Report No. ML.11094
Date: 4th April 2011

Client: LEIAB Lundberg & Erikkson Industri AB
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SWEDEN

Title THERMAL SIMULATION OF A QUADRI-GLAZED CASEMENT WINDOW TO PRODUCE AN ENERGY RATING

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British Fenestration Rating Council

Signed ....M Levitt....

Date....4/4/11....

1.INTRODUCTION

The British Fenestration Rating Council (BFRC) was approached by Terence Frost, Business Development for LEIAB, and instructed to undertake a thermal simulation of their metal-clad timber-framed window. Sufficient information was obtained from LEIAB to enable the standard side next to fixed window to be modelled. The data obtained and reported herein are based upon the information supplied and the BFRC accepts no responsibility for accuracy and/or interpretation.

2. PROGRAM

The finite difference two dimensional program used in this simulation was THERM 5.2 by the Lawrence Berkeley National Laboratory, part of the University of California. The program was verified by the author for its compliance with the ten test examples in EN.ISO 10077-2. This Standard was used in this study with the frame cavity radiation reduced radiation characteristics being addressed by using a detailed rather than a simplified model. The whole window *U* value calculation equation was taken from EN.ISO.10077-1 and these functions were built into the summary spreadsheet forming the conclusion of this work.

THERM 5.2 has a mesh minimum size of approximately 0.2mm in both the x and the y directions and was considered sensitive enough to deal with the materials and their geometries.

3. MATERIALS AND PROPERTIES

Thermal conductivities in W/(m·K) from EN.10456 or from manufacturer's EN.674 or 675 independent data given after each material

3.1. Main frame.- softwood timber. 0.13

3.2. External metal cladding – aluminium silicon alloy

3.3 Gaskets and seals
External cladding/timber.50mmx1mm butyl tape. 0.25
Sash/fixed frame 4mm cellular rubber.0.06
Sash glazing bead 14mmx14mm x 3mm EPDM. 0.24
Weather gasket on sash – silicone rubber. 0.40

3.4. Glazing - Glass – 1.0
Fixed light – quadri-glazed with 12mm glazing spaces filled with 90% Argon. Hard coat 'K' on surface 2 and soft coat Optitherm S3 on surfaces 4 and 7
Opening light – Triple glazed with secondary external glazing soaced 45mm from surface No.3 – air-filled. Coatings and gas fill as for fixed light, surfaces 1 & 2 being on external secondary glazing pane.
Spacers - Specified as 'warm edge' and taken as SwisSpacer box model 0.18. Secondary 3mm sealant hot melt butyl 0.24

4. LEIAB SUPPLIED DATA

4.1. Air permeability from SP Sveriges Tekniska Forskningsinstitut Report PX07011 – B of 26/10/10. Graphical interpolation of the positive and negative pressure graphs illustrated shows an average air permeability of 0.8 $m^3/m^2.h$

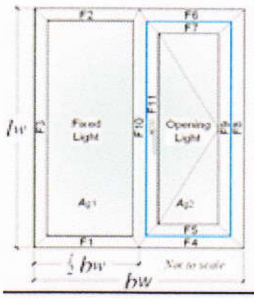
4.2 A Pilkington Spectrum download supplied but not illustrated in this report gave a g value of 0.43 but this was for a 14mm glazing space and not for the less efficient 12mm used in this assessment. In addition the air space for the secondary glazing was 40mm and not the 45 mm used from the drawings supplied by LEIAB although this 5mm difference is not so significant as the 2mm glazing space.

The Pilkington Spectrum downloads produced by the author gave g values of 0.43 for the quadri-glazed and 0.44 for the 3+1 glazing. The former value was used in the energy calculation as a worst case figure. The *U* values produced by Spectrum were not used as the spreadsheet requires 3 decimal places of accuracy in its initial calculation stages whereas Spectrum can only give 2 decimal places.

5. CONCLUSION

Based upon the information and data supplied using, where possible, worst case scenarios, it is concluded that an LEIAB side next to fixed window has an energy index of 8kWh/m^2.y and an 'A' rating.

ANNEX 1. Summary Spreadsheet



Sample Style:
Casement
Fixed Light / Side Hung

Blue line illustrates opening light length (air leakage)

Report Number:	ML.11094
Report Date:	04 April 2011
Project Details:	LEIAB Casement

Issue No.21: 04 [illegible]

Input Values:
Yellow input, green intermediary, blue finals — X' DP is no.of decimal places to enter

Parameter	Symbol		Units
Total window height 0DP	l_w	1480	mm
Total window width 0DP	b_w	1230	mm

Nominal 4mm etc to 0DP, others 1DP

Glazing dimensions and properties:			
Thickness of pane 1		4	mm
Pane 1/2 distance		12	mm
Gas fill (1/2)		Argon 90%	
Thickness of pane 2		4	mm
Complete next 3 cells for TG IGU			
Pane 2/3 distance		12	mm
Gas fill (2/3)		Argon 90%	
Thickness of pane 3		32.5	mm
Glazing Trans. - 3DP	U_g	0.539	W/(m²·K)
g-value - 2DP	$g_\perp$	0.43	

Thermal transmittance of window from hot box test

U_w - 2DP		W/(m²·K)

Frame dimensions:	(b_f)	Without gasket (mm)	Gasket protrusion (mm)	With gasket (mm)	Total
All frame values to nearest 0.5mm, gaskets to 1DP	F1 fixed sill	73	0.0	73	
	F2 fixed head	73	0.0	73	
	F3 fixed jamb	73	0.0	73	
F4 + F5 sash sill	F4 fixed sash sill	73	n/a	73	140.5
	F5 moving sash sill	67.5	0.0	67.5	
F6 + F7 sash head	F6 fixed sash head	32.5	n/a	32.5	100
	F7 moving sash head	67.5	0.0	67.5	
F8 + F9 sash jamb	F8 Fixed sash jamb	32.5	n/a	32.5	100
	F9 moving sash jamb	67.5	0.0	67.5	
F10 + F11 mullion	F10 fixed mullion	41.5		41.5	109
	F11 moving mullion	67.5	0.0	67.5	
	Total gasket area		0	m²	

Window Dimensions:	Length	Width	Area No gasket	Area With gasket
Section	(m)	(m)	(m²)	(m²)
Fixed Light	1.3340	0.5213	0.6953	0.6953
Opening light	1.2395	0.4268	0.5290	0.5290
Total glazing, A_g			1.2243	1.2243
Frame	(m)	(m)	(m²)	(m²)
F1	0.6150	0.0730	0.0415	0.0415
F2	0.6150	0.0730	0.0415	0.0415
F3	1.4800	0.0730	0.1027	0.1027
F4	0.6150	0.0730	0.0191	0.0191
F5	0.5618	0.0675	0.0334	0.0334
F6	0.6150	0.0325	0.0430	0.0430
F7	0.5618	0.0675	0.0334	0.0334
F8	1.4800	0.0325	0.0464	0.0464
F9	1.3745	0.0675	0.0882	0.0882
F10	1.4800	0.0415	0.0588	0.0588
F11	1.3745	0.0675	0.0882	0.0882
Total Frame			0.5961	0.5961
Total Window, A_w			1.8204	1.8204
Percentage fixed light glass area			38.20%	38.20%
Percentage opening light glass area			29.06%	29.06%
Percentage glass area (total)			67.25%	67.25%

Where a U_f value from hot box testing is available, no L_f^{2D} or L_ψ^{2D} values need to be entered

Frame conductance:		W/(m·K)	b_p (mm)		W/(m·K)	b_p (mm)
	All L values to 4DP. All b values to 0DP					
F1 fixed sill	L_f^{2D}	0.2416	190	L_ψ^{2D}	0.2593	190
F2 fixed head		0.2416	190		0.2593	190
F3 fixed jamb		0.2416	190		0.2593	190
F4 + F5 sash sill		0.2062	190		0.2402	190
F6 + F7 sash head		0.2062	190		0.2402	190
F8 + F9 sash jamb		0.2062	190		0.2402	190
F10 + F11 mullion		0.0782	380		0.0953	380

Frame: Section	b_f (no gaskets) (m)	U_f (W/(m²·K))	Frame areas (no gaskets) (m²)	Heat flow (W/K)	Ψ (W/(m·K))	l_g (m)	Heat flow (W/K)
F1 fixed sill	0.0730	2.0165	0.0415	0.0836	0.0097	0.5213	0.0050
F2 fixed head	0.0730	2.0165	0.0415	0.0836	0.0097	0.5213	0.0050
F3 fixed jamb	0.0730	2.0165	0.1027	0.2071	0.0097	1.3340	0.0129
F4 + F5 sash sill	0.1405	0.7958	0.0525	0.0418	0.0260	0.4268	0.0111
F6 + F7 sash head	0.1000	1.1181	0.0763	0.0853	0.0260	0.4268	0.0111
F8 + F9 sash jamb	0.1000	1.1181	0.1346	0.1505	0.0260	1.2395	0.0322
F10 + F11 mullion	0.1090	-1.0146	0.1470	-0.1492	0.0011	1.2868	0.0014
Totals			0.5961	0.5028		Total	0.0788

Solar Factor, g-value:		
	F_w	0.9
	g_w	0.26
U_{window}	U_w	**0.68** W/(m²·K)

Air Leakage loss:					
Air leakage at 50 Pa per hour & per unit length of opening light (BS 6375-1) - 2DP				0.80	m³/(m·h)
Opening light length	3.8725	m	Total air leakage	3.098	m³/h
L_{50}	1.70	m³/(m²·h)	Heat loss = 0.0165 L_{50}	0.03	W/(m²·K)

Other parameters needed for calculation, taken from simulations:

λ_p =	0.035	W/(m·K)	R_{se} =	0.04	m²·K/W	R_{si} =	0.13	m²·K/W
Panel thickness, $d_p = d_g$ = 0.0645 m								
R_p =	1.8429	m²·K/W	R_{tot} =	2.0129	m²·K/W	U_p =	0.4968	W/(m²·K)

BFRC Rating kWh/(m²·yr)	Label index	EWER Rating Scale	Window Rating
≥ 0 ⇦	8	⇨ A ⇦	A
-10 to <0		B	
-20 to <-10		C	
-30 to <-20		D	
-50 to <-30		E	
-70 to <-50		F	
<-70		G	

BFRC Rating =	
218.6 g_{window} - 68.5 x (U_{window} + Effective L_{50}	8.20
Climate zone is:	UK

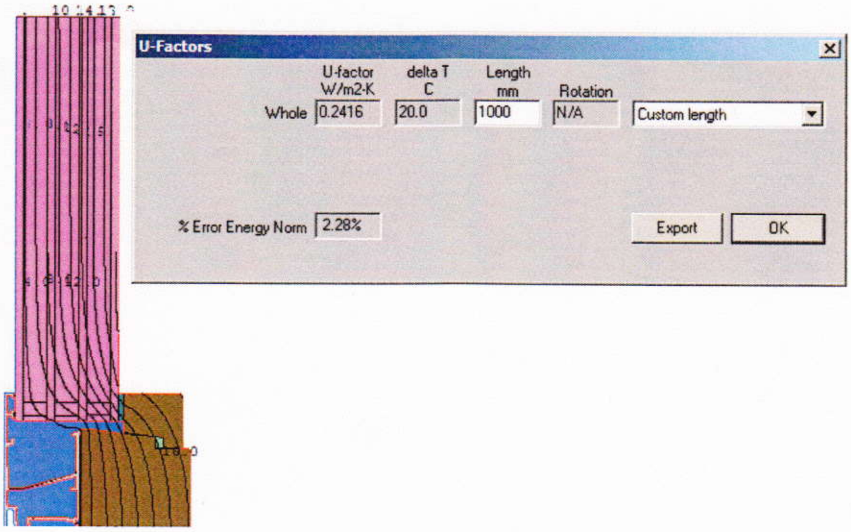
Thermal transmittance, W/(m²·K)	U_{window}	0.7
Solar factor	g_{window}	0.26
Window air leakage heat loss, W/(m²·K)	L_{factor}	0.03

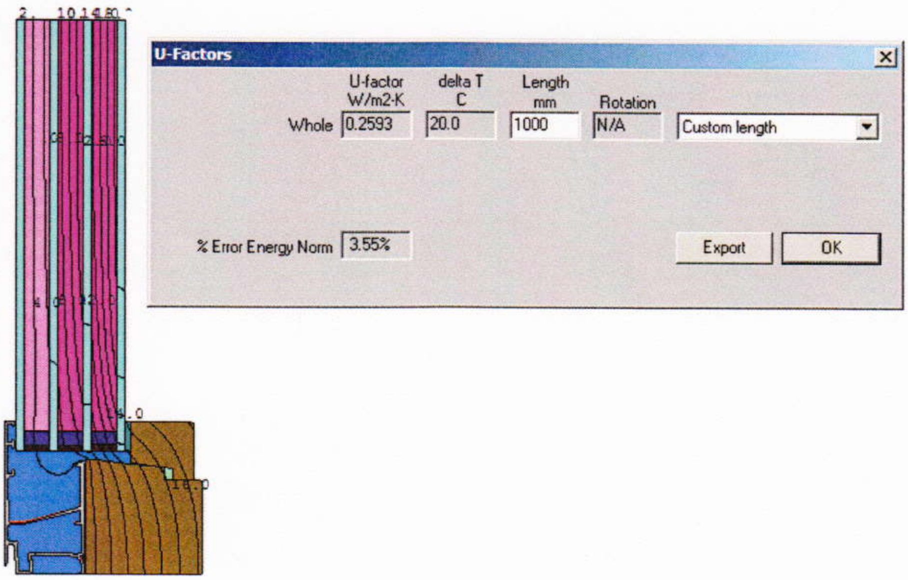
Simulator Name: Maurice Levitt

British Fenestration Rating Council

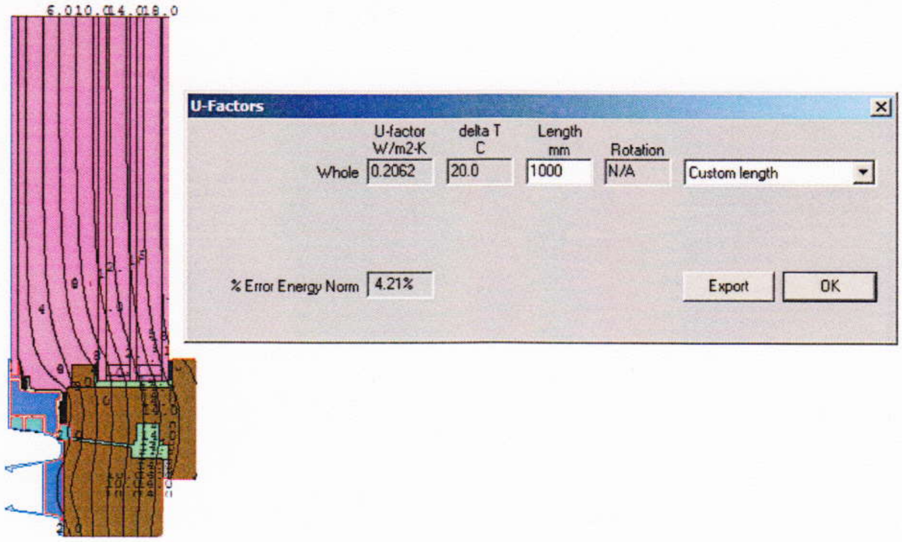
BFRC Certified Simulator 012

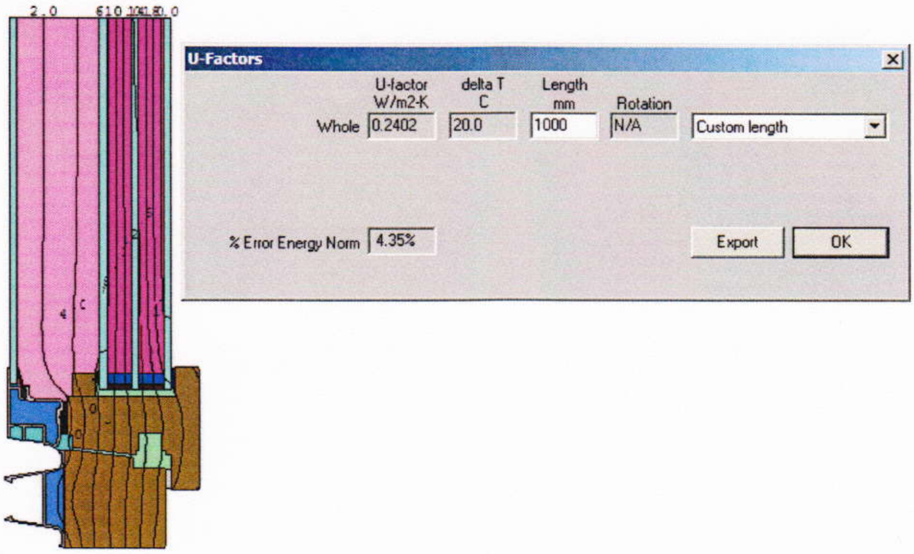
ANNEX 2.1. Therm models of fixed frame



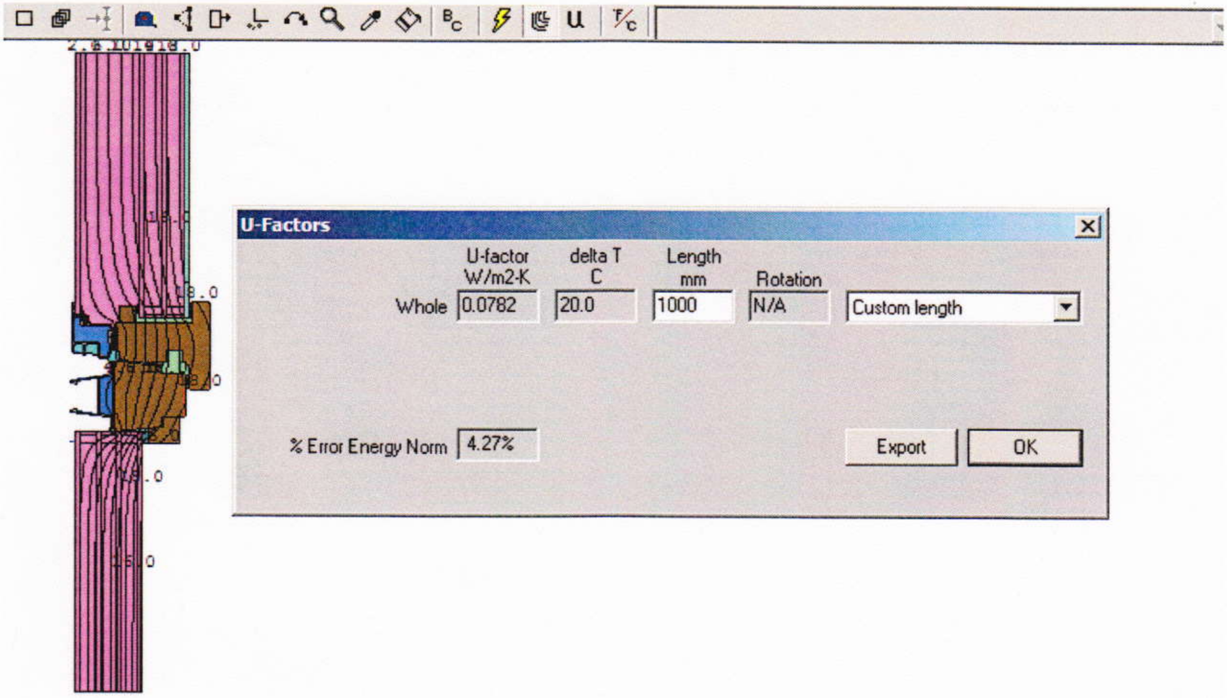


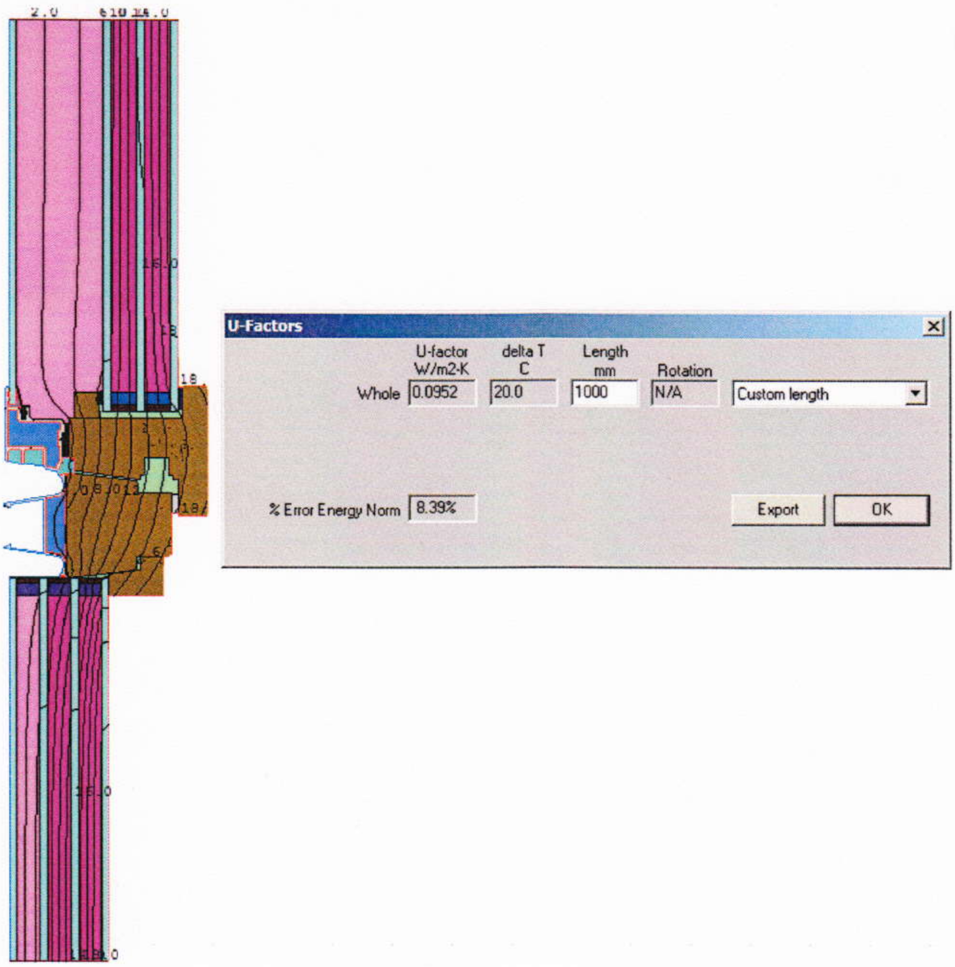
ANNEX 2.2. Therm models of sash frame





ANNEX 2.3. Therm models of mullion frame





ANNEX 3. EN.673 for quadri-glazing

Version 9 July 2010. Calculations according to BS EN 673:1998 (A1)

Number of spaces: 3

Help

Spaces		Pane 1	1	Pane 2	2	Pane 3	3	Pane 4
Glazing orientation	Vertical							
Resistivity panes	1 m·K/W							
Outside			90%		90%		90%	
			Gas		Gas		Gas	
			Argon		Argon		Argon	
Thickness (mm)		4.0	12	4.0	12	4	12	4
Normal emissivity			0.15 / 0.89		0.03 / 0.89		0.89 / 0.03	
$\sum d_j \cdot r_j$= 0.016			Uncoated		Uncoated		Uncoated	

Emissivities

Calculate

For uncoated surfaces input 0.89 for normal emissivity, which corresponds to a corrected emissivity of 0.837

Iteration number	U value W/(m²·K)	$\sum 1/h_s$ (m²·K)/W	λeff W/(mK)	ΔT	λeff W/(mK)	ΔT	λeff W/(mK)	ΔT
1	0.548	1.63983	0.0277	5	0.0199	5	0.0199	5
2	0.548	1.63983	0.0277	3.96	0.0199	5.52	0.0199	5.52

EN.673 for 3+1 glazing

Version 9 July 2010. Calculations according to BS EN 673:1998 (A1)

Number of spaces: 3

Help

Spaces		Pane 1	1	Pane 2	2	Pane 3	3	Pane 4
Glazing orientation	Vertical							
Resistivity panes	1 m·K/W							
Outside			100%		90%		90%	
			Gas		Gas		Gas	
			Air		Argon		Argon	
Thickness (mm)		4.0	45	4.0	12	4	12	4
Normal emissivity			0.15 / 0.89		0.03 / 0.89		0.89 / 0.03	
$\sum d_j \cdot r_j$= 0.016			Uncoated		Uncoated		Uncoated	

Emissivities

Calculate

For uncoated surfaces input 0.89 for normal emissivity, which corresponds to a corrected emissivity of 0.837

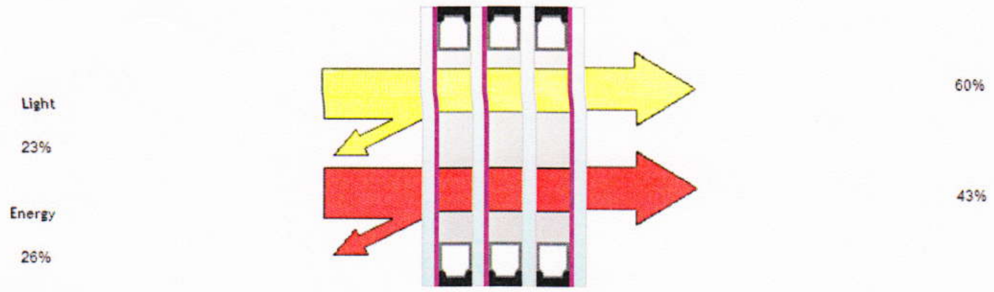
Iteration number	U value W/(m²·K)	$\sum 1/h_s$ (m²·K)/W	λeff W/(mK)	ΔT	λeff W/(mK)	ΔT	λeff W/(mK)	ΔT
1	0.533	1.69074	0.0929	5	0.0199	5	0.0199	5
2	0.529	1.70742	0.0898	4.3	0.0199	5.35	0.0199	5.35
3	0.529	1.70476	0.0903	4.4	0.0199	5.3	0.0199	5.3
4	0.529	1.70518	0.0902	4.38	0.0199	5.31	0.0199	5.31

ANNEX 4. Pilkington Spectrum for quadri-glazing

Glass 1 Pilkington K Glass, Annealed, 4 mm
Glass 2 Pilkington Optitherm S3, Annealed, 4 mm
Glass 3 Pilkington Optifloat Clear, Annealed, 4 mm
Glass 4 Pilkington Optitherm S3, Annealed, 4 mm

Flip Coating

Cavity 1 12 Gas 1 Argon (90%)
Cavity 2 12 Gas 2 Argon (90%)
Cavity 3 12 Gas 3 Argon (90%)



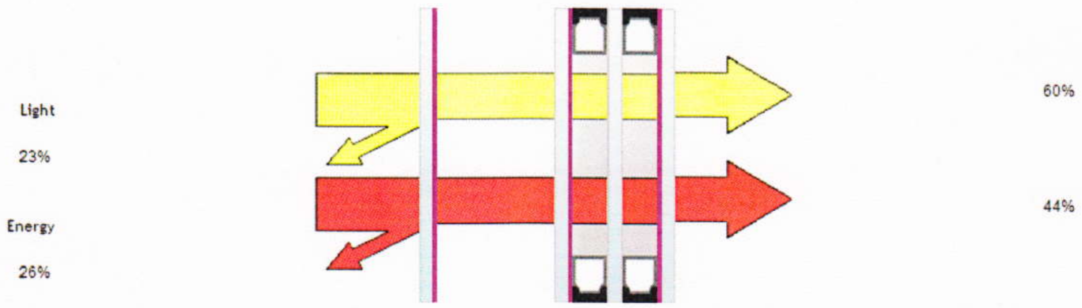
Product Code	U Value	UV %	Light %			Energy %			Solar Factor	Shading Coeff.	
4K-12Ar-S(3)4-12Ar-4-12Ar-S(3)4	W/m²K	T_{uv}	LT	LR out	LR in	ET	ER	EA	g	T SC	S SC
	0.5	9	60	23	24	35	26	39	0.43	0.50	0.40

Performance Code	Sound Reduction	Ra	Thickness	Weight	Date
U-value/Light/Energy	R_w dB ($C;C_{tr}$)	96	mm	kg/m²	05/04/2011
0.5 / 60 / 43	NPD		52	40.00	

Pilkington Spectrum for 3+1 glazing

Glass 1 Pilkington K Glass, Annealed, 4 mm
Glass 2 Pilkington Optitherm S3, Annealed, 4 mm
Glass 3 Pilkington Optifloat Clear, Annealed, 4 mm
Glass 4 Pilkington Optitherm S3, Annealed, 4 mm

Cavity 1 40 Gas 1 Air
Cavity 2 12 Gas 2 Argon (90%)
Cavity 3 12 Gas 3 Argon (90%)



Product Code	U Value	UV %	Light %			Energy %			Solar Factor	Shading Coeff.	
4K+40+S(3)4-12Ar-4-12Ar-S(3)4	W/m²K	T_{uv}	LT	LR out	LR in	ET	ER	EA	g	T SC	S SC
	0.5	9	60	23	24	35	26	39	0.44	0.50	0.40

Performance Code	Sound Reduction	Ra	Thickness	Weight	Date
U-value/Light/Energy	R_w dB ($C;C_{tr}$)	96	mm	kg/m²	05/04/2011
0.5 / 60 / 44	NPD		80	40.00	