SM&T Project 3032 - Contract MATI-CT 940063
REPORT OF THE NPL HOT BOX MEASUREMENTS USING THE PROCEDURES SPECIFIED IN prEN 12412-1 WITH 1.2 m X 1.2 m GLAZED CALIBRATION PANELS

Ray Williams & David Hall

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ABSTRACT

This report gives the experimental details of the Wall Guarded Hot Box (WGHB) measurements, carried out by NPL, on four glazed calibration panels, two made by NPL, one by EMPA and one by IFT. These measurements were carried out as part of SM&T Project 3032. The report also outlines the principles of the draft CEN standard procedures for measuring the U-value of windows and window components in a hot box. It gives details of the construction method used to make the glazed calibration panels (required by those standards) and describes how the thermal conductances of these panels were calculated. Details of the calculations carried out to derive the total surface resistance, surround panel heat transfer coefficient and convective fractions are given. Finally the graphs of those properties, which are required to derive subsequent U-values of window systems from hot box measurements, are included.

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LIST OF SYMBOLS

Symbol	Physical Quantity	Unit
A	Area	m^2
F	Fraction	-
θ	Celsius temperature	°C
Φ	Heat flow rate	W
q	Density of heat flow rate	W/m^2
R	Areal thermal resistance	$m^2.K/W$
H	Heat exchange coefficient	$W/m^2.K$
h	Surface coefficient of heat transfer	$W/m^2.K$
d	Thickness	m
C	Conductance	$W/m^2.K$
ΔT	Temperature difference	K

Subscript	Symbol
Convection (air)	a
Baffle	b
Calibration	c
Exterior (cold)	e
Interior (hot)	i
Surround panel	sur
Total	t
Radiant	r
Input	in
Measured	m

1 PRINCIPLE OF THE NEW DRAFT CEN STANDARDS

1.1 THE CEN STANDARDS

There are draft CEN standards for U-value measurements of the following:-

• A glazed unit	prEN 1098 (similar to BS 6993 Part 2)
• A window frame section	CEN/TC 89 WG7 N26E rev 10.96
• A whole glazed window assembly	prEN 12412-1

These standards use a new method to derive a number of important parameters; a method that relies totally on hot box measurements of glazed, calibrated reference panels

1.2 THE FEATURES OF THE NEW METHODOLOGY

The objective of this approach is to enable the following operations to be carried out without measuring the surface temperature of the test element.

- normalize the measured U-value to a standard total surface resistance value
- calculate the boundary loss around the window edges
- calculate the environmental temperature on the hot and cold sides

1.3 AN OUTLINE OF THE NEW METHODOLOGY

The CEN measurement approach is the same for all three standards. The method involves the following steps:-

i) Making at least two glazed, calibrated reference panels with the following approximate dimensions:

- 4 mm glass / 12 mm insulation / 4 mm glass
- 4 mm glass / 50 mm insulation / 4 mm glass
- For whole window systems the recommended size of panel is 1.48 m x 1.23 m
- For insulated glazing panels the recommended panel size is 1.2 m x 1.2 m.

ii) The thermal conductance of these panels must be calculated by measurements of the thermal conductivity of the insulation material and the thickness of the panel and/or insulation material.

iii) Three U-value measurements must then be made of each glazed reference panel, as described in the standard.

iv) From these measurements the following three graphs are produced:-

a) Total surface resistance vs heat flux density. This is used to normalize the measured

U-value to the standard surface resistance of 0.17 m^2.K/W.

b) Surround panel heat exchange coefficient vs the mean temperature of the surround panel for the two calibrated reference panels. This is used to derive the total power through the surround panel, which is needed to calculate the power through the test element.

c) Convective fraction vs heat flux density for the hot and cold sides. This is used to calculate the environmental temperatures of the hot and cold sides.

2 FABRICATION OF THE CALIBRATION PANELS

2.1 CALIBRATION PANEL SIZES

This report describes the measurements carried out on glazed calibration panels measuring 1.20 m x 1.20 m.

2.2 FIXING THE GLASS TO THE EPS

Each panel is made from a sheet of Expanded Polystyrene (EPS) material sandwiched between two sheets of 4 mm thick, toughened glass. The EPS is fixed to the glass using Dow Corning 7091 compound in 4 x 4 array, equally distributed over the EPS surface. Each adhesion point is approximately 35 mm in diameter.

2.3 THICKNESS MEASUREMENTS OF THE CORE MATERIAL AND FINISHED PANEL

The thickness of the 1.20 m x 1.20 m NPL EPS and the glazed panel were measured in 25 places using a dial gauge, accurate to 0.01 mm, mounted on a caliper mechanism (see Figure 1) suspended from a gantry over the vertically mounted panel. The details of those measurements are shown in Tables 1 to 4.

Figure 1 Caliper mechanism for thickness measurement

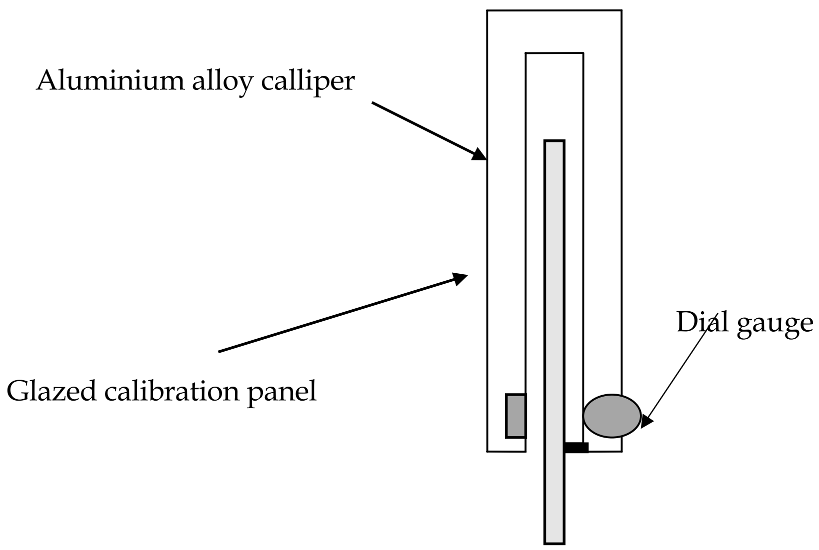

Table 1 Details of thickness measurements for TT105

	A	B	C	D	E
1	20.45	20.52	20.36	20.61	20.56
2	20.33	20.43	20.35	20.58	20.52
3	20.12	20.24	20.24	20.30	20.33
4	20.13	20.22	20.23	20.27	20.36
5	20.17	20.16	20.29	20.26	20.42

Table 2 Summary of thickness measurements for TT105

Mean thickness (mm) of the EPS core and of the glazed panel TT105		
EPS average thickness	=	11.96
Standard deviation	=	0.12
Minimum thickness	=	11.74
Maximum thickness	=	12.16
Glass thickness (at edges)	=	3.88
Glazed panel average thickness	=	20.34
Standard deviation	=	0.14
Minimum thickness	=	20.12
Maximum thickness	=	20.61
Average Air Gap	=	0.32 (per side)

Table 3 Details of thickness measurements for TT106

	A	B	C	D	E
1	68.35	68.65	68.65	68.51	68.14
2	68.27	68.51	68.49	68.34	68.03
3	68.38	68.64	68.51	68.26	68.02
4	68.44	68.45	68.37	68.13	68.01
5	68.38	68.28	68.21	68.21	68.12

Table 4 Summary of thickness measurements for TT106

Mean thickness (mm) of the EPS core and of the glazed panel TT106		
EPS average thickness	=	59.77
Standard deviation	=	0.19
Minimum thickness	=	59.51
Maximum thickness	=	60.35
Glazed panel average thickness	=	68.33
Standard deviation	=	0.19
Minimum thickness	=	68.00
Maximum thickness	=	68.65
Average air gap	=	0.41 (per side)
Glass thickness (at edges)	=	3.88

2.4 THERMAL CONDUCTIVITY MEASUREMENTS OF THE CORE MATERIAL

The thermal conductivity of the 12 mm thick EPS material used in TT105 was measured in the NPL 610 mm x 610 mm Guarded Hot Plate Apparatus (See Table 5). The specimen required was cut from the same sheet as the material that was used in TT105 and then machined flat to within 0.2 mm, the flatness specified in BS 874 Part 2 Section 2.1.

Table 5 NPL measured thermal conductivity of the EPS used in TT105

Thermal Conductivity of Expanded Polystyrene used in TT105 Thickness in GHP = 11.57 mm		
Mean specimen temperature (°C)	Temperature difference across specimen (°C)	Thermal conductivity W/(m.K)
3.3	16.8	0.0303
10.3	16.4	0.0311
20.0	15.9	0.0321

The uncertainty of the measurements on the 11.6 mm thick EPS is estimated as ± 3% at the 95% confidence level. This figure is larger than normally quoted, as the specimens do not meet the normal thickness requirements for the measurement.

The thermal conductivity of the 59 mm thick EPS material was measured in the NPL 610 mm x 610 mm Guarded Hot Plate Apparatus (See Table 6). The single specimen was machined flat to within 0.2 mm, the flatness specified in BS 874 Part 2 Section 2.1. The overall measurement uncertainty is estimated to be within ±2.0% at the 95% confidence level. These results are shown in Table 4.

Table 6 Thermal conductivity of the EPS material used in TT106

Thermal Conductivity of Expanded Polystyrene used in TT106 Thickness in GHP = 59.15 mm		
Mean specimen temperature (°C)	Temperature Difference across specimen (°C)	Thermal conductivity W/(m.K)
4.9	16.2	0.0337
11.7	15.9	0.0345
20.0	16.6	0.0356

2.5 CALCULATION OF CALIBRATION PANEL CONDUCTANCE

The thermal conductivity of the EPS at each experimental mean temperature was calculated from the data in Tables 5 and 6. The thermal conductivity of glass was taken to be 1 W/m.K. The thermal conductance of the panels were calculated in two ways:

i. The thermal resistance of the air gap between the glass and the EPS and the thermal resistance of the adhesive spots were estimated. The overall thermal conductance of the calibration panels, at the specific mean temperatures of the hot box tests, were then calculated to include the effects of the air gap and the adhesive.

ii. The thickness of the EPS material was assumed to be equal to the average distance between the two sheets of glass. In this case the effects of the air gap and adhesive were neglected.

The details of those calculations are shown in Table 10. The conductance value used for this project was that produced using method ii) as decided at the 1st project meeting. This avoids the need to measure the thickness of the EPS material without the glazing in place.

3 THE HOT BOX MEASUREMENTS OF THE NPL PANELS

3.1 EXPERIMENTAL DETAILS

The hot box measurements were carried out in the NPL Wall Guarded Hot Box, which is described in NPL Report QU 91. The calibration panels were mounted in a 150 mm thick EPS surround panel, 25 mm from the cold face of the surround panel as shown in Figure 2. The thermal properties were then measured in the NPL WGHB in the normal way.

The hot and cold surface temperatures of the panels are measured by nine thermocouples on each face. The thermocouples were placed in the centre of squares of equal area. The thermocouples are made from 0.2 mm diameter PTFE coated wire. The thermocouples have been calibrated in the following manner. Five 1.2 m long thermocouples were cut at equal distances along each reel of wire used. These five thermocouples were calibrated by the NPL Temperature Standards Section and an equation relating temperature with output voltage derived from all five sets of data. The thermocouples used in the WGHB have had the PTFE insulation removed for at least 50 mm from the hot junction. The thermocouples are fixed to the glass surface with paper masking tape, after first smearing the bare wire with ZnO loaded silicone grease. The portion of wire in contact with the glass is always fixed horizontally.

Additional thermocouples were used to measure the surround -panel reveal temperature in the hot box.

Three measurements were made with different heat flux densities as specified in prEN 12412-1.

3.2 THE MEASUREMENT RESULTS

Six sets of measurement data were obtained, each being the average of five sets of readings taken every two hours, after equilibrium had been reached. The results are shown in Tables 11 to 16.

The experimental data were used to calculate the heat flux density through the calibration panel. Details of the calculations to derive total surface resistance and the surround panel heat transfer coefficient are given in Table 19 and details of the calculations of the convective fraction for the hot and cold boxes can be seen in Tables 17 and 18. These calculations were carried out as specified in prEN 12412-1. The summary of the important measurement parameters, together with the values which are derived from them to plot the graphs required by the CEN draft standards, are presented in Table 7.

These graphs required are as follows:-

Figure 3 Heat Flux Density v. Total Surface resistance

Figure 4 Surround panel heat transfer coefficient v. Surround panel mean temperature.

Figure 5 Convective fraction for the hot and cold sides v. heat flux densities.

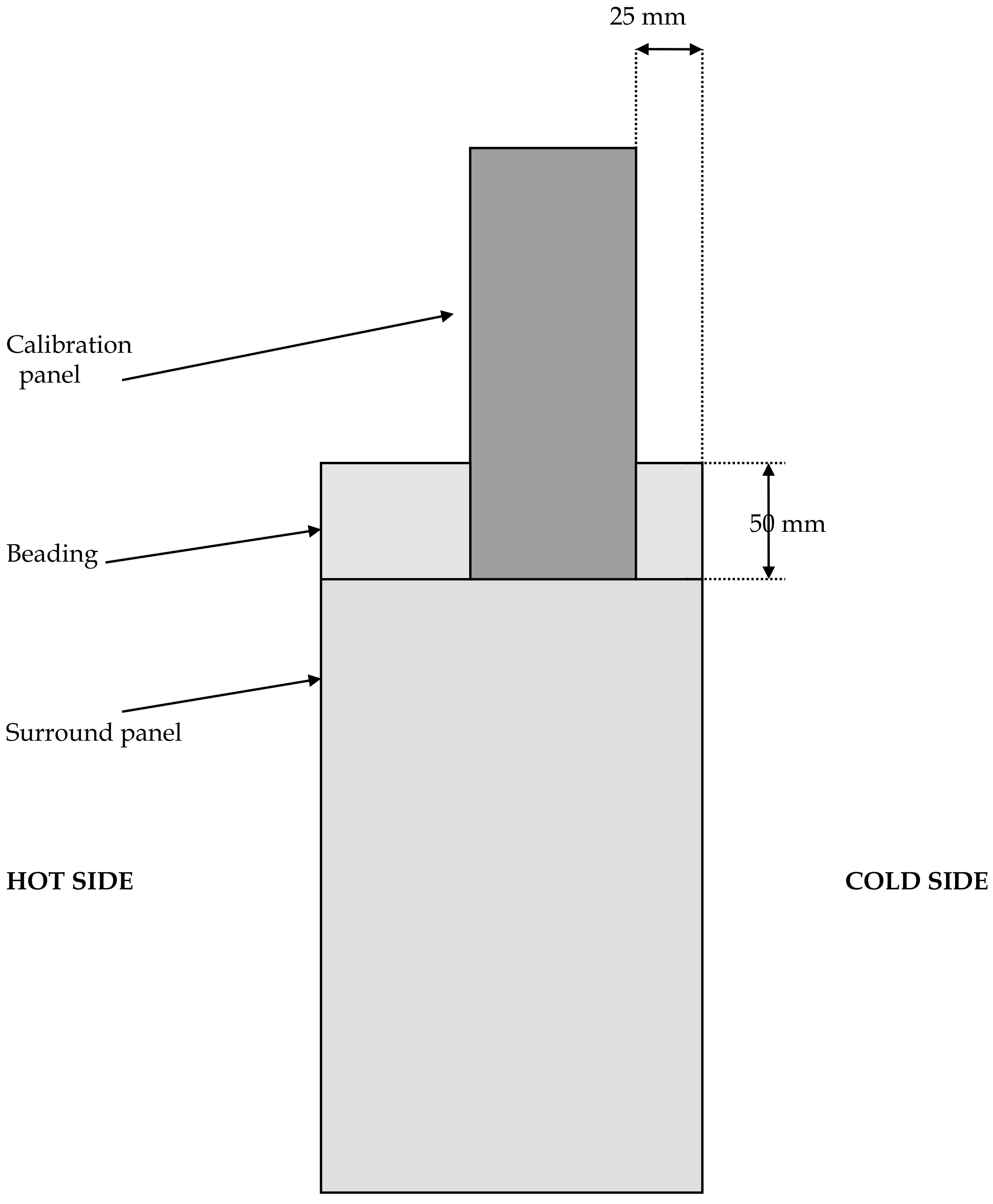

Figure 2 Specimen mounting details

Table 7 Summary of measured and calculated values for TT105 and TT106

NPL Calibration Panels		TT105			TT106		
d thickness	[m]	0.02034			0.0683		
A Area of panel	[m2]	1.221			1.218		
Test number		1	2	3	1	2	3
θsur {Surround mean temp.}	[°C]	17.79	12.43	6.14	16.68	11.32	5.06
Δθsur {Surround temp. diff. }	[°C]	9.67	19.33	30.81	13.61	23.21	34.88
θ_m {mean panel temperature}	[°C]	17.28	11.17	4.16	16.35	10.82	4.38
Cold temperatures - measured							
θa.e {air}	[°C]	12.73	2.30	-9.97	9.66	-0.67	-12.93
θb.e {baffle}	[°C]	12.75	2.37	-9.87	9.68	-0.62	-12.87
θc.e {cal panel}	[°C]	13.58	4.03	-7.32	10.00	-0.07	-12.08
θsur.p.e {reveal - estimated}	[°C]	12.95	2.76	-9.27	9.87	-0.29	-12.38
θsur.e {surround temp.}	[°C]	12.95	2.76	-9.27	9.87	-0.29	-12.38
Hot temperatures - measured							
θa.i {air}	[°C]	23.75	23.26	22.83	23.96	23.67	23.56
θb.i {baffle}	[°C]	23.25	22.41	21.63	23.60	23.11	22.79
θc.i {cal panel}	[°C]	20.98	18.32	15.64	22.70	21.71	20.83
θsur.i {reveal}	[°C]	22.36	20.70	19.53	22.50	21.94	21.60
θsur.i {surround temp.}	[°C]	22.62	22.09	21.54	23.48	22.92	22.50
Φm {Measured hot box power}	[W]	29.87	57.43	89.39	17.46	30.18	44.11
v.i {air flow hot}	[m/s]	0.2	0.2	0.2	0.2	0.2	0.2
v.e {air flow cold]	[m/s]	1.6	1.6	1.6	1.6	1.6	1.6
Λcal {Calc conductance}	$W/m^2.K$	2.460	2.436	2.361	0.575	0.564	0.553
Φcal {power cal panel - calc.}	[W]	22.21	42.51	66.18	8.90	14.97	22.16
$h_{r.i}$ {radiant sur coef- hot}	$W/m^2.K$	4.632	4.548	4.466	4.669	4.634	4.605
hr.e{radiant sur coef- cold}	$W/m^2.K$	4.205	3.781	3.318	4.060	3.637	3.174
ha.i{convective coef- hot}	$W/m^2.K$	3.005	3.540	4.027	2.875	3.219	3.545
ha.e{convective coef- cold}	$W/m^2.K$	17.22	16.56	17.32	17.65	17.32	18.39
Fa.i {Convective fraction - hot}		0.393	0.438	0.474	0.381	0.410	0.435
Fa.e {Convective fraction - cold}		0.804	0.814	0.839	0.813	0.826	0.853
Rtc {Total res. cal.panel}	$m^2.K/W$	0.178	0.173	0.166	0.179	0.175	0.169
Hsur {Surround panel coef}	W/K	0.791	0.772	0.753	0.630	0.655	0.629

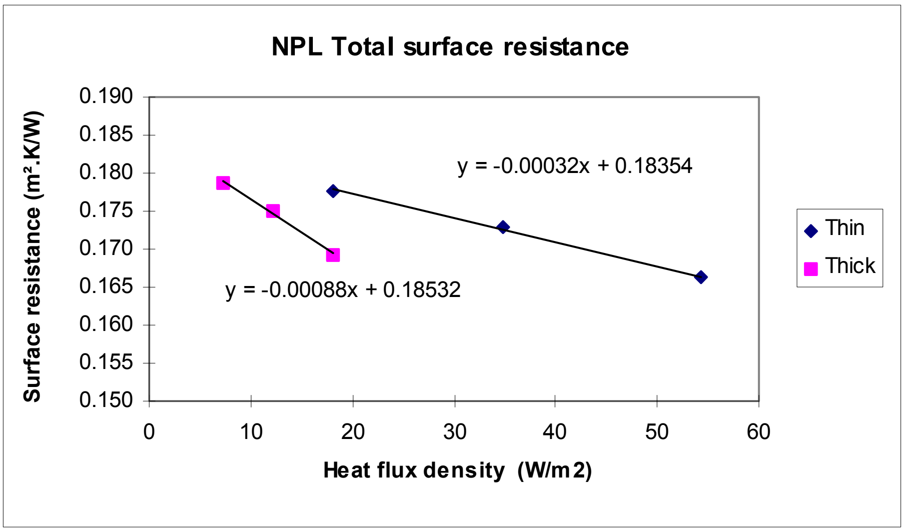

Figure 3 Heat flux density vs Total surface resistance

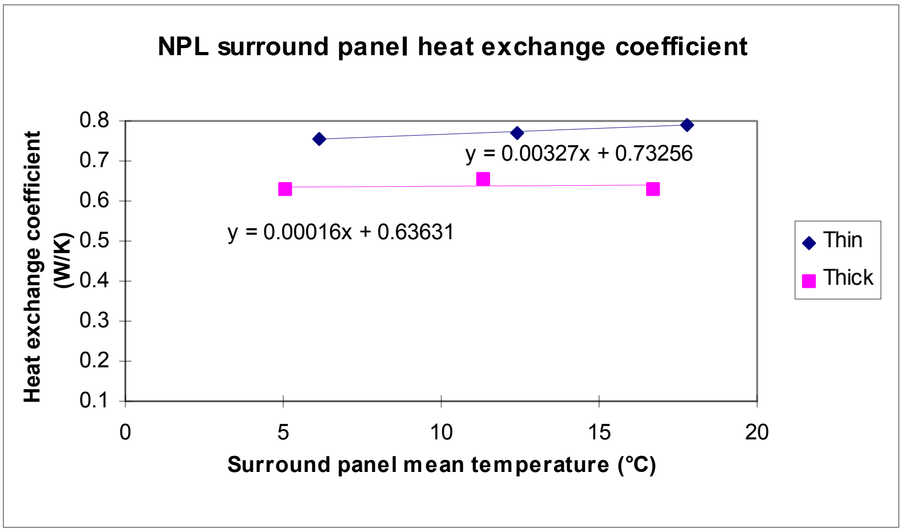

Figure 4 Surround panel heat transfer coefficient vs Surround panel mean temperature

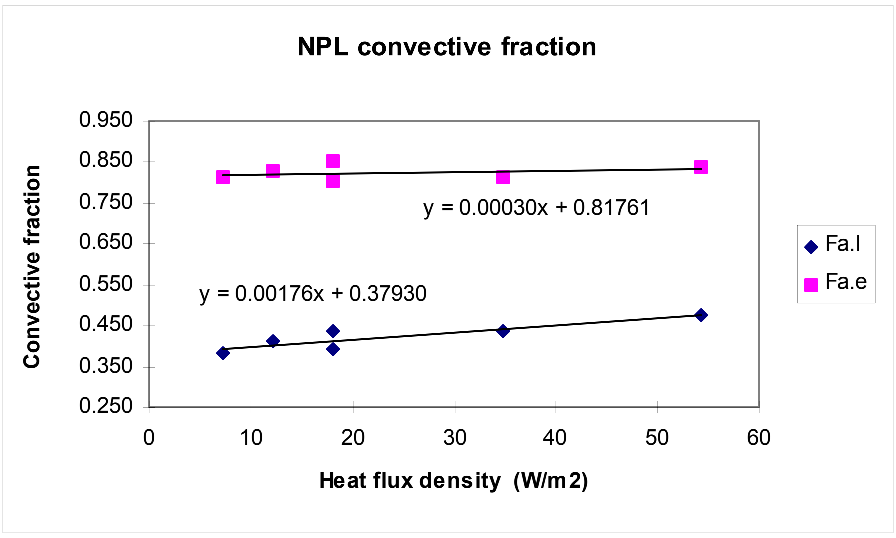

Figure 5 Convective fraction vs Heat flux density

4 UNCERTAINTIES WITH THE NPL MEASUREMENTS AND PANELS

4.1 WGHB MEASUREMENTS

An error analysis of the NPL WGHB is presented in NPL Report QU 91, page 8. The uncertainty in the measurement of conductance of a double-glazed panel mounted in a holder requiring a boundary loss correction is +5.5% to -6.5% at the 95% confidence level. This uncertainty is confirmed by the results of the measurements on fifteen homogeneous reference panels of different constructions with thermal conductances ranging from 0.6 to 6.8 W/m^2K. The measured thermal conductance of those panels were all within ± 5% of the value calculated from thermal conductivity data measured with the NPL guarded hot-plate apparatus. The uncertainty of the guarded hot-plate measurements was ±3% or better.

4.2 CALCULATED CONDUCTANCE OF THE INSTRUMENTED PANELS

The individual uncertainties associated with the calculated conductance of the calibration panels are shown below in Tables 8 and 9.

Table 8 Uncertainty in the calculated conductance of TT105

EPS thickness error	± 2.0 %
EPS thermal conductivity error	± 4.0 %
Sampling error	± 1.0 %
Total uncertainty (summed in quadrature)	± 4.6 %
Air gap error	-1.2 %
	+0%
Total uncertainty	**+4.6%**
	-5.8%

Table 9 Uncertainty in the calculated conductance of TT106

EPS thickness error	±2.0 %
EPS thermal conductivity error	±4.0 %
Sampling error	±1.0 %
Total uncertainty (summed in quadrature)	±4.6%
Air gap error	-.5 %
	+0%
Total uncertainty	**+4.6 %**
	- 5.1%

Table 10 Calculation of thermal conductance of the calibration panels

			TT105C	TT105A	TT105B	TT106C	TT106A	TT106B
Panel height		(m)	1.100	1.100	1.100	1.100	1.100	1.100
Panel width		(m)	1.100	1.100	1.100	1.100	1.100	1.100
Panel area		(m²)	1.210	1.210	1.210	1.210	1.210	1.210
Glass thickness		(m)	.00388	.00388	.00388	.00388	.00388	00388
EPS thickness		(m)	.01196	.01196	.01196	.05977	.05977	.05977
Overall panel thickness		(m)	.02034	.02034	.02034	.06833	.06833	.06833
Panel mean temperature	(T)	(°C)	4.16	11.17	17.28	4.38	10.82	16.35
EPS thermal conductivity @ mean T		(W/m.K)	.03028	.03125	.03157	.03364	.03434	.03499
Glass thermal conductivity		(W/m.K)	1.000	1.000	1.000	1.000	1.000	1.000
Air thermal conductivity		(W/m.K)	0.025	0.025	0.025	0.025	0.025	0.025
Adhesive diameter		(m)	0.040	0.040	0.040	0.040	0.040	0.040
Number of adhesive spots each side			16	16	16	16	16	16
Adhesive thermal conductivity		(W/m.K)	0.200	0.200	0.200	0.200	0.200	0.200
Air gap thickness per side		(m)	.00032	.00032	.00032	.00041	.00041	.00041
Adhesive thickness		(m)	.00032	.00032	.00032	.00041	.00041	.00041
Adhesive area per spot		(m²)	.00126	.00126	.00126	.00126	.00126	.00126
Total area of adhesive		(m²)	.020106	.020106	.020106	.020106	.020106	.020106
Area of panel without adhesive		(m²)	1.18989	1.18989	1.18989	1.18989	1.18989	1.18989
Resistance EPS (real thickness)		(m².K/W)	.39505	.38267	.37885	1.77663	1.74042	1.70809
Resistance EPS (air as EPS)		(m².K/W)	.41585	.40283	.39881	1.80095	1.76424	1.73147
Resistance 2 off sheets glass		(m².K/W)	.00775	.00775	.00775	.00775	.00775	.00775
Resistance air gap - 2 sides		(m².K/W)	.02520	.02520	.02520	.03272	.03272	.03272
Resistance adhesive - 2 sides		(m².K/W)	.00315	.00315	.00315	.00409	.00409	.00409
Tot/resis. glass/air/eps/air/glass		(m².K/W)	.42800	.41562	.41180	1.81710	1.78089	1.74856
Tot/resis. glass/adh./eps/adh./glass		(m².K/W)	.40595	.39357	.38975	1.78847	1.75226	1.71993
Tot/resis. glass/eps/glass		(m².K/W)	.42360	.41058	.40656	1.80870	1.77199	1.73922
Areal/resis. glass/air/eps/air/glass		(K/W)	.35969	.34929	.34608	1.5271	1.4967	1.4695
Areal/resis. glass/adh./eps/adh./glass		(K/W)	20.19007	19.57462	19.38471	88.9514	87.1502	85.5422
Overall panel resistance REAL		(m².K/W)	.42761	.41523	.41142	1.81662	1.78041	1.74807
Overall panel resistance ignore air		(m².K/W)	.42360	.41058	.40656	1.80870	1.77199	1.73922
Conductance of panel incl air gap		(W/m².K)	2.339	2.408	2.431	0.550	0.562	0.572
Conductance of panel ignore air gap		(W/m².K)	2.361	2.436	2.460	0.553	0.564	0.575
% difference (real-assumed/real)			0.94	1.12	1.18	0.44	0.47	0.51
Measured conductance (*)		(W/m².K)	2.436	2.515	2.539	0.565	0.586	0.565
Difference meas. - calc (inc air)			4.011	4.233	4.267	2.524	4.125	-1.303
Difference meas. - calc (no air)			3.104	3.147	3.124	2.097	3.670	-1.819

(*) Measured using the traditional method specified in BS 874 Part 3 Section 3.1.

Table 11 Hot box measurement data for TT105 at 5°C

Table 12 Hot box measurement data for TT105 at 10°C

Table 13 Hot box measurement data for TT105 at 15°C

Table 14 Hot box measurement data for TT106 at 5°C

Table 15 Hot box measurement data for TT106 at 10°C

Table 16 Hot box measurement data for TT106 at 15°C

CONVECTIVE FRACTION TT105 & TT106 plus 50 mm BEADING
NB All the view factors calculated using Table Annex B: prEN 1098

1.2 m x 1.2 m glazed calibration panels

Depth of reveal on hot side	TT105	104.16 mm
Depth of reveal on hot side	TT106	56.17 mm

Depth of reveal on cold side for both panels 25 mm

fcb (rad view factor cal panel to baffle)	TT105	0.836
fpp (rad.view factor surnd pan reveal to surnd pan reveal	TT105	0.129
fcp (rad. view factor cal panel to surnd pan reveal	TT105	0.164
fbp (rad. view factor baffle to surnd pan reveal	TT105	0.164
fpb (rad. view factor surnd pan reveal to baffle	TT105	0.436
fcb (radiation view factor cal panel to baffle)	TT106	0.907
fpp (rad. view factor surnd pan reveal to surnd pan reveal	TT106	0.079
fcp (rad. view factor cal panel to surnd pan reveal	TT106	0.093
fbp (rad. view factor baffle to surnd pan reveal	TT106	0.093
fpb (rad. view factor surnd pan reveal to baffle	TT106	0.460
fcb (radiation view factor cal panel to baffle)	25 mm	0.960
fpp (rad. view factor surnd pan reveal to surnd pan reveal	25 mm	0.037
fcp (rad, view factor cal panel to surnd pan reveal	25 mm	0.040
fbp (rad. view factor baffle to surnd pan reveal	25 mm	0.040
fpb (rad. view factor surnd panel rev to baffle	25 mm	0.482

Stefan's constant	5.67e-8
Absolute zero	273.15
Emissivity cal panel	.83
Emissivity baffle	.95

Table 17 Calculation of convective fraction - Part 1

Table 18 Calculation of convective fraction - Part 2

Table 19 Calculation of Total surface resistance and Surround panel heat exchange coefficient

5 U-VALUE MEASUREMENTS OF THE EMPA AND IFT PANELS

5.1 THICKNESS MEASUREMENTS OF THE PANELS

The thickness of the EMPA and IFT calibration panels were determined by using the method of measurement used for the NPL Calibration panels. The details and summary of the measurements carried out with the EMPA panel, using this method, is given in Tables 20 and 21 and for the IFT panel in Tables 22 and 23.

Table 20 Details of the thickness measurements for TT107 (EMPA panel)

	A	**B**	**C**	**D**	**E**
1	20.49	20.30	20.36	20.24	20.25
2	20.42	20.17	20.24	20.15	20.16
3	20.48	20.23	20.29	20.22	20.22
4	20.38	20.16	20.19	20.09	20.11
5	20.35	20.12	20.11	20.03	20.11

Table 21 Summary of the thickness measurements for TT107

Mean thickness (mm) of glazed panel TT107		
Glazed panel average thickness	=	20.235
Standard deviation	=	0.12
Minimum thickness	=	20.49
Maximum thickness	=	20.03

Table 22 Details of the thickness measurements for TT111 (IFT Panel)

	A	B	C	D	E
1	58.00	58.11	58.32	58.22	58.16
2	57.98	58.23	58.34	58.20	57.99
3	57.83	58.16	58.08	58.12	58.04
4	57.60	57.85	57.98	57.98	58.06
5	57.73	57.92	58.00	58.12	58.36

Table 23 Summary of the thickness measurements for TT111

Mean thickness (mm) of the glazed panel TT111		
Glazed panel average thickness	=	58.055
Standard deviation	=	0.18
Minimum thickness	=	57.60
Maximum thickness	=	58.34

6 THE HOT BOX MEASUREMENTS OF IFT AND EMPA PANELS

6.1 EXPERIMENTAL DETAILS

The hot box measurements of the IFT and EMPA panels were carried out in the NPL Wall Guarded Hot Box. The panels were mounted in a 150 mm thick EPS surround, 25 mm from the cold face of the surround panel as shown in Figure 2. The measurements were carried out exactly as described in section 3 at a mean temperature of approximately 10°C.

6.2 THE MEASUREMENT RESULTS

Each set of measurement data comprises five readings taken at two hour intervals, after equilibrium had been reached.

The WGHB measurement data are shown in Tables 24 and 25.

The standardised U-value of the EMPA and IFT panels were calculated from the measured data using the procedures specified in prEN 12412-1 and the graphs shown in Figures 3, 4 and 5. A summary of those calculations are shown in Table 26.

The standardised U-values of the two panels were:

- IFT 58 mm panel at 13.3°C = 0.58 W/m^2K
- EMPA 20 mm panel at 12.7°C = 1.73 W/m^2K

Table 24 Hot box measurement details for TT107 (EMPA panel)

Table 25 Hot box measurement details for TT111 (IFT panel)

Measured by	**NPL**	Surround panel thickness (mms)	150				
Panel ID				**EMPA**		**IFT**	
Panel thickness mm	(1.20 m x 1.20 m nominal size)			20.20		58.06	
MEASURED VALUES							
Hot side values							
Air temp	(°C)			23.20		23.77	
Baffle temp	(°C)			22.35		23.24	
Reveal temp	(°C)			20.52		20.37	
Element surface temp	(°C)			18.25		21.84	
Cold side values							
Air temp	(°C)			2.11		2.8	
Baffle temp	(°C)			2.17		2.84	
Element surface temp	(°C)			3.80		3.34	
Surround panel values							
Hot side temp	(°C)			22.70		23.11	
Cold side temp	(°C)			2.54		3.32	
Difference temp	(°C)			20.16		19.79	
Mean temp surround	(°C)			12.62		13.215	
Mean temp of test element	(°C)			11.03		12.59	
Area	(m^2)			1.219		1.222	
Power to hot box	(W)			58.52		27.623	
CALCULATIONS							
Hsur - panel thickness	68.3	(0.63631+(0.00016*MeanT))		12.62	0.6383	13.22	0.6384
Hsur - panel thickness	20.3	(0.73256+(0.00327*MeanT))		12.62	0.7738	13.22	0.7758
Hsur - test element		mean temp/Hsur =		12.62	0.7741	13.22	0.6677
Power density through the test element		W/m²		35.204		11.791	
Environmental Temperatures							
Cold side convective fraction		(0.81761+(0.0003*Hfd))			0.8282		0.8211
Hot side convective fraction		(0.3793+(0.00176*Hfd))			0.4413		0.4001
Mean hot radient temp		Calculated elsewhere	°C	22.05		22.89	
Mean cold radient temp (Assumed to be the same as baffle temp)			°C	2.17		2.84	
Hot environmental temp			°C	22.56		23.242	
Cold environmental temp			°C	2.12		2.81	
Environmental temperature difference			°C	20.437		20.435	
U-value CEN & measured directly			W/m².K	1.7226	[*]	0.577	[*]
Tot surface res. from	Thin	(0.18354-(0.00032*Hfd))	m².K/W	0.1723	*0.163*		
Tot surface res. from	Thick	(0.18532-(0.00088*Hfd))				0.1749	*0.179*
Standardised U-value (Total surface resistance = 0.17 m².K/W)			W/m².K	**1.73**	***1.70***	**0.58**	***0.58***
Standardised Conductance			W/m².K	**2.45**	***2.40***	**0.64**	***0.64***

(*) Obtained using a corrected total surface resistance graph
(see NPL Report CBTM 2 Figure 14)

Table 26 Standardised U-value calculations for EMPA and IFT panels

7 DISCUSSION

A full discussion of the results of these measurements is given in the summary report of the project (NPL Report CBTM 2 Section 7).

8 CONCLUSIONS

The calibration panels were used to produce the three graphs required by the draft CEN Standards. Although the graph of total surface resistance with heat flux density looks very different to the example given in prEN 12412-1, its effect on the measured U-values for the EMPA and IFT panels is quite small. The measured standardised U-value of the 20 mm panel only changes by 1.2% when the graph is corrected to produce a smooth curve. The U-value of the thick panel was unaffected by that correction. The measured standardised U-values are within 5.2% of the calculated U-value of the thin panel and within 1.2% of the calculated U-value for the thick panel. This is well within the measurement uncertainty of the Hot Box and the uncertainty in the calculated U-values of the panels.

A detailed analysis of this method and the results of the calibration measurements made by IFT, EMPA, TNO, BBRI and NPL are given in NPL Report CBTM 2.

The measured, standardised U-values of the IFT and EMPA glazed calibration panels were:

- IFT 58 mm panel at 13.3°C = 0.58 W/m^2K
- EMPA 20 mm panel at 12.7°C = 1.73 W/m^2K