NPL Report QM 132

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DEPARTMENT OF THE ENVIRONMENT
PARTNERS IN TECHNOLOGY
- Technical Infrastructure Programme -

Validation of thermal performance design tools for window frame construction:- an independent verification by agreed measurement procedures.

DOE Research Contract 39/3/279 -
Hot-box measurements of eight window systems.

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ABSTRACT

This report presents the results of U-value measurements made on eight glazed window systems as part of the DOE "Partners in Technology Programme". The frames measured were i) thermally broken Aluminium frame; ii) Hard wood frame; iii) UPVC frame; iv) high performance thermally broken double window. The frames were measured with different air filled double glazed units with different air gaps, number of low-E coated surfaces, spacer bar systems and with a secondary glazed unit. The measurements were carried out in the NPL Wall Guarded Hot Box using the procedures specified in draft CEN standard prEN 12412-1 and a conventional, "direct" procedure. The results of hot box measurements of two glazed calibration panels, reported in NPL report QM115, were used to evaluate the window U-values.

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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	Heat flux density	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	$W/m^2.K$
W	Power	W
E	Environmental temperature	°C

Subscript	Symbol
Convection (air)	a
Baffle	b
Calibration	c
Exterior (cold)	e
Interior (hot)	i
Surround panel	sur
Boundary	bound
Total	t
Radiant	r
Input	in
Measured	m
Direct	dir
Window	win
CEN method	CEN

1 BACKGROUND AND OBJECTIVES

The July 1995 revision of Part L of the Building Regulations requires, for the first time, double-glazed windows to be used in residential properties. Furthermore, although it provides tables of U-values for different types of windows it states *"In the absence of certified manufacturers' data the indicative U-values for components given in Table 7 can be used. If certified manufacturers' data is available, however, it should be used in preference"*.

However, the calculation methods being developed by the industry are sensitive to the input conditions and neither measurement nor calculation methods for whole-window heat transfer are covered by British or CEN standards. There is CEN activity aimed at producing standards for whole-window, door frames and frame sections by 1997. But it will be many years before the validity of those new standards are established. The industry have therefore identified an urgent need to establish standard hot-box measurement procedures and compare them with the calculation techniques currently available.

This project will establish standard measurement and calculation conditions and will verify them by comparing hot-box measurements at the National Physical Laboratory (NPL) with values calculated by the Centre for Window and Cladding Technology (CWCT). It has been 50% funded by the DOE through their "Partners in Technology Programme" and 50% from the window industry. The industrial partners are Caradon Everest, Anglian, Zenith and BAC and the Associate Partners are Pilkingtons, British Plastics Federation, British Woodworking Federation, the Glass and Glazing Federation and the Council for Aluminium in Buildings.

The main objective of this project is to independently validate the procedures for measuring, simulating and calculating window system U-values that are currently being developed. These procedures are urgently required by the industry as a means of demonstrating that their products comply with the requirements of Part L of the UK Building Regulations.

This was achieved by doing the following:

- Defining standard measurement and calibration procedures that incorporate the needs of the industry, best practice in other countries and the requirement to produce realistic and reproducible U-values for window systems.

  Verifying the validity of the measurement and calculation procedures chosen, by comparing measured and calculated U-values for the Aluminium, UPVC and Wood framed windows.

- Comparing the simulated U-values produced by a high specification FEA program with those produced by a low-cost window frame thermal property software package.

In the first phase of the project, the U-value measurements and calculations were made on window systems that are typical of the three main frame material types. When the results from this phase were shown to be acceptable the details of Phase II were decided. This approach gave the opportunity to resolve problems encountered when dealing with straightforward window designs, before advancing to more complex ones.

2 MEASUREMENT METHODS

2.1 MEASUREMENT PROCEDURES USED

At a meeting of all the partners held on the 9th May 1995, it was decided to use the measurement procedures specified in the draft standard CEN TC89/WG7 prEN 12412-1.

2.2 THE CEN STANDARDS

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

A glazed unit	prEN 1098 (BS 6993 Part 2)
A window frame section	CEN/TC 89 N 216 E rev. 02.1995
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

2.3 THE PRINCIPLES OF THE CEN METHODOLOGY

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

normalise 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

2.4 AN OUTLINE OF THE NEW METHODOLOGY IN PRACTICE

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

i) Fabricating 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 size of panel is 1.2 m x 1.2 m.

ii) The thermal conductance of these panels must be determined by carrying out thermal conductivity measurements of the insulation material and thickness measurements 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 the latter measurements the following graphs are produced:-

- Total surface resistance vs heat flux density. This is used to normalise the measured U-value to the standard surface resistance of 0.17 m^2.K/W. See NPL Report QM 115 page 11.

- Surround panel 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 needed to calculate the power through the test element. See NPL Report QM 115 page 12.

  Convective fraction vs the heat flux density for the hot and cold sides. This is used to calculate the environmental temperatures of the hot and cold sides. See NPL Report QM 115 page 13.

  The measurement data used to produce the three calibration graphs are given in Table B9 in ANNEX B.

3 THE WINDOW DESIGNS

At the first project meeting held on 9th May 1995, it was decided to use three window frames of the size recommended by the CEN window standard, that is, 1.48 m high x 1.23 m wide. Each window comprises one opening casement, one top opening light and one fixed light. Table 1 shows the main details of these windows (TT089, TT090 and TT091).

The results of these Phase I measurements were reviewed at a second meeting held on 22/01/96. At that meeting, five more window systems were selected to be measured and simulated. Those systems (TT100, TT101, TT102, TT103 and TT104) are also described in Table 1.

Table 1 Details of the window systems measured and simulated.

NPL ID No.	Frame details				Glazing details			
	Frame material	Thermal break type	Number of cavities	Reinforcement	Size (mm)	Gas type	Coating	Space bar type
TT090	PVC-U	n/a	3	mullion only	4/16/4	Air	Pilkington K 3rd surface [1]	Al
TT089	Al (alloy)	4 mm urethane resin	n/a	n/a	4/16/4	Air	Pilkington K 3rd surface [1]	Al
TT091	Wood (Hard)	n/a	n/a	n/a	4/16/4	Air	Pilkington K 3rd surface [1]	Al
TT100	Wood (Hard)	n/a	n/a	n/a	4/16/4 Plus 4mm secondary glazing unit (Inside)	Air	Pilkington K 3rd surface [1]	Al
TT101	Al (alloy)	4 mm urethane resin	n/a	n/a	6/12/6	Air	Both panes plain glass	Al
TT102	Wood (Hard)	n/a	n/a	n/a	4/12/4 [2]	Air	Pilkington K 3rd Surface [1]	High Perf. [3]
TT103	Al (alloy)	4 mm urethane resin	n/a	n/a	4/16/4	Air	Pilkington K 2nd & 3rd Surfaces [1]	Al
TT104	Al (alloy) [4]	26 mm Polyamide	n/a	n/a	8/12/4 Plus 6mm secondary window (Outside) [5]	Air	Pilkington K 4th & 5th Surfaces [1]	High perf.

[1] Surfaces are numbered from the outside to inside.

[2] The use of a 12 mm air gap was not intentional.

[3] Thermally broken aluminium spacer bar supplied by Azon Ltd.

[4] None of the surfaces were coated, all surfaces were bright aluminium. An attempt was made to increase the emissivity of all the surfaces visible by spraying them with deodorant containing Aluminium Chlorohydrate. This procedure has been shown using thermal imaging to be effective in increasing the emissivity of metallic surfaces. It is unlikely that the overall emissivity value of all radiating surfaces was 0.9.

[5] The 4/12/4 IGU unit was specified in the drawing but a frame requiring a 4/16/4 unit was made. An additional piece of 4 mm thick glass was used to bring the IGU up to the required overall thickness. The additional glass was placed on the room side of the IGU. There will be a small contact resistance associated with the interface between the two surfaces.

Detailed drawings for the different frame sections are given in the APPENDIX as Figures A1, A2, A3 and A4 for the Aluminium window, Figures A5, A6, A7 and A8 for the PVC-U window and in Figures A9 and A10 for the hardwood window and Figure A11 for the high performance Aluminium double window. Further details about the materials used in these frames can be found in the Centre for Window and Cladding Technology Report - CWCT/NPL-QM/3.

4 HOT BOX MEASUREMENTS ON THE CALIBRATION PANELS

These are described in detail in NPL Report QM115. The data used to plot the important graphs can be seen in Table B9 in APPENDIX B. The equations of the graphs used to derive the Window U-values are given below.

Heat Flux Density (q) vs Total Surface Resistance ($1/h_t$)

$$(1/h_t) = 0.20333 - 0.02144\text{Log}_{10}(q)$$

Surround Panel Heat Transfer Coefficient (H_{sur}) vs Surround Panel Mean Temperature θ_{sur}

For 67.8 mm thick panel $H_{sur} = 0.614664 - 0.001169(\theta_{sur})$ .....(2)

For 19.69 mm thick panel $H_{sur} = 0.572202 - 0.000898(\theta_{sur})$ .....(3)

Convective Fraction (F) vs Heat Flux Density (q)

Cold Side $F_{a.e} = 0.850002 + 0.000194(q)$ .....(4)

Hot Side $F_{a.i} = 0.384906 + 0.001643(q)$

5 HOT BOX MEASUREMENTS ON THE WINDOWS

5.1 THE HOT BOX

The hot box measurements were carried out in the NPL Wall Guarded Hot Box (WGHB), which is described in detail in NPL Report QU 91. Where appropriate this apparatus meets

all the requirements of BS 874 Part 3: Section 3.1 1987.

5.2 MEASUREMENT DETAILS

5.3.1 Mounting the window in the surround panel

The windows were mounted in a 150 mm thick expanded polystyrene (EPS) surround panel as specified in prEN 12412-1. The thermal properties are measured in the NPL WGHB in the normal way. The windows were mounted 25 mm from the cold face of the surround panel as shown in Figure 1.

5.3.2 Thermocouple fixing method

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.

5.3.3 Thermocouple positions

Surface thermocouples are not required when carrying out U-value measurements to the CEN standard. However, thermocouples were fixed to the surfaces of the windows for two reasons. Firstly to enable comparisons with the surface temperatures obtained by simulation and secondly to enable the thermal transmittance to be calculated directly from measured values.

Additional thermocouples were used to measure the surround-panel reveal temperature in the hot-box, which is required to calculate the radiation exchange between the window and the surround panel.

The positions of the thermocouples on these windows is shown in Figure 2 and the hot and cold temperatures measured at these points for the eight window systems are shown in Figures 3, 4, 5, 6, 7, 8, 9 and 10.

5.3.4 The temperature conditions used

The measurement conditions specified in the draft CEN standard for hot-box measurements on glazed window assemblies (prEN 12412-1) were used.

5.4 CALCULATION OF U-VALUES

5.4.1 Details of the measurements

The measurement results are obtained by taking the average of five sets of readings taken every two hours after equilibrium has been reached. The details of those five measurements for each of the eight window systems are shown in Tables B1, B2, B3, B4, B5, B6, B7 and B8 in APPENDIX B. The U-values of the windows were calculated from this measurement data in the two ways described in 5.4.2 and 5.4.3.

5.4.2 The directly measured U-values

An "average" surface temperature of each of the windows was obtained by area weighting the temperatures recorded by the surface mounted thermocouples on the different parts of the windows. The developed area of the frame sections were used. The resultant surface temperature was used to calculate environmental temperatures and surface resistances. The U-value was standardised to include a total surface resistance value of 0.17 $m^2.K/W$ as shown in equation 6.

$$U_{dir} = 1/(1/U_m - R_m + 0.17) \quad \text{.....(6)}$$

The power through the test element was corrected for the heat flow through the surround panel, around the window edge, (marked Φ_{surr} in Figure 1). A calculated value of 3% was used for this component. This figure was calculated for 1.2 m x 1.2 m calibration panels using a 2D finite element model, which was then adjusted to allow for different values of (U) and the ratio of area to perimeter.

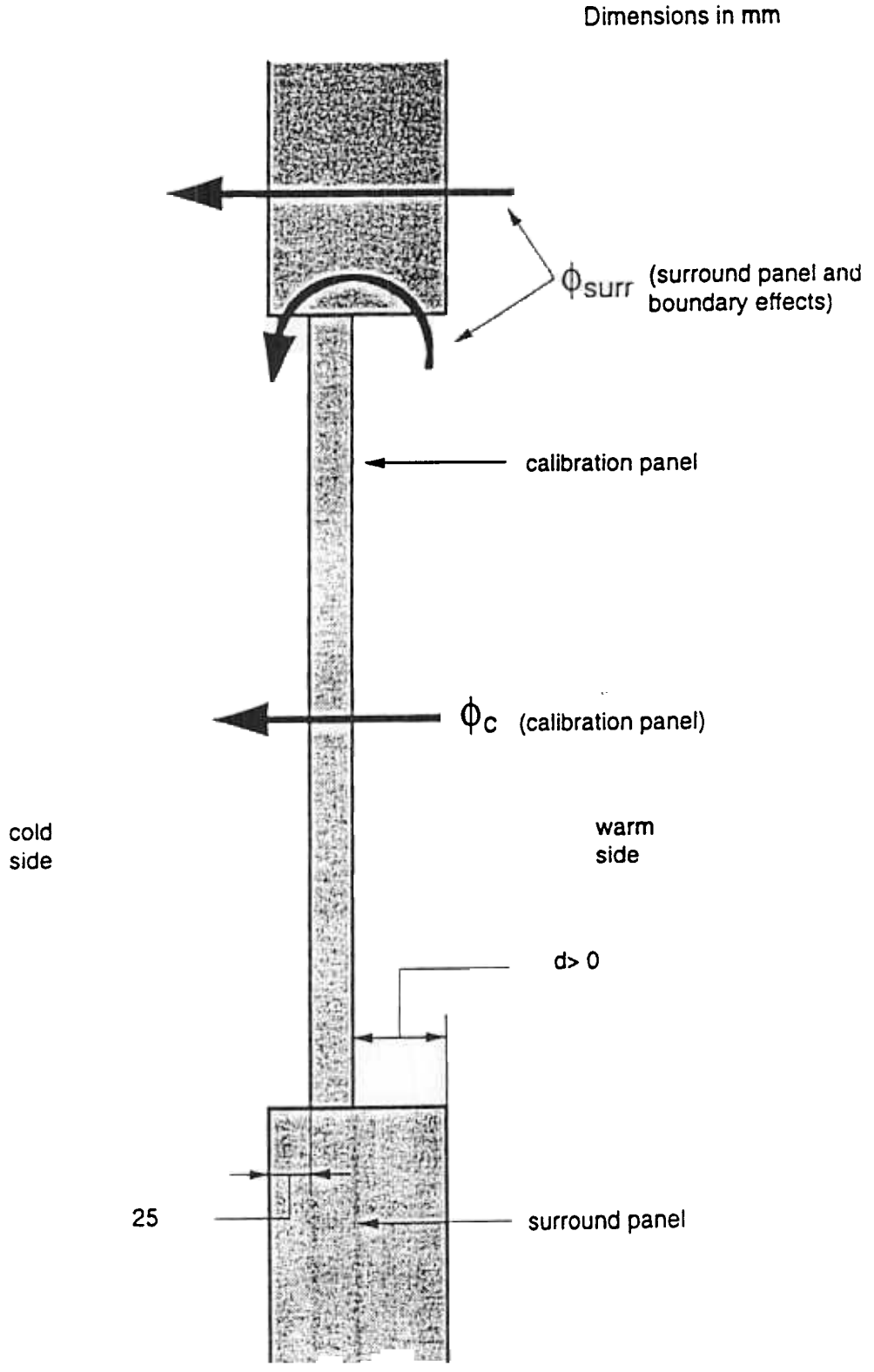

Figure 1 Specimen Mounting Details

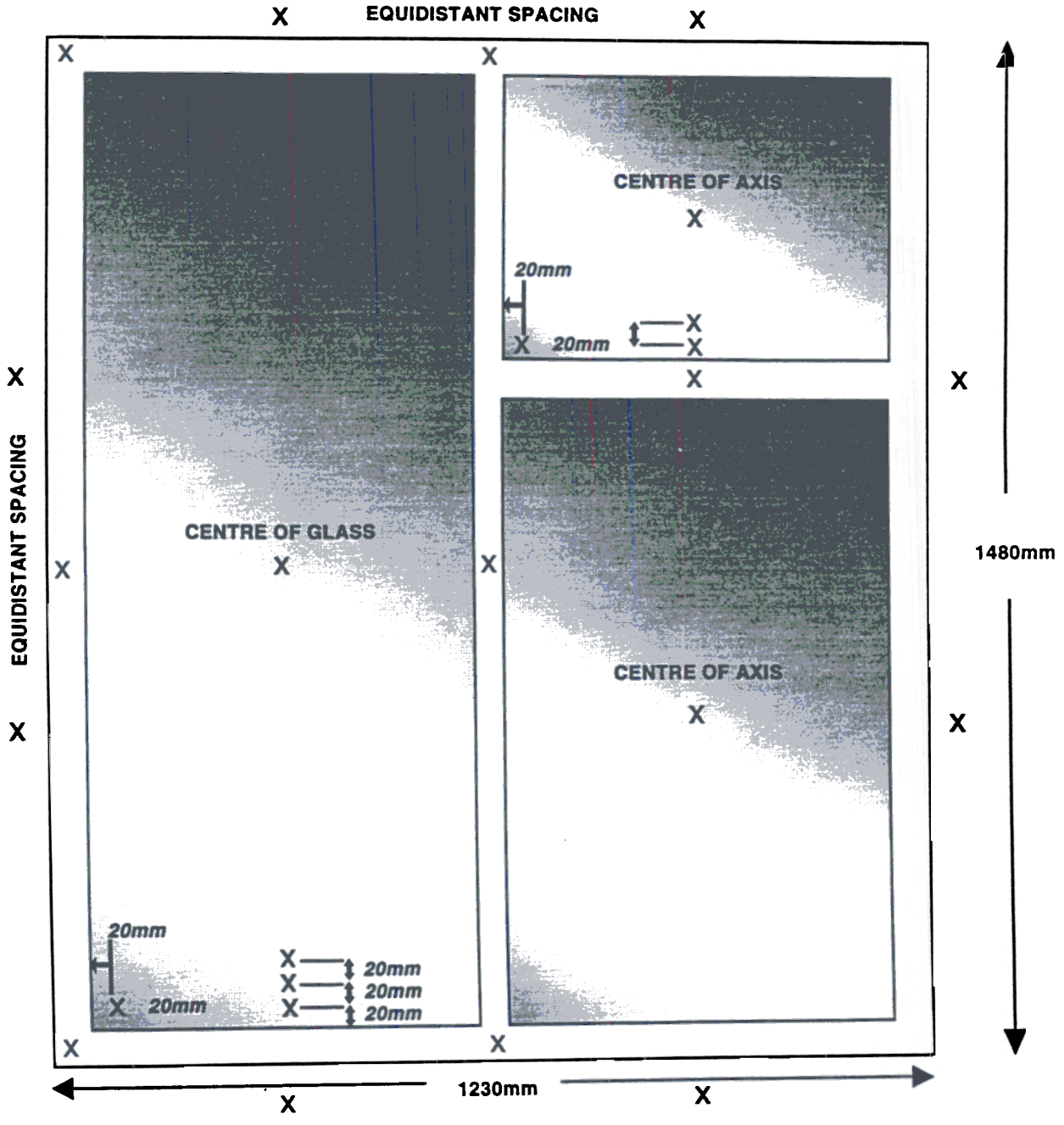

Figure 2 Position of the thermocouples on the window surfaces

Hot Box

Air Temperature: 22.12 °C Environmental Temperature: 21.34 °C

Cold Box

Air Temperature: 1.75 °C Environmental Temperature: 1.76 °C

File Number/Date/Time: 89-72 7/10/95 15:04

Hot Side (Bold) , Cold Side and Reveal (°C)

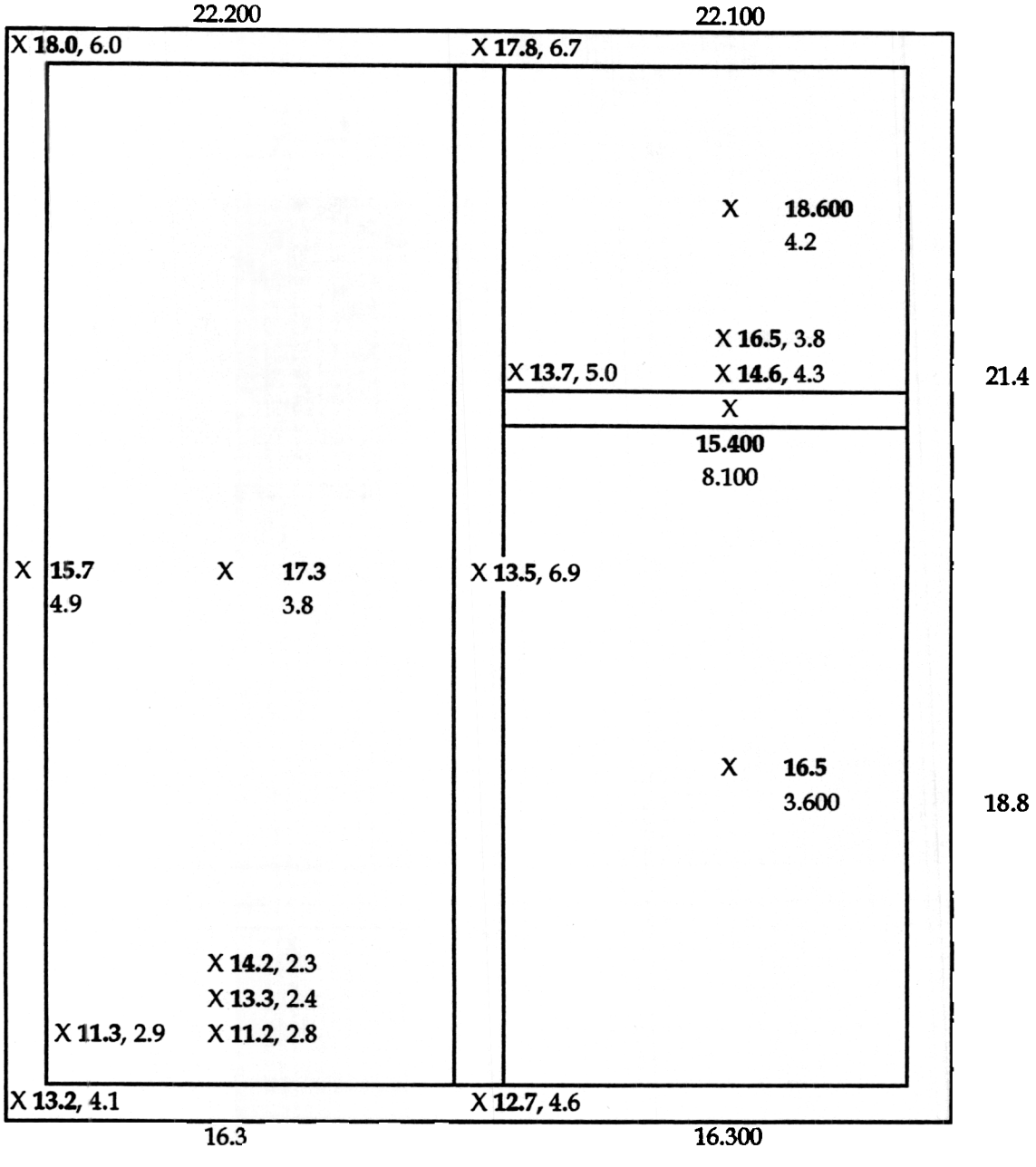

Figure 3 Surface temperatures for TT089 - Al frame - IGU 4/16/4 1 low-E

Hot Box

Air Temperature: 22.94 °C Environmental Temperature: 22.01 °C

Cold Box

Air Temperature: 2.29 °C Environmental Temperature: 2.30 °C

File Number/Date/Time: 91-40, 13/10/95, 00:58

Hot Side (Bold) , Cold Side and Reveal (°C)

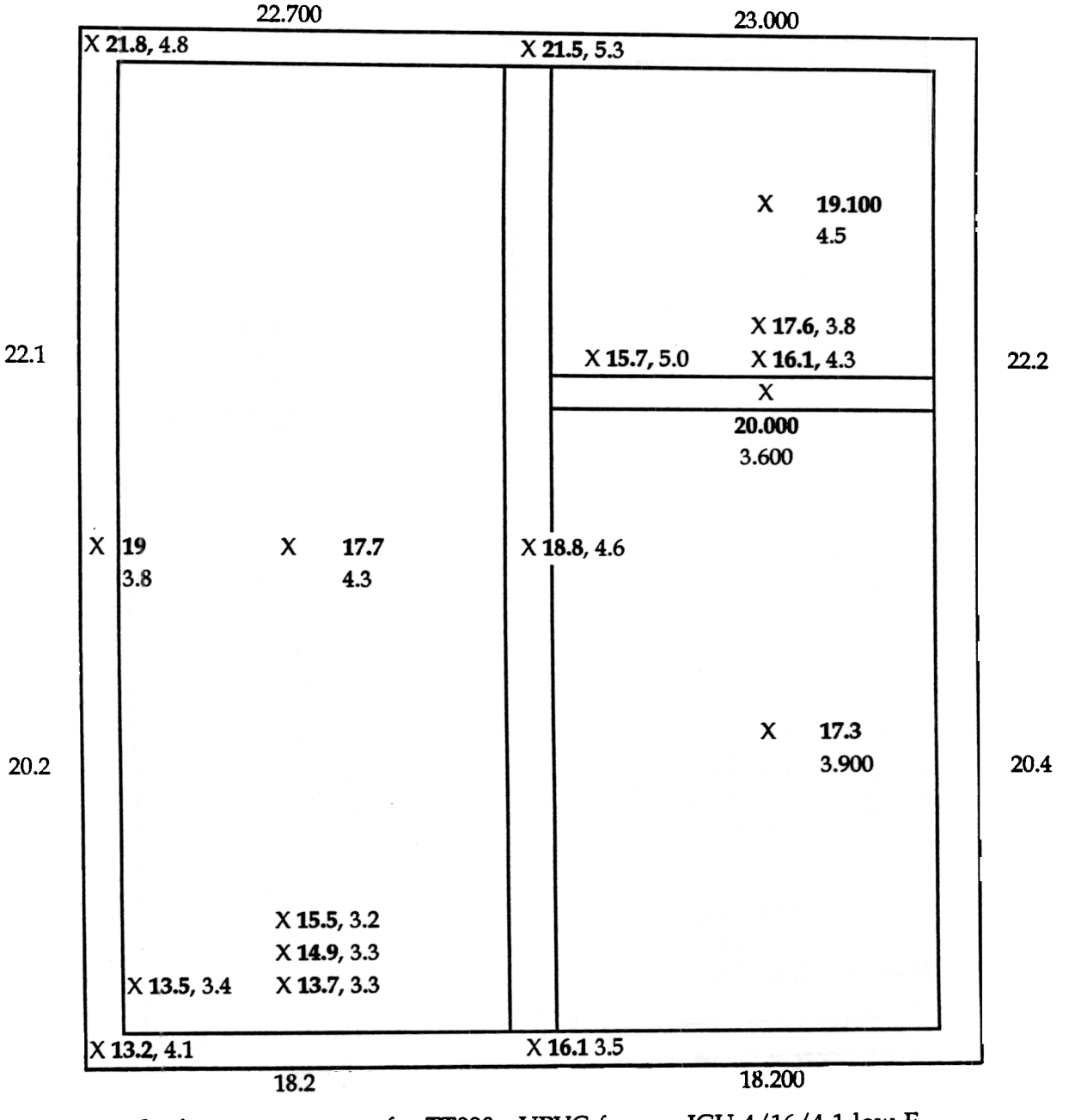

Figure 4 Surface temperatures for TT090 - UPVC frame - IGU 4/16/4 1 low-E

Hot Box

Air Temperature: 22.79 °C Environmental Temperature: 21.81 °C

Cold Box

Air Temperature: 2.18 °C Environmental Temperature: 2.19 °C

File Number/Date/Time: 91-43, 20/10/95, 06:19

Hot Side (Bold) , Cold Side and Reveal (°C)

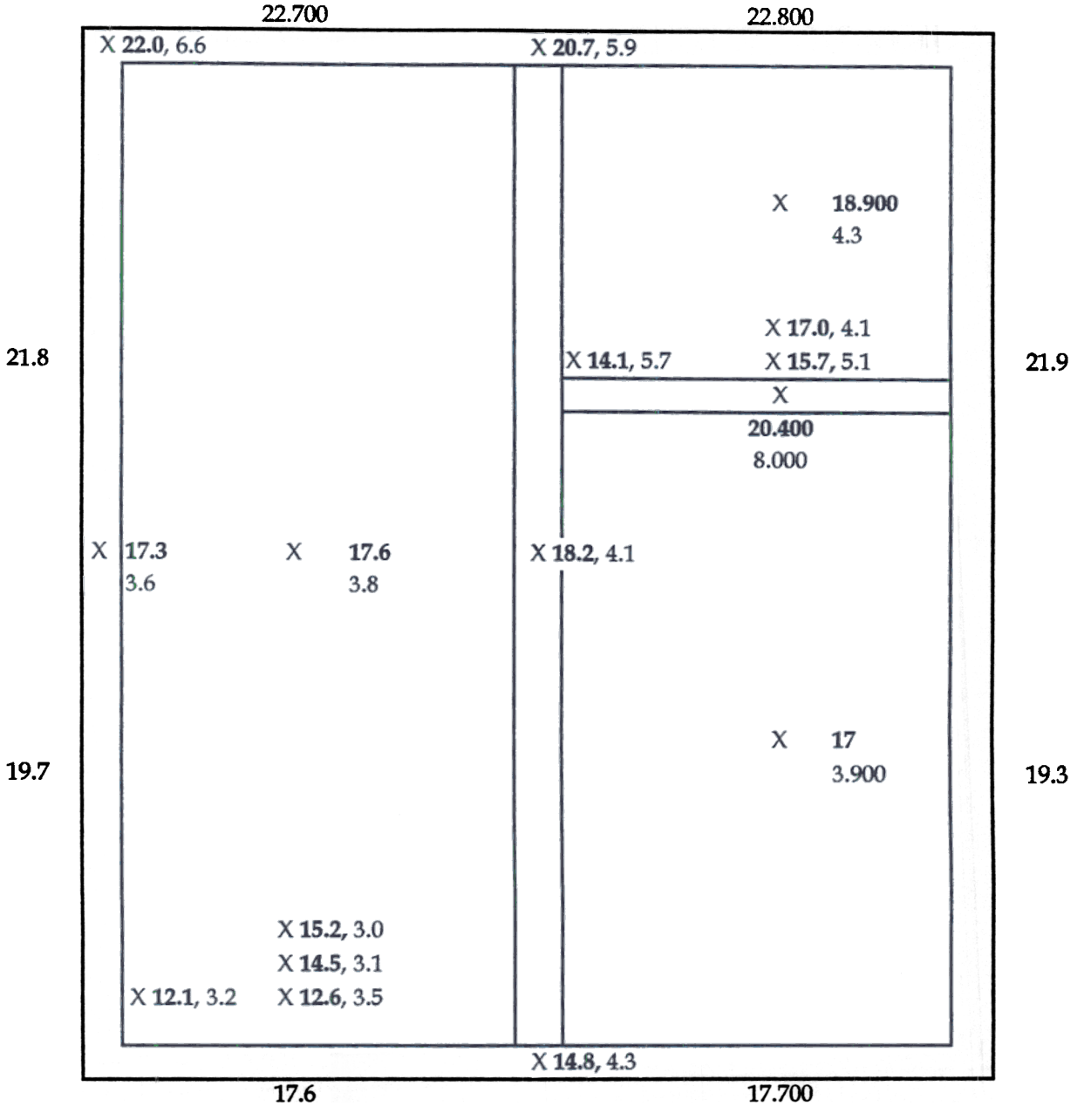

Figure 5 Surface temperatures for TT091 Wood frame - IGU 4/16/4 1 low-E

Hot Box

Air Temperature: 24.28 °C **Environmental Temperature:** 23.07 °C

Cold Box

Air Temperature: 2.08 °C **Environmental Temperature:** 2.09 °C

File Number/Date/Time: 100-60, 14/11/96, 06:16

Hot Side (Bold) , *Secondary Unit (Italics)*, Cold Side and Reveal (°C)

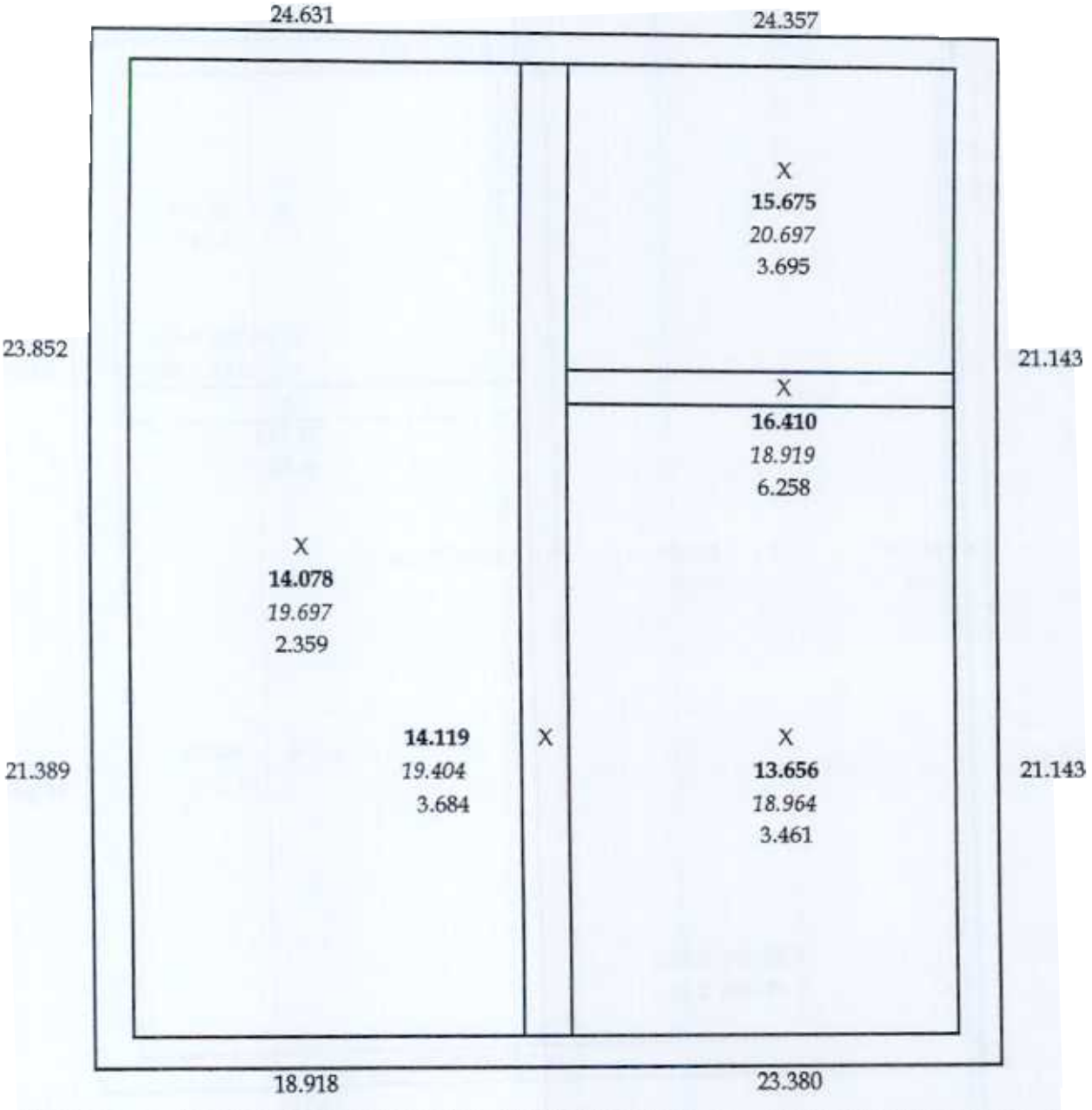

Figure 6 Surface temperatures for TT100 Wood frame - IGU 4/16/4 1 low-E + Secondary Glazed Unit

Hot Box

Air Temperature: 22.34 °C Environmental Temperature: 21.35 °C

Cold Box

Air Temperature: 2.41 °C Environmental Temperature: 2.42 °C

File Number/Date/Time: 101-84, 19/11/96, 00:26

Hot Side (Bold) , Cold Side and Reveal (°C)

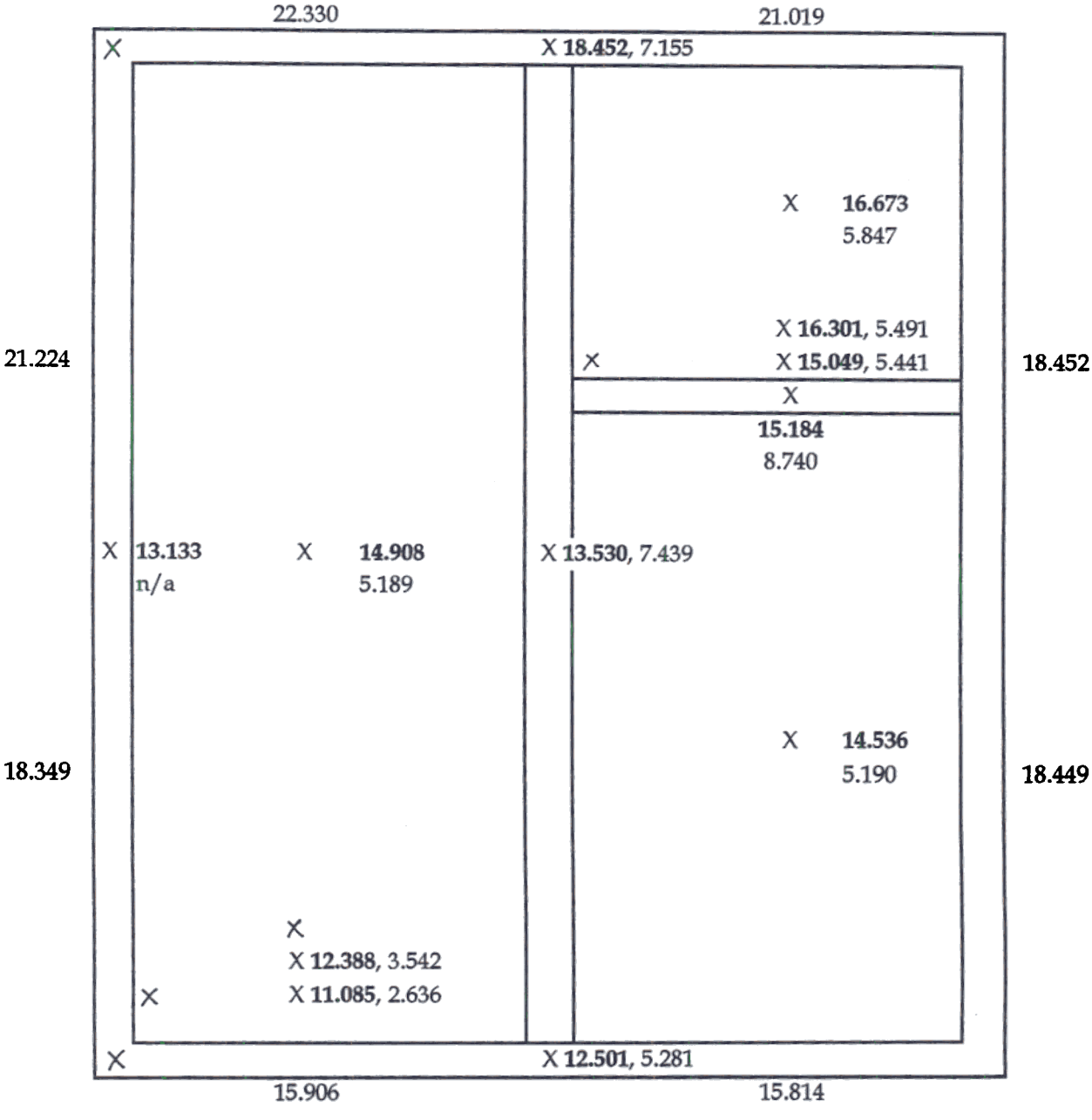

Figure 7 Surface temperatures for TT101 - Aluminium frame - IGU 6/16/6 plain glass

Hot Box

Air Temperature: 24.11°C Environmental Temperature: 23.21 °C

Cold Box

Air Temperature: 2.94 °C Environmental Temperature: 2.95 °C

File Number/Date/Time: 102-113, 25/11/96, 08:54

Hot Side (Bold) , Cold Side and Reveal (°C)

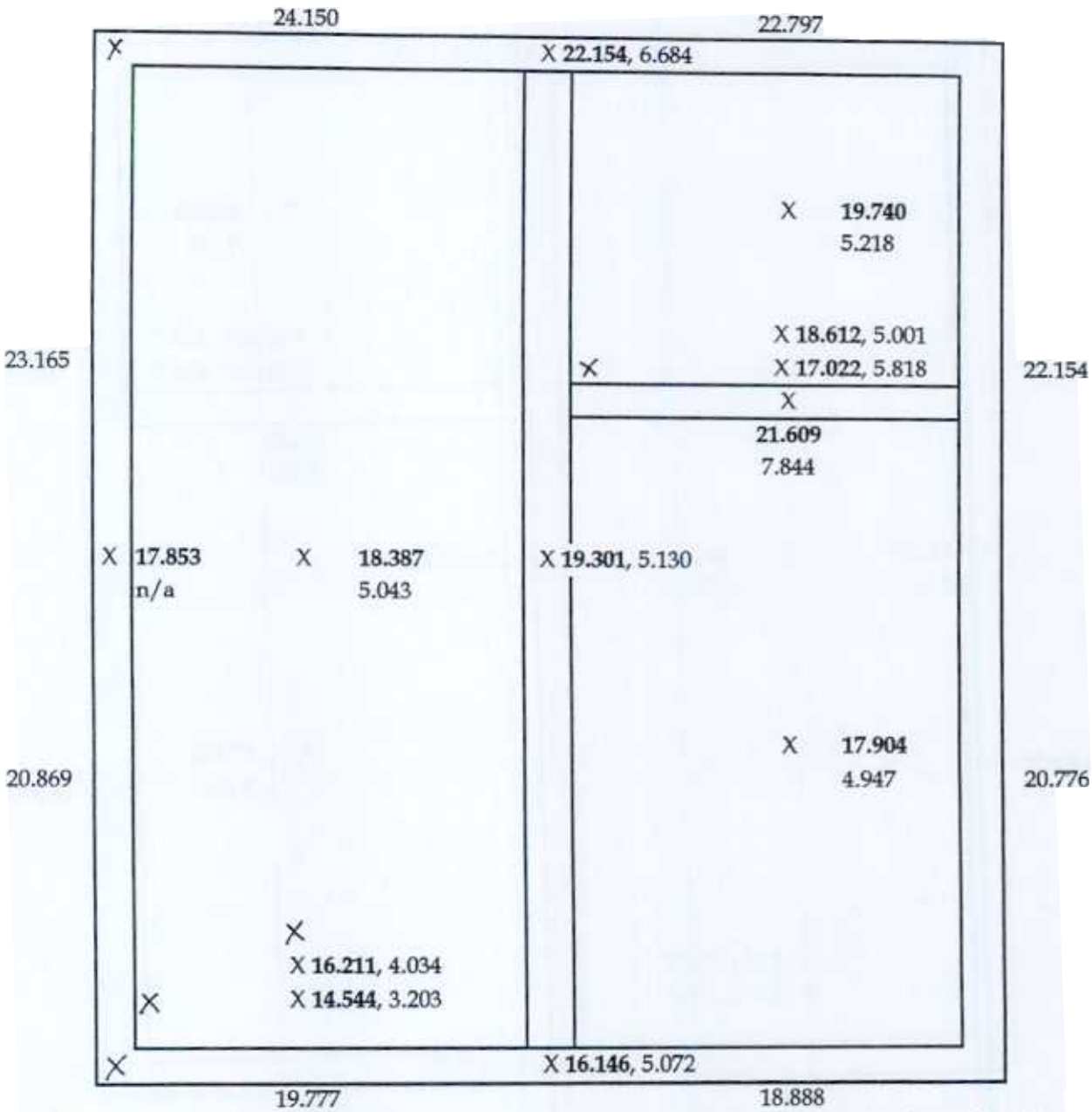

Figure 8 Surface temperatures for TT102 - Wood frame - IGU 4/12/4 1 low-E + thermally broken spacer bar system

Hot Box

Air Temperature: 22.65°C Environmental Temperature: 21.72°C

Cold Box

Air Temperature: 2.09°C Environmental Temperature: 2.11°C

File Number/Date/Time: 103-62, 285/11/96, 07:41

Hot Side (Bold) , Cold Side and Reveal (°C)

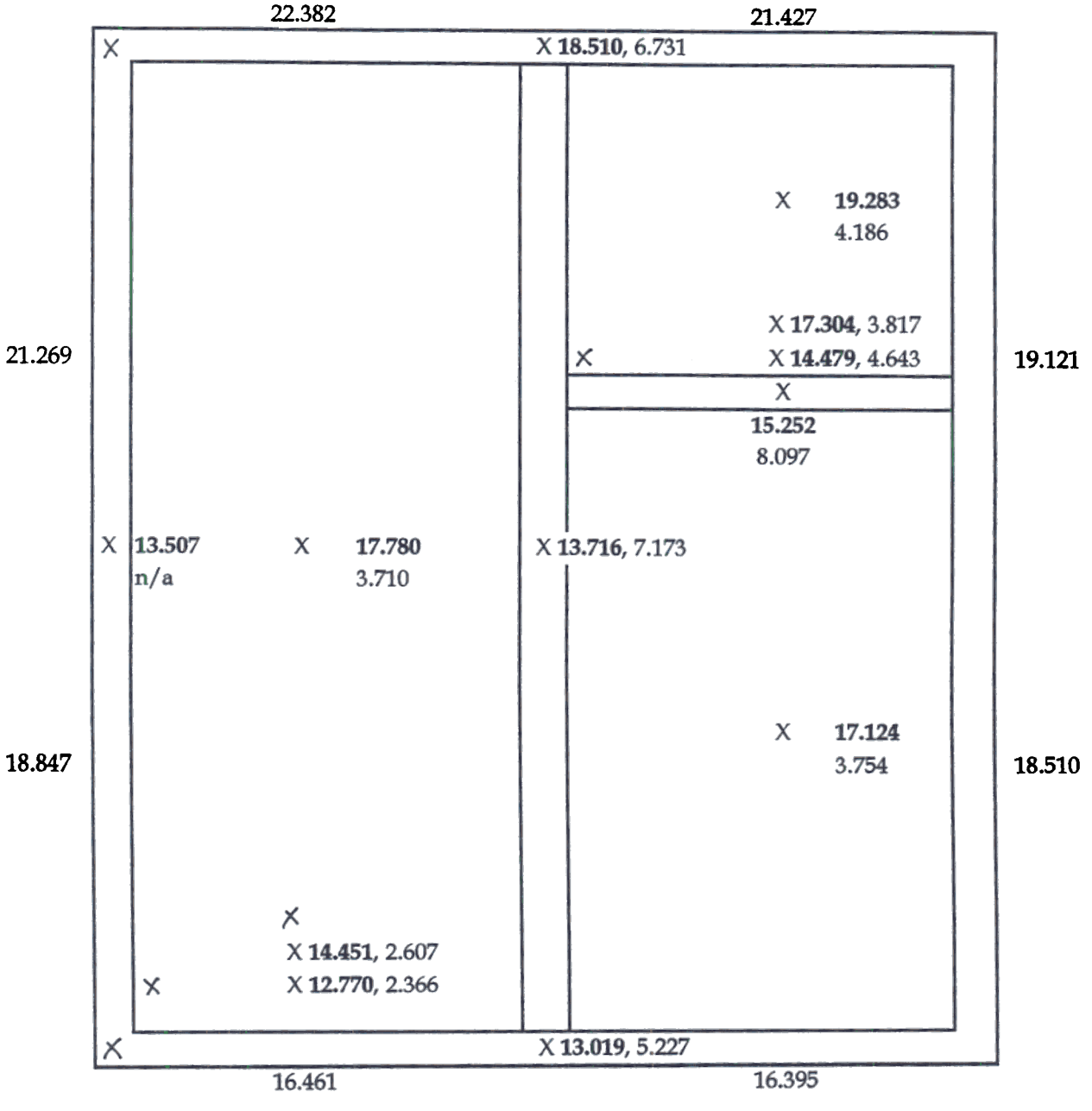

Figure 9 Surface temperatures for TT103 - Aluminium frame - IGU 4/16/4 2 low-E

Hot Box

Air Temperature: 22.83°C Environmental Temperature: 21.90°C

Cold Box

Air Temperature: 1.91°C Environmental Temperature: 1.93°C

File Number/Date/Time: 104-87, 03/12/96, 07:10

Hot Side (Bold) , Cold Side and Reveal (°C)

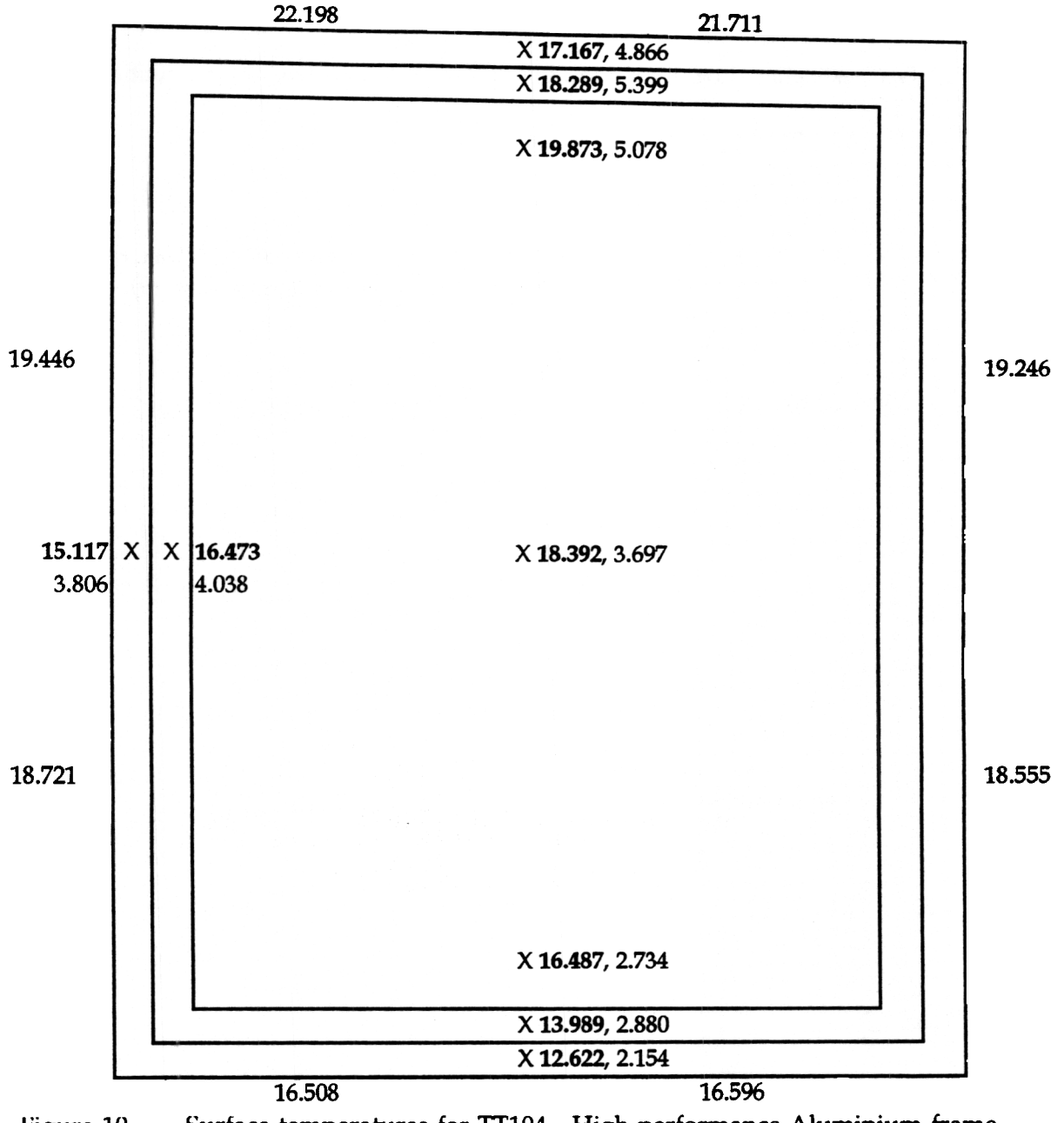

Figure 10 Surface temperatures for TT104 - High performance Aluminium frame - IGU 6/12/4 1 low-E + single glazed window.

5.4.3 The CEN method

The power through the surround panel (W_{sur}) is calculated from the surround panel heat transfer coefficient (equations (2) and (3)). A linear relationship between the surround panel heat transfer coefficient and the calibration panel thickness is assumed.

The heat flux density through the window (q_{win}) is then calculated from the power through the surround panel (W_{sur}), the total power into the hot box (W_t), the Area of the surround panel (A_{sur}) and the area of the window (A_{win}), as shown in equation (7).

$$(W_t - W_{sur})/A_{win} \quad \text{.....(7)}$$

The environmental temperatures (E_i) and (E_e) are calculated from the measured air temperatures and the convective fractions calculated from equations (4) and (5).

The total surface resistance during the measurement ($1/h_t$) is derived from equation (1).

The U-value (U) is calculated using equation (8)

$$U = q_{win}/(E_i - E_e) \quad \text{.....(8)}$$

The measured U-value was then normalised to include the standard total surface resistance value of 0.17 m^2.K/W to give the CEN method U-value (U_{CEN}) using equation (9).

$$U - (1/h_t) + 0.17 \quad \text{.....(9)}$$

These calculations for the eight window systems are shown in Tables 3, 4, 5, 6, 7, 8, 9 and 10.

5.4.4 Summary of measured U-values.

The U-values of the eight window systems, calculated using the two procedures, are shown below in Table 2.

Table 2 Summary of U-values measured using the CEN and "direct" procedures

Window frame ID	Measured U prEN 12412-1 standardised ($0.17 m^2.K/W$) U_{CEN} ($W/m^2.K$)	Measured U "direct method" standardised ($0.17 m^2.K/W$) U_{Dir} ($W/m^2.K$)	Difference U-value $\frac{U_{Dir}-U_{CEN}}{U_{CEN}}$ (%)
TT089 - Al(1) 4/16/4 1K	2.53	2.41	-4.7
TT090 - UPVC 4/16/4 1K	1.90	1.82	-4.2
TT091 - HWood 4/16/4 1K	2.15	2.02	-6.0
TT100 - HWood 4/16/4 1K & Sec. glazing	1.58	1.55	-1.9
TT101 - Al(1) 6/12/6 0K	3.17	3.18	0.3
TT102 - HWood 4/12/4 1K + low λ S/Bar	2.16	2.08	-3.7
TT103 - Al(1) 4/16/4 2K	2.41	2.35	-2.5
TT104 - Al(2) 8/12/4 2K + 6mm Sec/unit	1.75[1]	1.80[1]	2.9

Note[1] The emissivity value of the surfaces of this frame are uncertain.

TT089 U-VALUE CEN CALC METHOD C:\CALC\CENCALB\CENTT089 28/01/97

Test element number TT089 1.48 m x 1.23 m nominal size Frame 30%

Customer.... DOE/Industry Project Project No. Q9TM07

Al. frame; 2 opening lights; Glazing - 4/16/4; air filled; 1 float glass & 1K glass 1.69 W/m2K
Frame thickness = 70mm

NOTE The method used to determine the standardised U-value is that set out in the draft CEN standard CEN/TC89/WG7 prEN12412-1

Data from calibration panels TT083 & TT084 used in these calculations (Using lambda values QM179)							Mean values		Meas. Values	Diff C-M/C
MEASURED VALUES										
Hot side values										
Air temp	(C)						22.14			
Baffle temp	(C)						20.78			
Reveal temp	(C)						19.20			
Cold side values										
Air temp	(C)						1.74			
Baffle temp	(C)						1.84			
Surround panel values										
Hot side temp	(C)						21.79			
Cold side temp	(C)						2.18			
Difference temp	(C)						19.61			
Mean temp	(C)						11.99			
Area	(m2)						1.848			
Power to hot box	(W)						103.86			
CALCULATIONS (CEN8384.101)										
Panel Ht Exch Coef for thin panel at		11.99	C	Cal Pan Thickness		19.69	.5614	(W/K)		
Panel Ht Exch Coef for thick panel a		11.99	C	Cal Pan Thickness		67.98	.6007	(W/K)		
Panel Ht Exch Coef for Specimen at		11.99	C	Test Element thick		70.00	.6023	(W/K)		
Power through specimen							49.817	W/m2	48.991	
Environmental Temperatures										
Cold side convective fraction				From graph CEN8384.005			.860			
Hot side convective fraction				From graph CEN8384.005			.467			
Mean hot radient temp				From CENFRACG			20.60	C		
Mean cold radient temp (Assumed to be the same as baffle temp)							1.84	C		
Hot environmental temp							21.32	C	21.47	-.7$
Cold environmental temp							1.75	C	1.76	-.3$
Environmental temperature difference							19.57	C	19.71	-.7$
U-value CEN Calc & Measured directly							2.546	W/m2.K	2.487	2.3**
Tot surface resistance from curves @		49.817W/m2		From graph CEN8384.006			.167	m2.K/W	.1580	5.4
Standardised U-value (Total surface resistance = 0.17 m2.K/W)							2.53	W/m2.K	2.41	4.4++

** These measured values were obtained by reducing the measured power by 3.0% - the calc. boundary loss.
$ These are calculated by calculating a mean surface temp by area weighting the surface t/c values
++ This is calculated using the directly measured U-values corrected for the measured surface coefficients

Table 3 Derivation of U-value for TT089

TT090 U-VALUE CEN CALC METHOD C:\CALC\CENCALIB\CENTT090 28/01/97

Test element number TT090 1.48 m x 1.23 m nominal size Frame 34%

Customer.... DOE/Industry Project Project No. Q9TM07

uPVC frame; 2 opening lights; Glazing - 4/16/4; air filled; 1 float glass & 1K glass 1.69 W/m2K
Frame thickness = 68.00 mm

NOTE The method used to determine the standardised U-value is that set out in the draft CEN standard CEN/TC89/WG7 prEN12412-1

Data from calibration panels TT083 & TT084 used in these calculations (Using Lambda values QM179)						Mean values		Meas. Values	Diff C-M/C
MEASURED VALUES									
Hot side values									
Air temp	(C)					22.96			
Baffle temp	(C)					21.34			
Reveal temp	(C)					20.87			
Cold side values									
Air temp	(C)					2.29			
Baffle temp	(C)					2.36			
Surround panel values									
Hot side temp	(C)					22.28			
Cold side temp	(C)					2.67			
Difference temp	(C)					19.61			
Mean temp	(C)					12.48			
Area	(m2)					1.845			
Power to hot box	(W)					80.90			
CALCULATIONS (Graph CEN8384.101)									
Panel Ht Exch Coef for thin panel at		12.48	C	Cal Pan Thickness	19.69	.5610	(W/K)		
Panel Ht Exch Coef for thick panel a		12.48	C	Cal Pan Thickness	67.98	.6001	(W/K)		
Panel Ht Exch Coef for Specimen at		12.48	C	Test Element thick	68.00	.6001	(W/K)		
Power through specimen						37.466	W/m2	36.967	1.3**
Environmental Temperatures									
Cold side convective fraction				From graph CEN8384.005		.857			
Hot side convective fraction				From graph CEN8384.005		.446			
Mean hot radient temp				From CENFRACG		21.29	C		
Mean cold radient temp (Assumed to be the same as baffle temp)						2.36	C		
Hot environmental temp						22.03	C	22.14	-.5$
Cold environmental temp						2.30	C	2.30	$
Environmental temperature difference						19.73	C	19.84	-.5$
U-value CEN Calc & Measured directly						1.899	W/m2.K	1.864	1.8**
Tot surface resistance from curves @	37.466W/m2			From graph CEN8384.006		.170	m2.K/W	.1578	7.0
Standardised U-value (Total surface resistance = 0.17 m2.K/W)						1.90	W/m2.K	1.82	4.0++

** These measured values were obtained by reducing the measured power by 3.0 % - the calc. boundary loss.
$ These are calculated by calculating a mean surface temperature by area weighting the surface t/c values
++ This is calculated using the directly measured U-values corrected for measured surface coefficients

Table 4 Derivation of U-value for TT090

TT091 U-VALUE CEN CALC METHOD C:\CALC\CENCALIB\CENTT091 16/11/95

Test element number TT091 1.48 m x 1.23 m nominal size Frame 41%

Customer.... DOE/Industry Project Project No. Q9TM07

Hardwood frame; 2 opening lights; Glazing - 4/16/4; air filled; 1 float glass & 1K glass 1.69 W/m2K
Frame thickness = 74.00 mm

NOTE The method used to determine the standardised U-value is that set out in the draft CEN standard CEN/TC89/WG7 prEN12412-1

Data from calibration panels TT083 & TT084 used in these calculations (Using lambda data QM179)					Mean values		Meas. Values	Diff C-M/C
MEASURED VALUES								
Hot side values								
Air temp	(C)				22.77			
Baffle temp	(C)				21.03			
Reveal temp	(C)				20.43			
Cold side values								
Air temp	(C)				2.21			
Baffle temp	(C)				2.27			
Surround panel values								
Hot side temp	(C)				22.13			
Cold side temp	(C)				2.61			
Difference temp	(C)				19.52			
Mean temp	(C)				12.37			
Area	(m2)				1.846			
Power to hot box	(W)				89.64			
CALCULATIONS (Graph CEN8384.101)								
Panel Ht Exch Coef for thin panel at	12.37	C	Cal Pan Thickness	20.01	.5611	(W/K)		
Panel Ht Exch Coef for thick panel a	12.37	C	Cal Pan Thickness	67.98	.6002	(W/K)		
Panel Ht Exch Coef for Specimen at	12.37	C	Test Element thick	74.00	.6051	(W/K)		
Power through specimen					42.163	W/m2	41.577	1.4**
Environmental Temperatures								
Cold side convective fraction			From graph CEN8384.005		.858			
Hot side convective fraction			From graph CEN8384.005		.454			
Mean hot radient temp			From CENFRACG		20.96	C		
Mean cold radient temp (Assumed to be the same as baffle temp)					2.27	C		
Hot environmental temp					21.78	C	21.95	-.8$
Cold environmental temp					2.22	C	2.22	-.1$
Environmental temperature difference					19.56	C	19.73	-.9$
U-value CEN Calc & Measured directly					2.155	W/m2.K	2.107	2.2**
Tot surface resistance from curves @	42.163W/m2		From graph CEN8384.006		.168	m2.K/W	.1506	10.6
Standardised U-value (Total surface resistance = 0.17 m2.K/W)					2.15	W/m2.K	2.02	5.8++

** These measured values were obtained by reducing the measured power by 3.0 % - the calc. boundary loss.
$ These are calculated by calculating a mean surface temperature by area weighting the surface t/c values
++ This is calculated using the directly measured U-values corrected for measured surface coefficients

Table 5 Derivation of U-value for TT091

WINDOW U-VALUE CEN CALCULATION METHOD CENTT100 28/01/97

Test element number TT100 1.48 m x 1.23 m nominal size 35% Frame

Customer.... Service Number = DOE PIT Project No. Q9TM07

Wood Window / Secondary Unit 1.26 W/m2K Frame thickness = 110.00 mm

NOTE: The method used to determine the standardised U-value is that specified in prEN 12412-1

Data from calibration panels TT083 & TT084 used in these calculations		Date Time	Date Time	Date Time	Date Time	Date Time	Mean values	Range (%)	Meas. Values	Diff C-M/C
MEASUREMENTS MADE IN THE WGHB		14/11/96 08.14hr	14/11/96 02.14hr	14/11/96 04.15hr	14/11/96 06.16hr	14/11/96 08.17hr				
MEASURED VALUES										
Hot side values										
Air temp	(C)						24.27	.1		
Baffle temp	(C)						22.97	.1		
Reveal temp	(C)						22.35	.2		
Cold side values										
Air temp	(C)						2.08	1.9		
Baffle temp	(C)						2.13	1.9		
Surround panel values										
Hot side temp	(C)						23.13	.2		
Cold side temp	(C)						2.55	2.7		
Difference temp	(C)						20.58	.4		
Mean temp	(C)						12.84			
Area	(m2)						1.840			
Power to hot box	(W)						75.25	.1		
CALCULATIONS										
Surround panel coefficients calculted using Report QM115 Graph 2										
Surround panel Ht Exchange Coef for 68.0 mm calibration panel @ 12.84							.5997			
Surround panel Ht Exchange Coef for 19.7 mm calibration panel @ 12.84							.5607			
Surround panel Ht Exchange Coef for 110.0 mm window system @ 12.84							.634	(W/K)		
Power through specimen							33.812	W/m2	33.790	.1**
Environmental Temperatures										
Cold side convective fraction	From Report QM 115 Graph 3						.857			
Hot side convective fraction	From Report QM 115 Graph 3						.440			
Mean hot radient temp	From CENFRAC2						22.92	C		
Mean cold radient temp (Assumed to be the same as baffle temp)							2.13	C		
Hot environmental temp							23.52	C	23.555	
Cold environmental temp							2.09	C	2.088	
Environmental temperature difference							21.43	C	21.467	-.2
U-value CEN & measured directly							1.578	W/m2.K	1.574	.2**
Tot surface resistance from curves @ 33.812W/m2	From Report QM 115 Graph 1						.169	m2.K/W	.1583	
Standardised U-value (Total surface resistance = 0.17 m2.K/W)							1.58	W/m2.K	1.55	2.0

** These measured values were obtained by direct measurements. The boundary loss was assumed to be 3%.

Table 6 Derivation of U-value for TT100

WINDOW U-VALUE CEN CALCULATION METHOD CENTT101 28/01/97

Test element number TT101 1.48 m x 1.23 m nominal size 30% Frame

Customer.... DOE PIT Project No. Q9TM07

Aluminium Window 6/12/6 plain glass 2.80 W/m2K Frame thickness = 75.00

NOTE: The method used to determine the standardised U-value is that specified in prEN 12412-1

Data from calibration panels TT083 & TT084 used in these calculations		Date Time	Date Time	Date Time	Date Time	Date Time	Mean values	Range (%)	Meas. Values	Diff C-M/C
MEASUREMENTS MADE IN THE WGHB		19/11/96 00.26hr	19/11/96 02.27hr	19/11/96 04.27hr	19/11/96 06.28hr	19/11/96 08.29hr				
MEASURED VALUES										
Hot side values										
Air temp	(C)						22.37	.2		
Baffle temp	(C)						20.52	.2		
Reveal temp	(C)						18.96	.2		
Cold side values										
Air temp	(C)						2.39	1.3		
Baffle temp	(C)						2.47	1.6		
Surround panel values										
Hot side temp	(C)						21.37	.2		
Cold side temp	(C)						2.80	1.1		
Difference temp	(C)						18.57	.3		
Mean temp	(C)						12.08			
Area	(m2)						1.847			
Power to hot box	(W)						123.39	.4		
CALCULATIONS										
Surround panel coefficients calculted using Report QM115 Graph 2										
Surround panel Ht Exchange Coef for	68.0 mm calibration panel @					12.08	.6005			
Surround panel Ht Exchange Coef for	19.7 mm calibration panel @					12.08	.5614			
Surround panel Ht Exchange Coef for	75.0 mm window system @					12.08	.606	(W/K)		
Power through specimen							60.712	W/m2	59.560	1.9**
Environmental Temperatures										
Cold side convective fraction	From Report QM 115 Graph 3						.862			
Hot side convective fraction	From Report QM 115 Graph 3						.485			
Mean hot radient temp	From CENFRAC2						20.36	C		
Mean cold radient temp (Assumed to be the same as baffle temp)							2.47	C		
Hot environmental temp							21.33	C	21.407	
Cold environmental temp							2.40	C	2.409	
Environmental temperature difference							18.93	C	18.998	-.4
U-value CEN & measured directly							3.207	W/m2.K	3.135	2.2**
Tot surface resistance from curves @ 60.712W/m2	From Report QM 115 Graph 1						.167	m2.K/W	.1745	
Standardised U-value (Total surface resistance = 0.17 m2.K/W)							3.17	W/m2.K	3.18	

** These measured values were obtained by direct measurements. The boundary loss was assumed to be 3%.

Table 7 Derivation of U-value for TT101

WINDOW U-VALUE CEN CALCULATION METHOD CENTT102 28/01/97

Test element number TT102 1.48 m x 1.23 m nominal size 35% Frame

Customer.... Service Number = DOE PIT Project No. Q9TM07

Wood Window 4/12/4 K glass & special spacer 1.92 W/m2K Frame thickness = 68.00

NOTE: The method used to determine the standardised U-value is that specified in prEN 12412-1

Data from calibration panels TT083 & TT084 used in these calculations		Date Time	Date Time	Date Time	Date Time	Date Time	Mean values	Range (%)	Meas. Values	Diff C-M/C
MEASUREMENTS MADE IN THE WGHB		25/11/96 00.51hr	25/11/96 02.52hr	25/11/96 04.52hr	25/11/96 06.53hr	25/11/96 08.54hr				
MEASURED VALUES										
Hot side values										
Air temp	(C)						24.10	.1		
Baffle temp	(C)						22.64	.1		
Reveal temp	(C)						21.58	.2		
Cold side values										
Air temp	(C)						2.93	1.4		
Baffle temp	(C)						2.98	1.7		
Surround panel values										
Hot side temp	(C)						23.18	.2		
Cold side temp	(C)						3.38	1.5		
Difference temp	(C)						19.79	.2		
Mean temp	(C)						13.28			
Area	(m2)						1.850			
Power to hot box	(W)						93.28	.1		
CALCULATIONS										
Surround panel coefficients calculted using Report QM115 Graph 2										
Surround panel Ht Exchange Coef for 68.0 mm calibration panel @						13.28	.5991			
Surround panel Ht Exchange Coef for 19.7 mm calibration panel @						13.28	.5603			
Surround panel Ht Exchange Coef for 68.0 mm window system @						13.28	.599	(W/K)		
Power through specimen							44.011	W/m2	43.311	1.6**
Environmental Temperatures										
Cold side convective fraction				From Report QM 115 Graph 3			.859			
Hot side convective fraction				From Report QM 115 Graph 3			.457			
Mean hot radient temp				From CENFRAC2			22.56	C		
Mean cold radient temp (Assumed to be the same as baffle temp)							2.98	C		
Hot environmental temp							23.27	C	23.406	
Cold environmental temp							2.93	C	2.939	
Environmental temperature difference							20.33	C	20.467	-.7
U-value CEN & measured directly							2.164	W/m2.K	2.116	2.2**
Tot surface resistance from curves @ 44.011W/m2				From Report QM 115 Graph 1			.168	m2.K/W	.1612	4.1
Standardised U-value (Total surface resistance = 0.17 m2.K/W)							2.156	W/m2.K	2.078	3.6

** These measured values were obtained by direct measurements. The boundary loss was assumed to be 3%.

Table 8 Derivation of U-value for TT102

WINDOW U-VALUE CEN CALCULATION METHOD CENTT103 28/01/97

Test element number TT103 1.48 m x 1.23 m nominal size 30% Frame

Customer.... Service Number = DOE PIT Project No. Q9TM07

Aluminium Window & 4/16/4 K glass 1.52 W/m2K Frame thickness = 75.00 mm

NOTE: The method used to determine the standardised U-value is that specified in prEN 12412-1

Data from calibration panels TT083 & TT084 used in these calculations		Date Time	Date Time	Date Time	Date Time	Date Time	Mean values	Range (%)	Meas. Values	Diff C-M/C
MEASUREMENTS MADE IN THE WGHB		27/11/96 23.37hr	28/11/96 01.38hr	28/11/96 03.39hr	28/11/96 05.40hr	28/11/96 07.41hr				
MEASURED VALUES										
Hot side values										
Air temp	(C)						22.64	.1		
Baffle temp	(C)						21.12	.1		
Reveal temp	(C)						19.28	.2		
Cold side values										
Air temp	(C)						2.09	2.4		
Baffle temp	(C)						2.17	2.8		
Surround panel values										
Hot side temp	(C)						22.61	.3		
Cold side temp	(C)						2.45	2.9		
Difference temp	(C)						20.16	.3		
Mean temp	(C)						12.53			
Area	(m2)						1.848			
Power to hot box	(W)						100.25	.3		
CALCULATIONS										
Surround panel coefficients calculted using Report QM115 Graph 2										
Surround panel Ht Exchange Coef for	68.0 mm calibration panel @					12.53	.6000			
Surround panel Ht Exchange Coef for	19.7 mm calibration panel @					12.53	.5610			
Surround panel Ht Exchange Coef for	75.0 mm window system @					12.53	.606	(W/K)		
Power through specimen							47.642	W/m2	46.922	1.5**
Environmental Temperatures										
Cold side convective fraction				From Report QM 115 Graph 3			.859			
Hot side convective fraction				From Report QM 115 Graph 3			.463			
Mean hot radient temp				From CENFRAC2			20.99	C		
Mean cold radient temp (Assumed to be the same as baffle temp)							2.17	C		
Hot environmental temp							21.75	C	21.825	
Cold environmental temp							2.10	C	2.104	
Environmental temperature difference							19.65	C	19.721	-.3
U-value CEN & measured directly							2.424	W/m2.K	2.379	1.9**
Tot surface resistance from curves @ 47.642W/m2				From Report QM 115 Graph 1			.168	m2.K/W	.1653	
Standardised U-value (Total surface resistance = 0.17 m2.K/W)							2.411	W/m2.K	2.353	2.4

** These measured values were obtained by direct measurements. The boundary loss was assumed to be 3%.

Table 9 Derivation of U-value for TT103

WINDOW U-VALUE CEN CALCULATION METHOD CENTT104 04/12/96

Test element number TT104 1.48 m x 1.23 m nominal size 32 % frame

Customer.... Service Number = DOE PIT Project Q9TM07

Double Window Frame thickness = 70.00

NOTE: The method used to determine the standardised U-value is that specified in prEN 12412-1

Data from calibration panels TT083 & TT084 used in these calculations		Date Time	Date Time	Date Time	Date Time	Date Time	Mean values	Range (%)	Meas. Values	Diff C-M/C
MEASUREMENTS MADE IN THE WGHB		02/12/96 23.06hr	03/12/96 01.07hr	03/12/96 03.08hr	03/12/96 05.09hr	03/12/96 07.10hr				
MEASURED VALUES										
Hot side values										
Air temp	(C)						22.85	.1		
Baffle temp	(C)						21.57	.1		
Reveal temp	(C)						19.18	.5		
Cold side values										
Air temp	(C)						1.94	2.8		
Baffle temp	(C)						2.00	2.3		
Surround panel values										
Hot side temp	(C)						22.18	.2		
Cold side temp	(C)						2.36	2.1		
Difference temp	(C)						19.82	.2		
Mean temp	(C)						10.18			
Area	(m2)						1.845			
Power to hot box	(W)						76.91	.3		
CALCULATIONS										
Surround panel coefficients calculted using Report QM115 Graph 2										
Surround panel Ht Exchange Coef for	68.0 mm calibration panel @					10.18	.6028			
Surround panel Ht Exchange Coef for	19.7 mm calibration panel @					10.18	.5631			
Surround panel Ht Exchange Coef for	70.0 mm window system @					10.18	.604	(W/K)		
Power through specimen							35.195	W/m2	35.899	-2.0**
Environmental Temperatures										
Cold side convective fraction				From Report QM 115 Graph 3			.857			
Hot side convective fraction				From Report QM 115 Graph 3			.443			
Mean hot radient temp				From CENFRAC2			20.60	C		
Mean cold radient temp (Assumed to be the same as baffle temp)							2.00	C		
Hot environmental temp							21.59	C	21.936	
Cold environmental temp							1.94	C	1.949	
Environmental temperature difference							19.65	C	19.987	
U-value CEN & measured directly							1.791	W/m2.K	1.796	
Tot surface resistance from curves @	35.195W/m2			From Report QM 115 Graph 1			.169	m2.K/W		
Standardised U-value (Total surface resistance = 0.17 m2.K/W)							1.789	W/m2.K	1.794	-.3

** These measured values were obtained by direct measurements. The boundary loss was assumed to be 3%

Table 10 Derivation of U-value for TT104

6 UNCERTAINTIES

An error analysis for this equipment is described in NPL Report QU 91, page 8. The uncertainty in the measurement of conductance of a double-glazed panel mounted in a surround 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 standard apparatus.

The uncertainty of the CEN method is currently the subject of international discussions. Detailed error analysis by EMPA (Switzerland) and TNO (Netherlands) have produced figures of ± 8% to the 95% confidence level.

7 DISCUSSION

- The calculated surround panel heat transfer coefficient is very sensitive to changes in the calculated calibration panel conductance. A 1% change in the predicted conductance of the 20 mm thick calibration panel produces a 6% change in the surround panel heat transfer coefficient.

  Despite this however, it can be shown that even if the heat transfer coefficient for the thin panel was increased by 42%, the calculated power through a window system with a U-value of 2.5 $W/m^2.K$ increases by only 0.25%.

  The most important effect of the calculated conductance value of the thin panel is in correcting the measured U-values to the standard total surface resistance value. For example by increasing the calculated conductance by 4.5% the standardised U-value of a window with a U-value of 2.5 $W/m^2.K$ will increase by 1.8%.

  The uncertainty in the calculated value of power through the test element is approximately the same as the uncertainty in the predicted conductance of the calibration panels. An advantage of the method is that this uncertainty figure will include many sources of error which have not necessarily been identified when using the direct measurement method. For example, errors due to the thermal conductivity of the surround panel material, thickness of the surround panel and any spurious heat transfer paths are effectively calibrated out when using this CEN procedure.

8 CONCLUSIONS

The results (see Table 2) show that when using the NPL WGHB, the method specified in CEN prEN12412-1 produces U-values for a whole-window system that are between 2% and 6% higher than those obtained by the direct measurement procedure. The CEN procedure eliminates the need to derive an area-weighted "mean" surface temperature and a figure for the "boundary loss" around the specimen edge; two issues that have proved difficult to standardise and have undoubtably contributed to inconsistent measurements results, from different laboratories in the past.

For a detailed review of these measured U-values compared to the simulated U-values see NPL Report QM131.

APPENDIX A Dimensions of the different frame sections measured.

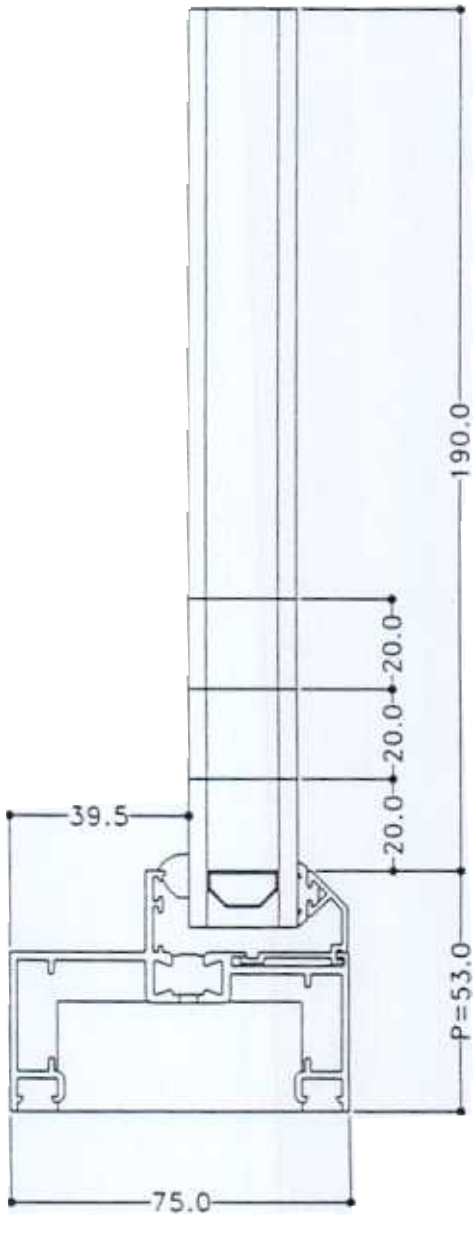

Figure A1 Dimensions of Aluminium Frame - frame section A

All dimensions in mm

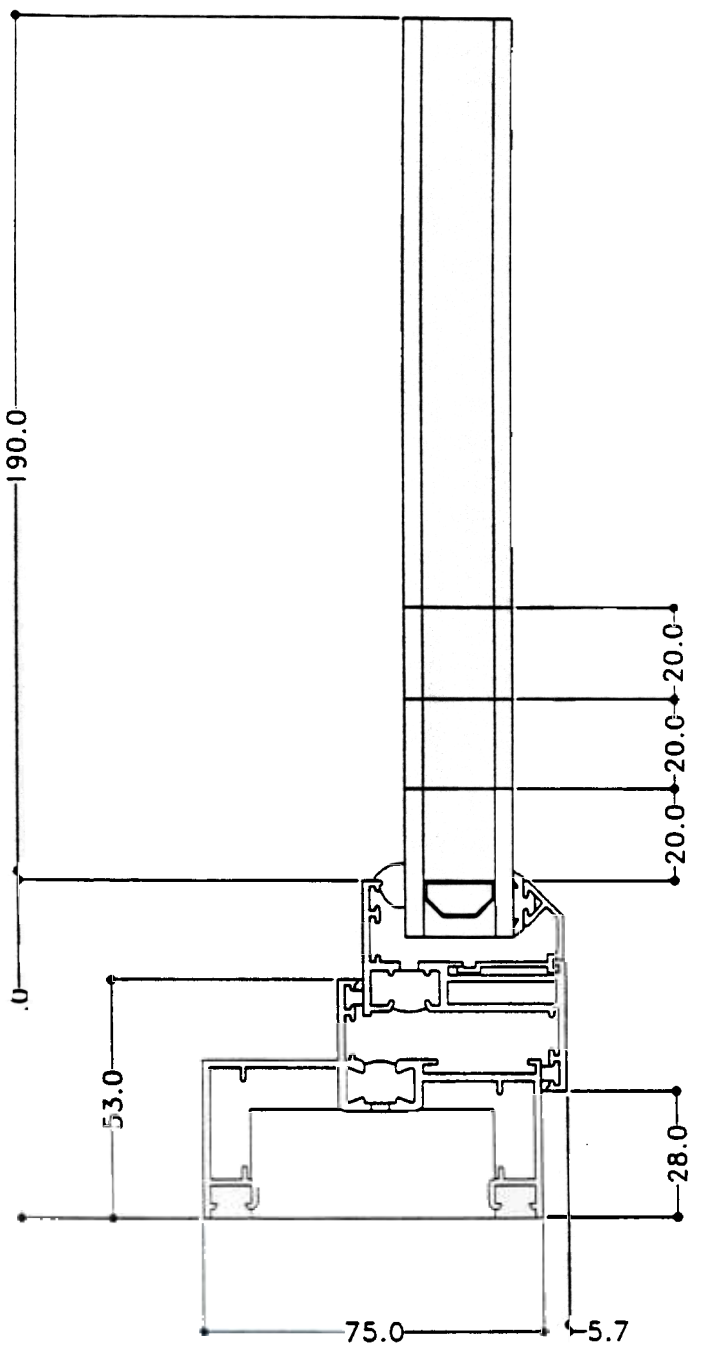

Figure A2 Dimensions of Aluminium Frame - frame section B

All dimensions in mm

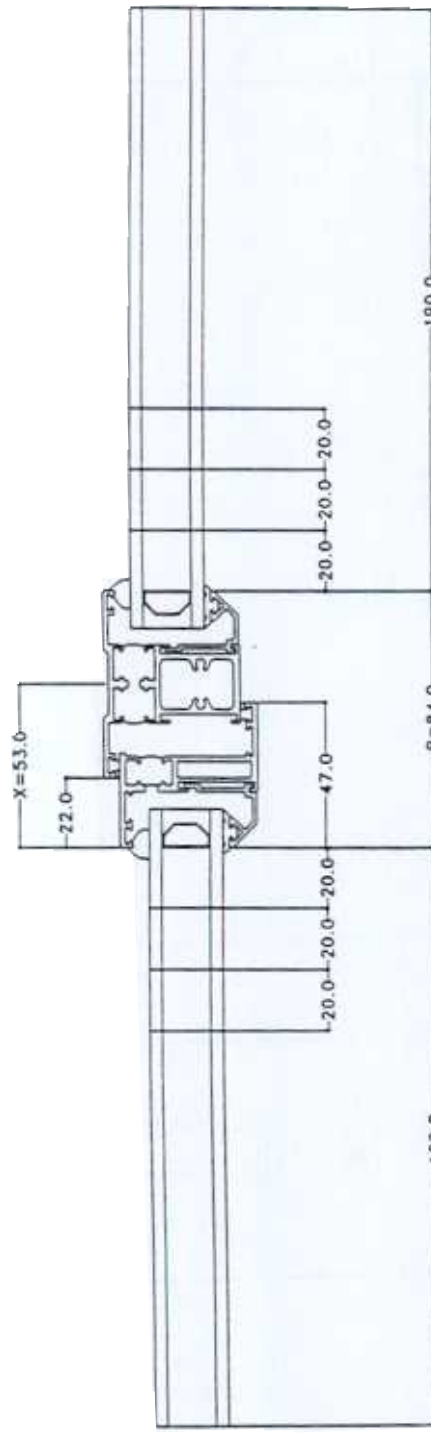

Figure A3 Dimensions of Aluminium Frame - frame section C

All dimensions in mm

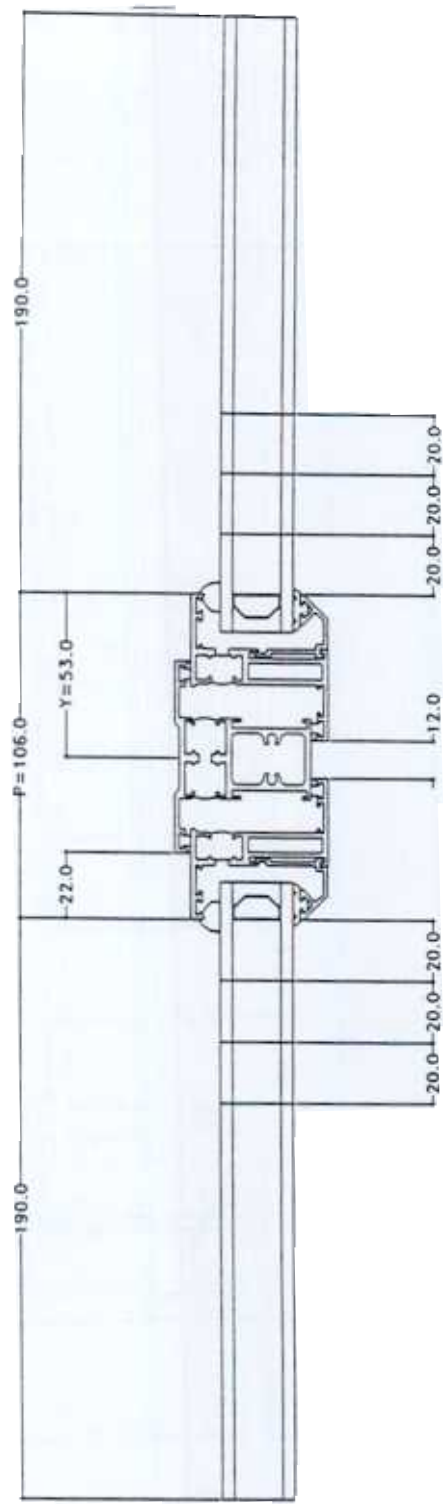

Figure A4 Dimensions of Aluminium Frame - frame section D

All dimensions in mm

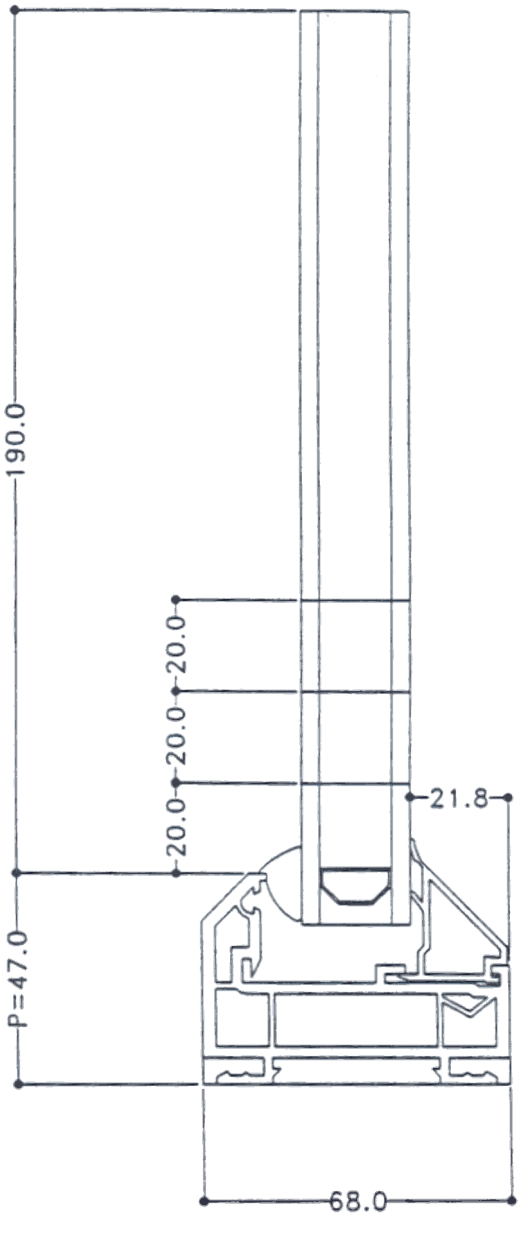

Figure A5 Dimensions of PVC-U Frame - frame section A

All dimensions in mm

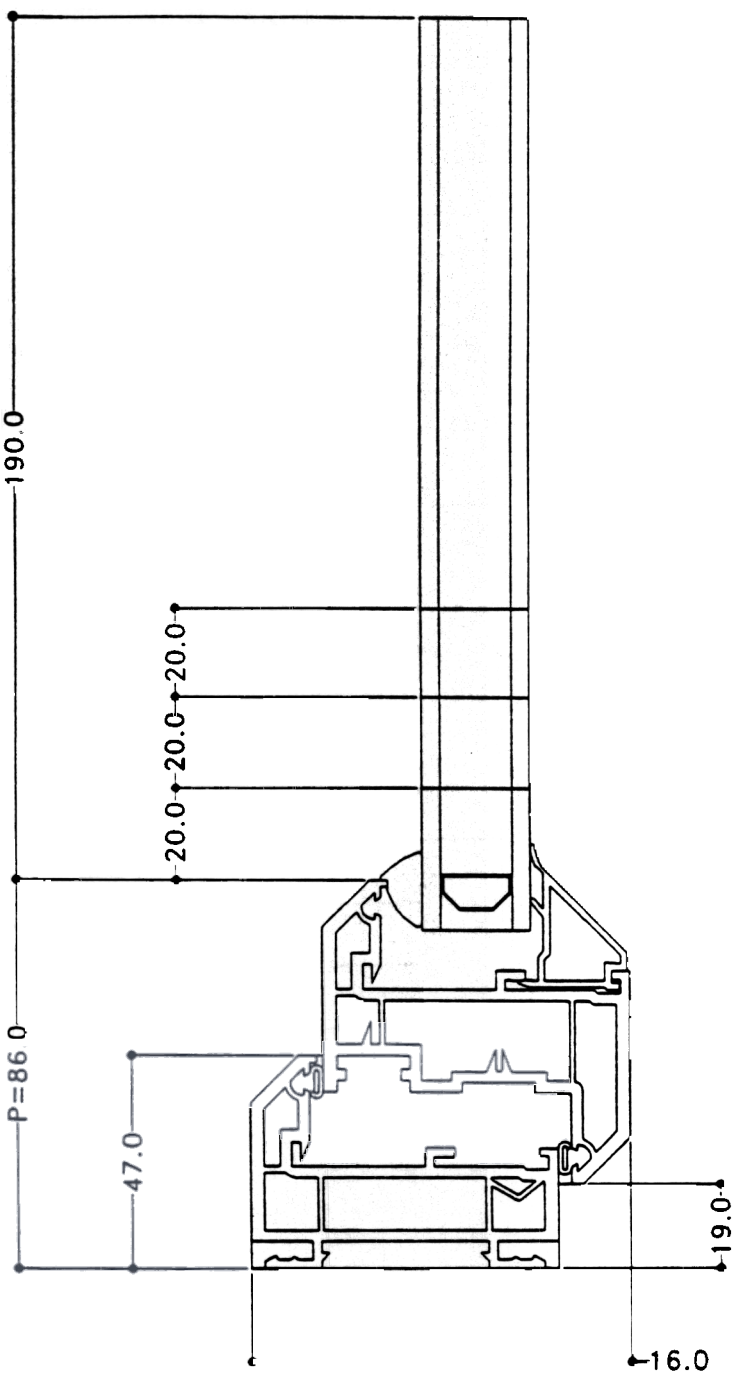

Figure A6 Dimensions of PVC-U Window - frame section B

All dimensions in mm

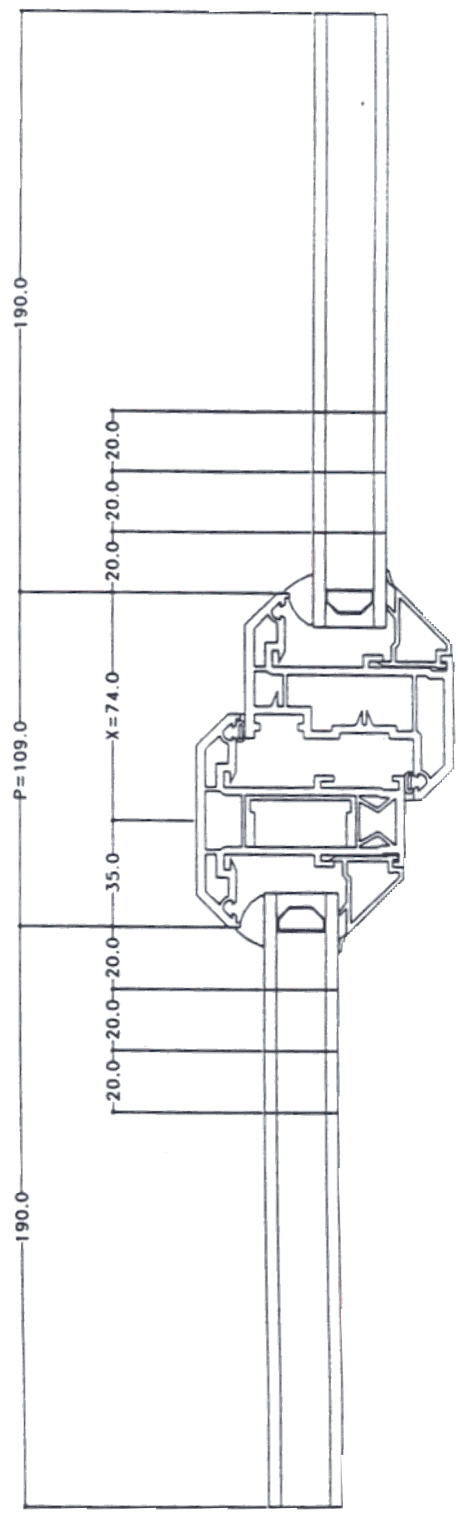

Figure A7 Dimensions of PVC-U Frame - frame section C

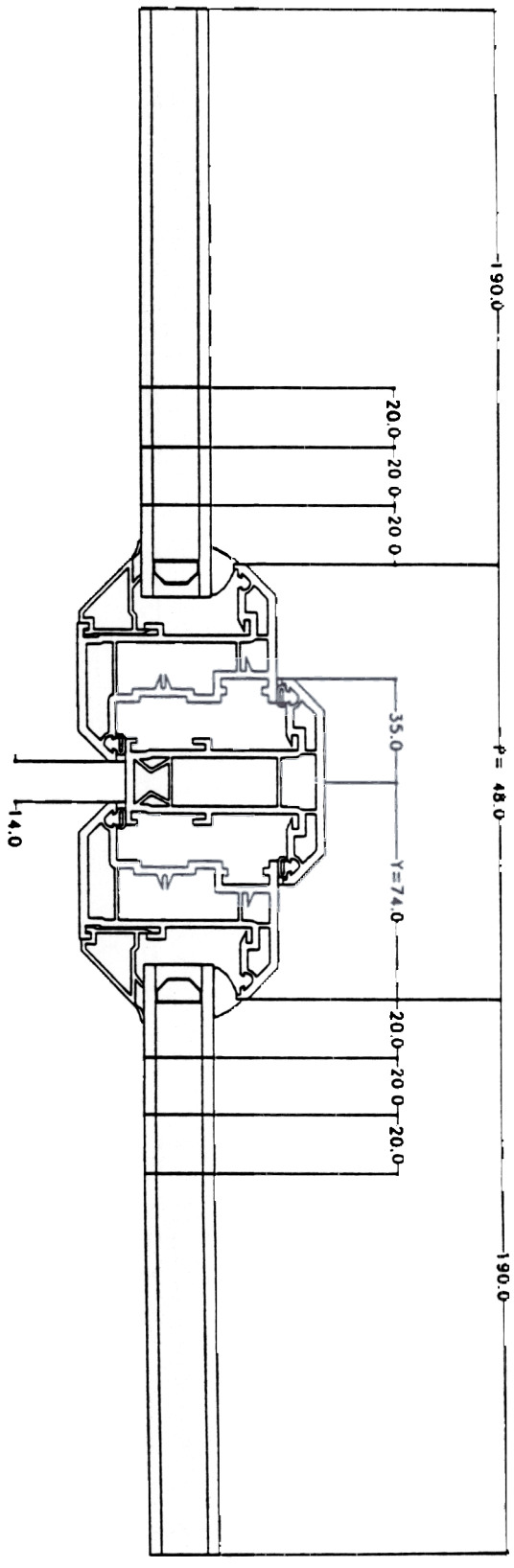

Figure A8 Dimensions of PVC-U Frame - frame section D

me ns mi

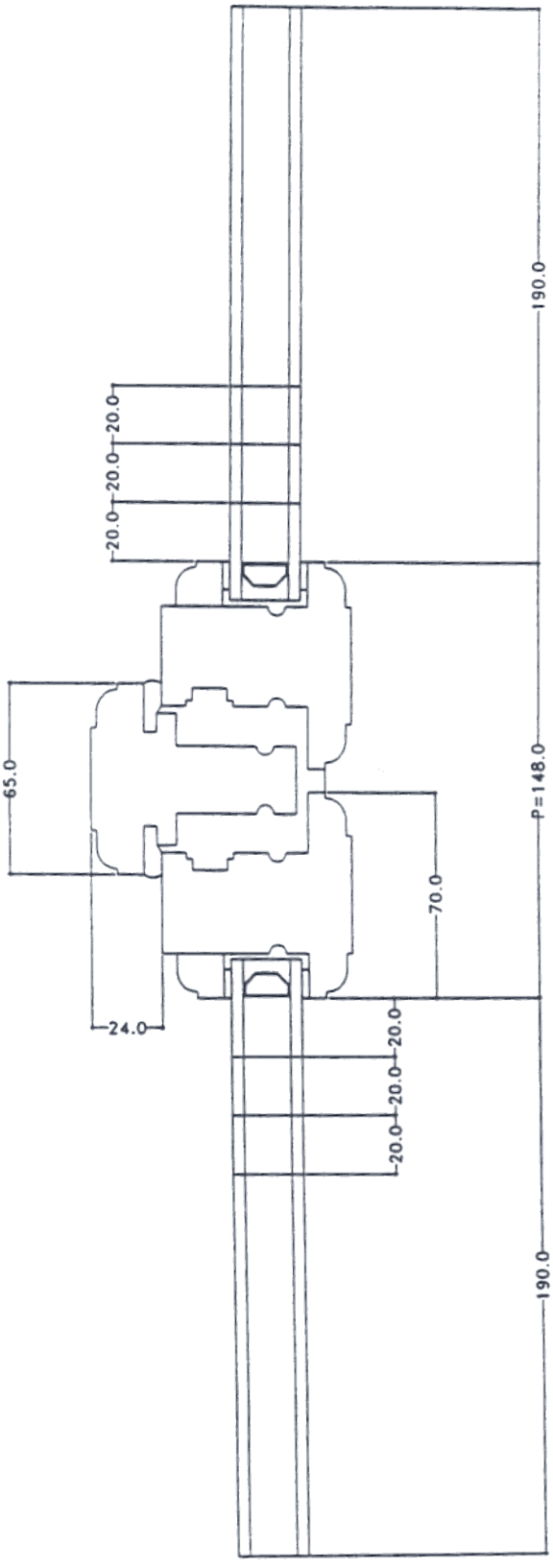

Figure A Dimensions of Wood frame frame section B

ANNEX B Hot Box Measurement Data

Table A2

Hot box measured data for TT090

Summary of experimental data TT090 **CALCULATIONS CARRIED OUT BY SPREADSHEET** **Sheet**

PVC-U Window Frame 1.4 X 1.23 m nominal dimensions 1.69 W/m2K **1.48 x 1.23 x 0.06 m NO BEADING**

Date & Time	Total Power Cor for HFM Off (W)	Surrd Surface Hot (C)	Surrd Surface Cold (C)	Power Thro' Insert -BL% (W)	Hot Surf Temp (C)		Cold Surf Temp (C)		Surf Temp Diff (C)	Air Temp. Hot (C)	Air Temp. Cold (C)	Air Temp. Diff (C)	Environ Temp Hot (C)	Environ Temp Cold (C)	Environ Temp Diff (C)	Atmos. Press. (mb)	Baffle Hot (C)	Baffle Cold (C)	Therm Cond (W/m2.K)	Therm Trans (W/m2.K)	Surface Res. Hot (m2.K/W)	Surface Res. Cold (m2.K/W)
TT090A	Area (m2)	1.84510	Area holder (m2) =		1.97490			B.LAMan	3.0	Mean T =	11.18		Th Con Holder =			.0411	Hr(c) =		5.69		Hr(h) =	4.7[illegible]
	Efth (mm)	n/a	Thick @ edge(mm) =		68.00			Em Fact H	.8332	Th Conductance no BL% =			2.72947 W/m2K				Stan.Tran		.17000	1.8222	Tot Res	.157[illegible]
								Em Fact C	.8332													
12/10/95 22.17hrs	81.1098	22.27	2.64	68.40559	18.19	XXX	4.18	XXX	12.63	22.94	2.25	20.69	22.13	2.27	19.86	1,021.2	21.33	2.33	2.6476	1.8666	.1064	.0511
13/10/95 00.29hrs	80.9124	22.31	2.65	68.19842	18.19	XXX	4.18	XXX	12.64	22.99	2.29	20.70	22.17	2.31	19.86	1,021.2	21.38	2.37	2.6396	1.8610	.1077	.0506
13/10/95 02.38hrs	80.9365	22.29	2.72	68.24896	18.19	XXX	4.18	XXX	12.58	22.97	2.32	20.65	22.15	2.34	19.81	1,021.0	21.35	2.40	2.6423	1.8676	.1071	.0491
13/10/95 04.48hrs	80.8191	22.27	2.64	68.12363	18.19	XXX	4.18	XXX	12.60	22.94	2.28	20.66	22.12	2.29	19.83	1,020.8	21.32	2.33	2.6367	1.8618	.1066	.0512
13/10/95 06.58hrs	80.7056	22.24	2.68	68.03975	18.19	XXX	4.18	XXX	12.58	22.94	2.29	20.65	22.12	2.30	19.81	1,021.1	21.31	2.35	2.6334	1.8611	.1066	.0510
Av.Values	80.8967	22.28	2.67	68.20727	18.19	XXX	4.18	XXX	12.61	22.96	2.29	20.67	22.14	2.30	19.84	1,021.1	21.34	2.36	2.6399	1.8636	.1069	.0501
% Varin	.5	.2	3.0	.5		XXX		XXX	.3	.2	3.1	.2	.2	3.0	.3		.3	3.0	.5	.4	1.3	3.[illegible]

WGHB data summary sheet GENERAL

ALL CALCULATIONS CARRIED OUT BY SPREADSHEET   Sheet   DIR100A

TT100   Holder Panel 1   Data entered by...DAH   Data entry checked by.....   Today's date   31/ 1/97
14 Nov 1996
Wood Window & Secondary Glazing Unit 1.26 W/m2Holder thermal conductivity data from 610 results   Service number..   DOE PIT Project Q9TH07

*** THE DATA MUST BE ENTERED IN THE ROWS ABOVE THE DOTTED LINE. THE DATA IS THEN AUTOMATICALLY READ INTO THE PART BELOW THE LINE AND THE RESULTS CALCULATED. ****

DATA IS READ DIRECTLY FROM A DATA FILE AS FOLLOWS: //I,Numbers,A:\sc5calc1.asc,All

1 Date & Time	2 Spec. Area (m^2)	3 Hold ThCn (W/m.K)	4 Atm. Prss (mb)	5 Total power (W)	6 Hold Hot Temp (C)	7 Hold Cold Temp (C)	8 Spec Hot Surf. (C)	9 Spec Cold Surf (C)	10 Air Temp Hot (C)	11 Air Temp Cold (C)	12 Baffle Hot Temp (C)	13 Baffle Cold Temp (C)	14 Diviny Offset (uV)	15 Bound Loss (%)	16 Stand. Sur. Res. (m^2.K/W)	17 Thick Effect (m)	18 Thick Edge (m)	
14 Nov 1996 00:14:00	1.840	.0412	1,022.4	75.179	23.11	2.51	19.70	3.58	24.26	2.06	22.95	2.12	-24.8	3.0				Line 1
14 Nov 1996 02:14:50	1.840	.0412	1,023.0	75.140	23.11	2.58	19.70	3.58	24.28	2.10	22.97	2.16	-24.7	3.0				Line 2
14 nov 1996 04:15:40	1.840	.0412	1,023.4	75.159	23.14	2.57	19.70	3.58	24.28	2.08	22.98	2.13	-24.5	3.0				Line 3
14 Nov 1996 06:16:29	1.840	.0412	1,024.0	75.176	23.13	2.55	19.70	3.58	24.28	2.08	22.97	2.14	-28.2	3.0				Line 4
14 Nov 1996 08:17:19	1.840	.0412	1,024.9	75.223	23.15	2.53	19.70	3.58	24.27	2.07	22.97	2.12	-22.4	3.0				Line 5
AVERAGES	1.840	.0412	1,023.5	75.175	23.13	2.55	19.70	3.58	24.27	2.08	22.97	2.13	-24.9	3.0				

********* NO DATA TO BE ENTERED BELOW THIS LINE **********

****** PRESS F9 to RECALCULATE RESULTS ********

Date & Time	Total Power Cor for HFM Off (W)	Surnd Surface Hot (C)	Surnd Surface Cold (C)	Power Thro' Insert -BL% (W)	Hot Surf Temp (C)	Cold Surf Temp (C)	Surf Temp Diff (C)	Air Temp. Hot (C)	Air Temp. Cold (C)	Air Temp. Diff (C)	Environ Temp Hot (C)	Environ Temp Cold (C)	Environ Temp Diff (C)	Atmos. Press. (mb)	[illegible] (C)	[illegible] (C)	Tr Cond (W/m2.K)	T Trans (W/m2.K)	S[illegible] Res. Hot (m2.K/W)	S[illegible] Res. Cold (m2.K/W)
Area (m2)	1.840	Area holder (m2) =		1.982			B.L%Man	3.0	Mean T =	11.638		Th Con Holder =			.0412					
Efth (mm)	n/a	Thick @ edge(mm) =		110.00			Em Fact H	.8332	Th Conductance no BL% =			2.161	W/m2K				Hr(c) =	5.783	Hr(h) = 2.0963	4.761
							Em Fact C	.8332									Stan.Tran		Tot Res	.1583
14 Nov 1996 00:14:00	75.256	23.110	2.510	62.166	19.697	3.578	16.119	24.260	2.060	22.200	23.542	2.071	21.471	1,022.4	22.950	2.120	2.096	1.5736	.1138	.0446
14 Nov 1996 02:14:50	75.217	23.110	2.580	62.165	19.697	3.578	16.119	24.280	2.100	22.180	23.559	2.110	21.448	1,023.0	22.970	2.160	2.096	1.5752	.1143	.0434
14 nov 1996 04:15:40	75.235	23.140	2.570	62.162	19.697	3.578	16.119	24.280	2.080	22.200	23.563	2.089	21.474	1,023.4	22.980	2.130	2.096	1.5732	.1144	.0441
14 Nov 1996 06:16:29	75.264	23.130	2.550	62.184	19.697	3.578	16.119	24.280	2.080	22.200	23.559	2.090	21.468	1,024.0	22.970	2.140	2.097	1.5742	.1143	.0440
14 Nov 1996 08:17:19	75.293	23.150	2.530	62.191	19.697	3.578	16.119	24.270	2.070	22.200	23.555	2.079	21.476	1,024.9	22.970	2.120	2.097	1.5738	.1141	.0444
Av.Values	75.253	23.128	2.548	62.174	19.697	3.578	16.119	24.274	2.078	22.196	23.555	2.088	21.468	1,023.5	22.968	2.134	2.096	1.5740	.1142	.0441
% Varia	.101	.040	.070	.047	.000	.000	.000	.020	.040	.090	.021	.040	.130	.244	.030	.040	.047	.127	.001	.001

Table A4

Hot box measured data for TT100

Table A6

Hot box measured data for TT102

WGHB data summary sheet GENERAL ALL CALCULATIONS CARRIED OUT BY SPREADSHEET Sheet DIR102A Today's date 28/ 1/97

TT102A Holder Panel 1 Data entered by...DAH Data entry checked by..... Service number... DOE PIT
25 Nov 1996
Wood Window & 4/12/4 K glass 1.92 W/m2K Holder thermal conductivity data from 610 results The surface temperatures are an area weighted average

*** THE DATA MUST BE ENTERED IN THE ROWS ABOVE THE DOTTED LINE. THE DATA IS THEN AUTOMATICALLY READ INTO THE PART BELOW THE LINE AND THE RESULTS CALCULATED. ****

DATA IS READ DIRECTLY FROM A DATA FILE AS FOLLOWS: //I,Numbers,A:\sc5calc1.asc,All

1 Date & Time	2 Spec. Area (m^2)	3 Hold ThCn (W/m.K)	4 Atm. Prss (mb)	5 Total power (W)	6 Hold Hot Temp (C)	7 Hold Cold Temp (C)	8 Spec Hot Surf. (C)	9 Spec Cold Surf (C)	10 Air Temp Hot (C)	11 Air Temp Cold (C)	12 Baffle Hot Temp (C)	13 Baffle Cold Temp (C)	14 Diviny Offset (uV)	15 Bound Loss (%)	16 Stand. Sur. Res. (m^2.K/W)	17 Thick Effect (m)	18 Thick Edge (m)	
25 Nov 1996 00:51:14	1.850	.0412	998.8	93.269	23.19	3.38	19.12	5.63	24.12	2.92	22.65	2.97	-25.5	3.0				Line 1
25 Nov 1996 02:52:03	1.850	.0412	998.1	93.160	23.14	3.36	19.12	5.63	24.09	2.90	22.62	2.95	-27.8	3.0				Line 2
25 Nov 1996 04:52:52	1.850	.0412	997.8	93.212	23.17	3.38	19.12	5.63	24.09	2.93	22.63	2.98	-22.5	3.0				Line 3
25 Nov 1996 06:53:41	1.850	.0412	997.6	93.198	23.19	3.41	19.12	5.63	24.10	2.94	22.64	2.99	-21.2	3.0				Line 4
25 Nov 1996 08:54:30	1.850	.0412	997.3	93.180	23.19	3.39	19.12	5.63	24.11	2.94	22.64	3.00	-24.3	3.0				Line 5
AVERAGES	1.850	.0412	997.9	93.204	23.18	3.38	19.12	5.63	24.10	2.93	22.64	2.98	-24.3	3.0				

********* NO DATA TO BE ENTERED BELOW THIS LINE ********** ****** PRESS F9 to RECALCULATE RESULTS ********

Hr(h) = 4.836
3.2117 Tot Res .1612

								Environ Temp Hot	Environ Temp Cold	Environ Temp Diff	Atmos. Press.	Baffle Hot	Baffle Cold			Surface Res. Hot	Surface Res. Cold
25 Nov 1996 00:51:14	93.349	23.190	3.380	80.184	19.116	2.920	21.200	23.420	2.933	20.487	998.8	22.650	2.970	3.214	2.1156	.0993	.0623
25 Nov 1996 02:52:03	93.247	23.140	3.360	80.101	19.116	2.900	21.190	23.393	2.913	20.481	998.1	22.620	2.950	3.211	2.1141	.0988	.0628
25 Nov 1996 04:52:52	93.282	23.170	3.380	80.130	19.116	2.930	21.160	23.398	2.943	20.455	997.8	22.630	2.980	3.212	2.1175	.0989	.0620
25 Nov 1996 06:53:41	93.264	23.190	3.410	80.117	19.116	2.940	21.160	23.406	2.952	20.454	997.6	22.640	2.990	3.211	2.1173	.0991	.0618
25 Nov 1996 08:54:30	93.256	23.190	3.390	80.099	19.116	2.940	21.170	23.411	2.955	20.456	997.3	22.640	3.000	3.210	2.1166	.0992	.0618
Av.Values	93.279	23.176	3.384	80.126	19.116	2.926	21.176	23.406	2.939	20.467	997.9	22.636	2.978	3.212	2.1162	.0990	.0621
% Varia	.109	.050	.050	.106	.000	.040	.189	.026	.042	.164	.150	.030	.050	.113	.161	.001	.001

Table A8

Hot box measured data for TT104

WGHB data summary sheet GENERAL   ALL CALCULATIONS CARRIED OUT BY SPREADSHEET   Sheet   DIR104A

TT104   Holder Panel 1   Data entered by...DAH   Data entry checked by.....   Today's date   28/ 1/97

03 Dec 1996

DOUBLE WINDOW coupled Aluminium 1.36 W/m2K   Holder thermal conductivity data from 610 results   The surface temperatures are an area weighted average   Service number... DOE PIT Project Q9TM07

*** THE DATA MUST BE ENTERED IN THE ROWS ABOVE THE DOTTED LINE. THE DATA IS THEN AUTOMATICALLY READ INTO THE PART BELOW THE LINE AND THE RESULTS CALCULATED. ****

WGHB_V05   DATA IS READ DIRECTLY FROM A DATA FILE AS FOLLOWS: //I,Numbers,A:\sc5calc1.asc,All

1 Date	& Time	2 Spec. Area (m^2)	3 Hold ThCn (W/m.K)	4 Atm. Prss (mb)	5 Total power (W)	6 Hold Hot Temp (C)	7 Hold Cold Temp (C)	8 Spec Hot Surf. (C)	9 Spec Cold Surf (C)	10 Air Temp Hot (C)	11 Air Temp Cold (C)	12 Baffle Hot Temp (C)	13 Baffle Cold Temp (C)	14 Diviny Offset (uV)	15 Bound Loss (%)	16 Stand. Sur. Res. (m^2.K/W)	17 Thick Effect (m)	18 Thick Edge (m)	
2 Dec 1996	23:06:00	1.8451	.041	1,014.1	76.872	22.188	2.344	17.275	3.852	22.842	1.959	21.569	2.013	-26.6	3.0				Line 1
3 Dec 1996	01:07:11	1.8451	.041	1,011.2	76.904	22.170	2.339	17.275	3.852	22.854	1.904	21.575	1.973	-20.6	3.0				Line 2
3 Dec 1996	03:08:23	1.8451	.041	1,007.6	76.885	22.184	2.365	17.275	3.852	22.854	1.957	21.574	2.019	-30.5	3.0				Line 3
3 Dec 1996	05:09:33	1.8451	.041	1,001.8	76.825	22.187	2.389	17.275	3.852	22.851	1.945	21.569	2.020	-29.3	3.0				Line 4
3 Dec 1996	07:10:44	1.8451	.041	996.7	76.660	22.146	2.349	17.275	3.852	22.833	1.911	21.548	1.980	-27.3	3.0				Line 5
AVERAGES		1.845	.0411	1,006.3	76.829	22.18	2.36	17.28	3.852	22.85	1.94	21.57	2.00	-26.9	3.0				

********* NO DATA TO BE ENTERED BELOW THIS LINE **********   ****** PRESS F9 to RECALCULATE RESULTS ********

Area (m2) 1.845   Area holder (m2) = 1.977   B.L%Man 3.0   Mean T = 10.564   Th Con Holder = .0411

Efth (mm) n/a   Thick @ edge(mm) = 70.00   Em Fact H .8332   Th Conductance no BL% = 2.675 W/m2K   Hr(c) = 5.671   Hr(h) = 4.765

Em Fact C .8332   Stan.Tran 2.5941   Tot Res .1910

Date	& Time	Total Power Cor for HFM Off (W)	Surnd Surface Hot (C)	Surnd Surface Cold (C)	Power Thro' Insert -BL% (W)	Hot Surf Temp (C)	Cold Surf Temp (C)	Surf Temp Diff (C)	Air Temp. Hot (C)	Air Temp. Cold (C)	Air Temp. Diff (C)	Environ Temp Hot (C)	Environ Temp Cold (C)	Environ Temp Diff (C)	Atmos. Press. (mb)	Baffle Hot (C)	Baffle Cold (C)	Therm Cond (W/m2.K)	Therm Trans (W/m2.K)	S[illegible] Res. Hot (m2.K/W)	S[illegible] Res. Cold (m2.K/W)
2 Dec 1996	23:06:00	76.955	22.188	2.344	64.274	17.275	3.852	13.423	22.842	1.959	20.883	22.022	1.971	20.052	1,014.1	21.569	2.013	2.595	1.7373	.1363	.0540
3 Dec 1996	01:07:11	76.968	22.170	2.339	64.293	17.275	3.852	13.423	22.854	1.904	20.950	22.029	1.919	20.110	1,011.2	21.575	1.973	2.596	1.7327	.1364	.0555
3 Dec 1996	03:08:23	76.980	22.184	2.365	64.311	17.275	3.852	13.423	22.854	1.957	20.897	22.029	1.970	20.059	1,007.6	21.574	2.019	2.597	1.7376	.1364	.0540
3 Dec 1996	05:09:33	76.916	22.187	2.389	64.260	17.275	3.852	13.423	22.851	1.945	20.906	22.025	1.961	20.063	1,001.8	21.569	2.020	2.595	1.7359	.1364	.0543
3 Dec 1996	07:10:44	76.745	22.146	2.349	64.095	17.275	3.852	13.423	22.833	1.911	20.922	22.006	1.926	20.080	996.7	21.548	1.980	2.588	1.7300	.1362	.0554
Av.Values		76.913	22.175	2.357	64.247	17.275	3.852	13.423	22.847	1.935	20.912	22.022	1.950	20.073	1,006.3	21.567	2.001	2.594	1.7347	.1363	.0546
% Varia		.306	.043	.050	.336	.000	.000	.000	.021	.055	.321	.023	.052	.292	1.724	.026	.047	.336	.441	.000	.001

All dimensions in mm

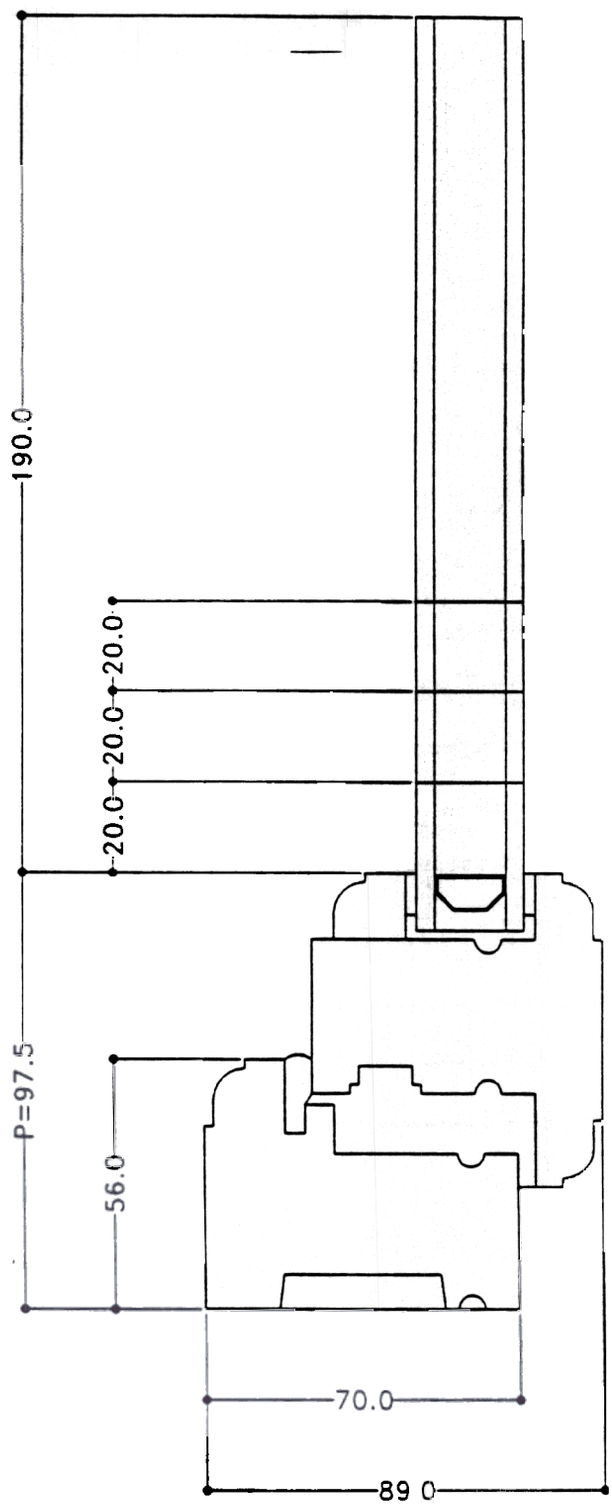

Figure A9 Dimensions of Wood Frame - frame section A

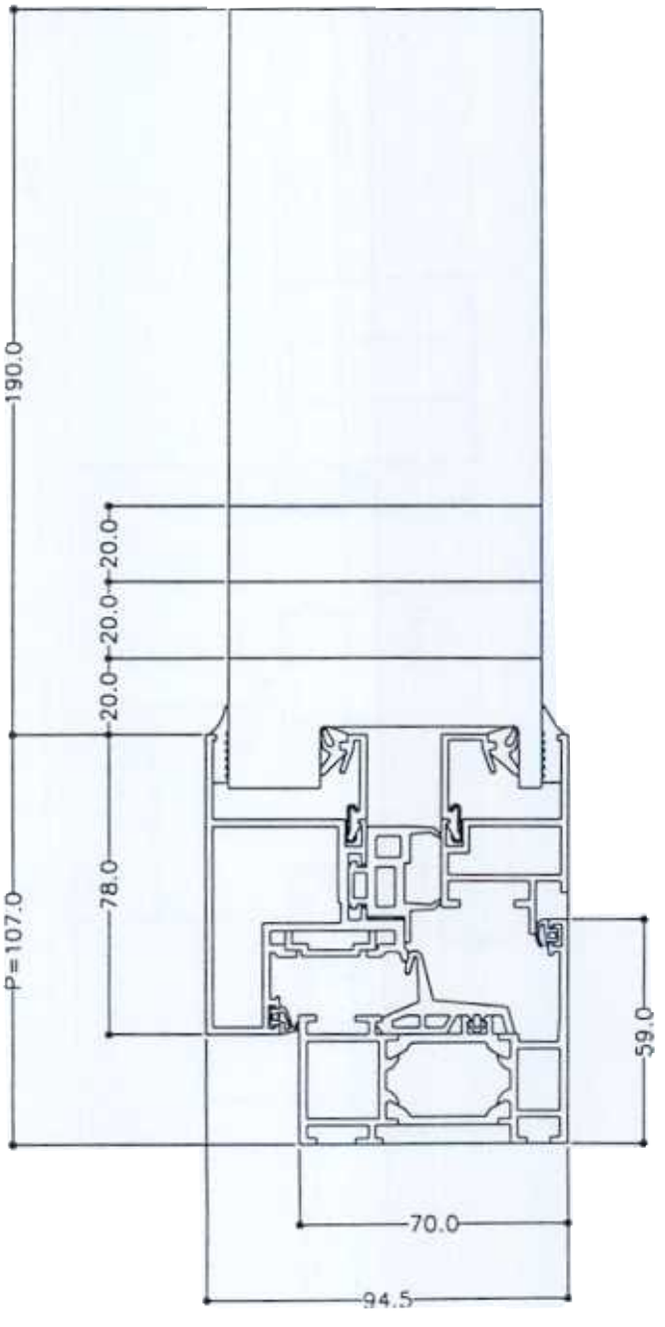

Figure A1Dimensions of High performance Aluminium Frame - frame section A.

Table A1

Hot box measured data for TT089

Summary of experimental data TT089 CALCULATIONS CARRIED OUT : SPREADSHEET Sheet SUM089B Today's date 28/ 1/97

Aluminium Window Frame 1.4 X 1.23 M nominal dimensions 1.69 W/m2K 1.48 x 1.23 x 0.06 m NO BEADING DATA ENTERED BY .... DAH CHECKED BY...

Date & Time	Total Power Cor for HFM Off (W)	S (C)	(C)	(W)	(C)		(C)		(C)	(C)	(C)	(C)	(C)	(C)	(C)	(mb)	(C)	(C)	(W/m2.K)	(W/m2.K)	(m2.K/W)	(m2.K/W)
TT089A	Area (m2) Efth (mm)	1.84770 n/a		Area holder (m2) = Thick @ edge(mm) =	1.97430 75.00			B.L%Man Em Fact H Em Fact C	3.0 .8332 .8332		Mean T = Th Conductance no BL% =	10.29		Th Con Holder = 4.22051 W/m2K		.0410		Hr(c) = Stan.Tran	5.62 .17000	2.4147	Hr(h) = Tot Res	4.77 .1580
07/10/95 06.44hrs	103.7727	21.79	2.24	90.46885	16.27	XXX	4.31	XXX	10.51	22.15	1.82	20.33	21.47	1.84	19.63	1,016.9	20.78	1.91	4.0939	2.4942	.1061	.0505
07/10/95 08.49hrs	103.7616	21.79	2.17	90.42159	16.27	XXX	4.31	XXX	10.54	22.15	1.76	20.39	21.47	1.78	19.69	1,018.7	20.79	1.86	4.0918	2.4851	.1063	.0517
07/10/95 10.56hrs	103.7989	21.80	2.12	90.42649	16.27	XXX	4.31	XXX	10.54	22.15	1.68	20.47	21.47	1.70	19.77	1,019.8	20.79	1.79	4.0920	2.4755	.1063	.0533
07/10/95 13.00hrs	104.0131	21.79	2.17	90.66555	16.27	XXX	4.31	XXX	10.52	22.13	1.71	20.42	21.46	1.73	19.73	1,020.1	20.77	1.81	4.1028	2.4875	.1057	.0526
07/10/95 15.04hrs	103.9416	21.77	2.19	90.61702	16.27	XXX	4.31	XXX	10.50	22.12	1.75	20.37	21.45	1.77	19.68	1,020.6	20.77	1.85	4.1006	2.4918	.1056	.0518
Av.Values	103.8576	21.79	2.18	90.51990	16.27	XXX	4.31	XXX	10.52	22.14	1.74	20.40	21.47	1.76	19.70	1,019.2	20.78	1.84	4.0962	2.4868	1060	.0520
% Varia	.2	.1	5.5	.3		XXX		XXX	.4	.1	8.0	.7	.1	7.6	.7	.4	.1	6.5	.3	.8	.6	5.3

Table A3 Hot box measured data for TT091

Summary of experimental data TT091 CALCULATIONS CARRIED OUT BY SPREADSHEET Sheet JM091B Today's date 28/ 1/97

Hard wood Window Frame 1.4 X 1.23 m nominal dimensions 1.69 W/m2K 1.48 x 1.23 x 0.06 m NO BEADING DATA ENTERED BY ...

Date & Time	Total Power Cor for HFM Off (W)	Surnd Surface Hot (C)	Surnd Surface Cold (C)	Power Thro' Insert -BL% (W)	Hot Surf Temp (C)		Cold Surf Temp (C)		Surf Temp Diff (C)	Air Temp. Hot (C)	Air Temp. Cold (C)	Air Temp. Diff (C)	Environ Temp Hot (C)	Environ Temp Cold (C)	Environ Temp Diff (C)	Atmos. Press. (mb)	Baffle Hot (C)	Baffle Cold (C)	Therm Cond (W/m2.K)	Therm Trans (W/m2.K)	Surface Res. Hot (m2.K/W)	Surface Res. Cold (m2.K/W)
TT091A	Area (m2)	1.84580		Area holder (m2) =		1.87620		B.L%Man	3.0	Mean T =		11.08	Th Con Holder =			.0411	Hr(c) =		5.67		Hr(h) =	4.78
	Efth (mm)	n/a		Thick @ edge(mm) =		70.00		Em Fact H	.8332	Th Conductance no BL% =				3.19091 W/m2K				Stan.Tran	.17000	2.0243	Tot Res	.1506
								Em Fact C	.8332													
19/10/95 21.50hrs	89.8237	22.07	2.63	76.96110	17.82	XXX	4.35	XXX	11.59	22.72	2.22	20.50	21.91	2.23	19.68	1,027.8	20.98	2.28	3.0952	2.1186	.0982	.0508
19/10/95 23.57hrs	89.6963	22.12	2.61	76.80095	17.82	XXX	4.35	XXX	11.65	22.76	2.20	20.56	21.95	2.21	19.73	1,027.0	21.02	2.26	3.0887	2.1086	.0991	.0516
20/10/95 02.04hrs	89.5940	22.16	2.65	76.70170	17.82	XXX	4.35	XXX	11.63	22.79	2.24	20.55	21.97	2.25	19.72	1,026.3	21.04	2.29	3.0848	2.1077	.0998	.0505
20/10/95 04.11hrs	89.4992	22.14	2.60	76.59410	17.82	XXX	4.35	XXX	11.66	22.79	2.19	20.60	21.97	2.20	19.77	1,025.5	21.05	2.25	3.0804	2.0994	.1000	.0517
20/10/95 06.19hrs	89.5696	22.14	2.58	76.65172	17.82	XXX	4.35	XXX	11.68	22.79	2.18	20.61	21.97	2.19	19.77	1,025.6	21.05	2.25	3.0827	2.1001	.0999	.0519
Av.Values	89.6365	22.13	2.61	76.74191	17.82	XXX	4.35	XXX	11.64	22.77	2.21	20.56	21.95	2.22	19.73	1,026.4	21.03	2.27	3.0864	2.1069	.0994	.0512
% Varia	.4	.4	2.7	.5		XXX		XXX	.6	.3	2.7	.5	.3	2.5	.5	.2	.3	1.8	.5	.9	1.8	2.7

Table A5

Hot box measured data for TT101

WGHB data summary sheet GENERAL   ALL CALCULATIONS CARRIED OUT BY SPREADSHEET   Sheet DIR101A   Today's date ?8/ 1/97

TT101A   Holder Panel 1   Data entered by...DAH   Data entry checked by.....   Service number. DOE PIT
19 Nov 1996
Aluminium window & 6/12/6 Glazing 2.80 W/m2K   Holder thermal conductivity data from 610 results

*** THE DATA MUST BE ENTERED IN THE ROWS ABOVE THE DOTTED LINE. THE DATA IS THEN AUTOMATICALLY READ INTO THE PART BELOW THE LINE AND THE RESULTS CALCULATED. ****

DATA IS READ DIRECTLY FROM A DATA FILE AS FOLLOWS: //I,Numbers,A:\sc5calc1.asc,All   The Surface temperatures are an area weighted average

1 Date & Time	2 Spec. Area (m^2)	3 Hold ThCn (W/m.K)	4 Atm. Prss (mb)	5 Total power (W)	6 Hold Hot Temp (C)	7 Hold Cold Temp (C)	8 Spec Hot Surf. (C)	9 Spec Cold Surf (C)	10 Air Temp Hot (C)	11 Air Temp Cold (C)	12 Baffle Hot Temp (C)	13 Baffle Cold Temp (C)	14 Diviny Offset (uV)	15 Bound Loss (%)	16 Stand. Sur. Res. (m^2.K/W)	17 Thick Effect (m)	18 Thick Edge (m)	
19 Nov 1996 00:26:16	1.847	.0410	1,003.0	123.372	21.35	2.81	14.72	6.11	22.34	2.41	20.50	2.49	-26.4	3.0				Line 1
19 Nov 1996 02:27:06	1.847	.0410	999.3	123.499	21.36	2.81	14.72	6.11	22.36	2.39	20.53	2.47	-24.7	3.0				Line 2
19 Nov 1996 04:27:56	1.847	.0410	994.2	123.425	21.36	2.78	14.72	6.11	22.37	2.38	20.52	2.45	-27.7	3.0				Line 3
19 Nov 1996 06:28:46	1.847	.0410	988.7	123.276	21.38	2.78	14.72	6.11	22.38	2.38	20.53	2.45	-29.6	3.0				Line 4
19 Nov 1996 08:29:37	1.847	.0410	983.1	122.992	21.39	2.80	14.72	6.11	22.38	2.39	20.54	2.47	-22.6	3.0				Line 5
AVERAGES	1.847	.0410	993.7	123.313	21.37	2.80	14.72	6.11	22.37	2.39	20.52	2.47	-26.2	3.0				

********** NO DATA TO BE ENTERED BELOW THIS LINE **********   ****** PRESS F9 to RECALCULATE RESULTS ********

Area (m2) 1.847   Area holder (m2) = 1.975   B.L%Man 3.0   Mean T = 10.417   Th Con Holder = .0410   Hr(c) = 5.566   Hr(h) = 4.836
Efth (mm) n/a   Thick @ edge(mm) = 75.00   Em Fact H .8332   Th Conductance no BL% = 7.140 W/m2K   Stan.Tran 6.9207 Tot Res .1745
Em Fact C .8332

Date & Time	Total Power Cor for HFM Off (W)	Surnd Surface Hot..... (C)	Surnd Surface ...Cold (C)	Power Thro' Insert -BL% (W)	Hot Surf Temp (C)	Cold Surf Temp (C)	Surf Temp Diff (C)	Air Temp. Hot (C)	Air Temp. Cold (C)	Air Temp. Diff (C)	Environ Temp Hot (C)	Environ Temp Cold (C)	Environ Temp Diff (C)	Atmos. Press. (mb)	Baff Hot.... (C)	(C)	(W/m2.K)	(W/m2.K)	(m2.K/W)	(m2.K/W)
19 Nov 1996 00:26:16	123.454	21.350	2.810	110.083	14.721	6.114	8.607	22.340	2.410	19.930	21.386	2.430	18.956	1,003.0	20.500	2.490	6.925	3.1442	1118	.0618
19 Nov 1996 02:27:06	123.576	21.360	2.810	110.196	14.720	6.114	8.606	22.360	2.390	19.970	21.409	2.410	18.998	999.3	20.530	2.470	6.933	3.1404	1121	.0621
19 Nov 1996 04:27:56	123.511	21.360	2.780	110.118	14.720	6.114	8.606	22.370	2.380	19.990	21.408	2.398	19.010	994.2	20.520	2.450	6.928	3.1362	1122	.0623
19 Nov 1996 06:28:46	123.368	21.380	2.780	109.968	14.720	6.114	8.606	22.380	2.380	20.000	21.415	2.398	19.018	988.7	20.530	2.450	6.918	3.1307	1125	.0624
19 Nov 1996 08:29:37	123.063	21.390	2.800	109.677	14.720	6.114	8.606	22.380	2.390	19.990	21.417	2.410	19.007	983.1	20.540	2.470	6.900	3.1241	1128	.0624
Av.Values	123.395	21.368	2.796	110.008	14.720	6.114	8.606	22.366	2.390	19.976	21.407	2.409	18.998	993.7	20.524	2.466	6.921	3.1351	1123	.0622
% Varia	.416	.040	.030	.472	.001	.000	.012	.040	.030	.350	.032	.032	.325	2.003	.040	.040	.472	.641	.001	.001

Table A7

Hot box measured data for TT103

WGHB data summary sheet GENERAL ALL CALCULATIONS CARRIED OUT BY SPREADSHEET Sheet DIR103A Today's date 28/ 1/97

TT103A Holder Panel 1 Data entered by...DAH Data entry checked by..... Service number. DOE PIT Project Q9TM07
27 Nov 1996
Aluminium Window & 4/16/4 Low E on 2 faces 1.52 W/m2K Holder thermal conductivity data from 610 results The surface temperatures are an area weighted average

*** THE DATA MUST BE ENTERED IN THE ROWS ABOVE THE DOTTED LINE. THE DATA IS THEN AUTOMATICALLY READ INTO THE PART BELOW THE LINE AND THE RESULTS CALCULATED. ****

DATA IS READ DIRECTLY FROM A DATA FILE AS FOLLOWS: //I,Numbers,A:\sc5calc1.asc,All

1 Date & Time	2 Spec. Area	3 Hold ThCn	4 Atm. Prss	5 Total power	6 Hold Hot Temp	7 Hold Cold Temp	8 Spec Hot Surf.	9 Spec Cold Surf	10 Air Temp Hot	11 Air Temp Cold	12 Baffle Hot Temp	13 Baffle Cold Temp	14 Divlny Offset	15 Bound Loss	16 Stand. Sur. Res.	17 Thick Effect	18 Thick Edge (m)	
27 Nov 1996 23:37:46	1.848	.0411	1,015.3	100.026	22.64	2.48	16.46	4.50	22.65	2.10	21.14	2.18	-23.8	3.0				Line 1
28 Nov 1996 01:38:35	1.848	.0411	1,016.2	100.094	22.62	2.43	16.46	4.50	22.64	2.07	21.12	2.16	-22.3	3.0				Line 2
28 Nov 1996 03:39:24	1.848	.0411	1,017.4	100.303	22.57	2.45	16.46	4.50	22.63	2.11	21.12	2.20	-25.3	3.0				Line 3
28 Nov 1996 05:40:12	1.848	.0411	1,018.6	100.177	22.59	2.41	16.46	4.50	22.62	2.06	21.11	2.14	-28.1	3.0				Line 4
28 Nov 1996 07:41:00	1.848	.0411	1,019.8	100.275	22.62	2.47	16.46	4.50	22.65	2.09	21.13	2.19	-24.9	3.0				Line 5
AVERAGES	1.848	.0411	1,017.5	100.175	22.61	2.45	16.46	4.50	22.64	2.09	21.12	2.17	-24.9	3.0				

********* NO DATA TO BE ENTERED BELOW THIS LINE ********** ****** PRESS F9 to RECALCULATE RESULTS ********

Area (m2) 1.848 Area holder (m2) = 1.974 B.L%Man 3.0 Mean T = 10.478 Th Con Holder = .0411 Hr(c) = 5.635 Hr(h) = 4.786
Efth (mm) n/a Thick @ edge(mm) = 75.00 Em Fact H .8332 Th Conductance no BL% = 4.036 W/m2K Stan.Tran 3.9220 Tot Res .1653
Em Fact C .8332

Date & Time	Total Power Cor for HFM Off (W)	Surnd Surface Hot (C)	Surnd Surface Cold (C)	Power Thro' Insert -BL% (W)	Hot Surf Temp (C)	Cold Surf Temp (C)	Surf Temp Diff (C)	(C)	Air Temp. Hot (C)	Air Temp. Cold (C)	Air Temp. Diff (C)	Environ Temp Hot (C)	Environ Temp Cold (C)	Environ Temp Diff (mb)	Atmos. Press. (C)	Baffle Hot (C)	Baffle Cold (W/m2.K)	Therm Cond (W/m2.K)	Therm Trans (m2.K/W)	Surface Res. Hot.....Cold (m2.K/W)
27 Nov 1996 23:37:46	100.100	22.640	2.480	86.565	16.460	4.496	11.964	22.650	2.100	20.550	21.836	2.116	19.720	1,015.3	21.140	2.180	3.915	2.3754	1148	.0508
28 Nov 1996 01:38:35	100.164	22.620	2.430	86.610	16.460	4.496	11.964	22.640	2.070	20.570	21.823	2.088	19.735	1,016.2	21.120	2.160	3.917	2.3748	1144	.0514
28 Nov 1996 03:39:24	100.382	22.570	2.450	86.859	16.460	4.496	11.964	22.630	2.110	20.520	21.821	2.128	19.693	1,017.4	21.120	2.200	3.929	2.3867	1141	.0504
28 Nov 1996 05:40:12	100.265	22.590	2.410	86.714	16.460	4.496	11.964	22.620	2.060	20.560	21.811	2.076	19.735	1,018.6	21.110	2.140	3.922	2.3777	1140	.0516
28 Nov 1996 07:41:00	100.353	22.620	2.470	86.815	16.460	4.496	11.964	22.650	2.090	20.560	21.834	2.110	19.723	1,019.8	21.130	2.190	3.927	2.3818	1144	.0508
Av.Values	100.253	22.608	2.448	86.712	16.460	4.496	11.964	22.638	2.086	20.552	21.825	2.104	19.721	1,017.5	21.124	2.174	3.922	2.3793	1143	.0510
% Varia	.281	.070	.070	.339	.000	.000	.000	.030	.050	.243	.025	.052	.212	.442	.030	.060	.339	.498	.001	.001

Table A9 Data measured with the calibration panels

		Calibration Panel TT083			Calibration Panel TT084		
d[m] thickness	[m]	0.02001			0.06798		
A area of panel	[m^2]	1.827			1.846		
Test number		1	2	3	1	2	3
$\theta_{c.mean}$ {mean panel temperature}	[°C]	14.53	11.20	6.49	15.32	10.70	4.74
Cold temperatures - measured							
$\theta_{a.e}$ {air}	[°C]	8.17	2.51	-5.73	8.00	-0.64	-12.06
$\theta_{b.e}$ {baffle}	[°C]	8.21	2.58	-5.64	8.04	-0.58	-11.98
$\theta_{c.e}$ {cal panel}	[°C]	9.56	4.37	-3.12	8.43	0.01	-11.08
$\theta_{sur.e}$ {reveal - estimated}	[°C]	8.43	2.88	-5.22	8.29	-0.20	-11.4
Hot temperatures - measured							
$\theta_{a.i}$ {air}	[°C]	23.28	22.97	22.69	23.62	23.42	23.33
$\theta_{b.i}$ {baffle}	[°C]	22.33	21.55	21.12	23.09	22.65	22.29
$\theta_{c.i}$ {cal panel}	[°C]	19.50	18.03	16.10	22.21	21.39	20.56
$\theta_{sur.i}$ {reveal}	[°C]	21.36	20.57	19.57	22.06	21.14	20.22
Φ_{in} {Hot box power - measured}	[W]	55.90	76.38	105.38	23.58	36.55	53.14
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
$C(\theta_{c.mean})$ {Calc conductance}	[$W/m^2.K$]	2.640	2.610	2.569	0.585	0.576	0.563
q_c {power cal panel - calc.}	[W/m_2]	26.27	35.66	49.37	8.063	12.30	17.82
$h_{r.i}$ {radiant sur coef- hot}	[$W/m^2.K$]	4.875	4.819	4.759	4.969	4.936	4.904
$h_{r.e}$ {radiant sur coef- cold}	[$W/m^2.K$]	4.136	3.903	3.580	4.108	3.746	3.301
$h_{a.i}$ {convective coef- hot}	[$W/m^2.K$]	3.508	3.945	4.054	3.042	3.432	3.785
$h_{a.e}$ {convective coef- cold}	[$W/m^2.K$]	22.89	22.90	22.35	22.40	22.28	21.12
$F_{a.i}$ {Convective fraction - hot}		0.419	0.450	0.460	0.380	0.410	0.436
$F_{a.e}$ {Convective fraction - cold}		0.847	0.854	0.862	0.845	0.856	0.865
R_{tc} {Total res. cal.panel}	[$m^2.K/W$]	0.174	0.168	0.168	0.185	0.180	0.177
H_{sur} {Surround panel coef}	[W/K]	0.550	0.575	0.559	0.592	0.610	0.605