	11.6421		
Thermal resistance cal panel	R_{cal} m ² .K/W	0.4035	0.4093	0.4161	1.5455	1.5206	1.5034		
Density of heat flow rate thro' cal panel	q_{cal} W/m ²	25.301	34.760	45.789	15.9432	11.2067	7.7439		
Warm blackbody radiant heat transfer coefficient baffle	$h_{cb,i}$ W/m ² .K	5.7966	5.7387	5.6811	5.8348	5.8703	5.8950		
Cold blackbody radiant heat transfer coefficient baffle	$h_{cb,e}$ W/m ² .K	5.1061	4.8008	4.4404	4.4334	4.8693	5.1954		
Warm blackbody radiant heat transfer coefficient reveal	$h_{cp,i}$ W/m ² .K	5.7636	5.7023	5.6269	5.8038	5.8485	5.8803		
Cold blackbody radiant heat transfer coefficient reveal	$h_{cp,e}$ W/m ² .K	5.1076	4.8147	4.4789	4.4376	4.8723	5.1975		
radiant heat transfer coefficient warm side	$h_{r,i}$ W/m ² .K	4.8844	4.8350	4.7840	4.8917	4.9219	4.9429		
radiant heat transfer coefficient cold side	$h_{r,e}$ W/m ² .K	4.2687	4.0134	3.7122	3.7215	4.0873	4.3610		
Mean radiant temperature warm side	$\theta_{r,i}$ °C	22.66	22.18	21.68	22.88	23.23	23.47		
Mean radiant temperature cold side	$\theta_{r,e}$ °C	8.67	2.71	-5.09	-4.06	4.58	10.72		
Warm side convective heat transfer coefficient	$h_{c,i}$ W/m ² .K	3.187	3.228	3.373	2.934	2.912	2.859		
Cold side convective heat transfer coefficient	$h_{c,e}$ W/m ² .K	16.643	16.860	15.569	18.417	18.187	18.645		
Warm side convective fraction	$F_{c,i}$ -	0.3948	0.4003	0.4135	0.3749	0.3717	0.3665		
Cold side convective fraction	$F_{c,e}$ -	0.7959	0.8077	0.8075	0.8319	0.8165	0.8104		
Warm side environmental temperature	$\theta_{hi,cal}$ °C	23.10	22.77	22.49	23.21	23.46	23.63		
Cold side environmental temperature	$\theta_{ne,cal}$ °C	8.55	2.57	-4.55	-4.19	4.49	10.66		
Environmental temperature difference	$\Delta\theta_{n,cal}$ K	14.55	20.20	27.04	27.40	18.97	12.97		
Warm side surface resistance	$R_{s,i}$ (m ² .K)/W	0.1239	0.1240	0.1226	0.1278	0.1277	0.1282		
Cold side surface resistance	$R_{s,e}$ (m ² .K)/W	0.0478	0.0479	0.0519	0.0452	0.0449	0.0435		
Total surface resistance	$R_{s,t}$ (m ² .K)/W	0.1717	0.1719	0.1745	0.1730	0.1725	0.1716		

Stefan-Boltzmann constant	5.670E-08 W/m ² .K ⁴
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Figure 6 prEN 12567-2 (Figs C1 & C2) - Calibration graphs Rothold3 - Horizontal HF



7.5 Results of measurements to prEN ISO/DIS 12567-2 with vertical heat flow

The 21 mm thick glazed calibration panel was installed in the special surround panel (NPL ID – Rothold3), mounted flush with the cold face of the surround panel as specified in prEN 12567-2. The thermal conductance of this panel was then measured in the hot box with a warm air temperature of 23.6°C and a cold air temperature of 2.7°C. The air speed in the cold box was adjusted to give a total surface resistance of $0.17 \pm 0.01 \text{ m}^2\cdot\text{K}/\text{W}$. The cold box air speed was then kept at this setting for the rest of the calibration measurements and indeed for all subsequent window measurements. The measurement schedule as specified in BS EN ISO 12567-1 was then carried out on the 21 mm thick glazed calibration panels, with vertical heat flow (cold box above hot box). The summary results for these three measurements are shown in Table 18, Table 19 and Table 20. The calculation procedures specified in prEN ISO 12567-2 were then used to produce Tables C1, C2, C3 and C4. These are shown in Table 21, Table 22 Table 23, . The two graphs required by the standard are shown in Figure 7.

Table 19 Data - 21 mm GCP - Rothold3 - prEN 12567-2 @ 24 °C & 9 °C - Vertical HF

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Table 20 Data - 21 mm GCP - Rothold3 - prEN 12567-2 @ 24°C & -6 °C - Vertical HF

R014B Rothold3
Vertical Heat Flow
TT206 - Flush with cold surround mount

RGW

Data entered by.....
Data entry checked by.....
Service number...

Programme ROT_LOG8.TXT
Hot fan volts 7
Cold fan setting 48

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18
Date	Specimen area (m ²)	Holder Th Cond. (W/m.K)	Atm. pressure (mb)	Total power (W)	Holder Hot temp (°C)	Holder Cold temp (°C)	Specimen surface Hot temp (°C)	Specimen surface Cold temp (°C)	Air Hot temp (°C)	Air Cold temp (°C)	Baffle Hot temp (°C)	Baffle Cold temp (°C)	Diviny Offset (uV)	Boundary loss used (W)	Boundary loss (W)	
30-Nov-03	6.29	1.8260	0.0340	0.0000	119.6981	23.0728	-5.5943	16.8711	-3.6405	23.9009	-5.9616	22.2654	4	0.0000	4.516	Line1
30-Nov-03	8.29	1.8260	0.0340	0.0000	119.3448	23.0415	-5.5013	16.8599	-3.5374	23.8840	-5.9868	22.2283	5	0.0000	4.517	Line2
30-Nov-03	10.29	1.8260	0.0340	0.0000	119.3448	23.0415	-5.5013	16.8599	-3.5374	23.8840	-5.9868	22.2283	5	0.0000	4.517	Line3
30-Nov-03	12.29	1.8260	0.0340	0.0000	119.7050	23.0103	-5.5360	16.8332	-3.5657	23.8646	-6.0024	22.2131	3	0.0000	4.516	Line4
30-Nov-03	14.29	1.8260	0.0340	0.0000	119.7566	23.0159	-5.4588	16.8377	-3.5022	23.8840	-5.9287	22.2296	3	0.0000	4.508	Line5
Averages	1.8260	0.03398		119.5699	23.036	-5.518	16.852	-3.557	23.884	-5.973	22.233	-5.707	4.2	0.000		

R014B																				
Area of specimen	1.8260	m ²	Thick @ edge		21.02 mm		Mean temp		6.65 °C		Hr (c)		5.680		Line1					
	Area holder	3.962	m ²	Holder thickness		0.15000 m		λ Holder		0.03398 W/m.K		Hr (h)		4.380						
Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95		Spec. Emis. Hot		0.9		Emissivity Factor Hot		0.8593			Tot Res				
			Baffle Emis. Cold		0.95		Spec. Emis. Cold		0.9		Emissivity Factor Cold		0.8593							
Total power Confor	Hot	Cold	Surface	Power through Insert	Hot surface temp	Cold surface temp	Temp diff	Air temperatures	Hot	Cold	diff	Hot	Cold	diff		Environmental temperatures	Hot	Cold	Thermal	Surface Resistance
HFM Off	(°C)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m ² .K)	(m ² .K/W)	
06:29:15	119.682	23.073	-5.594	93.953	16.871	-3.641	20.512	23.901	-5.962	29.863	22.957	-5.934	28.891	28.876	22.265	-5.755	2.508	1.781	0.118	0.045
08:29:19	119.327	23.041	-5.501	93.709	16.860	-3.537	20.397	23.884	-5.987	29.871	22.928	-5.947	28.876	28.876	22.228	-5.703	2.516	1.777	0.118	0.047
10:29:15	119.327	23.041	-5.501	93.709	16.860	-3.537	20.397	23.884	-5.987	29.871	22.928	-5.947	28.876	28.876	22.228	-5.703	2.516	1.777	0.118	0.047
12:29:21	119.693	23.010	-5.536	94.071	16.833	-3.566	20.399	23.865	-6.002	29.867	22.913	-5.964	28.878	28.878	22.213	-5.727	2.526	1.784	0.118	0.047
14:29:17	119.744	23.016	-5.459	94.187	16.838	-3.502	20.340	23.884	-5.929	29.813	22.930	-5.890	28.821	28.821	22.230	-5.649	2.536	1.790	0.118	0.046
Av. Values	119.555	23.036	-5.518	93.926	16.852	-3.557	20.409	23.884	-5.973	29.857	22.931	-5.937	28.868	28.868	22.233	-5.707	2.520	1.782	0.118	0.046
	Variation	0.35%	0.063	0.136	0.51%	0.038	0.138	0.84%	0.036	0.074	0.19%	0.043	0.074	0.24%	0.052	0.107	1.09%	0.70%	0.000	0.002
Surround temp difference	28.555 °C																			
Surround mean temperature	8.759 °C																			
	Atmospheric pressure																			
	not measured																			
	mb																			
	Calc																			
	Error																			
	5.2																			

Table 21 prEN 12567-2 (Table C1) - Calibration data - Rothold3 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical heat flow								
Measured values			Thin panel TT206 Vertical heat flow			Thick panel TT207 Horizontal heat flow		
d	overall thickness	m	0.02102			0.05774		
A	area of panel	m ²	1.8260			1.82169		
S _{sur}	area of surround panel	m ²	3.96159			3.96591		
A _t	hot box metering area	m ²	5.7876			5.7876		
L	perimeter length	m	5.42			5.42		
Test number			2	1	3	5	4	6
Cold temperatures			R014C	R014A	R014B	R019B	R019A	R019C
θ _{ce}	air	°C	8.21	3.67	-5.97	-4.21	4.47	10.65
θ _{se,b}	baffle	°C	8.35	3.85	-5.71	-4.08	4.57	10.71
θ _{se,cal}	calibration panel	°C	9.49	5.33	-3.56	-3.47	4.99	11.00
θ _{se,p}	reveal surface	°C	8.41	3.25	-3.53	-3.90	4.69	10.79
θ _{se,sur}	surround panel	°C	8.41	3.96	-5.52	-3.87	4.71	10.80
Warm temperatures								
θ _{ci}	air	°C	24.11	24.05	23.88	23.77	23.85	23.9052
θ _{si,b}	baffle	°C	23.19	22.88	22.23	22.94	23.28	23.4998
θ _{si,cal}	calibration panel	°C	20.18	19.08	16.85	21.17	22.03	22.6381
θ _{si,p}	reveal surface	°C	22.15	21.57	20.38	21.89	22.54	23.01
θ _{si,sur}	surround panel	°C	23.62	23.45	23.04	22.72	23.12	23.3997
φ _{in}	input power	W	64.78	82.46	119.55	54.41	38.01	26.1942
v _i	air flow warm side (down)	m/s	0.1	0.1	0.1	0.1	0.1	0.1
v _e	air flow cold side (up)	m/s	4.1	4.1	4.1	4.6	4.6	4.6

Table 22 prEN 12567-2 (Table C2) - Calibration data - Rothold3 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical heat flow				
Values resulting from mounting instructions		Remarks	Thin panel TT206 Vertical heat flow	Thick panel TT207 - Results from EN 12567-1 calibration measurements
Total thickness of the calibration panel	mm	-	21.016	57.738
Total thickness of the surround panel	mm	-	149.67	149.67
Surround panel reveal depth - warm side	mm	-	128.65	40
Surround panel reveal depth - cold side	mm	-	0.00	51.93
Thermal conductivity of the surround panel	W/(m.K)	E0	0.0344	0.0344
Emissivity of the calibration panel			0.88	0.88
Emissivity of the reveal			0.92	0.92
Emissivity of the baffle			0.95	0.95
Ψ_{edge} for $\lambda = 0.0334$ (W/(m.K))	W/(m.K)		-	0.00636
Warm side view factors	f_{cbi}	Table A1	0.8338	0.944
	f_{ppi}	Table A1	0.12535	0.0472
	f_{cpi}	equation (A.11)	0.1662	0.056
	f_{bpi}	equation (A.11)	0.1662	0.056
	f_{pbi}	equation (A.12)	0.4373	0.4764
	α_{cbi}	equation (A.8)	0.7019	0.7910
Cold side view factors	α_{cpi}	equation (A.9)	0.1415	0.04765
	f_{cbe}	Table A.1	1.0000	0.92757
	f_{ppe}	Table A.1	0.0000	0.06070
	f_{cpe}	equation (A.11)	0.0000	0.0724
	f_{bpe}	equation (A.11)	0.0000	0.0724
	f_{pbe}	equation (A.12)	0.5000	0.4697
radiant factors	α_{cbe}	equation (A.8)	0.8360	0.7777
	α_{cpe}	equation (A.9)	0.00000	0.06165

Table 23 prEN 12567-2 (Table C3) - Calibration data - Rothold3 - Vertical HF

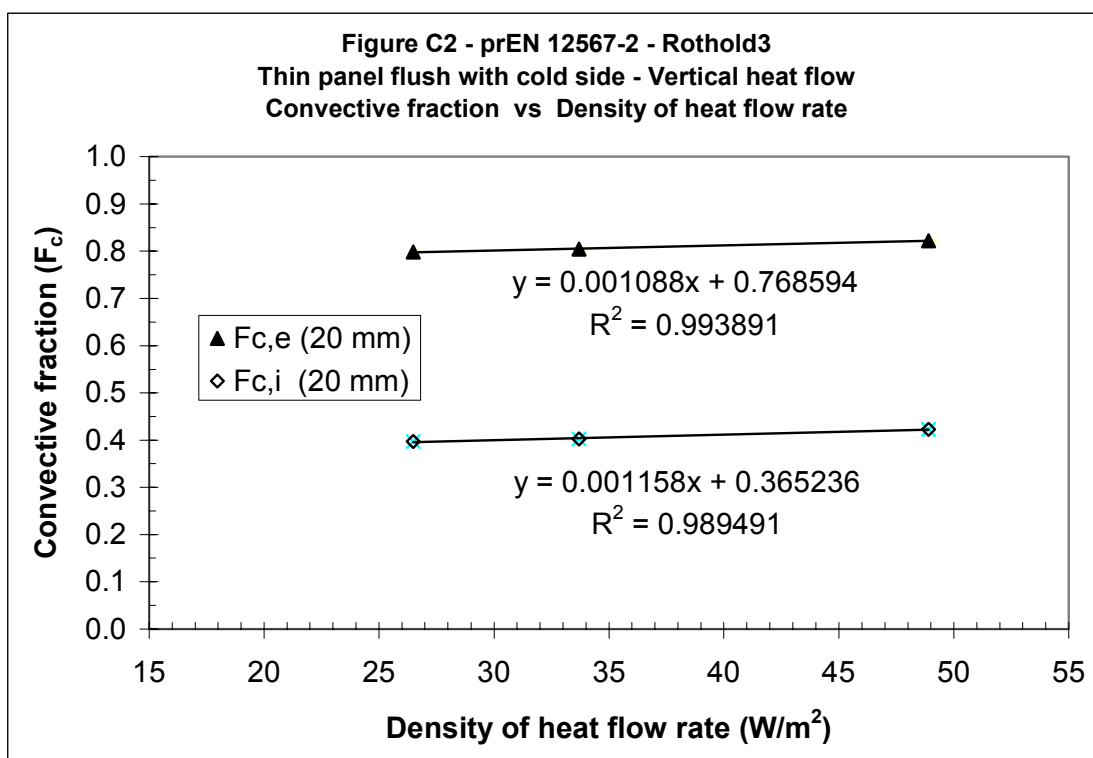
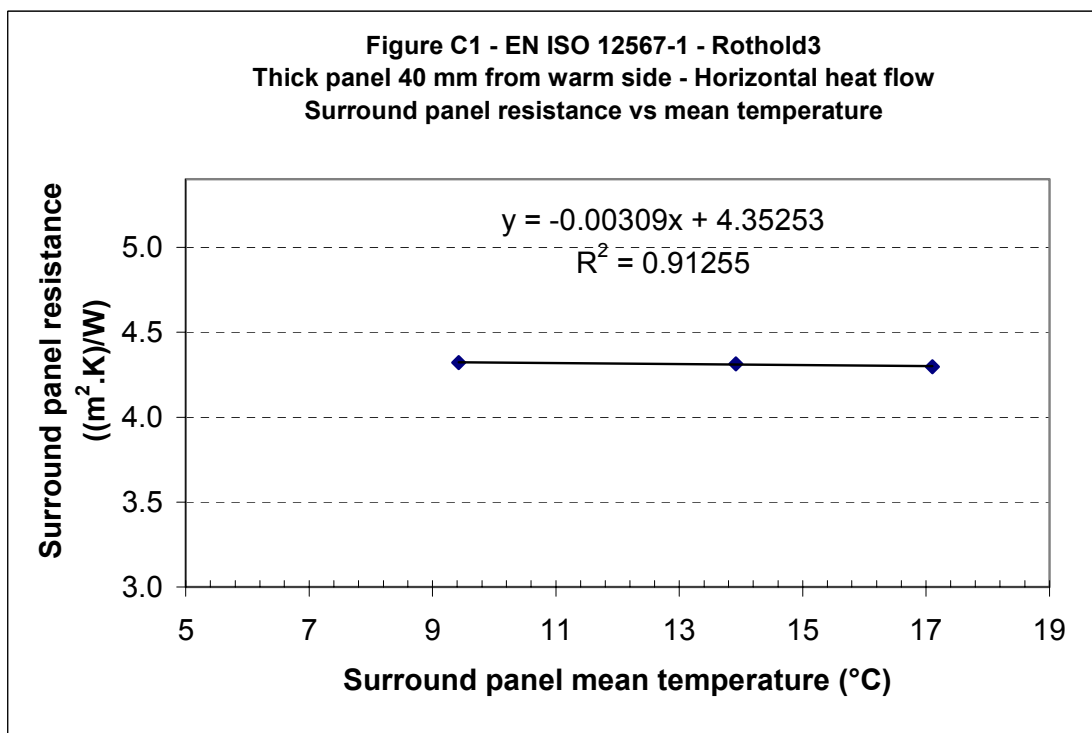
prEN 12567-2 Roof light and Projecting Windows calibration - Vertical heat flow						
Data element			Remarks	Thick panel TT207 - Results from EN 12567-1 calibration measurements		
Temperature difference air	$\Delta\theta_c$	K	-	27.97781	19.384	13.259
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	-	26.59255	18.414	12.602
Temperature mean surround	$\theta_{me,sur}$	°C	-	9.42	13.92	17.10
Heat flow rate into the box	Φ_{in}	W	-	54.41166	38.012	26.194
Heat flow rate through the calibration panel	Φ_{cal}	W	equation 9	29.04361	20.415	14.107
Heat flow rate around perimeter	Φ_{edge}	W	equation 10	0.964429	0.6682	0.4571
Power through surround panel ($\Phi_{in} - \Phi_{cal} - \Phi_{edge}$)	Φ_{sur}	W	-	24.40363	16.929	11.63
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	equation 8	4.321639	4.3137	4.2972
Optional check with thermal conductivity data						
Temperature mean surround	$\theta_{me,sur}$	°C		9.42	13.92	17.10
thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)		0.0340	0.0344	0.0347
Thickness of the holder panel	d_{sur}	m		0.1501	0.1501	0.1501
Thermal resistance of the surround panel	$R_{sur(check)}$	(m ² .K)/W		4.409	4.360	4.321
Difference in resistance				2.0	1.1	0.5

Table 24 prEN 12567-2 (Table C4) - Calibration data - Rothold3 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical heat flow									
Data element	Remarks	Thin panel TT206 Vertical heat flow			Thick panel TT207 - Results from EN 12567-1 calibration measurements				
Mean temperature cal panel	$\theta_{me,cal}$ °C	14.84	12.20	6.65	8.85	13.51	16.82		
Surface temp diff cal panel	$\Delta\theta_{s,cal}$ K	10.69	13.75	20.41	24.64	094	11.64		
Thermal resistance cal panel	R_{cal} m ² .K/W	0.4035	0.4079	0.4173	1.5455	1.5206	1.5034		
Density of heat flow rate thro' cal panel	q_{cal} W/m ²	26.499	33.700	48.904	15.9432	11.2067	7.7439		
Warm blackbody radiant heat transfer coefficient baffle	$h_{cb,i}$ W/m ² .K	5.8129	5.7712	5.6874	5.8348	5.8703	5.8950		
Cold blackbody radiant heat transfer coefficient baffle	$h_{cb,e}$ W/m ² .K	5.0899	4.8592	4.3911	4.4334	4.8693	5.1954		
Warm blackbody radiant heat transfer coefficient reveal	$h_{cp,i}$ W/m ² .K	5.7823	5.7327	5.6333	5.8038	5.8485	5.8803		
Cold blackbody radiant heat transfer coefficient reveal	$h_{cp,e}$ W/m ² .K	5.0918	4.8435	4.4446	4.4376	4.8723	5.1975		
radiant heat transfer coefficient warm side	$h_{r,i}$ W/m ² .K	4.8984	4.8622	4.7893	4.8917	4.9219	4.9429		
radiant heat transfer coefficient cold side	$h_{r,e}$ W/m ² .K	4.2551	4.0623	3.6709	3.7215	4.0873	4.3610		
Mean radiant temperature warm side	$\theta_{r,i}$ °C	23.01	22.66	21.92	22.88	23.23	23.47		
Mean radiant temperature cold side	$\theta_{r,e}$ °C	8.35	3.85	-5.71	-4.06	4.58	10.72		
Warm side convective heat transfer coefficient	$h_{c,i}$ W/m ² .K	3.225	3.278	3.502	2.934	2.912	2.859		
Cold side convective heat transfer coefficient	$h_{c,e}$ W/m ² .K	16.828	16.680	16.970	18.417	18.187	18.645		
Warm side convective fraction	$F_{c,i}$ -	0.3970	0.4027	0.4224	0.3749	0.3717	0.3665		
Cold side convective fraction	$F_{c,e}$ -	0.7982	0.8042	0.8221	0.8319	0.8165	0.8104		
Warm side environmental temperature	$\theta_{n,cal}$ °C	23.45	23.22	22.75	23.21	23.46	23.63		
Cold side environmental temperature	$\theta_{ne,cal}$ °C	8.23	3.71	-5.93	-4.19	4.49	10.66		
Environmental temperature difference	$\Delta\theta_{n,cal}$ K	15.21	19.51	28.68	27.40	18.97	12.97		
Warm side surface resistance	$R_{s,i}$ (m ² .K)/W	0.1231	0.1228	0.1206	0.1278	0.1277	0.1282		
Cold side surface resistance	$R_{s,e}$ (m ² .K)/W	0.0474	0.0482	0.0484	0.0452	0.0449	0.0435		
Total surface resistance	$R_{s,t}$ (m ² .K)/W	0.1705	0.1711	0.1691	0.1730	0.1725	0.1716		

Stefan-Boltzmann constant	5.670E-08 W/m ² .K ⁴
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Figure 7 prEN 12567-2 (Figs C1 & C2) - Calibration graphs - Rothold3 - Vertical HF



8 Calibration of Rothold2 to EN 12567-Parts 1 and 2

8.1 Calibration of Rothold2 to BS EN ISO 12567-1

These measurements are fully described in NPL Report CBTLM 26

8.2 Calibration of Rothold2 to prEN 12567-2 – Horizontal heat flow

The 21 mm thick glazed calibration panel was installed in the ordinary surround panel (NPL ID – Rothold2), mounted flush with the cold face of the surround panel as specified in prEN 12567-2. The thermal conductance of this panel was then measured in the hot box with a warm air temperature of 23.6°C and a cold air temperature of 2.7°C. The air speed in the cold box was adjusted to give a total surface resistance of $0.17 \pm 0.01 \text{ m}^2\text{K/W}$. The cold box air speed was then kept at this setting for the rest of the calibration measurements and indeed for all subsequent window measurements. The measurement schedule as specified in BS EN ISO 12567-1 was then carried out on the 21 mm thick glazed calibration panels, with vertical heat flow (cold box above hot box). The summary results for these three measurements are shown in Table 25, Table 26 and Table 27. The calculation procedures specified in prEN ISO 12567-2 were then used to produce Tables C1, C2, C3 and C4. These are shown in Table 28, Table 29, Table 30 and Table 31. The two graphs required by the standard are shown in Figure 8.

Table 25 Data - 21 mm GCP - Rothold2 - prEN 12567-2 @ 24 °C & 3 °C - Horizontal HF

R08A Rothold2
Horizontal Heat Flow
TT206 - Flush mount - Vertical mount

Data entered by.... **RGW**
Data entry checked by....
Service number....

Programme ROT_LOG8.TXT
Hot fan volts 7
Cold fan setting 48

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18
Date	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air temp	Air temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss actual	
	(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(µV)	(W)	(W)	
10-Feb-03	5:55	1.82594	0.03366	0.03309	80.0635	22.897	3.26379	18.483	4.57446	23.601	2.9429607	22.365	3.122828	3.2	0.000	1.797
10-Feb-03	7:55	1.82594	0.03365	0.03309	80.1475	22.882	3.24936	18.4721	4.58133	23.591	2.9210986	22.350	3.111391	5.6	0.000	1.790
10-Feb-03	9:55	1.82594	0.03365	0.03309	79.9688	22.877	3.24979	18.4716	4.58505	23.588	2.9416638	22.340	3.125482	6	0.000	1.798
10-Feb-03	11:55	1.82594	0.03365	0.03309	80.0692	22.887	3.23773	18.4671	4.56587	23.587	2.9230075	22.351	3.107672	3.2	0.000	1.796
10-Feb-03	13:55	1.82594	0.03365	0.03309	79.9805	22.882	3.24527	18.4727	4.59164	23.582	2.9238048	22.351	3.119216	3.3	0.000	1.798
Averages		1.8259	0.03366		80.0455	22.885	3.249	18.473	4.580	23.590	2.931	3.117	4.3	0.000	1.796	

R08A													
Area of specimen	1.8259	m ²	Thick @ edge		21.02	mm	Mean temp		11.53	°C	Hr (c)		5.730
Area holder	3.962	m ²	Holder thickness		0.14967	m	λ Holder		0.03366	W/m.K	Hr (h)		4.812
Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95		Spec. Emis. Hot		0.9		Tot Res		0.1741
			Baffle Emis Cold		0.95		Spec. Emis. Cold		0.9				
							Emissivity Factor Hot		0.8593				
							Emissivity Factor Cold		0.8593				

	Total power Corfor HFMOff	Surround Surface		Power through Insert - BL %	Hot surface temp	Cold surface temp	Surface Temp diff	Air temperatures			Environmental temperatures			Baffle temperatures			Thermal		Surface Resistance	
		Hot	Cold					Hot	Cold	diff	Hot	Cold	diff	Hot	Cold	diff	(W/m².K)	(W/m².K)	(m².K/W)	(m².K/W)
05:55:10	80.052	22.897	3.264	62.562	18.483	4.574	13.908	23.601	2.943	20.658	22.829	2.970	19.859	22.365	3.123	2.463	1.725	0.127	0.047	
07:55:12	80.127	22.882	3.249	62.638	18.472	4.581	13.891	23.591	2.921	20.670	22.817	2.950	19.867	22.350	3.111	2.470	1.727	0.127	0.048	
09:55:15	79.945	22.877	3.250	62.461	18.472	4.585	13.887	23.588	2.942	20.646	22.809	2.970	19.839	22.340	3.125	2.463	1.724	0.127	0.047	
11:55:07	80.058	22.887	3.238	62.554	18.467	4.566	13.901	23.587	2.923	20.664	22.815	2.951	19.864	22.351	3.108	2.464	1.725	0.127	0.047	
13:55:10	79.968	22.882	3.245	62.476	18.473	4.592	13.881	23.582	2.924	20.658	22.813	2.954	19.859	22.351	3.119	2.465	1.723	0.127	0.048	
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Av. Values	80.030	22.885	3.249	62.538	18.473	4.580	13.894	23.590	2.931	20.659	22.817	2.959	19.858	22.351	3.117	2.465	1.725	0.127	0.047	
Variation	0.23%	0.020	0.026	0.28%	0.016	0.026	0.20%	0.019	0.022	0.11%	0.020	0.020	0.14%	0.025	0.018	0.25%	0.22%	0.000	0.001	
Surround temp difference											Atmospheric pressure		not measured		mb		Calc		2.445	
Surround mean temperature																	Error		0.8	

Table 26 Data - 21 mm GCP - Rothold2 - prEN 12567-2 @ 24 °C & 10 °C - Horizontal HF

R08B				Data entered by.....										RGW			
Rothold2				Data entry checked by.....										Programme			
TT206 - Flush mount - Vertical mount				Service number....										Hot fan volts			
														Cold fan setting			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Date	time	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss actual	
		(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(W)	(W)	
13-Feb-03	3:03	1.82594	0.03431		53.0629	23.220	10.312	20.250	11.200	23.693	10.131	22.849	10.252	2.6	0.000	1.180	Line1
13-Feb-03	5:04	1.82594	0.03431		53.1549	23.203	10.259	20.226	11.142	23.672	10.098	22.839	10.202	-0.4	0.000	1.181	Line2
13-Feb-03	7:04	1.82594	0.03431		53.0686	23.197	10.264	20.234	11.160	23.671	10.088	22.835	10.201	3.2	0.000	1.182	Line3
13-Feb-03	9:03	1.82594	0.03431		52.9841	23.205	10.272	20.242	11.174	23.670	10.090	22.841	10.215	1.9	0.000	1.182	Line4
13-Feb-03	11:04	1.82594	0.03431		52.9796	23.189	10.322	20.229	11.208	23.665	10.148	22.831	10.263	6.4	0.000	1.176	Line5
Averages		1.8259	0.03431		53.0500	23.203	10.286	20.236	11.177	22.839	10.111	22.839	10.227	2.7	0.000	1.180	

R08B										
Area of specimen	1.8259	m²	Thick @ edge	21.02	mm	Mean temp	15.71	°C	Hr (c)	5.796
Area holder	3.962	m²	Holder thickness	0.14967	m	λ Holder	0.03431	W/m.K	Hr (h)	5.180
Boundary correction	0.000	Watts	Baffle Emis. Hot	0.95		Emissivity Factor Hot			Tot Res	0.1746
			Baffle Emis Cold	0.95		Emissivity Factor Cold		0.8593		

Thermal Surface Resistance																				
Total power Corfor	Surround Surface	Hot	Cold	Power through Insert	Hot surface temp	Cold surface temp	Surface Temp diff	Air temperatures	Environmental temperatures	Baffle temperatures	Thermal	Thermal	Surface Resistance							
HFM Off	Hot (°C)	Cold (°C)	(°C)	(W)	(°C)	(°C)	(°C)	Hot (°C)	Cold (°C)	diff (°C)	Hot (°C)	Cold (°C)	Hot Cold Trans Cond							
03:03:59	53.053	23.220	10.312	41.331	20.250	11.200	9.050	23.693	10.131	13.562	23.154	10.151	13.003	22.849	10.252	2.501	1.741	0.128	0.046	
05:04:01	53.156	23.203	10.259	41.401	20.226	11.142	9.084	23.672	10.098	13.574	23.139	10.114	13.025	22.839	10.202	2.496	1.741	0.128	0.045	
07:04:02	53.057	23.197	10.264	41.312	20.234	11.160	9.074	23.671	10.088	13.583	23.137	10.107	13.030	22.835	10.201	2.493	1.736	0.128	0.047	
09:03:00	52.977	23.205	10.272	41.232	20.242	11.174	9.068	23.670	10.090	13.580	23.140	10.111	13.030	22.841	10.215	2.490	1.733	0.128	0.047	
11:04:01	52.956	23.189	10.322	41.272	20.229	11.208	9.020	23.665	10.148	13.517	23.131	10.167	12.965	22.831	10.263	2.506	1.743	0.128	0.046	
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Av.Values	53.040	23.203	10.286	41.310	20.236	11.177	9.059	23.674	10.111	13.563	23.140	10.130	13.010	22.839	10.227	2.497	1.739	0.128	0.046	
Variation	0.38%	0.031	0.063	0.41%	0.024	0.067	0.71%	0.028	0.060	0.49%	0.022	0.060	0.51%	0.018	0.062	0.63%	0.60%	0.000	0.002	
Surround temp difference											Atmospheric pressure		not measured		mb		Calc		2.487	
Surround mean temperature															Error		0.4			

Table 27 Data - 21 mm GCP - Rothold2 - prEN 12567-2 @ 24 °C & -4°C - Horizontal HF

R08C				Data entered by..... RGW										Programme		ROT_LOG7.TXT	
TT206 - Flush mount - Vertical mount				Data entry checked by.....										Hot fan volts		7	
				Service number....										Cold fan setting		48	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	
Date	time	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot temp	Specimen surface Cold temp	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss actual	
		(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(W)	(W)	
1.0105																	
15-Feb-03	8:26	1.82594	0.0331		105.60557	22.5846	-3.50024	16.8389	-1.78674	23.497	-3.940537	21.892	-3.71664	1.2	0.000	2.387	
15-Feb-03	10:26	1.82594	0.0331		105.81698	22.5798	-3.49041	16.8314	-1.78847	23.491	-3.939013	21.884	-3.71265	2.8	0.000	2.386	
15-Feb-03	12:26	1.82594	0.0331		105.83879	22.5586	-3.52863	16.8286	-1.81662	23.47	-3.964064	21.874	-3.73555	0.1	0.000	2.387	
15-Feb-03	14:26	1.82594	0.03309		105.78959	22.5431	-3.55331	16.7974	-1.83432	23.469	-3.996084	21.861	-3.76924	2.8	0.000	2.389	
15-Feb-03	16:26	1.82594	0.03309		105.62235	22.5107	-3.58083	16.7823	-1.86798	23.462	-4.033219	21.841	-3.78951	2.1	0.000	2.392	
Averages		1.8259	0.03310		105.7347	22.555	-3.531	16.816	-1.819	23.478	-3.975	21.870	-3.745	1.8	0.000	2.388	
R08C																	
Area of specimen	1.8259	m²	Thick @ edge		mm		Mean temp		°C		7.50		°C		Hr (c)		
Area holder	3.962	m²	Holder thickness		m		λ Holder		W/m.K		0.03310		W/m.K		Hr (h)		
Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95		Spec. Emis. Hot		0.9		Emissivity Factor Hot		0.8593		Tot Res		
			Baffle Emis Cold		0.95		Spec. Emis. Cold		0.9		Emissivity Factor Cold		0.8593		0.1720		
Total power Corfor	Surround Surface		Power through Insert		Hot surface temp		Cold surface temp		Surface Temp diff		Air temperatures Hot		Air temperatures Cold		Environmental temperatures Hot		
HFMO Off	(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		
(W)	(°C)		(W)		(°C)		(°C)		(°C)		(°C)		(°C)		(W/m².K)(W/m².K)(m².K/W)		
08:26:52	105.601	22.585	-3.500	82.750	16.839	-1.787	18.626	23.497	-3.941	27.438	22.518	-3.909	26.426	21.892	-3.717	2.433	
10:26:55	105.807	22.580	-3.490	82.968	16.831	-1.788	18.620	23.491	-3.939	27.430	22.512	-3.907	26.420	21.884	-3.713	2.440	
12:26:58	105.838	22.559	-3.529	82.985	16.829	-1.817	18.645	23.470	-3.964	27.434	22.500	-3.932	26.432	21.874	-3.736	2.438	
14:26:50	105.779	22.543	-3.553	82.918	16.797	-1.834	18.632	23.469	-3.996	27.465	22.488	-3.964	26.452	21.861	-3.769	2.437	
16:26:54	105.615	22.511	-3.581	82.757	16.782	-1.868	18.650	23.462	-4.033	27.495	22.471	-3.999	26.470	21.841	-3.790	2.430	
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Av. Values	105.728	22.555	-3.531	82.876	16.816	-1.819	18.635	23.478	-3.975	27.452	22.498	-3.942	26.440	21.870	-3.745	2.436	
Variation	0.22%	0.074	0.090	0.28%	0.057	0.081	0.16%	0.035	0.094	0.24%	0.046	0.092	0.19%	0.051	0.077	0.44%	
Surround temp difference			°C		Atmospheric pressure		not measured		mb		Calc		2.405		0.001		
Surround mean temperature			°C								Error		1.3				

Table 28 prEN 12567-2 (Table C1) - Calibration data - Rothold2 - Horizontal HF

prEN 12567-2 Roof light and Projecting Windows calibration - Horizontal heat flow								
Measured values			Thin panel TT206 Horizontal heat flow			Thick panel TT207 Horizontal heat flow		
d	overall thickness	m	0.02102			0.05774		
A	area of panel	m ²	1.8259			1.82466		
S _{sur}	area of surround panel	m ²	3.96166			3.96294		
A _t	hot box metering area	m ²	5.7876			5.7876		
L	perimeter length	m	5.42			5.42		
Test number			2	1	3	5	4	6
Cold temperatures			R08B	R08A	R08C	R020C	R020E	R020D
θ _{ce}	air	°C	10.11	2.93	-3.97	-4.246	4.33	10.54
θ _{se,b}	baffle	°C	10.23	3.12	-3.74	-4.11	4.44	10.62
θ _{se,cal}	calibration panel	°C	11.18	4.58	-1.82	-3.50	4.86	10.91
θ _{se,p}	reveal surface	°C	10.29	3.25	-3.53	-3.95	4.56	10.70
θ _{se,sur}	surround panel	°C	10.29	3.25	-3.53	-3.92	4.56	10.70
Warm temperatures								
θ _{ci}	air	°C	23.67	23.59	23.48	23.774	23.79	23.8416
θ _{si,b}	baffle	°C	22.84	22.35	21.87	22.96	23.22	23.4458
θ _{si,cal}	calibration panel	°C	20.24	18.47	16.82	21.19	21.96	22.5833
θ _{si,p}	reveal surface	°C	20.99	21.15	20.19	21.91	22.48	22.957
θ _{si,sur}	surround panel	°C	23.20	22.89	22.56	22.78	23.09	23.3729
φ _{in}	input power	W	53.04	80.03	105.73	52.93	37.09	25.366
v _i	air flow warm side (down)	m/s	0.1	0.1	0.1	0.1	0.1	0.1
v _e	air flow cold side (up)	m/s	4.1	4.1	4.1	4.6	4.6	4.6

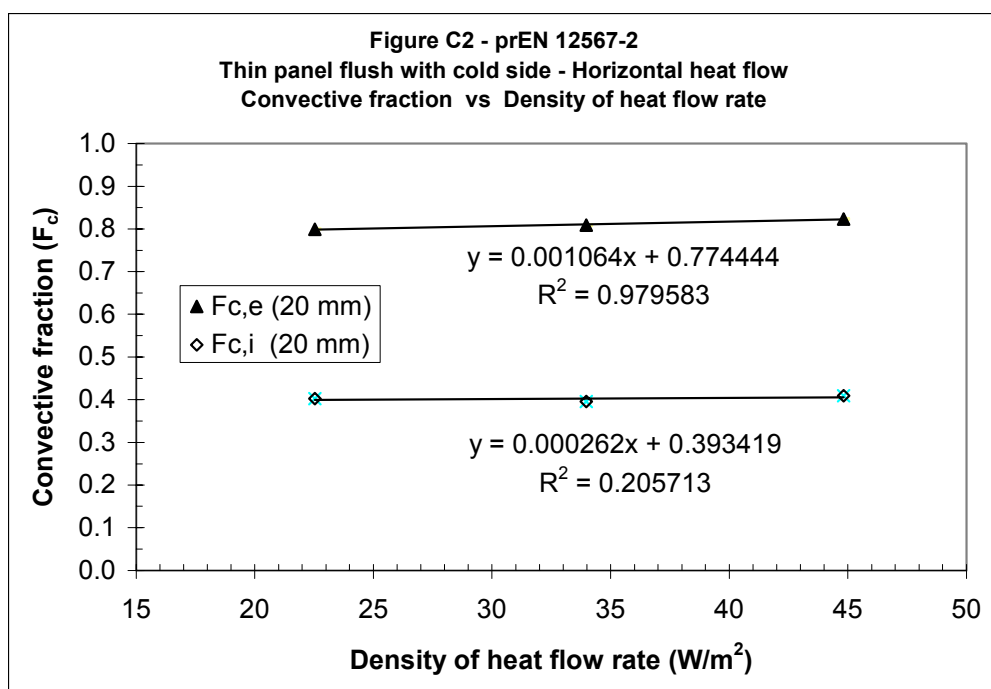
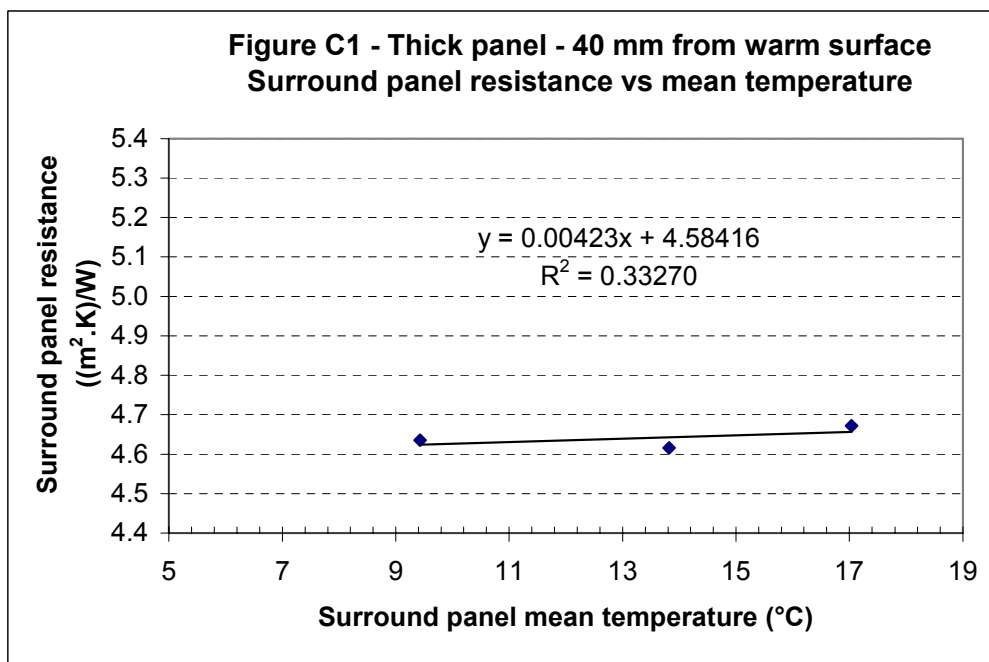
Table 29 prEN 12567-2 (Table C2) - Calibration data - Rotahold2 - Horizontal HF

prEN 12567-2 Roof light and Projecting Windows calibration - Horizontal heat flow				
Values resulting from mounting instructions		Remarks	Thin panel TT206 Horizontal heat flow-flush	Thick panel TT207 - Results from EN 12567-1 calibration measurements
Total thickness of the calibration panel	mm	-	21.016	57.738
Total thickness of the surround panel	mm	-	149.67	149.67
Surround panel reveal depth - warm side	mm	-	128.65	40
Surround panel reveal depth - cold side	mm	-	0.00	51.93
Thermal conductivity of the surround panel	W/(m.K)	E0	0.0337	0.0338
Emissivity of the calibration panel			0.88	0.88
Emissivity of the reveal			0.92	0.92
Emissivity of the baffle			0.95	0.95
Ψ_{edge} for $\lambda = 0.0334$ (W/(m.K))	W/(m.K)		-	0.00636
Warm side view factors	f_{cbi}	Table A1	0.8338	0.944
	f_{ppi}	Table A1	0.12535	0.0472
	f_{cpi}	equation (A.11)	0.1662	0.056
	f_{bpi}	equation (A.11)	0.1662	0.056
	f_{pbi}	equation (A.12)	0.4373	0.4764
	α_{cbi}	equation (A.8)	0.7019	0.7910
radiant factors	α_{cpi}	equation (A.9)	0.1415	0.04765
Cold side view factors	f_{cbe}	Table A.1	1.0000	0.92757
	f_{ppe}	Table A.1	0.0000	0.06070
	f_{cpe}	equation (A.11)	0.0000	0.0724
	f_{bpe}	equation (A.11)	0.0000	0.0724
	f_{pbe}	equation (A.12)	0.5000	0.4697
	α_{cbe}	equation (A.8)	0.8360	0.7777
radiant factors	α_{cpe}	equation (A.9)	0.00000	0.06165

Table 30 prEN 12567-2 (Table C2) - Calibration data - Rothold2 - Horizontal HF

prEN 12567-2 Roof light and Projecting Windows calibration - Horizontal heat flow						
Data element			Remarks	Thick panel TT207 - Results from EN 12567-1 calibration measurements		
Temperature difference air	$\Delta\theta_c$	K	-	28.02041	19.46	13.306
Temperature difference surface, surround	$\Delta\theta_{s,\text{sur}}$	K	-	26.69242	18.526	12.67
Temperature mean surround	$\theta_{\text{me},\text{sur}}$	°C	-	9.43	13.82	17.04
Heat flow rate into the box	Φ_{in}	W	-	52.92797	37.092	25.366
Heat flow rate through the calibration panel	Φ_{cal}	W	equation 9	29.14052	20.517	14.159
Heat flow rate around perimeter	Φ_{edge}	W	equation 10	0.965897	0.6708	0.4587
Power through surround panel ($\Phi_{\text{in}} - \Phi_{\text{cal}} - \Phi_{\text{edge}}$)	Φ_{sur}	W	-	22.82154	15.904	10.748
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	equation 8	4.635115	4.6163	4.6713
Optional check with thermal conductivity data						
Temperature mean surround	$\theta_{\text{me},\text{sur}}$	°C		9.43	13.82	17.04
thermal conductivity of surround @ $\theta_{\text{me},\text{sur}}$	λ_{sur}	W/(m.K)		0.0331	0.0338	0.0344
Thickness of the holder panel	d_{sur}	m		0.14967	0.1497	0.1497
Thermal resistance of the surround panel	$R_{\text{sur}(\text{check})}$	(m ² .K)/W		4.52386	4.4303	4.3552
Difference in resistance				-2.45928	-4.1977	-7.2576

Figure 8 prEN 12567-2 (Figs C1 & C2) - Calibration graphs - Rotahold2 - Horizontal HF



8.3 Calibration of Rothold2 to prEN 12567-2 – Vertical heat flow

The 21 mm thick glazed calibration panel was installed in the ordinary surround panel (NPL ID – Rothold2), mounted flush with the cold face of the surround panel as specified in prEN 12567-2. The thermal conductance of this panel was then measured in the hot box with a warm air temperature of 23.6°C and a cold air temperature of 2.7°C. The air speed in the cold box was adjusted to give a total surface resistance of $0.17 \pm 0.01 \text{ m}^2 \cdot \text{K/W}$. The cold box air speed was then kept at this setting for the rest of the calibration measurements and indeed for all subsequent window measurements. The measurement schedule as specified in BS EN ISO 12567-1 was then carried out on the 21 mm thick glazed calibration panels, with vertical heat flow (cold box above hot box). The summary results for these three measurements are shown in Table 32, Table 33 and Table 34. The calculation procedures specified in prEN ISO 12567-2 were then used to produce Tables C1, C2, C3 and C4. These are shown in Table 35, Table 36, Table 37 and Table 38. The two graphs required by the standard are shown in Figure 9.

8.4 Summary of all calibration coefficients

A summary of all the coefficients of the all the calibration graphs for the different conditions and for both surround panels is given in Table 39.

Table 32 Data - 21 mm GCP - Rothold2 - prEN 12567-2 @ 24°C & 3°C - Vertical HF

R09A Rothold2
TT206 Mounted flush & vertically up heat-flow

RGW
Data entered by....
Data entry checked by....
Service number....

Programme ROT_LOG8.TXT
Hot fan volts 7
Cold fan setting 48

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18
Date	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	Boundary loss used	Boundary loss actual	
	(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(µV)	(W)	(W)	
"28/02/2003 07:42:18	1.8259	0.0337	0.0	84.670	23.5039	2.937	18.892	4.392	24.111	2.617	22.884	2.807	0.70	0.000	1.870	Line1
"28/02/2003 10:03:05	1.8259	0.0337	0.0	84.794	23.4814	2.984	18.882	4.415	24.084	2.715	22.865	2.881	5.30	0.000	1.859	Line2
"28/02/2003 12:03:09	1.8259	0.0337	0.0	84.678	23.4913	3.029	18.883	4.462	24.109	2.732	22.873	2.915	-0.30	0.000	1.860	Line3
"28/02/2003 14:03:12	1.8259	0.0337	0.0	84.459	23.4598	2.990	18.867	4.443	24.068	2.692	22.846	2.883	-0.20	0.000	1.860	Line4
"28/02/2003 16:03:05	1.8259	0.0337	0.0	84.980	23.488	3.002	18.874	4.433	24.101	2.715	22.870	2.890	2.00	0.000	1.861	Line5
Averages	1.8259	0.03368		84.7160	23.485	2.989	18.880	4.429	24.095	2.694	22.868	2.875	1.5	0.000	1.862	

R09A																																													
Area of specimen	1.8259	m ²	Thick @ edge		21.02		mm		Mean temp		11.65		°C		Hr (c)		5.757																												
Area holder	3.962	m ²	Holder thickness		0.14967		m		λ Holder		0.03368		W/mK		Hr (h)		4.800																												
Boundary correction	0.000	Watts	Baffle Emis. Hot		0.95				Spec. Emis. Hot		0.9		Emissivity Factor Hot		0.8593		0.1698																												
			Baffle Emis Cold		0.95				Spec. Emis. Cold		0.9		Emissivity Factor Cold		0.8593																														
Total power Corfor HFM Off		Surround		Surface		Hot		Cold		Power through Insert		- BL %		Surface Temp diff		Cold surface temp		Hot surface temp		Air temperatures		Hot		Cold		diff		Environmental temperatures		Hot		Cold		diff		Thermal		Cond		Trans		Thermal		Surface Resistance	
(W)		(°C)		(°C)		(°C)		(°C)		(W)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(°C)		(W/m².K)		(W/m².K)		(W/m².K)		(m².K/W)		(m².K/W)			
00:00:00		84.667	23.504	2.937	66.330	18.892	4.392	14.500	24.111	2.617	21.494	23.364	2.646	20.717	22.884	2.807	2.505	1.753	0.123	0.048																									
00:00:00		84.775	23.481	2.984	66.500	18.882	4.415	14.467	24.084	2.715	21.369	23.345	2.740	20.605	22.865	2.881	2.517	1.768	0.123	0.046																									
00:00:00		84.679	23.491	3.029	66.435	18.883	4.462	14.421	24.109	2.732	21.377	23.357	2.760	20.597	22.873	2.915	2.523	1.766	0.123	0.047																									
00:00:00		84.459	23.460	2.990	66.209	18.867	4.443	14.424	24.068	2.692	21.376	23.325	2.722	20.603	22.846	2.883	2.514	1.760	0.123	0.047																									
00:00:00		84.972	23.488	3.002	66.708	18.874	4.433	14.441	24.101	2.715	21.386	23.354	2.741	20.613	22.870	2.890	2.530	1.772	0.123	0.046																									
		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*																								
Av. Values		84.711	23.485	2.989	66.436	18.880	4.429	14.451	24.095	2.694	21.400	23.349	2.722	20.627	22.868	2.875	2.518	1.764	0.123	0.047																									
Variation		0.61 %	0.044	0.092	0.75 %	0.025	0.070	0.54 %	0.043	0.116	0.59 %	0.039	0.114	0.58 %	0.038	0.108	0.97 %	1.07 %	0.001	0.002																									
Surround temp difference		20.496		°C		Atmospheric pressure										not measured		mb		Calc		2.447																							
Surround mean temperature		13.237		°C														Error		2.9																									

Table 35 prEN 12567-2 (Table C1) - Calibration data - Rothold2 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical up heat flow								
Measured values			Thin panel TT206			Thick panel TT207		
d	overall thickness	m	0.02102			0.05774		
A	area of panel	m ²	1.8259			1.82466		
S _{sur}	area of surround panel	m ²	3.96166			3.96294		
A _t	hot box metering area	m ²	5.7876			5.7876		
L	perimeter length	m	5.42			5.42		
Test number			2	1	3	5	4	6
Cold temperatures								
θ _{ce}	air	°C	9.99	2.69	-4.23	-4.29	4.33	10.54
θ _{se,b}	baffle	°C	10.12	2.88	-4.00	-4.15	4.44	10.62
θ _{se,cal}	calibration panel	°C	11.14	4.43	-1.92	-3.51	4.86	10.91
θ _{se,p}	reveal surface	°C	10.18	2.99	-3.82	-3.95	4.56	-7.34
θ _{se,sur}	surround panel	°C	10.18	2.99	-3.82	-3.95	4.56	10.70
Warm temperatures								
θ _{ci}	air	°C	24.15	24.09	24.01	23.78	23.79	23.8416
θ _{si,b}	baffle	°C	23.32	22.87	22.44	22.96	23.22	23.4458
θ _{si,cal}	calibration panel	°C	20.61	18.88	17.29	21.20	21.96	22.5833
θ _{si,p}	reveal surface	°C	22.44	21.57	20.76	21.91	22.48	21.75
θ _{si,sur}	surround panel	°C	23.74	23.48	23.25	22.79	23.09	23.3729
ϕ _{in}	input power	W	56.12	84.71	110.84	52.78	37.09	25.366
v _i	air flow warm side (down)	m/s	0.1	0.1	0.1	0.1	0.1	0.1
v _e	air flow cold side (up)	m/s	4.1	4.1	4.1	4.6	4.6	4.6

Table 36 prEN 12567-2 (Table C2) - Calibration data - Rothold2 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical up heat flow							
Values resulting from mounting instructions		Remarks	Thin panel TT206	Thick panel TT207			
Total thickness of the calibration panel	mm	-	21.016	57.738			
Total thickness of the surround panel	mm	-	149.67	149.67			
Surround panel reveal depth - warm side	mm	-	128.654	40			
Surround panel reveal depth - cold side	mm	-	0.00	51.93			
Thermal conductivity of the surround panel	W/(m.K)	E0	0.0337	0.0338			
Emissivity of the calibration panel			0.88	0.88			
Emissivity of the reveal			0.92	0.92			
Emissivity of the baffle			0.95	0.95			
Ψ_{edge} for $\lambda = 0.0334$ (W/(m.K))	W/(m.K)	Table B.1	-	0.00636			
Warm side	view factors	f_{cbi}	Table A.1	0.8338	0.944		
		f_{ppi}	Table A.1			0.1253	0.0472
		f_{cpi}	equation (A.11)				
	f_{bpi}	equation (A.11)	0.16623	0.056			
	f_{pbi}	equation (A.12)	0.16623	0.056			
	radiant factors	f_{pbi}	equation (A.12)	0.43733	0.4764		
		α_{cbi}	equation (A.8)	0.43733	0.4764		
		α_{cpi}	equation (A.9)	0.7019	0.7910		
			0.14154	0.04765			
Cold side	view factors	f_{cbe}	Table A.1	1.0000	0.92757		
		f_{ppe}	Table A.1			0.0000	0.06070
		f_{cpe}	equation (A.11)				
	f_{bpe}	equation (A.11)	0.0000	0.0724			
	f_{pbe}	equation (A.12)	0.0000	0.0724			
	radiant factors	f_{pbe}	equation (A.12)	0.5000	0.4697		
		α_{cbe}	equation (A.8)	0.5000	0.4697		
		α_{cpe}	equation (A.9)	0.8360	0.7777		
			0.00000	0.06165			

Table 37 prEN 12567-2 (Table C3) - Calibration data - Rothold2 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical up heat flow						
Data element			Remarks	Thick panel TT207		
Temperature difference air	$\Delta\theta_c$	K	-	28.07	19.46	13.306
Temperature difference surface, surround	$\Delta\theta_{s,\text{sur}}$	K	-	26.735	18.526	12.67
Temperature mean surround	$\theta_{\text{me},\text{sur}}$	°C	-	9.42	13.82	17.04
Heat flow rate into the box	Φ_{in}	W	-	52.781	37.092	25.366
Heat flow rate through the calibration panel	Φ_{cal}	W	equation 9	29.173	20.517	14.159
Heat flow rate around perimeter	Φ_{edge}	W	equation 10	0.9676	0.6708	0.4587
Power through surround panel ($\Phi_{\text{in}} - \Phi_{\text{cal}} - \Phi_{\text{edge}}$)	Φ_{sur}	W	-	22.641	15.904	10.748
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	equation 8	4.6795	4.6163	4.6713
Optional check with thermal conductivity data						
Temperature mean surround	$\theta_{\text{me},\text{sur}}$	°C		9.42	13.82	17.04
thermal conductivity of surround @ $\theta_{\text{me},\text{sur}}$	λ_{sur}	W/(m.K)		0.0331	0.0338	0.0344
Thickness of the holder panel	d_{sur}	m		0.1497	0.1497	0.1497
Thermal resistance of the surround panel	$R_{\text{sur}(\text{check})}$	(m ² .K)/W		4.5241	4.4303	4.3552
Difference in resistance				-3.4354	-4.1977	-7.2576

Table 38 prEN 12567-2 (Table C4) - Calibration data - Rothold2 - Vertical HF

prEN 12567-2 Roof light and Projecting Windows calibration - Vertical up heat flow									
Data element	Remarks	Thin panel TT206	Thick panel TT207						
Mean temperature cal panel	$\theta_{ne,cal}$ °C	15.87	11.65	7.69	8.84	13.41	16.75		
Surface temp diff cal panel	$\Delta\theta_{s,cal}$ K	9.46	14.45	19.22	24.71	17.1045	11.6689		
Thermal resistance cal panel	R_{cal} m ² .K/W	0.4019	0.4088	0.4155	1.5456	1.5212	1.5038		
Density of heat flow rate thro' cal panel	q_{cal} W/m ²	23.548	35.350	46.250	15.9879	11.2445	7.7598		
Warm blackbody radiant heat transfer coefficient baffle	$h_{cb,i}$ W/m ² .K	5.8293	5.7651	5.7063	5.8362	5.8664	5.8917		
Cold blackbody radiant heat transfer coefficient baffle	$h_{cb,e}$ W/m ² .K	5.1831	4.8101	4.4734	4.4305	4.8621	5.1905		
Warm blackbody radiant heat transfer coefficient reveal	$h_{cp,i}$ W/m ² .K	5.8032	5.7270	5.6572	5.8048	5.8445	5.8412		
Cold blackbody radiant heat transfer coefficient reveal	$h_{cp,e}$ W/m ² .K	5.1847	4.8131	4.4781	4.4353	4.8653	4.7186		
radiant heat transfer coefficient warm side	$h_{r,i}$ W/m ² .K	4.9129	4.8571	4.8059	4.8928	4.9186	4.9385		
radiant heat transfer coefficient cold side	$h_{r,e}$ W/m ² .K	4.3331	4.0213	3.7398	3.7191	4.0813	4.3276		
Mean radiant temperature warm side	$\theta_{r,i}$ °C	23.17	22.65	22.16	22.90	23.17	23.35		
Mean radiant temperature cold side	$\theta_{r,e}$ °C	10.12	2.88	-4.00	-4.13	4.44	9.30		
Warm side convective heat transfer coefficient	$h_{c,i}$ W/m ² .K	3.086	3.267	3.405	2.955	2.889	3.161		
Cold side convective heat transfer coefficient	$h_{c,e}$ W/m ² .K	16.491	16.774	16.667	17.638	18.080	1.998		
Warm side convective fraction	$F_{c,i}$ -	0.3858	0.4021	0.4147	0.3766	0.3700	0.3903		
Cold side convective fraction	$F_{c,e}$ -	0.7919	0.8066	0.8167	0.8259	0.8158	0.3159		
Warm side environmental temperature	$\theta_{ne,cal}$ °C	23.55	23.23	22.93	23.23	23.40	23.54		
Cold side environmental temperature	$\theta_{ne,cal}$ °C	10.01	2.73	-4.19	-4.26	4.35	9.69		
Environmental temperature difference	$\Delta\theta_{r,cal}$ K	13.54	20.50	27.12	27.50	19.05	13.85		
Warm side surface resistance	$R_{s,i}$ (m ² .K)/W	0.1250	0.1231	0.1218	0.1274	0.1281	0.1235		
Cold side surface resistance	$R_{s,e}$ (m ² .K)/W	0.0480	0.0481	0.0490	0.0468	0.0451	0.1581		
Total surface resistance	$R_{s,t}$ (m ² .K)/W	0.1730	0.1712	0.1708	0.1742	0.1732	0.2815		

Stefan-Boltzmann constant	5.670E-08 W/m ² .K ⁴
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Figure 9 prEN 12567-2 (Figs C1 & C2) - Calibration graphs - Rothhold2 - Vertical HF

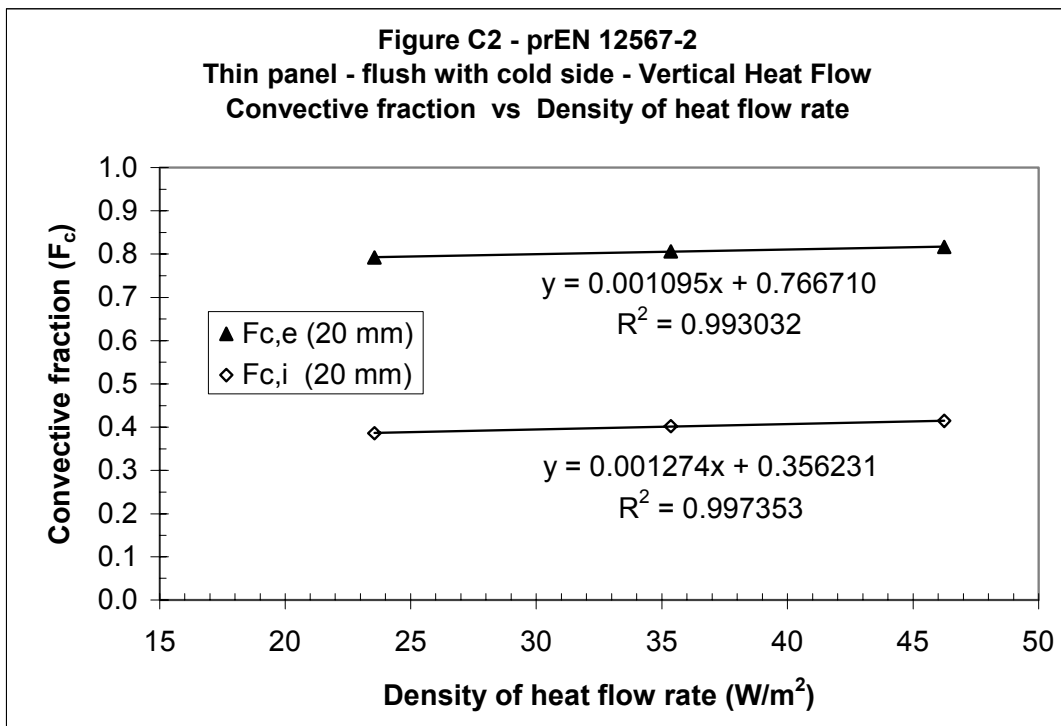
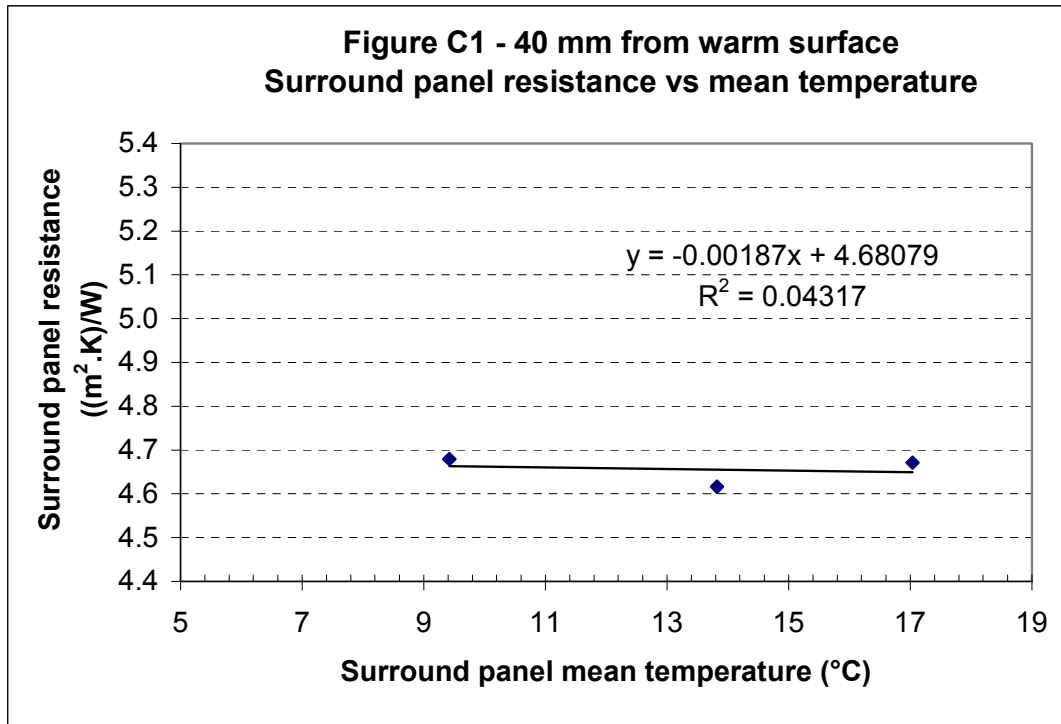


Table 39 Calibration coefficients for EN 12567 parts 1 and 2 for Rothold2 & Rothold3

Rothold 2 BS EN ISO 12567-1					
Figure D1	Surround panel resistance vs Surround panel mean temperature		$R_{sur} =$	0.0042255	x $\theta_{me,sur}$ + 4.584159
Figure D2	Total surface resistance vs Density of heat flow rate		$R_{s,t} =$	0.00001	x q_{cal} + 0.17495
Figure D3	Convective fraction vs Density of heat flow rate	Cold side	$F_{c,e} =$	0.000081	x q_{cal} + 0.806917
		Hot side	$F_{c,i} =$	0.000898	x q_{cal} + 0.361349
Rothold 2 prEN 12567-2 - Horizontal heat flow					
Figure C1	Surround panel resistance vs Surround panel mean temperature		$R_{sur} =$	0.0042255	x $\theta_{me,sur}$ + 4.584159
Figure C2	Convective fraction vs Density of heat flow rate	Cold side	$F_{c,e} =$	0.000258	x q_{cal} + 0.806631
		Hot side	$F_{c,i} =$	0.001097	x q_{cal} + 0.361911
Rothold 2 prEN 12567-2 - Vertical heat flow					
Figure C1	Surround panel resistance vs Surround panel mean temperature		$R_{sur} =$	0.0042255	x $\theta_{me,sur}$ + 4.584159
Figure C2	Convective fraction vs Density of heat flow rate	Cold side	$F_{c,e} =$	0.001095	x q_{cal} + 0.766710
		Hot side	$F_{c,i} =$	0.001274	x q_{cal} + 0.356231
Rothold 3 BS EN ISO 12567-1					
Figure D1	Surround panel resistance vs Surround panel mean temperature		$R_{sur} =$	-0.003092	x $\theta_{me,sur}$ + 4.35253
Figure D2	Total surface resistance vs Density of heat flow rate		$R_{s,t} =$	0.0000243	x q_{cal} + 0.17490
Figure D3	Convective fraction vs Density of heat flow rate	Cold side	$F_{c,e} =$	-0.000297	x q_{cal} + 0.816558
		Hot side	$F_{c,i} =$	0.000877	x q_{cal} + 0.361482
Rothold 3 prEN 12567-2 - Horizontal heat flow					
Figure C1	Surround panel resistance vs Surround panel mean temperature		$R_{sur} =$	-0.003092	x $\theta_{me,sur}$ + 4.35253
Figure C2	Convective fraction vs Density of heat flow rate	Cold side	$F_{c,e} =$	0.000550	x q_{cal} + 0.784267
		Hot side	$F_{c,i} =$	0.000918	x q_{cal} + 0.370503
Rothold 3 prEN 12567-2 - Vertical heat flow					
Figure C1	Surround panel resistance vs Surround panel mean temperature		$R_{sur} =$	-0.003092	x $\theta_{me,sur}$ + 0.172987
Figure C2	Convective fraction vs Density of heat flow rate	Cold side	$F_{c,e} =$	0.001088	x q_{cal} + 0.768594
		Hot side	$F_{c,i} =$	0.001158	x q_{cal} + 0.365236

9 MEASUREMENTS AND CALCULATIONS OF “IDEAL” SKYLIGHT

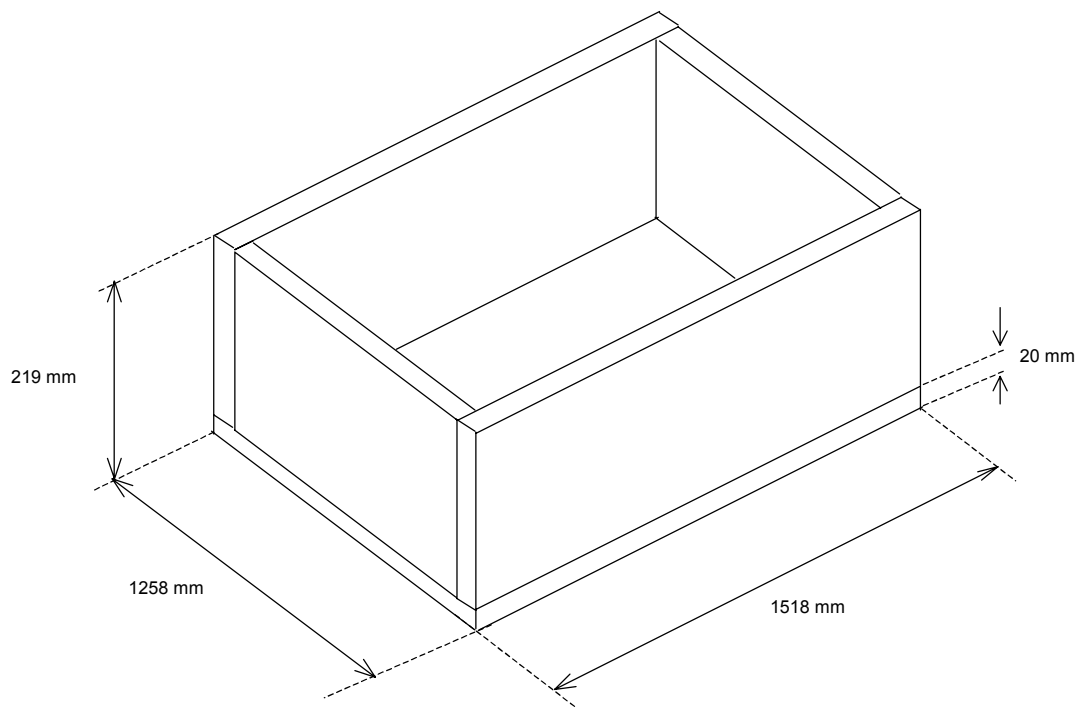
9.1 Reasons for measuring an “ideal” skylight

- This structure is an attempt to produce a reference specimen for measurements at different orientations, of products that project into the cold box air stream.
- By making a simple, rectangular structure from expanded polystyrene it's thermal properties could be calculated fairly accurately.
- Using such a structure the effects on the air flow speed, air temperature and local heat transfer coefficients could be determined.
- The measurement procedures specified in prEN 12567-2 could be studied

9.2 Description of “ideal” skylight

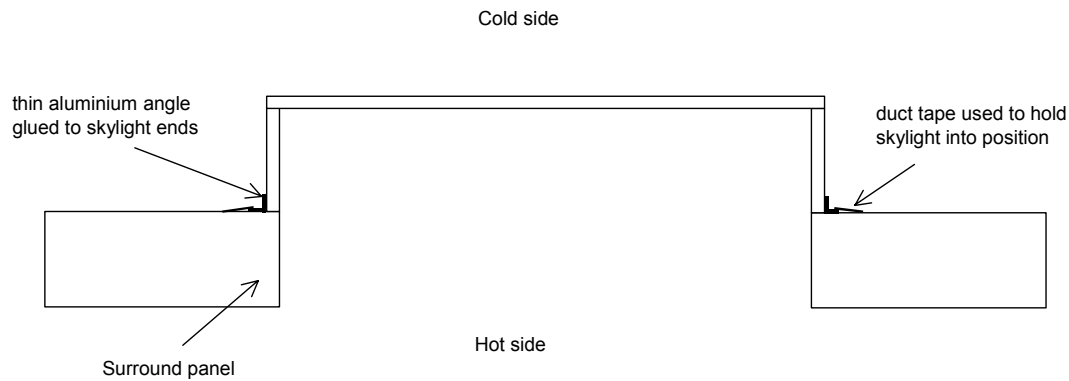
This was a rectangular open fronted box made from 20 mm thick expanded polystyrene. A sketch of the EPS skylight can be seen in Figure 10.

Figure 10 Sketch of EPS ideal skylight



Thin aluminium angle was glued to each end of the ideal skylight to enable it to be secured to the surround panel using duct tape alone. A sketch of the ideal skylight fixed to the surround panel can be seen in Figure 11.

Figure 11 Sketch of ideal skylight fixed to surround panel



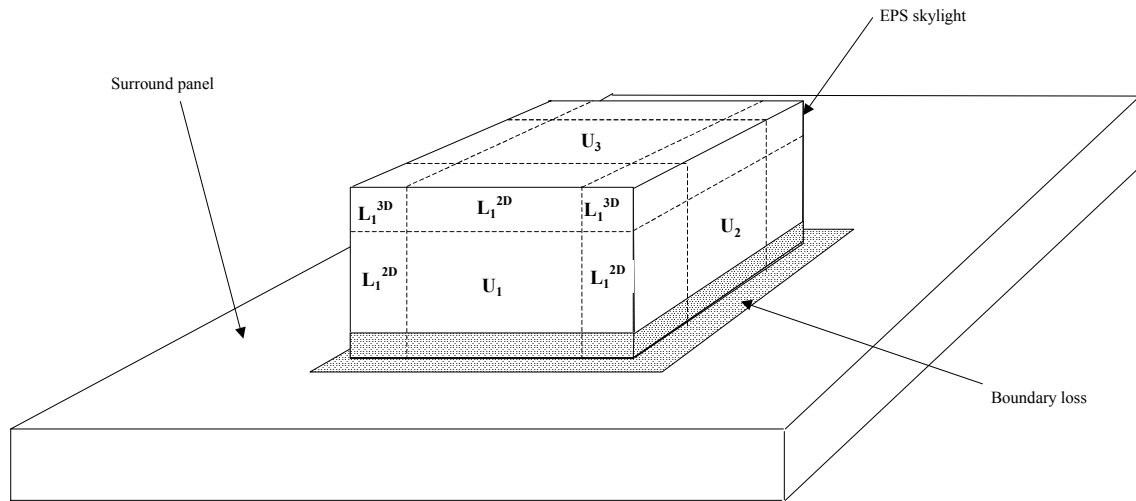
9.3 Calculated U-value of “ideal skylight”

The thermal conductivity of the EPS material used to make the skylight was measured in a guarded hot plate apparatus (NPL Test Report PP21/E03070079). The thermal conductivity and thickness data taken from that report are shown in Table 40.

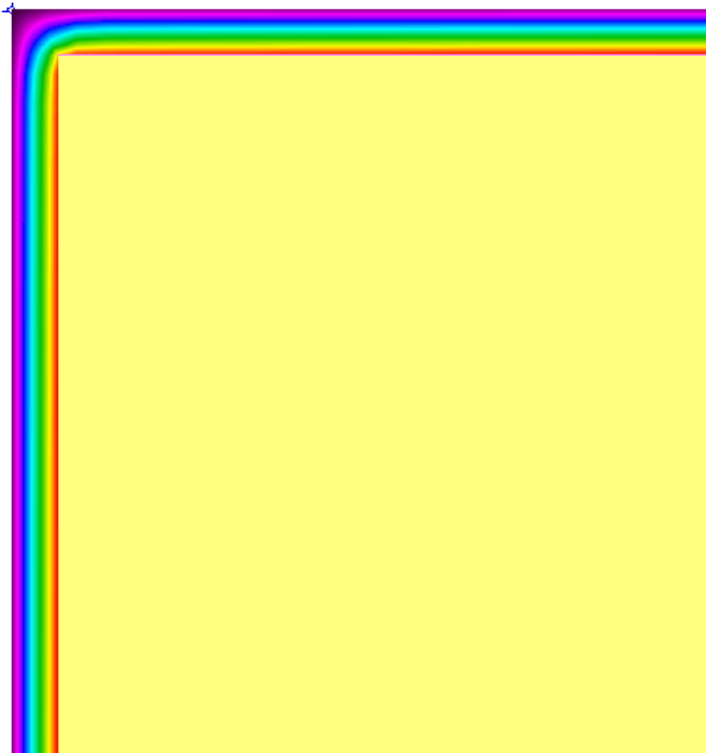
Table 40 Thermal conductivity data for EPS used in ideal skylight

Thermal Conductivity Results for QM310 (thickness = 19.61 mm)				
Date of measurement	Mean temperature difference /K	Mean Density of heat flow rate /(W/m ²)	Mean test temperature /°C	Thermal conductivity /(W/m·K)
15/07/03	18.3	30.2	5.0	0.0323
16/07/03	18.1	30.9	15.1	0.0335

The procedure adopted to calculate the U-value of the ideal structure was that specified in BS EN ISO 10211-1:1996 *Thermal bridges in building construction – Calculation of heat flows and surface temperatures – Part 1: General methods*. The calculation concept adopted by this standard is to calculate a thermal coupling coefficient ($L_{i,j}$) which is defined as the heat flow per unit temperature difference between two environments i and j which are thermally connected by the construction under consideration. The different components that need to be evaluated when using this approach are shown in Figure 12

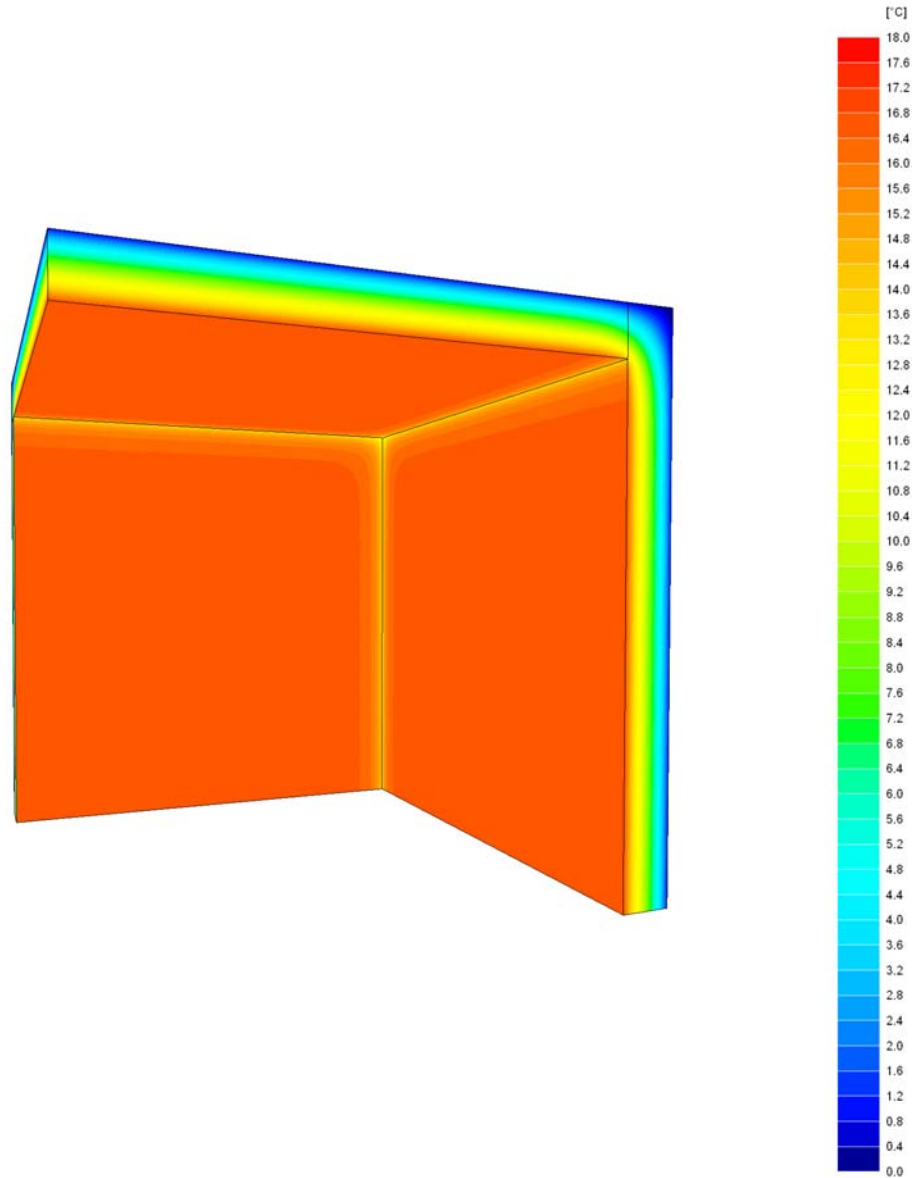
Figure 12 The heat flow regions evaluated

The Lawrence Berkeley Laboratory FEA software tool - THERM 5.2.14 - was used to calculate the heat transfer through the parts of the structure with 2D heat flows (HF) and the boundary heat flows at the specimen edge, referred to as the boundary loss. An edge section was modelled using the radiation enclosure feature of THERM. The model of the skylight edges is shown with colour coded isotherms in Figure 13.

Figure 13 EPS skylight THERM model

The Physibel 3D FEA software package TRISCO was used to calculate the heat transfer through the corners. The 3D model of the skylight corner is shown in Figure 14, again with colour coded isothermal regions.

Figure 14 TRISCO model of EPS skylight corner



The calculation method is summarised in the equation below.

$$L_{ij} = \sum_{n=1}^N L_{n(i,j)}^{3D} + \sum_{m=1}^M L_{m(i,j)}^{2D} \cdot l_m + \sum_{k=1}^K U_{k(i,j)} \cdot A_k$$

where

$L_{n(i,j)}^{3D}$ = is the thermal coupling coefficient obtained from a 3-D calculation for part n of the skylight.

$L_{m(i,j)}^{2D}$ = is the linear thermal coupling coefficient obtained from a 2-D calculation for part m of the skylight.

l_m = is the length over which the value $L_{m(i,j)}^{2D}$ applies

$U_{k(i,j)}$ = is the thermal transmittance obtained from a 1D calculation for part k of the skylight.

A_k = is the area over which the value U_k applies

N = is the number of 3D parts

The details of the calculations made to produce the $L_{m(i,j)}^{2D}$ and the $L_{n(i,j)}^{3D}$ values are shown in Table 41 and the details of the calculations made of the overall U-value of the EPS skylight for vertical upward heat flow are shown in Table 42 and for horizontal heat flow in Table 43.

9.4 Description of measurements made of the EPS skylight

The measurements of the EPS skylight were made with it mounted on the surround panel Rothold2 in the Rotatable Wall Guarded Hot Box. Measurements were carried out as follows:

- i. with the skylight mounted vertically (horizontal heat flow)
- ii. with the skylight mounted horizontally (vertically up heat flow).

In each case the U-value was derived from the measured values in two ways:

- i. using the procedures specified in prEN 12567-2:
- ii. using the classic procedures as described in BS EN ISO 8990

Some additional measurements were carried out with either special thermocouple and/or air velocity probe layouts and with different air flow regimes in the HOT side. A list of those measurements is given below:

- i. vertically up heat flow with no hot box fan
- ii. horizontal heat flow with additional thermocouples and the air velocity probe “inside” the skylight near the centre of the back surface
- iii. vertically up heat flow with additional thermocouples and the air velocity probe “inside” the skylight near the centre of the back surface

Table 41 Details of calculations made of the 2D & 3D heat flows

Calculation of the 2d heat transfer	
Heat flow at the EDGES - 1D calculation	
Width of vertical up HF	0.28 m ²
Width of horizontal HF	0.3 m ²
Heat flow through 1 m of vertically up HF	7.561337 W
Heat flow through 1 m of horizontal HF	7.786042 W
Total power through 1 m length of corner 1D method	15.34738 W
Heat flow at the EDGES - 2D calculation from THERM	
U-value of section from THERM-Radiation enclosure	1.3635 W/m ² .K
Power through 1 m of edge from THERM	15.8166 W
Extra heat flow 2D - 1D values	0.469221 W/m
Total length of edge	6.22 m
Total power through edge sections	2.920431 W

Calculation of the 3D heat transfer	
Heat flow at the CORNERS - 1D calculation	
Internal width of EPS with horizontal HF number 1	0.2 m
Internal height of EPS with horizontal HF number 1	0.2 m
Internal width of EPS with horizontal HF number 2	0.2 m
Internal height of EPS with horizontal HF number 2	0.2 m
Internal width of EPS with vertically up HF number 1	0.2 m
Internal height of EPS with vertically up HF number 1	0.2 m
Area of EPS with horizontal HF number 1	0.04 m ²
Area of EPS with horizontal HF number 2	0.04 m ²
Area of EPS with vertically up HF number 1	0.04 m ²
Total internal area of corner	0.12 m ²
Heat flow through EPS with horizontal HF number 1	1.038139 m ²
Heat flow through EPS with horizontal HF number 2	1.038139 W
Heat flow through EPS with vertically up HF number 1	1.080191 W
Heat flow through EPS with horizontal HF number 3 [Note 1]	1.038139
Total power through 0.23 x 0.23 x 0.23 m corner 1D method	3.114417 W
Heat flow at the CORNERS - 3D calculation from TRISCO	
Power through this corner from TRISCO	3.23 W
Power through corner using 1D method	3.114417 W
Extra heat flow 3D - 1D values	0.115583 W/m
Total length of edge	6.22 m
Total power through edge sections	0.71939 W

Note 1

The TRISCO model used only uses 1 internal heat transfer coefficient of 7.69 W/m².K

Table 42 U-value calculation details - EPS skylight –Vertically up HF

Overall U-value calculation	
Internal length of long sides of EPS skylight	1.48 m
Internal length of short sides of EPS skylight	1.23 m
Internal depth of EPS skylight	0.201 m
Internal area of the 2 long sides	0.5950 m ²
Internal area of the 2 short sides	0.4945 m ²
Internal area of the top surface	1.8204 m ²
Total area	2.9098 m ²
Aperture	1.8204 m ²
Total surface resistance with horizontal HF	0.17 m ² .K/W
Total surface resistance with vertically up HF	0.14 m ² .K/W
Thermal conductivity of the EPS @ 10 °C	0.0328 W/m.K
Thickness of EPS used to make skylight	0.0197 m
Thermal conductance of the EPS	1.6650 W/m ² .K
Thermal resistance of the EPS	0.6006 m ² .K/W
Total resistance of EPS + boundaries with vertically up HF	0.7406 m ² .K/W
Total resistance of EPS + boundaries with horizontal HF	0.7706 m ² .K/W
Air temperature difference	20 K
Density of heat flow with horizontal HF	25.9535 W/m ²
Density of heat flow with vertically up HF	27.0048 W/m ²
Heat flow with horizontal HF through EPS	28.2742 W
Heat flow with vertically up HF through EPS	49.1595 W
Total 1D heat flow through EPS with 20 °C temp diff	77.4337 W
Total length of EPS skylight with 2D HF	6.22 m
Power through 1m length of 2D HF edge	0.4692 W
Total 2D heat flow through EPS	2.920 W
Total number of corners where 3D HF takes place	4.00
Power through each 3D HF corner	0.12 W
Total 3D heat flow through EPS	0.46 W
Total heat flow through EPS with 20 °C drop	80.8165 W
Calculated U-value of EPS skylight	2.22 W/m².K

Table 43 U-value calculation details - EPS skylight –Horizontal HF

Overall U-value calculation	Horizontal heat flow
Internal length of long sides of EPS skylight	1.48 m
Internal length of short sides of EPS skylight	1.23 m
Internal depth of EPS skylight	0.201 m
Internal area of the each of the long sides	0.2975 m ²
Internal area of each of the short sides	0.2472 m ²
Internal area of the top surface	1.8204 m ²
Aperture	1.8204 m ²
Total surface resistance with horizontal HF	0.17 m ² .K/W
Total surface resistance with vertically up HF	0.14 m ² .K/W
Total surface resistance with vertically down HF	0.21 m ² .K/W
Thermal conductivity of the EPS @ 10 °C	0.0328 W/m.K
Thickness of EPS used to make skylight	0.0197 m
Thermal conductance of the EPS	1.6650 W/m ² .K
Thermal resistance of the EPS	0.6006 m ² .K/W
Total resistance of EPS + boundaries with vertically up HF	0.7406 m ² .K/W
Total resistance of EPS + boundaries with vertically down HF	0.8106 m ² .K/W
Total resistance of EPS + boundaries with horizontal HF	0.7706 m ² .K/W
Air temperature difference	20 K
Density of heat flow with horizontal HF	25.9535 W/m ²
Density of heat flow with vertically up HF	27.0048 W/m ²
Density of heat flow with vertically down HF	24.6728 W/m ²
Heat flow with horizontal HF through EPS	62.6870 W
Heat flow with vertically up HF through EPS	6.6764 W
Heat flow with vertically down HF through EPS	6.0999 W
Total 1D heat flow through EPS with 20 °C temp diff	69.3634 W
Total length of EPS skylight with 2D HF	6.22 m
Power through 1m length of 2D HF edge	0.4692 W
Total 2D heat flow through EPS	2.920 W
Total number of corners where 3D HF takes place	4.00
Power through each 3D HF corner	0.12 W
Total 3D heat flow through EPS	0.46 W
Total heat flow through EPS with 20 °C drop	72.7461 W
Calculated U-value of EPS skylight	2.00 W/m².K

9.5 Results of measurements on EPS skylight

9.5.1 Horizontal heat flow & prEN 12567-2 & ISO 8990 procedures.

The specimen was mounted as shown in Figure 11 and measured with horizontal heat flow. The detailed results using the ISO 8990 procedures can be seen in Table 44 and the details of the U-value derivation using the procedures specified in prEN 12567-2 can be seen in Table 45, Table 46 and Table 47. The hot and cold air temperatures can be seen in Figure 15 and the surface temperatures of the skylight can be seen in Figure 16. With the specimen still in the vertical position (horizontal heat flow) the measurement was repeated with additional thermocouples on the skylight “roof”; in the air near the roof; on the hot baffle and the air velocity probe mounted inside the skylight. The hot and cold air temperatures in these places can be seen in Figure 17 along with the hot side surface resistances calculated for a few places on the inside surface of the EPS roof.

9.5.2 Vertical heat flow & prEN 12567-2 & ISO 8990 procedures

Without altering the specimen, the apparatus was rotated to put the specimen in the horizontal position and the measurement repeated with vertically up heat flow. The detailed results using the ISO 8990 procedures can be seen in Table 48 and the details of the U-value derivation using the procedures specified in prEN 12567-2 can be seen in Table 49, Table 50 and Table 51. The hot and cold air temperatures can be seen in Figure 18 and the surface temperatures of the skylight can be seen in Figure 19. With the specimen still in the vertical position (horizontal heat flow) the measurement was repeated with additional thermocouples on the skylight “roof”; in the air near the roof; on the hot baffle and the air velocity probe mounted inside the skylight. The hot and cold air temperatures in these places can be seen in Figure 20.

9.5.3 Vertical heat flow & no warm side fan & prEN 12567-1 & ISO 8990 procedures

With the specimen in the horizontal position (vertically up heat flow) the warm side fan was turned off and the measurement repeated. The detailed results using the ISO 8990 procedures can be seen in Table 52 and the details of the U-value derivation using the procedures specified in prEN 12567-2 can be seen in Table 53, Table 54 and Table 55. The hot and cold air temperatures can be seen in Figure 21. Additional thermocouples were used on the skylight “roof”; in the air near the roof; on the hot baffle and the air velocity probe was mounted inside the skylight. The hot and cold air temperatures in these places can be seen in along with the hot side surface resistances calculated for a few places on the inside surface of the EPS roof in Figure 22.

Holder panel ID	Rothhold2
R10a	Ho
EPS Ideal Skylight	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Date & Time	Specimen area	Holder Th Cond.	Holder	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen Hot surface	Specimen Cold surface	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Divinity boundary loss
	(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(%)
"28/04/2003 03:50:48	1.793	0.0337	0.0	92.015	23.065	3.253	18.688	4.243	23.687	3.067	21.907	3.246	-0.30	
"28/04/2003 05:50:45	1.793	0.0337	0.0	91.953	23.058	3.200	18.625	4.187	23.697	3.032	21.900	3.209	4.00	
"28/04/2003 07:50:40	1.793	0.0337	0.0	91.952	23.043	3.182	18.584	4.173	23.674	2.967	21.878	3.168	5.20	
"28/04/2003 09:50:45	1.793	0.0337	0.0	91.640	23.048	3.207	18.558	4.191	23.670	2.995	21.871	3.194	-1.30	
"29/04/2003 11:47:13	1.793	0.0337	0.0	91.626	23.029	3.258	18.616	4.242	23.676	3.053	21.873	3.244	-2.50	
Averages	1.793	0.0337	0.0	91.837	23.049	3.220	18.614	4.207	23.681	3.023	21.886	3.212	1.02	

Date & Time		Total power		Surround Surface		Power		Surface		Air temperatures			Environmental temperatures			Baffle temperatures			Thermal			Surface Resistance		
		Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	
Corfor	HFEM Off	(W)	(°C)	(°C)	(°C)	through Insert	minus BL%	surface temp	Temp diff	Hot	Cold	diff	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(m².K/W)	(m².K/W)	(m².K/W)	
Area of specimen		1.7932	m²	Thick @ edge				mm		Bound Loss (W)		3.148	Mean temp		11.411		°C		Hr (c)		5.722			
	Area holder	3.9945	m²	Holder thickness				m					λ Holder		0.0337		W/m.K		Hr (h)		4.807			
Fifth		n/a	mm	Baffle Emis. Hot						Spec. Emis. Hot		0.9	Emissivity Factor		Hot		0.8511		Tot Res		0.1345			
				Baffle Emis Cold						Spec. Emis. Cold		0.9	Emissivity Factor		Cold		0.8511							
"28/04/2003 03:50:48		92.015	23.065	3.253	4.243	14.445	23.687	3.067	20.621	22.790	3.083	19.707	21.907	3.246	2.744	2.011	0.103	0.029						
"28/04/2003 05:50:45		91.941	23.058	3.200	4.187	14.437	23.697	3.032	20.666	22.778	3.048	19.731	21.900	3.209	2.741	2.005	0.105	0.029						
"28/04/2003 07:50:40		91.935	23.043	3.182	4.173	14.412	23.674	2.967	20.707	22.752	2.986	19.766	21.878	3.168	2.745	2.002	0.105	0.030						
"28/04/2003 09:50:45		91.644	23.048	3.207	4.191	14.367	23.670	2.995	20.675	22.741	3.014	19.726	21.871	3.194	2.743	1.998	0.106	0.030						
"29/04/2003 11:47:13		91.634	23.029	3.258	4.242	14.374	23.676	3.053	20.623	22.754	3.071	19.684	21.873	3.244	2.744	2.004	0.105	0.030						
		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
Av. Values		91.834	23.049	3.220	4.207	14.407	23.681	3.023	20.658	22.763	3.040	19.723	21.886	3.212	2.743	2.004	0.105	0.030						
Variation		0.42%	0.036	0.076	0.070	0.54%	0.027	0.099	0.42%	0.049	0.097	0.42%	0.035	0.078	0.17%	0.66%	0.003	0.001						
Surround temp difference		19.829		°C		Atmospheric pressure		0.0		mb		CEN as measured		U-value		2.069								
Surround mean temperature		13.134		°C								% difference				-3.1								

Table 45 EPS skylight - Horizontal HF – prEN 12567-2 - Table C5

Table C5 Window Data and measurement results			
frame width	w	m	0.0196
frame insertion into surround panel	w	m	0.1497
depth of reveal	d _p	m	0.1497
surround panel thickness	d _{sur}	m	0.1497
area of window	A _{sp}	m ²	1.7932
area of surround panel	A _{sur}	m ²	3.9945
perimeter length	L	m	5.382
Warmside View factor - calibration to baffle	f _{cb}	1 - 1.3 x d _{p,e}	0.8054
Warmside View factor - surround panel reveal to surround panel reveal	f _{pp}	1 x d _{p,e}	0.1497
Warmside View factor - calibration panel to surround panel reveal	f _{cp}	A.11	0.1946
Warmside View factor - Surround panel reveal to baffle	f _{pb}	A.12	0.4252
Warmside View factor - baffle to surround panel reveal	f _{bp}	A.11	0.1946
Hemispherical emissivity calibration panel	ε _{cal}		0.837
Hemispherical emissivity baffle	ε _b		0.94
Hemispherical emissivity reveal	ε _p		0.94
Warmside Radiant factor from cal panel to baffle	α _{cb}	A.8	0.638
Warmside Radiant factor from cal panel to surround panel	α _{cp}	A.9	0.162

Table 46 EPS skylight - Horizontal HF – prEN 12567-2 - Table C6

Table C6 Window measurement results			
Cold temperatures			
air	θ _{ce}	°C	3.02
baffle	θ _{se,b}	°C	3.21
reveal surface	θ _{se,p}	°C	n/a
surround panel	θ _{se,sur}	°C	3.22
Warm temperatures			
air	θ _{ci}	°C	23.68
baffle	θ _{si,b}	°C	21.89
reveal surface	θ _{si,p}	°C	21.05
surround panel	θ _{si,sur}	°C	23.05
input power	φ _{in}	W	91.83
air flow warm side (down)	v _i	m/s	0.24
air flow cold side (up)	v _e	m/s	3.1

Table 47 EPS skylight - Horizontal HF - prEN12567-2 - Table C7

Table C7 Calculation of the thermal transmittance of specimen - R10a					Remarks
Temperature mean surround panel	$\theta_{me,sur}$	°C	13.134		-
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	4.7919		Figure D1 / regression
Type of installation - Kerb (K) or Insert (I)	K				
Thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)	0.0337		-
Ψ_{edge} for w (mm) = 19.6	Ψ_{edge}	W/(m.K)	0.02831		Table B.3:
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	19.829		-
Temperature difference air	$\Delta\theta_c$	K	20.658		
Input power to hot box	ϕ_{in}	W	91.834		
Power through surround panel	Φ_{sur}	W	16.529		equation 12
Edge zone heat flow	Φ_{edge}	W	3.1477		equation 10
Heat flow density through specimen	q_{sp}	W/m ²	40.2406		equation 11
Warm side convective fraction	$F_{c,i}$	-	0.4040		Figure D3 / regression
Cold side convective fraction	$F_{c,e}$	-	0.8172		Figure D3 / regression
Total surface resistance	$R_{s,t}$	(m ² .K)/W	0.1714		Figure D2 / regression
Mean radiant temperature warm side	$\theta_{r,i}$	°C	21.72		equation A.3
Mean radiant temperature cold side	$\theta_{r,e}$	°C	3.21		equation A.2
Warm side environmental temperature	θ_{ni}	°C	22.511		equation 7
Cold side environmental temperature	θ_{ne}	°C	3.057		equation 7
Environmental temperature difference	$\Delta\theta_{n,cal}$	K	19.453		
Environmental temperature mean	$\theta_{n,cal}$	°C	12.784		
U-value measured	U_m	W/(m².K)	2.069		equation 13
Uncertainty	ΔU_m	W/(m ² .K)	0.11		

Figure 15 EPS skylight - horizontal heat flow - Air temperatures

HOT SIDE AIR TEMPERATURES					COLD SIDE AIR TEMPERATURES						
All t/cs	23.85	Windows	23.69	Doors	23.64	All Air	3.03	Windows	3.07	Doors	3.05
	24.35	24.1	24.03	24.01	24.24		3.04	3.07	3.16	3.01	3.00
	24.26	24.01	23.8	23.86	24.17		3.00	3.07	3.14	3.01	2.98
	24.17	23.89	23.31	23.73	24.07		3.02	3.06	3.11	3.02	2.99
	24.14	23.64	23.35	23.59	24.03		3.00	3.04	3.13	3.02	2.98
	24.11	23.23	22.99	23.07	24.02		3.00	2.96	3.01	2.98	2.98

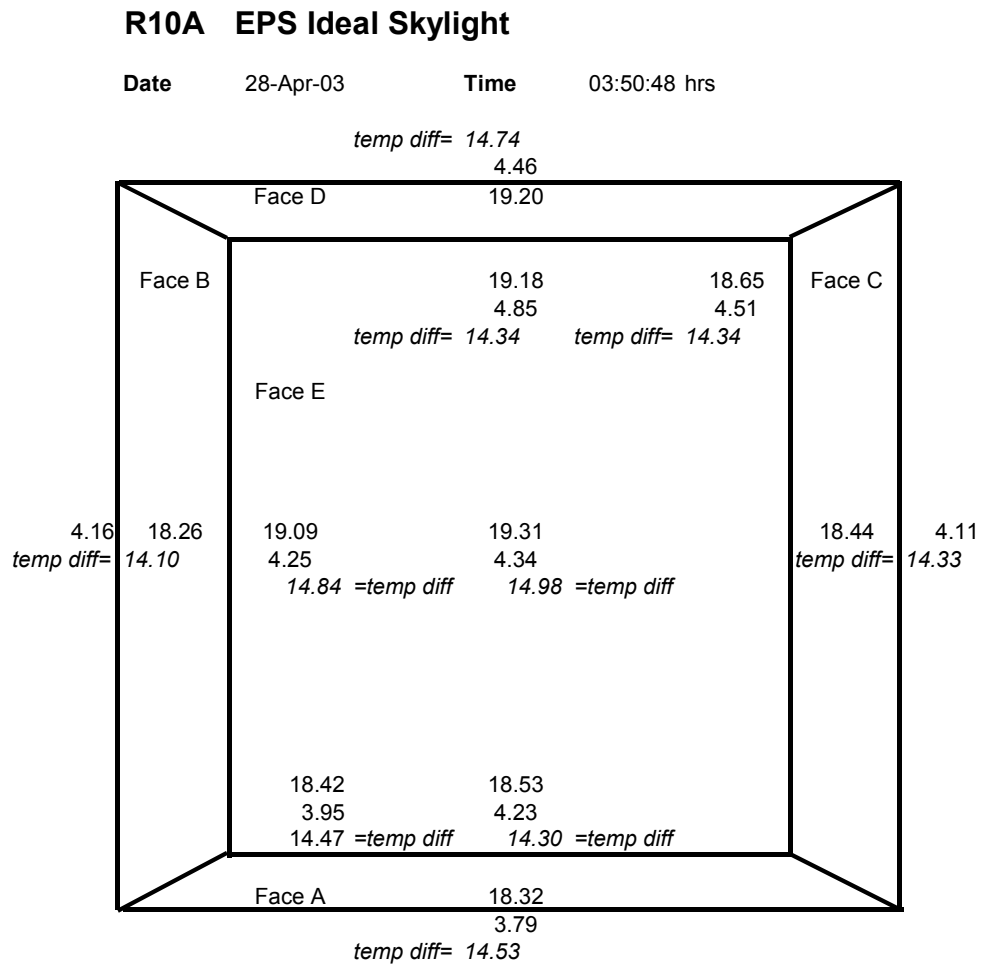
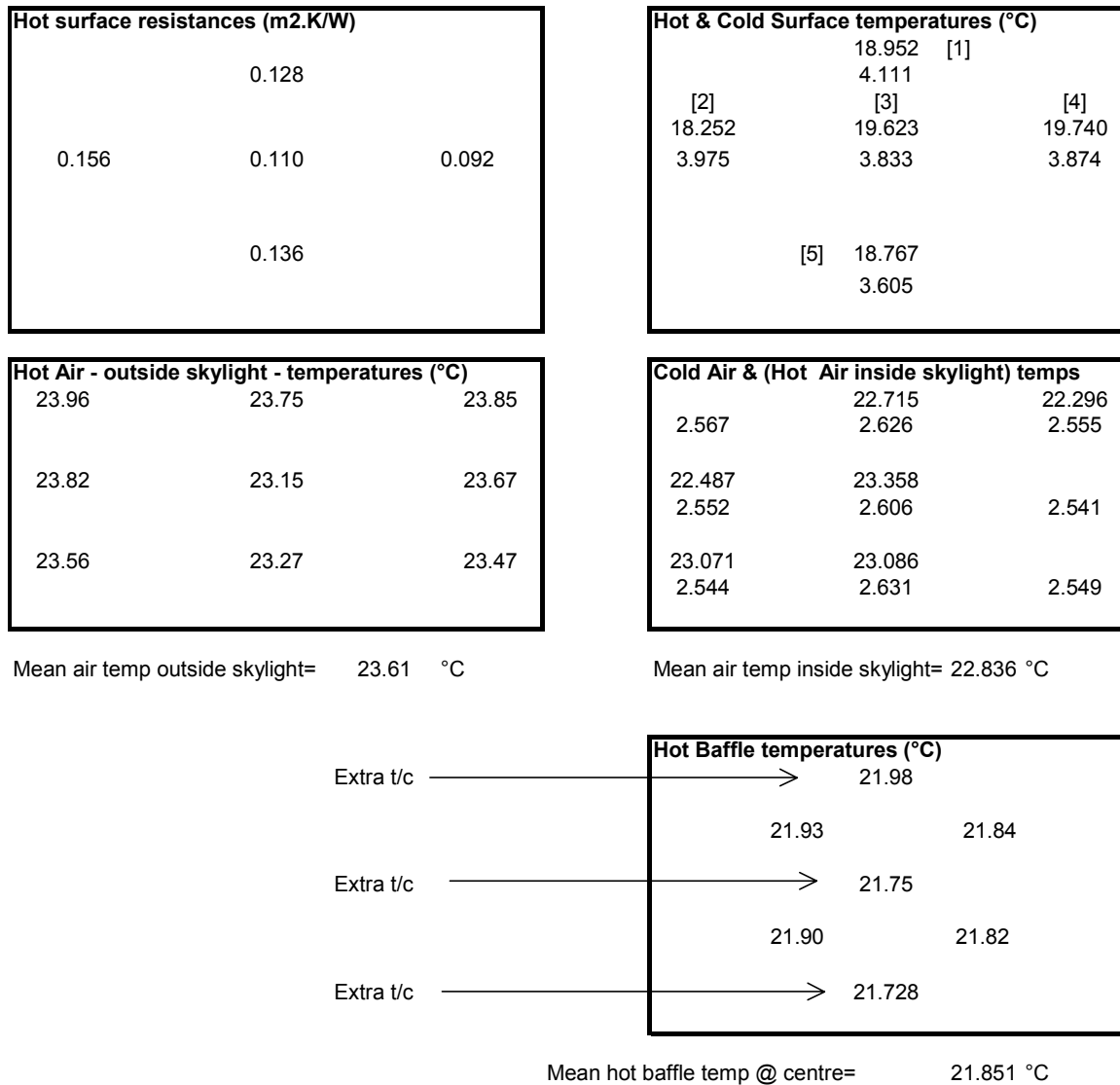
Figure 16 EPS skylight - horizontal heat flow - Surface temperatures

Figure 17 EPS skylight - Horizontal heat flow - Special temperatures

Holder panel ID	Rothold2
R10b	
EPS Skylight-Vertical HF	
Rotatable Hot Box	

Date & Time		Total power		Surround Surface		Power		Hot surface		Cold surface		Surface Temp diff		Air temperatures		Environmental temperatures		Baffle temperatures		Thermal		Surface Resistance	
		Corfor	HEM Off	Hot	Cold	through Insert	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Trans	Hot	Cold
		(W)	(°C)	(°C)	(°C)	(W)	minus BL%	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(m².K/W)	(m².K/W)	
Area of specimen	1.7932	m²				Thick @ edge																	
	Area holder	3.9945	m²			Holder thickness																	
	Eth	n/a	mm			Baffle Emis. Hot																	
						Baffle Emis Cold																	
2 May 2003 05:05:00	95.242	23.466	3.007	3.007	73.800	19.096	4.040	15.056	23.636	2.825	20.811	22.981	22.981	2.843	20.138	22.217	3.022	2.734	2.044	0.094	0.029	0.029	
2 May 2003 07:05:00	94.805	23.447	3.075	3.075	73.440	19.076	4.110	14.966	23.640	2.900	20.740	22.973	22.973	2.917	20.056	22.206	3.082	2.737	2.042	0.095	0.029	0.029	
2 May 2003 09:05:44	94.837	23.451	3.073	3.073	73.467	19.077	4.110	14.967	23.645	2.887	20.758	22.972	22.972	2.904	20.067	22.196	3.073	2.737	2.042	0.095	0.029	0.029	
2 May 2003 11:05:41	95.210	23.463	3.073	3.073	73.829	19.091	4.110	14.981	23.643	2.897	20.747	22.981	22.981	2.914	20.067	22.208	3.082	2.748	2.052	0.094	0.029	0.029	
2 May 2003 13:05:38	95.423	23.456	3.051	3.051	74.029	19.093	4.080	15.013	23.652	2.862	20.791	22.982	22.982	2.880	20.103	22.197	3.054	2.750	2.054	0.094	0.029	0.029	
Av. Values	95.103	23.457	3.056	3.056	73.713	19.087	4.090	14.997	23.643	2.874	20.769	22.978	22.978	2.891	20.086	22.205	3.063	2.741	2.047	0.095	0.029	0.029	
	Variation	0.65%	0.018	0.068	0.068	0.80%	0.021	0.070	0.60%	0.016	0.075	0.34%	0.011	0.073	0.41%	0.022	0.060	0.60%	0.59%	0.001	0.000	0.000	
Surround temp difference			°C	CEN as measured U-value																			2.119
Surround mean temperature			°C	% difference																			-3.4

Table 49 EPS skylight - Vertically up HF - prEN12567-2 - Table C5

Table C5 Window Data and measurement results			
frame width	w	m	0.0200
frame insertion into surround panel	w	m	0.1497
depth of reveal	d _p	m	0.1497
surround panel thickness	d _{sur}	m	0.1497
area of window	A _{sp}	m ²	1.7932
area of surround panel	A _{sur}	m ²	3.9945
perimeter length	L	m	5.382
Warmside View factor - calibration to baffle	f _{cb}	1 - 1.3 x d _{p,e}	0.8054
Warmside View factor - surround panel reveal to surround panel reveal	f _{pp}	1 x d _{p,e}	0.1497
Warmside View factor - calibration panel to surround panel reveal	f _{cp}	A.11	0.1946
Warmside View factor - Surround panel reveal to baffle	f _{pb}	A.12	0.4252
Warmside View factor - baffle to surround panel reveal	f _{bp}	A.11	0.1946
Hemispherical emissivity calibration panel	ε _{cal}		0.837
Hemispherical emissivity baffle	ε _b		0.94
Hemispherical emissivity reveal	ε _p		0.94
Warmside Radiant factor from cal panel to baffle	α _{cb}	A.8	0.638
Warmside Radiant factor from cal panel to surround panel	α _{cp}	A.9	0.162

Table 50 EPS skylight - Vertically up HF - prEN12567-2 - Table C6

Table C6 Window measurement results			
Cold temperatures			
air	θ _{ce}	°C	2.87
baffle	θ _{se,b}	°C	3.06
reveal surface	θ _{se,p}	°C	n/a
surround panel	θ _{se,sur}	°C	3.06
Warm temperatures			
air	θ _{ci}	°C	23.64
baffle	θ _{si,b}	°C	22.20
reveal surface	θ _{si,p}	°C	21.09
surround panel	θ _{si,sur}	°C	23.46
input power	φ _{tn}	W	95.10
air flow warm side (down)	v _i	m/s	0.48
air flow cold side (up)	v _e	m/s	3.17

Table 51 EPS skylight - Vertically up HF - prEN12567-2 - Table C7

Table C7 Calculation of the thermal transmittance of specimen - R10b					Remarks
Temperature mean surround panel	$\theta_{me,sur}$	°C	13.256	-	-
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	4.7896	Figure D1 / regression	
Type of installation - Kerb (K) or Insert (I)	K				
Thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)	0.0337	-	
Ψ_{edge} for w (mm) = 20.0	Ψ_{edge}	W/(m.K)	0.02731	Table B.3:	
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	20.401	-	
Temperature difference air	$\Delta\theta_c$	K	20.769		
Input power to hot box	ϕ_{in}	W	95.103		
Power through surround panel	Φ_{sur}	W	17.014	equation 12	
Edge zone heat flow	Φ_{edge}	W	3.0526	equation 10	
Heat flow density through specimen	q_{sp}	W/m ²	41.8464	equation 11	
Warm side convective fraction	$F_{c,i}$	-	0.4095	Figure D3 / regression	
Cold side convective fraction	$F_{c,e}$	-	0.8125	Figure D3 / regression	
Total surface resistance	$R_{s,t}$	(m ² .K)/W	0.1710	Figure D2 / regression	
Mean radiant temperature warm side	$\theta_{r,i}$	°C	21.98	equation A.3	
Mean radiant temperature cold side	$\theta_{r,e}$	°C	3.06	equation A.2	
Warm side environmental temperature	θ_{ni}	°C	22.661	equation 7	
Cold side environmental temperature	θ_{ne}	°C	2.909	equation 7	
Environmental temperature difference	$\Delta\theta_{n,cal}$	K	19.752		
Environmental temperature mean	$\theta_{n,cal}$	°C	12.785		
U-value measured	U_m	W/(m².K)	2.119	equation 13	
Uncertainty	ΔU_m	W/(m ² .K)	0.18		

Figure 18 EPS skylight - Vertically up heat flow - Air temperatures

HOT SIDE AIR TEMPERATURES					R10b	COLD SIDE AIR TEMPERATURES					
All t/c: 24.01	Windows	23.65	Doors	23.73	2 May 2003 09:05:44	All Air	2.85	Windows	2.89	Doors	2.87
24.75	24.5	24.3	24.2	24.4		2.84	2.87	2.99	2.86	2.87	
24.6	24.2	24	24	24.3		2.82	2.88	2.95	2.86	2.84	
24.6	23.6	23.7	23.2	24.3		2.82	2.87	2.92	2.85	2.84	
24.5	23.6	23.4	23.1	24.2		2.80	2.85	2.94	2.86	2.83	
24.4	23.5	23.5	23.2	24.1		2.79	2.78	2.82	2.80	2.82	

Figure 19 EPS skylight - Vertically up heat flow - Surface temperatures

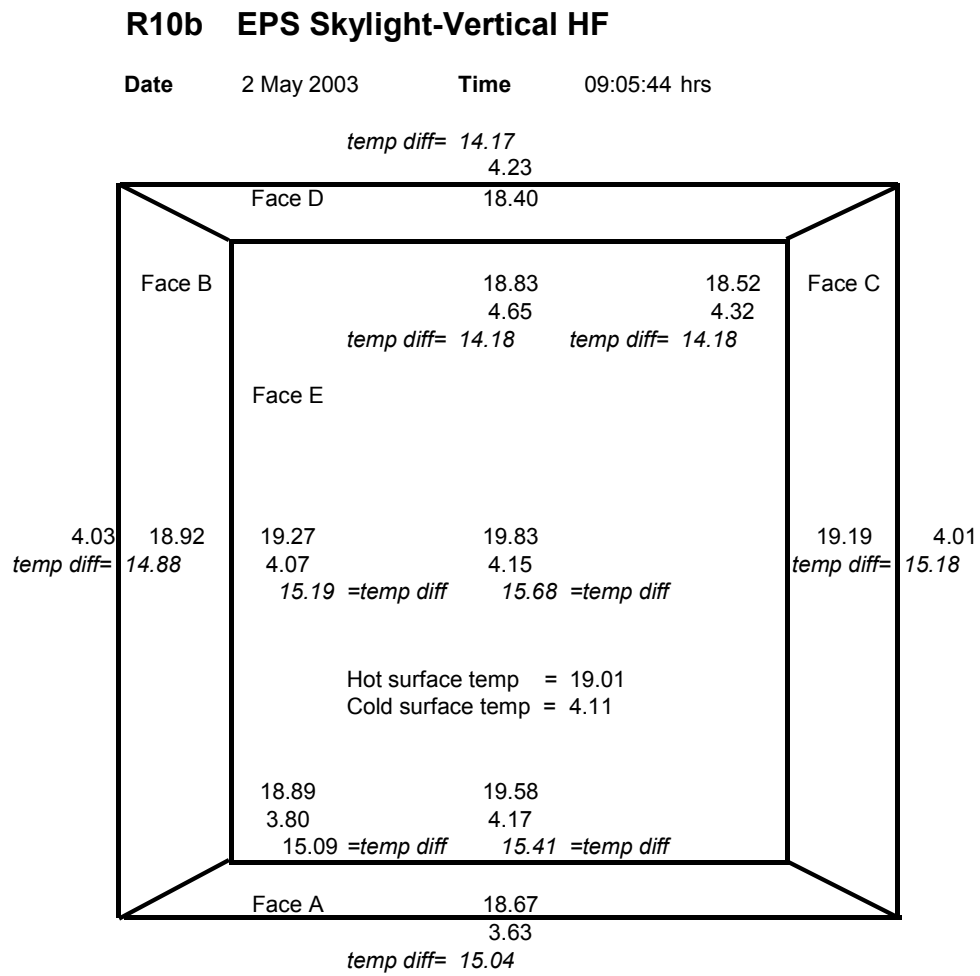


Figure 20 Vertically up heat flow - Special temperatures**R10D****28-Jul-03****06:59:42 hrs****Hot surface resistances (m².K/W)**

	0.117	
0.148	0.102	0.018
	0.106	

Hot & Cold Surface temperatures (°C)

	19.214	[1]
	4.145	
[2]	[3]	[4]
18.522	19.768	21.850
3.975	3.843	3.794
	[5]	19.691
		3.608

Hot Air - outside skylight - temperatures (°C)

24.12	23.89	23.91
23.60	23.39	23.25
23.38	23.20	22.93

Cold Air & (Hot Air inside skylight) temps

	22.336	22.271
2.488	2.580	2.555
22.425	22.928	
2.462	2.539	2.469
23.096	23.128	
2.457	2.560	2.469

Mean air temp outside skylight= 23.52 °C

Mean air temp inside skylight= 22.697 °C

Extra t/c

Extra t/c

Extra t/c

Hot Baffle temperatures (°C)

→	22.10	
	22.18	21.98
→	21.90	
	22.24	22.02
→	22.103	

Mean hot baffle temp @ centre= 22.076 °C

Holder panel ID
R10E

Rothold2

Vertical Heat Flow + Extra air, baffle & surface t/cs, No hot box fan

[illegible]

Table 53 EPS skylight - Vertically up HF - No hot box fan - prEN12567-2 - Table C5

Table C5 Window Data and measurement results			
frame width	w	m	0.0196
frame insertion into surround panel	w	m	0.1497
depth of reveal	d _p	m	0.1497
surround panel thickness	d _{sur}	m	0.1497
area of window	A _{sp}	m ²	1.7932
area of surround panel	A _{sur}	m ²	3.9945
perimeter length	L	m	5.382
Warmside View factor - calibration to baffle	f _{cb}	1 - 1.3 x d _{p,e}	0.8054
Warmside View factor - surround panel reveal to surround panel reveal	f _{pp}	1 x d _{p,e}	0.1497
Warmside View factor - calibration panel to surround panel reveal	f _{cp}	A.11	0.1946
Warmside View factor - Surround panel reveal to baffle	f _{pb}	A.12	0.4252
Warmside View factor - baffle to surround panel reveal	f _{bp}	A.11	0.1946
Hemispherical emissivity calibration panel	ε _{cal}		0.837
Hemispherical emissivity baffle	ε _b		0.94
Hemispherical emissivity reveal	ε _p		0.94
Warmside Radiant factor from cal panel to baffle	α _{cb}	A.8	0.638
Warmside Radiant factor from cal panel to surround panel	α _{cp}	A.9	0.162

Table 54 EPS skylight - Vertically up HF - No hot box fan - prEN12567-2 - Table C6

Table C6 Window measurement results			
Cold temperatures			
air	θ _{ce}	°C	2.50
baffle	θ _{se,b}	°C	2.69
reveal surface	θ _{se,p}	°C	A
surround panel	θ _{se,sur}	°C	2.69
Warm temperatures			
air	θ _{ci}	°C	22.35
baffle	θ _{si,b}	°C	21.24
reveal surface	θ _{si,p}	°C	21.05
surround panel	θ _{si,sur}	°C	22.68
input power	φ _{in}	W	93.61
air flow warm side (down)	v _i	m/s	0.28
air flow cold side (up)	v _e	m/s	3.11

Table 55 EPS skylight - Vertically up HF - No hot box fan - prEN12567-2 - Table C7

Table C7 Calculation of the thermal transmittance of specimen - R10E					Remarks
Temperature mean surround panel	$\theta_{me,sur}$	°C	12.682	-	-
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	4.8003	Figure D1 / regression	
Type of installation - Kerb (K) or Insert (I)	K				
Thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)	0.0336	-	
Ψ_{edge} for w (mm) = 19.6	Ψ_{edge}	W/(m.K)	0.02831	Table B.3:	
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	19.993	-	
Temperature difference air	$\Delta\theta_c$	K	19.854		
Input power to hot box	ϕ_{in}	W	93.614		
Power through surround panel	Φ_{sur}	W	16.636	equation 12	
Edge zone heat flow	Φ_{edge}	W	3.0252	equation 10	
Heat flow density through specimen	q_{sp}	W/m ²	41.2420	equation 11	
Warm side convective fraction	$F_{c,i}$	-	0.4042	Figure D3 / regression	
Cold side convective fraction	$F_{c,e}$	-	0.8183	Figure D3 / regression	
Total surface resistance	$R_{s,t}$	(m ² .K)/W	0.1715	Figure D2 / regression	
Mean radiant temperature warm side	$\theta_{r,i}$	°C	21.20	equation A.3	
Mean radiant temperature cold side	$\theta_{r,e}$	°C	2.69	equation A.2	
Warm side environmental temperature	θ_{ni}	°C	21.666	equation 7	
Cold side environmental temperature	θ_{ne}	°C	2.530	equation 7	
Environmental temperature difference	$\Delta\theta_{n,cal}$	K	19.136		
Environmental temperature mean	$\theta_{n,cal}$	°C	12.098		
U-value measured	U_m	W/(m².K)	2.155	equation 13	
Uncertainty	ΔU_m	W/(m ² .K)	0.18		

Figure 21 EPS skylight - Vertically up heat flow - No hot box fan - Air temperatures

HOT SIDE AIR TEMPERATURES					R10E 30-Jul-03 07:21:50	COLD SIDE AIR TEMPERATURES				
All t/c: 22.93	Windows	22.36	Doors	22.86		All Air	2.50	Windows	2.52	Doors
24.98	25.3	24.7	24	22.1		2.48	2.51	2.63	2.52	2.55
24.6	23.8	22.6	22.1	21.7		2.43	2.50	2.59	2.51	2.52
24.2	21.9	21.8	22	21.8		2.43	2.49	2.56	2.50	2.52
23.8	22.9	22.1	22.1	21.8		2.42	2.47	2.58	2.50	2.51
23.4	23.1	22.4	22.2	21.8		2.42	2.40	2.45	2.45	2.49

Figure 22 EPS skylight - Vertically up heat flow - No hot box fan - Special temperatures**R10E****30-Jul-03****07:21:50 hrs**

Hot surface resistances (m ² .K/W)		
	0.090	
0.140	0.108	0.069
	0.128	

Hot & Cold Surface temperatures (°C)		
	19.905	[1]
	4.202	
[2]	[3]	[4]
18.272	19.271	20.199
3.975	3.822	3.740
	[5]	18.622
		3.556

Hot Air - outside skylight - temperatures (°C)		
23.78	22.59	22.08
21.92	21.85	21.99
22.86	22.07	22.06

Cold Air & (Hot Air inside skylight) temps		
	23.121	23.116
2.503	2.593	2.555
22.588	23.074	
2.485	2.562	2.501
22.395	22.938	
2.467	2.575	2.503

Mean air temp outside skylight 22.36 °C**Mean air temp inside skylight 22.87 °C**

Hot Baffle	
Extra t/c →	21.47
	21.59 21.19
Extra t/c →	21.07
	21.21 20.98
Extra t/c →	21.159

Mean hot baffle temp @ centre= 21.239 °C

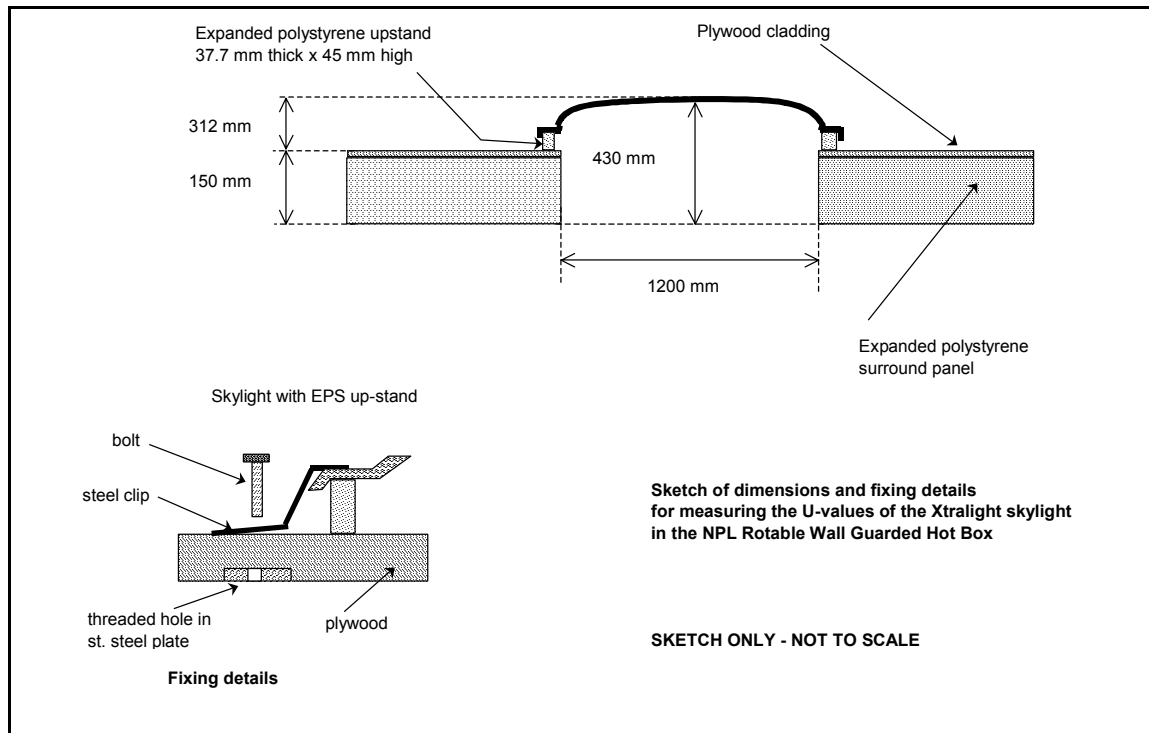
10 MEASUREMENT OF THE XTRALITE SKYLIGHT

10.1 Description of skylight and mounting arrangements

These measurements were carried out on a commercial skylight provided by Xtralite Ltd. The skylight was a double skinned, square based dome. A photograph of the skylight mounted in the surround panel ready to be installed in the Rotatable hot box, can be seen in Figure 23. A sketch showing the how the skylight was fixed to the surround panel is shown in Figure 24.

Figure 23 Xtralite skylight mounted in surround panel



Figure 24 Schematic diagram of skylight and fixing arrangement

10.2 Description of measurements made of Xtralite skylight

The skylight was mounted as described in Section 10.1, in the special surround panel Rothold3. It was then measured mounted vertically – with horizontal heat flow and then rotated into the horizontal position with vertically up heat flow. Again the U-value was calculated from the measured data in two ways; firstly using the basic method specified in BS EN ISO 8990 and secondly as specified in prEN 12567-2. The results of those measurements are given in Sections 10.3 and 10.4. For both methods an additional correction had to be made for the heat transfer through the EPS upstand. This was calculated from the upstand thermal conductivity, thickness, area and the temperature difference across it.

10.3 Results of measurements of Xtralite skylight - with horizontal heat flow

The detailed results using the ISO 8990 procedures can be seen in Table 56 and the details of the U-value derivation using the procedures specified in prEN 12567-2 can be seen in Table 57, Table 58 and Table 59. The hot and cold air temperatures and the surface temperatures of the skylight and upstand can be seen in Figure 25.

Table 56 Xtralite skylight - Horizontal HF - ISO 8990 Calculations

Holder panel ID

Rothold3

Xtralite Skylight - Horizontal heat flow

Rotatable Hot Box

R18D

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Date & Time	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen surface Hot	Specimen surface Cold	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	boundary loss
	(m²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(%)
1 Mar 2004"04:59:20"	1.440	0.0344	0.0	92.986	22.873	4.562	17.759	5.952	23.651	4.361	21.445	4.510	4.10	
1 Mar 2004"06:59:27"	1.440	0.0344	0.0	93.003	22.876	4.556	17.796	5.929	23.655	4.333	21.452	4.499	0.40	
1 Mar 2004"08:59:25"	1.440	0.0344	0.0	93.112	22.873	4.575	17.816	5.960	23.663	4.371	21.469	4.522	4.30	
1 Mar 2004"10:59:25	1.440	0.0344	0.0	93.222	22.870	4.544	17.831	5.932	23.664	4.333	21.445	4.492	-0.20	
1 Mar 2004"12:59:22	1.440	0.0344	0.0	92.994	22.863	4.554	17.841	5.942	23.629	4.391	21.439	4.516	-3.00	
Averages	1.440	0.0344	0.0	93.063	22.871	4.558	17.809	5.943	23.652	4.358	21.450	4.508	1.12	

Date & Time	Total power	Surround Surface Hot	Cold	Power thro' insert & Upstand minus BL	Holder Hot surface temp	Holder Cold surface temp	Surface Temp diff	Air temperatures Hot	Air temperatures Cold	diff	Environmental temperatures Hot	Environmental temperatures Cold	diff	Baffle temperatures Hot	Baffle temperatures Cold	Thermal Cond	Thermal Trans	Surface Resistance Hot	Surface Resistance Cold
	(W)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(W/m².K)	(m².K/W)	(m².K/W)
Area of specimen	1.4403	m²		Thick @ edge			mm	Bound Loss (W)		3.002		Mean temp		11.876	°C		Hr (c)	5.682	
Area holder	4.3473	m²		Holder thickness		0.15000	m					λ Holder		0.0344	W/m.K		Hr (h)	4.885	
Eith	n/a	mm		Baffle Emis. Hot		0.94		Spec. Emis. Hot		0.9		Emissivity Factor		Hot			Tot Res	0.1321	
				Baffle Emis Cold		0.94		Spec. Emis. Cold				Emissivity Factor		Cold					
1 Mar 2004"04:59:20"	92.973	22.873	4.562	69.166	17.759	5.952	11.807	23.651	4.361	19.290	22.580	4.376	18.204	21.445	4.510	4.067	2.638	0.100	0.033
1 Mar 2004"06:59:27"	93.001	22.876	4.556	69.204	17.796	5.929	11.867	23.655	4.333	19.321	22.592	4.350	18.241	21.452	4.499	4.049	2.634	0.100	0.033
1 Mar 2004"08:59:25"	93.098	22.873	4.575	69.320	17.816	5.960	11.857	23.663	4.371	19.292	22.607	4.387	18.220	21.469	4.522	4.059	2.641	0.100	0.033
1 Mar 2004"10:59:25	93.223	22.870	4.544	69.410	17.831	5.932	11.900	23.664	4.333	19.331	22.602	4.340	18.253	21.445	4.492	4.050	2.640	0.099	0.033
1 Mar 2004"12:59:22	93.003	22.863	4.554	69.217	17.841	5.942	11.900	23.629	4.391	19.238	22.584	4.403	18.181	21.439	4.516	4.039	2.643	0.099	0.032
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Av. Values	93.060	22.871	4.558	69.263	17.809	5.943	11.866	23.652	4.358	19.294	22.593	4.373	18.220	21.450	4.508	4.053	2.639	0.099	0.033
Variation	0.27%	0.014	0.030	0.35%	0.083	0.031	0.79%	0.035	0.058	0.48%	0.027	0.054	0.39%	0.030	0.030	0.71%	0.35%	0.002	0.001
Surround temp difference		18.313	°C				Atmospheric pressure		0.0	mb							CEN as measured U-value	2.687	
Surround mean temperature		13.715	°C														% difference	-1.8	

Table 57 Xtralite skylight - Horizontal HF - Table C5

Table C5 Window Data and measurement results			
frame width	w	m	0.0370
frame insertion into surround panel	w	m	0.1500
depth of reveal	d _p	m	0.1500
surround panel thickness	d _{sur}	m	0.15
area of window	A _{sp}	m ²	1.4403
area of surround panel	A _{sur}	m ²	4.3473
perimeter length	L	m	4.800
Warmside View factor - calibration to baffle	f _{cb}	1 -1.3 x d _{p,e}	0.805
Warmside View factor - surround panel reveal to surround panel reveal	f _{pp}	1 x d _{p,e}	0.15
Warmside View factor - calibration panel to surround panel reveal	f _{cp}	A.11	0.195
Warmside View factor - Surround panel reveal to baffle	f _{pb}	A.12	0.425
Warmside View factor - baffle to surround panel reveal	f _{bp}	A.11	0.195
Hemispherical emissivity calibration panel	ε _{cal}		0.837
Hemispherical emissivity baffle	ε _b		0.94
Hemispherical emissivity reveal	ε _p		0.94
Warmside Radiant factor from cal panel to baffle	α _{cb}	A.8	0.637
Warmside Radiant factor from cal panel to surround panel	α _{cp}	A.9	0.162

Table 58 Xtralight skylight - Horizontal HF - Table C6

Table C6 Window measurement results			
Cold temperatures			
air	θ _{ce}	°C	4.36
baffle	θ _{se,b}	°C	4.51
reveal surface	θ _{se,p}	°C	A
surround panel	θ _{se,sur}	°C	4.56
Warm temperatures			
air	θ _{ci}	°C	23.65
baffle	θ _{si,b}	°C	21.45
reveal surface	θ _{si,p}	°C	20.30
surround panel	θ _{si,sur}	°C	22.87
input power	φ _{in}	W	93.06
air flow warm side (down)	v _i	m/s	0.2
air flow cold side (up)	v _e	m/s	4.2

Table 59 Xtralite skylight - Horizontal HF - Table C7

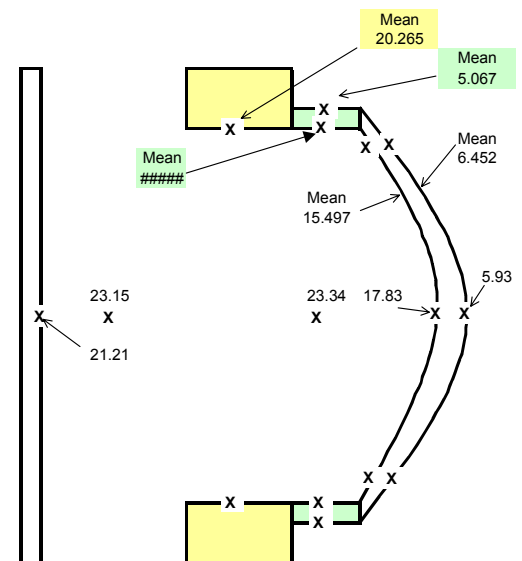
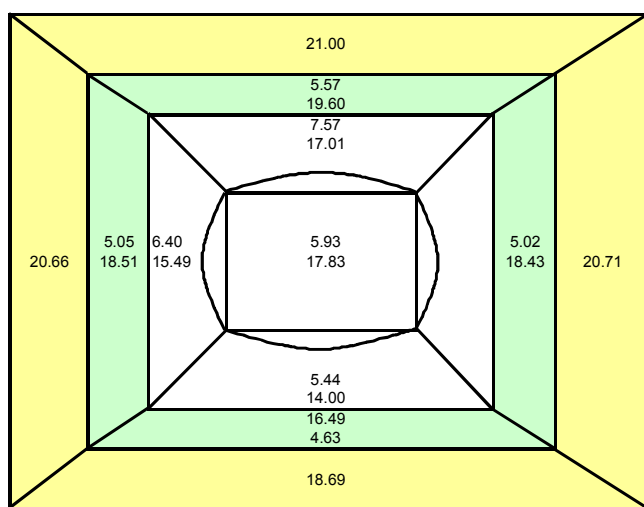
Table C7 Calculation of the thermal transmittance of specimen - R18D					Remarks
Temperature mean surround panel	$\theta_{me,sur}$	°C	13.715	-	-
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	4.3101	Figure D1 / regression	
Type of installation - Kerb (K) or Insert (I)	K				
Thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)	0.0344	-	
Ψ_{edge} for w (mm) = 37.0	Ψ_{edge}	W/(m.K)	0.01978	Table B.3:	
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	18.313	-	
Temperature difference air	$\Delta\theta_c$	K	19.294		
Input power to hot box	ϕ_{in}	W	93.060		
Power through surround panel & Upstand	Φ_{sur}	W	21.018	equation 12	
Edge zone heat flow	Φ_{edge}	W	3.00	equation 10 ^[1]	
Heat flow density through specimen	q_{sp}	W/m ²	47.9344	equation 11	
Warm side convective fraction	$F_{c,i}$	-	0.4145	Figure D3 / regression	
Cold side convective fraction	$F_{c,e}$	-	0.0000	Figure D3 / regression	
Total surface resistance	$R_{s,t}$	(m ² .K)/W	0.1744	Figure D2 / regression	
Mean radiant temperature warm side	$\theta_{r,i}$	°C	21.22	equation A.3	
Mean radiant temperature cold side	$\theta_{r,e}$	°C	4.51	equation A.2	
Warm side environmental temperature	θ_{ni}	°C	22.227	equation 7	
Cold side environmental temperature	θ_{ne}	°C	4.508	equation 7	
Environmental temperature difference	$\Delta\theta_{n,cal}$	K	17.719		
Environmental temperature mean	$\theta_{n,cal}$	°C	13.367		
U-value measured	U_m	W/(m².K)	2.705	equation 13	
Uncertainty	ΔU_m	W/(m ² .K)	0.23		

Note [1] 1.09 Watts added to make this value the same as the one simulated using THERM (Because plywood cladding alters the value - from 1.9 to 3 Watts)

Figure 25 Xtralite skylight - Horizontal HF - temperature profiles

R018D Xtralight-Horizontal heat flow
1 Mar 2004

10:59:25 hrs



Hot reveal	20.265 °C
Hot upstand	18.256 °C
Cold upstand	5.067 °C
Hot specimen	15.497 °C
Cold specimen	6.452 °C

ASSUME REVEAL TEMPERATURE INCLUDES UPSTAND TEMPERATURE

Reveal area	0.72 m ²	Reveal area weighted	15.59
Upstand area	0.216 m ²	Upstand area weighted	4.213
Total area	0.936 m ²	Area weighted reveal temp.	19.8

10.4 Results of measurements of Xtralite skylight - with vertically up HF

The detailed results using the ISO 8990 procedures can be seen in Table 61 and the details of the U-value derivation using the procedures specified in prEN 12567-2 can be seen in Table 62, Table 63 and Table 64. The hot and cold air temperatures and the surface temperatures of the skylight and upstand can be seen in Figure 26.

11 DISCUSSION

11.1 Accuracy of the NPL Rotatable Hot Box measurements.

The measurements carried out to validate the NPL Rotatable Wall Guarded Hot Box are described NPL Report CBTLM 25. The measurement uncertainty when carrying out thermal transmittance measurements of windows following the procedures specified in BS EN ISO 12567-1 is estimated to be within $\pm 5.5\%$ based on a standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95 %. The uncertainty budget is given in NPL Procedure document QPCBTLM/B/652.

11.2 Agreement between measured and calculated values for the EPS skylight

A summary of the measured and calculated U-values of the EPS skylight, for the different heat flow conditions and hot box air speed, are shown in Table 60.

Table 60 Summary of measured and calculated U-values for EPS skylight

Test number	Date	HF direction	Measurement procedure	Cold box fan speed	Hot box fan volts	U-value measured $W/m^2.K$	U-value calculated $W/m^2.K$	% Difference $\frac{(Calc - Meas)}{Meas}$
10A	28/04/2003	Horizontal	ISO 8990	48.0	7	2.00	2.00	0.0
10A	28/04/2003	Horizontal	Part 2	48.0	7	2.07	2.00	-3.3
10A	28/04/2003	Horizontal	Part 1	48.0	7	2.04	2.00	-2.2
10B	02/05/2003	Vertical	ISO 8990	48.0	7	2.02	2.22	9.9
10B	02/05/2003	Vertical	Part 2	48.0	7	2.12	2.22	4.8
10E	29/07/2003	Vertical	ISO 8990	48.5	No fan	2.08	2.22	6.6
10E	29/07/2003	Vertical	Part 2	48.5	No fan	2.16	2.22	3.0

The values in Table 60 show quite good agreement between the measured and calculated U-values. It would be extremely difficult to use the actual surface resistance values in the calculation that were developed in the measurement.

The agreement for horizontal heat flow is somewhat better than for vertical heat flow. The EN ISO 12567-2 procedures show better agreement with the calculated values for the vertical heat flow configuration than the straightforward calculation procedure referred to as the ISO 8990 method.

The effect of the special calibration measurements required by Part 2 document seem quite small.

Holder panel ID Rothold3
R18B Xtralite Skylight - Vertical HF

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Date & Time	Specimen area	Holder Th Cond.	Atm. pressure	Total power	Holder Hot temp	Holder Cold temp	Specimen Hot surface	Specimen Cold surface	Air Hot temp	Air Cold temp	Baffle Hot temp	Baffle Cold temp	Diviny Offset	boundary loss
	(m ²)	(W/m.K)	(mb)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(uV)	(%)
16/02/2004 23:51	1.440	0.0344	0.0	101.990	23.353	3.775	17.967	5.394	23.540	3.544	21.839	3.700	-0.70	
17/02/2004 01:51	1.440	0.0344	0.0	102.230	23.346	3.787	17.914	5.263	23.559	3.527	21.825	3.708	2.40	
17/02/2004 03:51	1.440	0.0344	0.0	102.084	23.338	3.824	17.952	5.379	23.505	3.578	21.815	3.755	4.80	
17/02/2004 05:51	1.440	0.0344	0.0	101.870	23.340	3.773	17.862	5.271	23.556	3.548	21.818	3.702	3.10	
17/02/2004 07:51	1.440	0.0344	0.0	102.212	23.328	3.783	17.937	5.271	23.532	3.505	21.810	3.698	4.50	
Averages	1.440	0.0344	0.0	102.077	23.341	3.789	17.926	5.315	23.538	3.540	21.822	3.712	2.82	

Date & Time		Total power		Surround Surface		Power		Hot		Cold		Surface		Air temperatures		Environmental temperatures		Baffle temperatures		Thermal		Surface Resistance	
		Corfor	HPM Off	Hot	Cold	thro' insert	Hot surface	Hot temp	Cold surface	Cold temp	Temp diff	Hot	Cold	diff	Hot	Cold	diff	Hot	Cold	Cond	Trans	Hot	Cold
		(W)	(°C)	(°C)	(°C)	(W)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(W/m².K)	(m².K/W)	(m².K/W)	(m².K/W)	
Area of specimen Area holder		1.4400	m²			Thick @ edge			37.00	mm	Bound Loss (W)	3.000	Mean temp		11.621	°C	Hr (c)		5.699				
		4.3476	m²			Holder thickness			0.15000	m			λ Holder		0.0344	W/m.K	Hr (h)		4.849				
	Efth	n/a	mm			Baffle Emis. Hot			0.94		Spec. Emis. Hot	0.9	Emissivity Factor	Hot		0.8511	Tot Res		0.1237				
						Baffle Emis Cold			0.94		Spec. Emis. Cold	0.9	Emissivity Factor	Cold		0.8511							
16/02/2004 23:51		101.992	23.353	3.775		76.904	17.967	5.394	12.573	12.573	23.540	3.544	19.997	22.794	3.560	19.234	21.839	3.700	4.248	2.777	0.090	0.034	
17/02/2004 01:51		102.222	23.346	3.787		77.153	17.914	5.263	12.651	12.651	23.559	3.527	20.032	22.793	3.545	19.248	21.825	3.708	4.235	2.784	0.091	0.032	
17/02/2004 03:51		102.069	23.338	3.824		77.054	17.952	5.379	12.573	12.573	23.505	3.578	19.926	22.767	3.597	19.170	21.815	3.755	4.256	2.791	0.090	0.033	
17/02/2004 05:51		101.861	23.340	3.773		76.796	17.862	5.271	12.591	12.591	23.556	3.548	20.008	22.779	3.563	19.216	21.818	3.702	4.236	2.775	0.092	0.032	
17/02/2004 07:51		102.198	23.328	3.783	*	77.154	17.937	5.271	12.666	12.666	23.532	3.505	20.027	22.777	3.525	19.253	21.810	3.698	4.230	2.783	0.090	0.033	
Av. Values		102.068	23.341	3.789	*	77.012	17.926	5.315	12.611	12.611	23.538	3.540	19.998	22.782	3.558	19.224	21.822	3.712	4.241	2.782	0.091	0.033	
	Variation	0.35%	0.025	0.051		0.47%	0.105	0.131	0.74%	0.054	0.073	0.053%	0.027	0.072	0.043%	0.029	0.058	0.57%	0.61%	0.57%	0.002	0.002	
Surround temp difference		Atmospheric pressure																		CEN as measured U-value		2.834	
Surround mean temperature																				% difference		-1.9	

Table 62 Xtralite skylight - Vertical HF - Table C5

Table C5 Window Data and measurement results			
frame width	w	m	0.0370
frame insertion into surround panel	w	m	0.1500
depth of reveal	d _p	m	0.1500
surround panel thickness	d _{sur}	m	0.15
area of window	A _{sp}	m ²	1.44
area of surround panel	A _{sur}	m ²	4.3476
perimeter length	L	m	4.800
Warmside View factor - calibration to baffle	f _{cb}	1 - 1.3 x d _{p,e}	0.805
Warmside View factor - surround panel reveal to surround panel reveal	f _{pp}	1 x d _{p,e}	0.15
Warmside View factor - calibration panel to surround panel reveal	f _{cp}	A.11	0.195
Warmside View factor - Surround panel reveal to baffle	f _{pb}	A.12	0.425
Warmside View factor - baffle to surround panel reveal	f _{bp}	A.11	0.195
Hemispherical emissivity calibration panel	ε _{cal}		0.837
Hemispherical emissivity baffle	ε _b		0.94
Hemispherical emissivity reveal	ε _p		0.94
Warmside Radiant factor from cal panel to baffle	α _{cb}	A.8	0.637
Warmside Radiant factor from cal panel to surround panel	α _{cp}	A.9	0.162

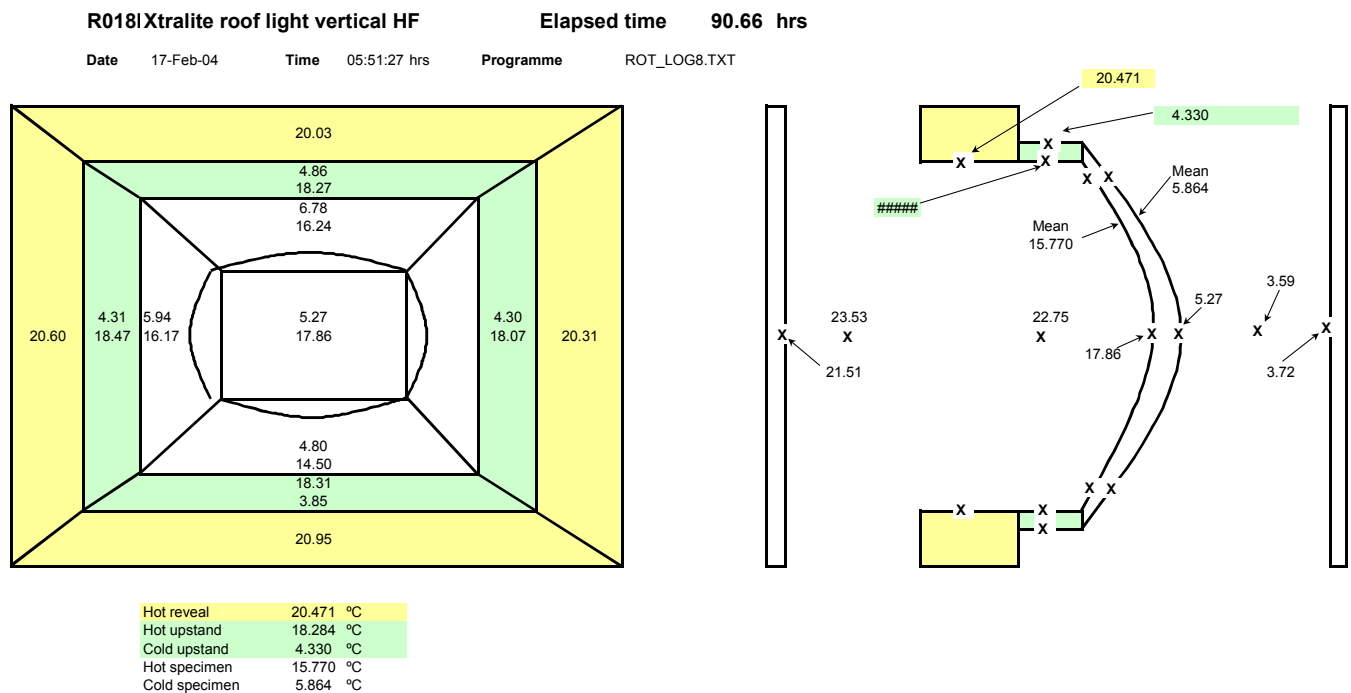
Table 63 Xtralite skylight - Vertical HF - Table C6

Table C6 Window measurement results			
Cold temperatures			
air	θ _{ce}	°C	3.54
baffle	θ _{se,b}	°C	3.71
reveal surface	θ _{se,p}	°C	A
surround panel	θ _{se,sur}	°C	3.79
Warm temperatures			
air	θ _{ci}	°C	23.54
baffle	θ _{si,b}	°C	21.82
reveal surface	θ _{si,p}	°C	20.30
surround panel	θ _{si,sur}	°C	23.34
input power	φ _{in}	W	102.07
air flow warm side (down)	v _i	m/s	0.2
air flow cold side (up)	v _e	m/s	4.2

Table 64 Xtralite skylight - Vertical HF - Table C7

Table C7 Calculation of the thermal transmittance of specimen - R18B					Remarks
Temperature mean surround panel	$\theta_{me,sur}$	°C	13.565	-	-
Thermal resistance of the surround panel	R_{sur}	(m ² .K)/W	4.3106	Figure D1 / regression	
Type of installation - Kerb (K) or Insert (I)	K				
Thermal conductivity of surround @ $\theta_{me,sur}$	λ_{sur}	W/(m.K)	0.0344	-	
Ψ_{edge} for w (mm) = 37.0	Ψ_{edge}	W/(m.K)	0.01978	Table B.3:	
Temperature difference surface, surround	$\Delta\theta_{s,sur}$	K	19.552	-	
Temperature difference air	$\Delta\theta_c$	K	19.998		
Input power to hot box	ϕ_{in}	W	102.068		
Power through surround panel & Upstand	Φ_{sur}	W	22.302	equation 12	
Edge zone heat flow	Φ_{edge}	W	3.0000	equation 10 ¹⁴	
Heat flow density through specimen	q_{sp}	W/m ²	53.3097	equation 11	
Warm side convective fraction	$F_{c,i}$	-	0.4270	Figure D3 / regression	
Cold side convective fraction	$F_{c,e}$	-	0.8266	Figure D3 / regression	
Total surface resistance	$R_{s,t}$	(m ² .K)/W	0.0000	Figure D2 / regression	
Mean radiant temperature warm side	$\theta_{r,i}$	°C	21.51	equation A.3	
Mean radiant temperature cold side	$\theta_{r,e}$	°C	3.71	equation A.2	
Warm side environmental temperature	θ_{ni}	°C	22.378	equation 7	
Cold side environmental temperature	θ_{ne}	°C	3.570	equation 7	
Environmental temperature difference	$\Delta\theta_{n,cal}$	K	18.808		
Environmental temperature mean	$\theta_{n,cal}$	°C	12.974		
U-value measured	U_m	W/(m².K)	2.834	equation 13	
Uncertainty	ΔU_m	W/(m ² .K)	0.24		

Note [1] 1.101 Watts added to make this value the same as the one simulated using THERM (Because plywood cladding alters the value - from 1.9 to 3 Watts)

Figure 26 Xtralite skylight - Vertical HF - temperature profiles

The use of the hot box fan is reducing the difference between the surface resistances developed with horizontal heat flow and vertical heat flow. The difference between the measured values (using Part 2 methodology) with horizontal heat flow and vertical heat flow (no fan) is 4.3%, while the difference between the measured and calculated values is 11%. This is almost certainly due to the actual surface resistances that are established being different to the ones used in the calculations which in turn may be influenced by the temperatures of the specimen surfaces. Further calculations need to be carried out with these data to determine if that is true.

11.3 Limitations of standard hot box design

In a classic hot-box apparatus, laminar air flow, parallel to the surface of the surround panel is established in both the hot and cold box – irrespective of the orientation of the hot and cold boxes. That type of air flow is not typical of the air flow system that is normally established in a room without air conditioning. So the actual warm side surface resistance will not be that established in practice.

The internal surface resistance (R_{si}) values given in EN 6946 for the three different conditions of heat flow are:-

- Heat flow vertically up $R_{si} = 0.10 \text{ m}^2\cdot\text{K/W}$
- Heat flow horizontal $R_{si} = 0.14 \text{ m}^2\cdot\text{K/W}$
- Heat flow vertically down $R_{si} = 0.17 \text{ m}^2\cdot\text{K/W}$

When the air is being blown across the surface of the specimen the internal resistance is almost certainly more like the value given for horizontal heat flow than the values given for vertically up and vertically down heat flow.

11.4 Measured local surface resistances

The local heat transfer coefficients on the warm surface of the EPS skylight were measured. The values for horizontal heat flow are shown in Figure 17 and for vertically up heat flow in Figure 20. The values for vertically up heat flow when the hot box fan was switched off, is shown in Figure 22. These values are subject to a large measurement uncertainty because the difference between the surface temperature and the environmental temperature is only about 3 °C. These local surface resistance values are compared in Figure 29. Although the figures in this table show the average surface resistance for horizontal heat flow to be larger than for vertical heat flow, the difference is not as large as predicted by the theoretical values. The difference in the average values of surface resistance for vertical heat flow, with and without the hot box fan, are not significant. There are very large differences between individual values. These differences appear to be systematic showing larger values on the left than on the right. This could be due to non-uniform, warm-side air speeds.

11.5 Effect of specimen configuration on air flow rates

A summary of the various measured air speeds and the specimen configurations that produced them, is given in Figure 30.

Throughout all those measurements the cold box fan was kept on the same setting. The apparatus uses an axial fan running the whole width of the box – with the motor outside the box. The motor speed is accurately controlled by a 3 phase converter system.

The values in Figure 30 show that the cold side air flow is significantly affected by:

- changing the thickness of the calibration panel
- changing the position in the surround panel aperture
- the geometry of the projecting specimen – with the EPS skylight the central air flow speed went up – with the domed skylight the central air speed went down.
- with projecting specimens the air speed in front of the surround panel was much lower than the central air speed.

Throughout all those measurements (except one marked *) the hot box fan was kept on the same setting. The apparatus uses an axial fan running the whole width of the box – with a DC motor inside the box. The motor speed is accurately controlled by using a regulated DC supply.

The values in Figure 30 show that the hot side air flow is:-

- not significantly affected by orientation (with flat panels) when the hot air fan is on
- increased with the domed Xtralite skylight with horizontal heat flow
- the central air speed for the Xtralite skylite was the same as with flat panels with vertical heat flow.
- with vertical heat flow, the air speed inside the EPS skylight was almost the same with and without the hot air fan on.

This last observation may be influenced by where inside the EPS skylight, the air velocity probe was actually sited. Computational Fluid Dynamic simulations carried out by Manz/Frank at the Swiss National Testing Laboratory (EMPA) shows clearly that the convective air flow regime inside such a specimen divides into two convection cells, with air flow occurring at the centre. The air velocity probes used are not directional so react equally to air flow in different directions. The results of the CFD simulation for a vertically mounted specimen are shown in Figure 27 and for a horizontally mounted specimen in Figure 28.

11.6 Effect of boundary layer thickness on air flow

The funnel effect of the converging boundary layers of the baffle and specimen can have an effect on air velocity. The thermal boundary layer was therefore calculated for an air flow of 4.6 m/s, at different points along the baffle and the EPS and Xtralight Skylights. The calculated boundary layer thickness are plotted in Figure 31 a) & b). From these figures it can be seen that for the EPS skylight, the converging boundary layers should have no effect but for the Xtralight skylight, the air flow probe (when centrally mounted) would not be in the free air stream and there would probably be an increase in air velocity at the place the centrally mounted air velocity probe was mounted (as observed). The method of calculating the boundary layer thickness (and average heat transfer coefficient) is given in Annex 1.

Figure 27 Air flow with horizontal heat flow

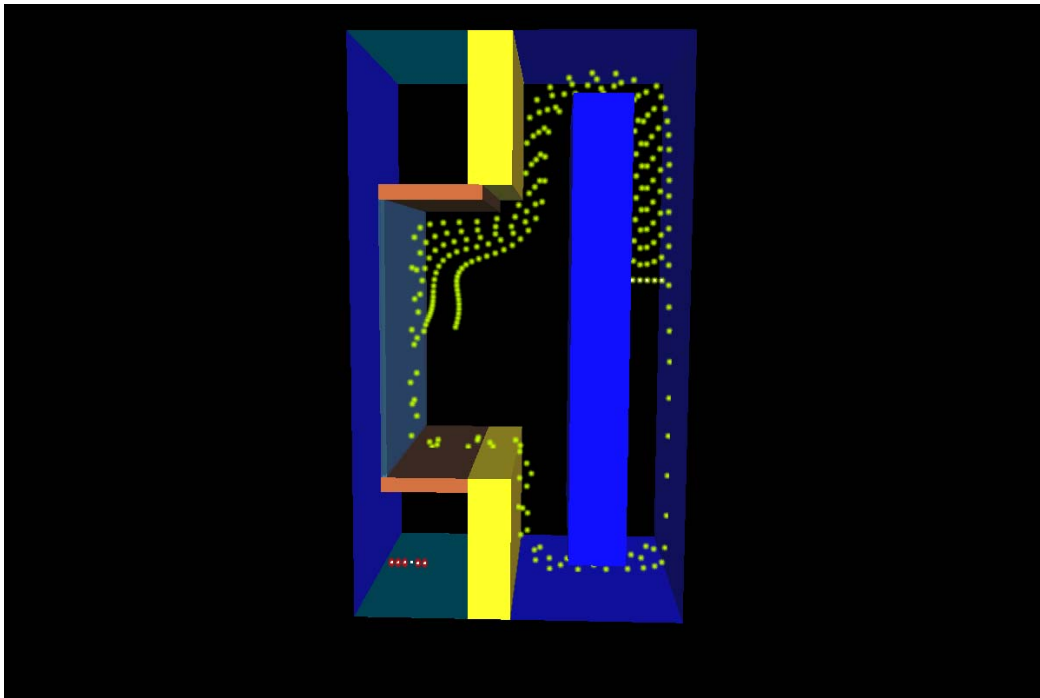


Figure 28 Air flow with vertical heat flow

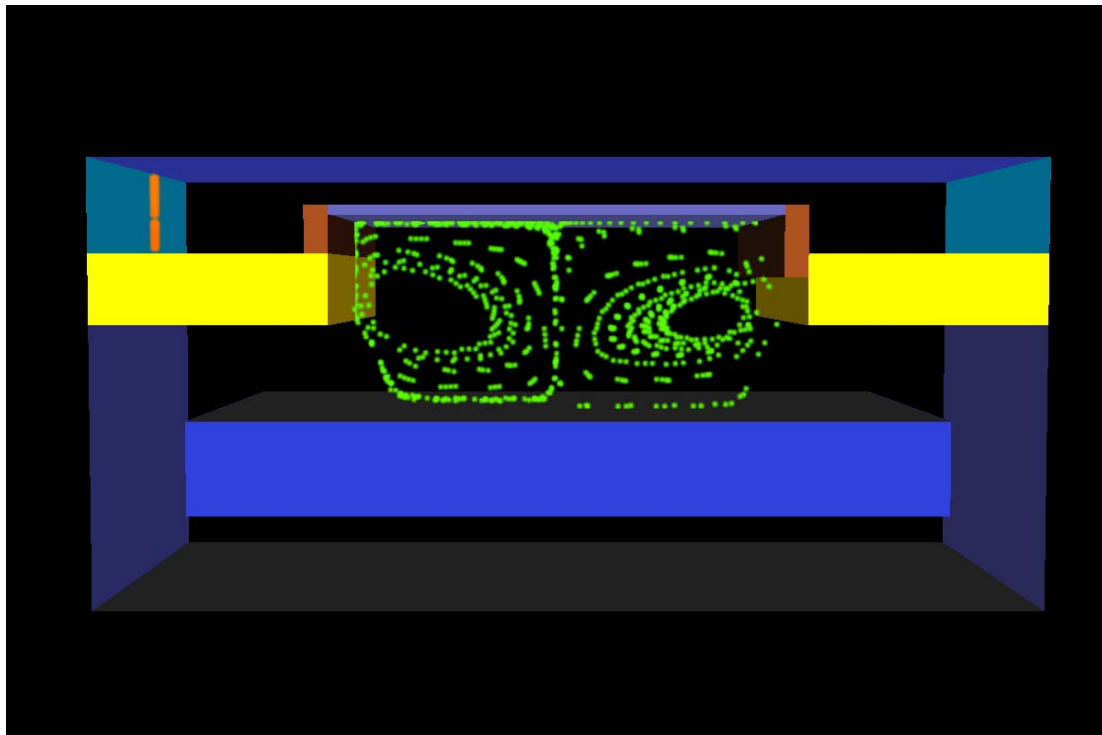
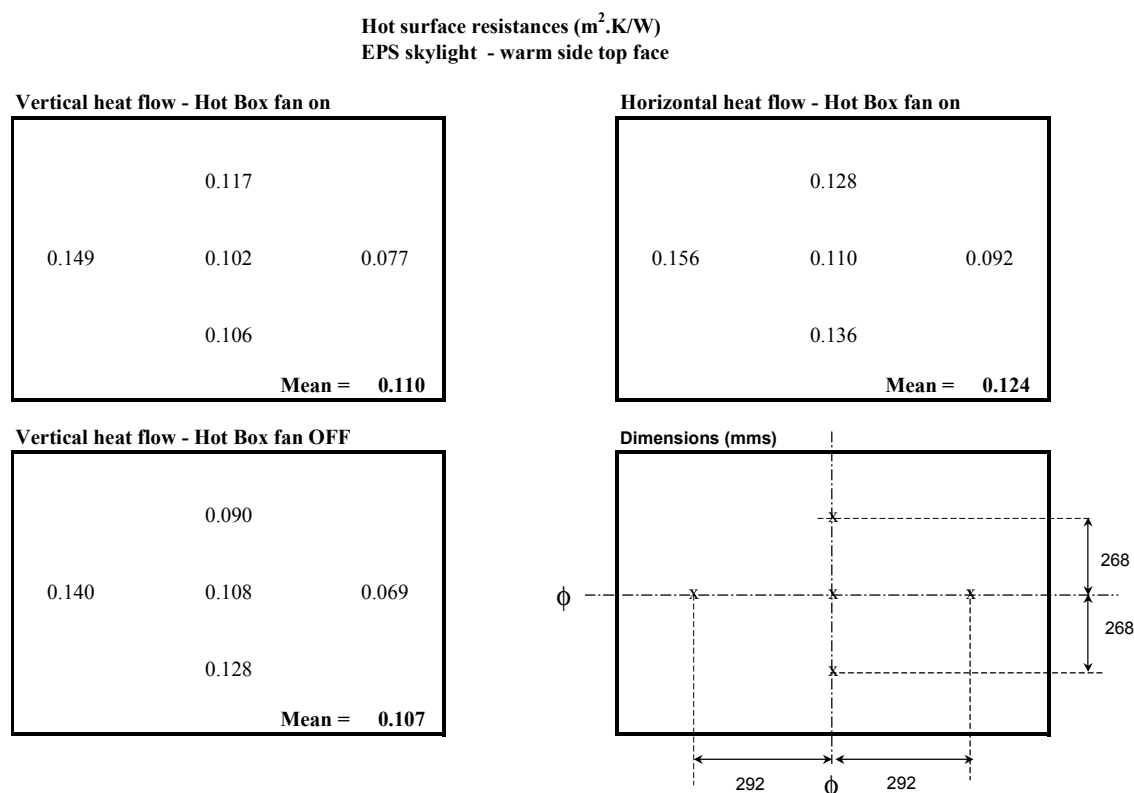


Figure 29 Summary of local surface resistance values

11.7 Effect of using the prEN 12567-2 methodology

The experimental data obtained when measuring the EPS skylight with horizontal heat flow was used to calculate the U-value using the coefficients produced when calibrating the surround panel as specified in EN ISO 12567-1. To do this the linear thermal transmittance value derived using the Part 2 document was used and the Cold reveal was made equal to the cold side surround panel temperature. No hot side reveal temperature was used. The resulting U-values are shown in Table 60. The Part 1 derivation was 1.4% lower than the Part 2 derivation.

12 CONCLUSIONS

12.1 Total surface resistance value during calibration with vertical heat flow

When carrying out the first measurement on the thin calibration panel a specific total surface resistance value has to be established. At the moment the value quoted in EN ISO 12567-1 Clause 6.2.2.1 is $0.17 \text{ m}^2\cdot\text{K}/\text{W}$. When carrying out those calibrations using vertical heat flow, it would be better if the total surface resistance value targeted was $0.14 \text{ m}^2\cdot\text{K}/\text{W}$, as given in EN 6946 for vertically up heat flow.

12.2 Adjustment of Cold Box air flow

When measuring deep structures prEN 12567-2 Clause 6.3 requires that “After installation of the test specimen the air velocity on the cold side shall be adjusted to give the same air velocity (within 10%) as found with the calibration panel, when setting the total thermal resistance.” This would have been impossible with our equipment when measuring the EPS skylight. The lower air resistance path around the projecting face, caused the air velocity in the centre of the back face to drop significantly (see the table in Figure 30) and we did not have enough power in our cold fan system to increase the air velocity enough to meet the air velocity requirement of the standard. This requirement should be reviewed and amended before the standard is published.

12.3 The effectiveness of the EN ISO 12567-2 methodology

The good agreement between the calculated and measured U-values shown in Table 60 demonstrate that the methodology specified in EN ISO 12567-2 to be basically sound.

12.4 Further work.

- a) Need to look at effect of having low thermal resistance “up-stand” as part of a projecting sample (instead of the expanded polystyrene up-stand used in these measurements). The resulting larger temperature differences between the up-stand surface and the “dome” would have a greater effect on radiant exchange.
- b) There is a need for further measurements of air flows around deeply projecting products – using multiple probes to enable a air flow profile to be determined. A possible method would be to use ultrasonic air flow measurement techniques..
- c) The U-value of the Xtralite skylight should be simulated and compared with these measurements.

Figure 30 Summary of measured air velocities

Surround panel ID	Specimen ID	Specimen description	Specimen position EN ISO - 12567	Date of test	Heat flow direction	Cold air velocity probe position	Hot air velocity probe position	Cold air velocity m/s	Hot air velocity m/s
Rothold2	R02J/L/M	Thin GCP	Part 1	25-Nov-02	Horizontal	Position 1	Position 1	4.1	-
Rothold2	R03H/J/K	Thick GCP	Part 1	28-Dec-02	Horizontal	Position 1	Position 1	4.7	0.36
Rothold2	R08A/B/C	Thin GCP	Part 2	10-Feb-03	Horizontal	Position 2	Position 2	5.8	0.28
Rothold2	R09A/B/C	Thin GCP	Part 2	28-Feb-03	Vertical	Position 2	Position 2	5.6	0.34
Rothold2	R10A	EPS skylight	Part 2	1-May-03	Horizontal	Position 3	Position 3	3.2	0.24
Rothold2	R10A	EPS skylight	Part 2	1-May-03	Horizontal	Position 4	Position 4	3.2	0.17
Rothold2	R10B	EPS skylight	Part 2	2-May-03	Vertical	Position 3	Position 3	3.1	0.48
Rothold2	R10B	EPS skylight	Part 2	2-May-03	Vertical	Position 4	Position 4	3.1	0.21
Rothold2	R10E	EPS skylight	Part 2	10-Jul-03	Vertical *	Position 4	Position 4	3.1	0.17 *
Rothold3	R18A	Xtralite	Part 2	13-Feb-04	Vertical	Position 5	Position 5	6.91	0.37
Rothold3	R18B	Xtralite	Part 2		Horizontal	Position 5	Position 5	6.79	0.5
Rothold3	R18B	Xtralite	Part 2		Horizontal	Position 6	Position 6	3.57	0.5

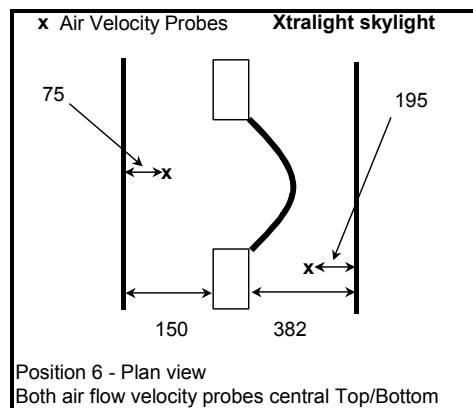
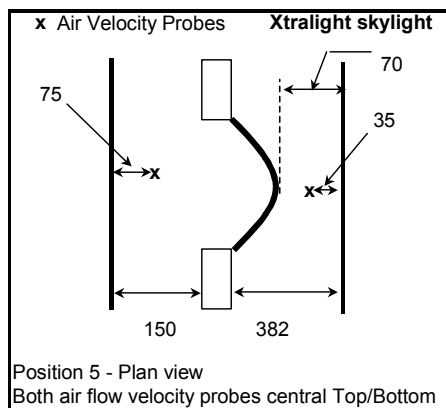
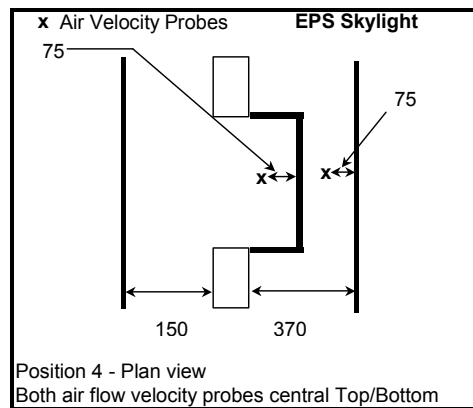
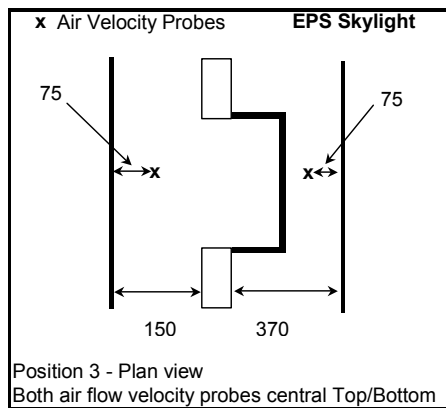
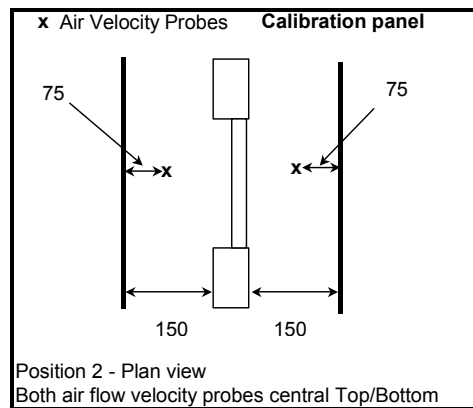
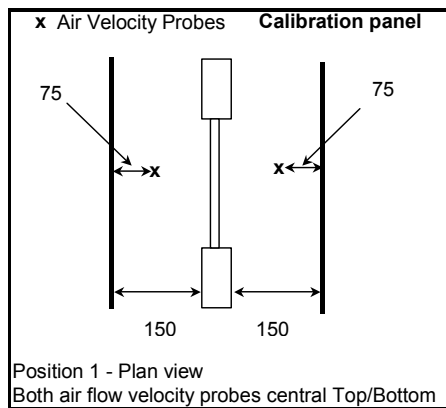
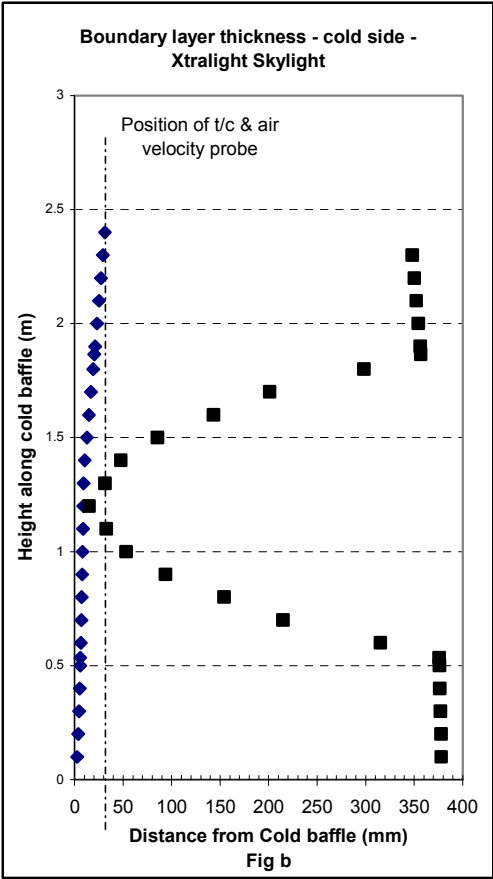
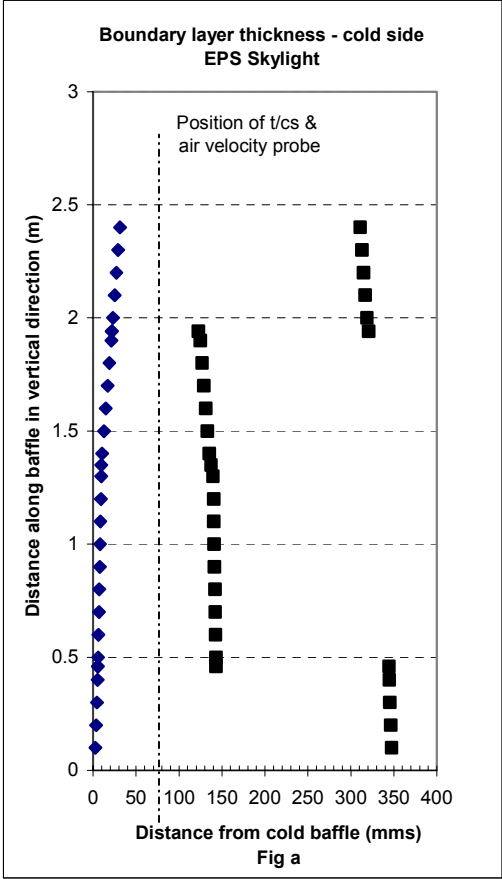


Figure 31 Thermal boundary layer thickness EPS & Xtralight skylights



ANNEX 1 Thermal boundary layer thickness calculations

Boundary layer thickness in the Rotatable hot box

PHYSICAL DATA

Stefan-Boltzmann constant σ $W/(m^2.K^4)$ 5.67E-08

Gas properties of Air

Air density @ ρ kg/m^3 @ 275 K 1.26794
 Air dynamic viscosity @ free stream temperature μ_{∞} $kg/(m.s)$ @ 275 K 1.72100E-05
 Air dynamic viscosity @ wall temperature μ_w $kg/(m.s)$ @279 K 1.73900E-05
 Air kinematic viscosity ν m/s^2 @ 275 K 1.25850E-05
 Air thermal conductivity @ λ $W/(m.K)$ @ 275 K 0.02432
 Air specific heat @ C $J/(kg.K)$ @ 275 K 1008

Experimental data

Distance along the air stream x m 1.20
 Free stream velocity U_{∞} m/s 4.6
 Free stream temperature T_e $^{\circ}C$ 2
 Surface temperature T_s $^{\circ}C$ 3.6
 Baffle temperature T_b $^{\circ}C$ 2.2
 Specimen surface emissivity ϵ_s 0.9
 Baffle surface emissivity ϵ_b 0.9
 Inter-surface emittance E 0.818 Equation 1
 Mean radiant temperature θ_r K 276.05

Critical Reynolds number (where turbulent flow starts) R_c 500000
 Prandtl number Pr 0.713 Equation 2
 Reynolds number Re_x 438617 Equation 3
 Average Nusselt number for laminar flow Nu_m 393 Equation 4
 Average Nusselt number for turbulent flow Nu_m 818 Equation 5
 Average Nusselt number for combined laminar and turbulent flow Nu_m 728 Equation 6

Thermal boundary layer thickness (laminar flow?) $\delta t(m)$ m 0.009 Equation 7
 Thermal boundary layer thickness (laminar & turbulent flow) $\delta t(m)$ m 0.0060 Equation 8
 Thermal boundary layer thickness used $\delta t(m)$ m 0.0090

Location where flow goes from laminar to turbulent - for given air spe x_c m 1.368 Equation 9
 Average Convective Heat transfer coefficient - laminar flow area h_m $W/m^2.K$ 7.96 Equation 10
 Average Convective Heat transfer coefficient - turbulent flow area h_m $W/m^2.K$ 16.59 Equation 10
 Convective heat transfer coefficient that applies in this region h_m $W/m^2.K$ 7.96
 Convective heat transfer coefficient that applies with both lam & turb h_m $W/m^2.K$ 14.75 Equation 10

Radiant heat transfer coefficient h_r $W/m^2.K$ 3.904 Equation 11
 Surface resistance in area of both laminar & turbulent flow R_s $m^2.K/W$ 0.054 Equation 12

Convective fraction F_e 0.791 Equation 13

Note: fluid properties should be calculated at the "film temp"
 this is the arithmetic mean of the wall temp and the external
 flow temp T

The equations used are shown below:

Intersurface emittance

$$E = \left(\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1 \right)^{-1} \quad \text{Equation 1}$$

Prandtl number

$$\text{Pr} = \frac{C_p \cdot \mu_\infty}{k} \quad \text{Equation 2}$$

Reynolds number

$$\text{Re} = \frac{u_\infty \cdot x}{\nu} \quad \text{Equation 3}$$

Average Nusselt number (laminar flow)

$$Nu_m = 0.664 \text{Pr}^{1/3} \cdot \text{Re}_L^{1/2} \quad \text{Equation 4}$$

Average Nusselt number (turbulent flow)

$$Nu_m = 0.029 \text{Pr}^{0.43} \cdot \text{Re}_L^{0.8} \quad \text{Equation 5}$$

Average Nusselt number (combined laminar and turbulent flow)

$$Nu_m = 0.036 \text{Pr}^{0.43} \cdot (\text{Re}_L^{0.8} - 9200) \cdot \left(\frac{\mu_\infty}{\mu_w} \right)^{0.25} \quad \text{Equation 6}$$

Thermal boundary layer thickness (laminar flow)

$$\delta(x) = \frac{4.96 \cdot x}{\text{Re}_x^{1/2}} \quad \text{Equation 7}$$

Thermal boundary layer thickness (laminar & turbulent flow)

$$\delta(x) = 0.381 \cdot \text{Re}_x^{-1/5} - 10,256 \cdot \text{Re}_x^{-1} \quad \text{Equation 8}$$

Location where flow goes from laminar to turbulent - for given air speed

$$x_c = \frac{\nu \cdot \text{Re}_c}{u_\infty} \quad (\text{Re}_c = 500,000) \quad \text{Equation 9}$$

Average Convective Heat transfer coefficient

$$h_m = \frac{Nu_m \cdot k}{L} \quad \text{Equation 10}$$

Radiant heat transfer coefficient

$$h_r = 4 \cdot \sigma \cdot E \cdot \theta_r^3 \quad \text{Equation 11}$$

Surface resistance

$$R_s = \left(\frac{1}{h_c} + \frac{1}{h_r} \right) \quad \text{Equation 12}$$