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INTERNAL DOCUMENT:

TARCOG AND VENETIAN VERIFICATION RESULTS

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1. INTRODUCTION

This document presents results of systematic verification of the Wincog family of computer program modules, Tarcog and Venetian. The verification was done against WIS computer program, selected spreadsheet calculations, and testing of individual routines. In addition, logical checks and random checks were done on a number of intermediate results, like calculated velocities, pressure differentials, view factors, etc.

WIS is the only other known program that implements ISO 15099 venetain blind optical and thermal analysis. While it is not possible to directly compare WIS program and Wincog, due to somewhat different basic algorithms for center of glass heat transfer calculations (EN 673, EN 10077-1) and relatively poor documentation of WIS program implementation, which does not precisely state which exact algorithms are implemented. However, despite these uncertainties, some valuable comparisons and important observations could be made.

2. VENETIAN VERIFICATION RESULTS

Optical properties calculations for Venetian blinds were carried out using VENETIAN module (which is a part of LayerOptics.dll), which incorporates direct implementation of ISO 15099 and several other variations. Examples from the ISO 15099 Annex C were selected so that direct comparisons could be made. Table 2-1 lists selected Venetian blind configurations that were used in this verification work. For nomenclature see Carli. 2005a.

Table 2-1**:** Venetian Blind Configurations

Venetian blind ID	**A45**	**B45**	**C45**	**C80**	**D45**
Slat distance, d [mm]	12	12	12	12	12
Slat width, W [mm]	16	16	16	16	16
Slat tilt angle, α [deg]	45	45	45	80	45
IR transmittance slat, $\tau_{s,IR}$	0.00	0.00	0.00	0.00	0.40
IR emissivity slat external (front) side, ε_s^f	0.90	0.90	0.90	0.90	0.55
IR emissivity slat internal (back) side, ε_s^b	0.90	0.90	0.90	0.90	0.55
Solar transmittance slat, τ_s	0.00	0.00	0.00	0.00	0.40
Solar reflectance slat external (front) side, ρ_s^f	0.70	0.55	0.70	0.70	0.50
Solar reflectance slat internal (back) side, ρ_s^b	0.70	0.55	0.40	0.40	0.50

Beside the standard ISO 15099 method of calculating bulk solar-optical and radiative properties of the Venetian blind (ISO. 2003), two other approaches were used to calculate these properties, primarily to verify integrity of bi-directional calculations, implemented in VENETIAN. Namely, integrating bi-directional matrices over the set of outgoing angles, bulk solar-optical or radiative properties (depending on the spectrum) can be also calculated and theoretically they should produce equivalent results. Term “equivalent” is used here to signify calculation errors introduced by the use of a finite number of outgoing angles, as opposed to infinite number, which would have to produce

identical results. Table 2-2 summarizes notation used for the three methods mentioned above.

Table 2-2**:** Notation Used to Designate Different Methods to Calculate Venetian Blind Diffuse Solar-Optical and Radiative Properties in Venetian

Designator	Description
REF	Reference values from ISO 15099 Annex C
ISO	Direct Implementation of ISO 15099 method
UNIF DIF	Integration of Bi-Directional Matrices (Eq. 83 in Carli. 2005a), obtained using Uniform Diffuse Approach (Sec. 3.3.3, p. 28 in Carli. 2005a)
DIRECT DIF	Integration of Bi-Directional Matrices obtained using Directional Diffuse Approach (Sec. 3.3.3, p. 30 in Carli. 2005a)
DIRECT DIF - New	Integration of Bi-Directional Matrices obtained using Directional Diffuse Approach, with updated formulas for calculation of outgoing radiance.

2.1. Calculation Results – SOL Range

Table 2-3 shows Venetian's interim results that correspond to "dir-dif" results from ISO 15099 – diffuse output as a result of directional input radiation, that reaches the blind at a certain incident angle. These interim results are part of Venetian's Uniform Diffuse calculations.

Table 2-3**:** Comparison of Direct to Diffuse SOL Transmittance and Reflectance ("**dir-dif**")

Blind configuration ID		**A45**		**B45**		**C45**		**C80**		**D45**	
Solar incidence angle		**0**	**60**	**0**	**60**	**0**	**60**	**0**	**60**	**0**	**60**
Solar "dir-dif" transm. ext (front) side	REF	0.141	0.073	0.090	0.047	0.096	0.051	0.012	0.005	0.373	0.277
	ISO	0.1407	0.0730	0.0903	0.0472	0.0957	0.0508	0.0109	0.0048	0.3733	0.2756
Solar "dir-dif" transm. int. (back) side	REF	0.141	0.288	0.090	0.216	0.076	0.271	0.011	0.027	0.373	0.306
	ISO	0.1407	0.2882	0.0903	0.2161	0.0759	0.2714	0.0101	0.0268	0.3733	0.3063
Solar "dir-dif" reflectance ext. (front) side	REF	0.394	0.558	0.295	0.430	0.371	0.544	0.622	0.678	0.418	0.567
	ISO	0.3936	0.5587	0.2952	0.4308	0.3707	0.5454	0.6308	0.6788	0.4184	0.5676
Solar "dir-dif" reflectance int. (back) side	REF	0.394	0.103	0.295	0.066	0.216	0.070	0.356	0.273	0.418	0.273
	ISO	0.3936	0.1030	0.2952	0.0661	0.2158	0.0701	0.3605	0.2735	0.4184	0.2733

Some of the results shown in Table 2-3 are slightly different from reference results due to a somewhat different approach in treating partially irradiated slat segments used in Venetian. Venetian incorporates modified procedure to account for partially irradiated slats, while ISO 15099 procedure consider slat either fully irradiated or fully shaded. Therefore, the results from Venetian are considered more accurate.

Table 2-4 shows integrated (diffuse) solar optical properties (SOL range). These results should correspond to "dif-dif" part of results in ISO 15099 Annex C. Venetian results are obtained using 3 methods, as indicated in Table 2-2, which are essentially methods used for calculation of FIR properties of the Venetian blind – with the only difference that in this case SOL properties of the slat material were used as input data.

Table 2-4**:** Comparison of Diffuse to Diffuse SOL Transmittance and Reflectance ("**dif-dif**")

Blind configuration ID		**A45**	**B45**	**C45**	**C80**	**D45***
Transmittance, external (front) side	Ref	0.332	0.294	0.291	0.0380	0.495
	ISO-DIF	0.3316	0.2941	0.2913	0.0375	0.4951
	Unif Dif	0.3325	0.2945	0.2917	0.042	0.4983
	Direct Dif	0.3849	0.3313	*0.3319*	*0.0487*	**0.5891**
	DIRECT DIF - New	0.3325	0.2944	0.2915	0.0424	0.4985
Transmittance, internal (back) side	Ref	0.332	0.294	0.291	0.0380	0.495
	ISO-DIF	0.3316	0.2941	0.2913	0.0375	0.4951
	Unif Dif	0.3325	0.2945	0.2915	0.0422	0.4983
	Direct Dif	0.3849	0.3313	*0.3232*	*0.0462*	**0.5891**
	DIRECT DIF - New	0.3325	0.2944	0.2915	0.0424	0.4985
Reflectance, external (front) side	Ref	0.345	0.260	0.323	0.604	0.380
	ISO-DIF	0.3445	0.2597	0.323	0.6041	0.3805
	Unif Dif	0.3497	0.2636	0.3276	0.6095	0.3868
	Direct Dif	0.4231	0.3174	0.3919	0.6165	**0.4826**
	DIRECT DIF - New	0.3507	0.2643	0.3282	0.6073	0.3884
Reflectance, internal (back) side	Ref	0.345	0.260	0.193	0.345	0.380
	ISO-DIF	0.3445	0.2597	0.193	0.3454	0.3805
	Unif Dif	0.3497	0.2636	0.196	0.3484	0.3868
	Direct Dif	0.4231	0.3174	0.2378	0.3525	**0.4826**
	DIRECT DIF - New	0.3507	0.2643	0.1967	0.3472	0.3884

***Note**: For D45, DIRECT DIF method gives irregular results: T + R > 1 !!!

Blue, italics values in Table 2-4 indicate irregular results for transmittance, where transmittance at the front and at the back side of the blind are not exactly equal. Note that this only happens with sample C, which is the only one having different optical properties of the material at two sides of the slats. These differences are very small and are probably due to the numerical integration related approximations, though. The boldfaced, red colored values indicate results that are outside the acceptable range of numerical accuracy and therefore are considered inaccurate. Further work will be

undertaken to find out what is the problem with these values. DIRECT DIF - New results are obtained using Directional-diffuse method with updated formulas for calculation of outgoing radiance (Klems, J.H. 2004, Klems, J.H. 2005).

Calculation of bi-directional transmittances of a Venetian blind takes into account two components: directional transmittance (part of incident radiation that passes through the blind without interaction with slat material), labeled dir-dir, and diffuse part of transmittance (which is a result of a series of Lambertian diffuse scattering of directional incident light), labeled dir-dif. Therefore, integration of BTDF matrices for SOL range across outgoing hemisphere should result in a sum of "dir-dir" and "dir-dif" properties for a given incident direction (profile angle). This result could be a property of interest as it allows direct comparison of measured results in a spectrophotometer with integrating sphere. Table 2-5 shows results of such integrations, compared to sums of "dir-dir" and "dir-dif" results from ISO 15099 Annex C. The boldfaced, red colored values indicate results that are outside the acceptable range of numerical accuracy and therefore are considered inaccurate. Further work will be undertaken to find out what is the problem with these values.

Table 2-5**:** Comparison of Direct to Hemispherical SOL Transmittance and Reflectance.

Blind configuration ID		**A45**		**B45**		**C45**		**C80**		**D45**	
Solar incidence angle		**0**	**60**	**0**	**60**	**0**	**60**	**0**	**60**	**0**	**60**
Solar transm. ext (front) side	REF*	0.198	0.073	0.147	0.047	0.153	0.051	0.012	0.005	0.430	0.277
	UNIF DIF**	**0.1416**	0.0734	**0.0909**	0.0475	**0.0963**	0.0511	0.0109	0.0048	**0.3757**	0.2774
Solar transm. int. (back) side	REF*	0.198	0.598	0.147	0.526	0.133	0.581	0.011	0.115	0.430	0.616
	UNIF DIF**	**0.1416**	0.6002	**0.0909**	0.5277	**0.0764**	0.5833	0.0101	0.1150	**0.3757**	0.6184
Solar reflectance ext. (front) side	REF*	0.394	0.558	0.295	0.430	0.371	0.544	0.622	0.678	0.418	0.567
	UNIF DIF**	0.3961	0.5622	0.2971	0.4335	0.3730	0.5488	0.6347	0.6831	0.4211	0.5712
Solar reflectance int. (back) side	REF*	0.394	0.103	0.295	0.066	0.216	0.070	0.356	0.273	0.418	0.273
	UNIF DIF**	0.3961	0.1036	0.2971	0.0665	0.2171	0.0705	0.3628	0.2752	0.4211	0.2750

Notes:

* These results represent sum of "dir-dir" + "dir-dif" components from the reference table in ISO 15099 Appendix C.

**Integration here is done for outgoing hemisphere only (i.e., for a selected incident angle, results are integrated over all outgoing angles), so it is single integration (as opposed to double integration from Table 2-4)

2.2. Calculation Results – FIR Range

Because of the assumption of purely diffuse properties in FIR range, there are no dir-dir or dir-dif components in this range and therefore there are no directional to hemispherical values of the type in Table 2-3 or Table 2-5. Table 2-6 presents results of calculations of diffuse FIR properties for the same set of configurations shown in Table 2-1..

Table 2-6**:** Comparison of FIR Transmittance and Emissivity.

Blind configuration ID		**A45**	**B45**	**C45**	**C80**	**D45**
IR transmittance, external (front) side	Ref	0.227	0.227	0.227	0.0245	0.385
	ISO-DIF	0.2270	0.2270	0.2270	0.0245	0.3849
	Unif Dif	0.2266	0.2266	0.2266	0.0288	0.3866
	Direct Dif	0.2316	0.2316	0.2316	0.0297	0.4300
	DIRECT DIF - new	0.2265	0.2265	0.2265	0.0289	0.3867
IR transmittance, internal (back) side	Ref	0.227	0.227	0.227	0.0245	0.385
	ISO-DIF	0.2270	0.2270	0.2270	0.0245	0.3849
	Unif Dif	0.2266	0.2266	0.2266	0.0288	0.3866
	Direct Dif	0.2316	0.2316	0.2316	0.0297	0.4300
	DIRECT DIF - new	0.2265	0.2265	0.2265	0.0289	0.3867
IR emissivity external (front) side	Ref	0.729	0.729	0.729	0.890	0.536
	ISO-DIF	0.7294	0.7294	0.7294	0.8901	0.5356
	Unif Dif	0.7292	0.7292	0.7292	0.8851	0.5320
	Direct Dif	0.7158	0.7158	0.7158	0.8832	0.4587
	DIRECT DIF - new	0.7291	0.7291	0.7291	0.8853	0.5310
IR emissivity internal (back) side	Ref	0.729	0.729	0.729	0.890	0.536
	ISO-DIF	0.7294	0.7294	0.7294	0.8901	0.5356
	Unif Dif	0.7292	0.7292	0.7292	0.8851	0.5320
	Direct Dif	0.7158	0.7158	0.7158	0.8832	0.4587
	DIRECT DIF - new	0.7291	0.7291	0.7291	0.8853	0.5310

Emissivities presented in Table 2-6 are obtained by using integration method described in Carli. 2005a (Eq. 83 and 84.), which means that integration is performed on bi-directional transmittances and reflectances, and emissivities are calculated using these bulk properties. On the other hand, FIR emissivities, labeled “Alt” and presented in Table 2-7 were obtained using alternative integration method: integration is performed over "bi-directional emissivities", calculated for each pair of incident and outgoing directions. Results of this alternative summations are available only through Venetian's output file *Venetian.dbg*, which is created in debug mode only. It is clear from the Table 2-7 that this alternative methodology does not provide any advantage in computational accuracy.

Table 2-7**:** Selected Bi-Directional results – FIR range – using alternative integration

Blind configuration ID		**A45**	**B45**	**C45**	**C80**	**D45**
IR emissivity external (front) side	Ref	0.729	0.729	0.729	0.890	0.536
	Unif Dif	0.7292	0.7292	0.7292	0.8851	0.5320
	Unif Dif Alt	0.7417	0.7417	0.7417	0.8976	0.5445
	Direct Dif	0.7158	0.7158	0.7158	0.8832	0.4587
	Direct Dif Alt	0.7283	0.7283	0.7283	0.8958	0.4713
	DIRECT DIF - new Alt	0.7417	0.7417	0.7417	0.8979	0.5435
IR emissivity internal (back) side	Ref	0.729	0.729	0.729	0.890	0.536
	Unif Dif	0.7292	0.7292	0.7292	0.8851	0.5320
	Unif Dif Alt	0.7417	0.7417	0.7417	0.8976	0.5445
	Direct Dif	0.7158	0.7158	0.7158	0.8832	0.4587
	Direct Dif Alt	0.7283	0.7283	0.7283	0.8958	0.4713
	DIRECT DIF - new Alt	0.7417	0.7417	0.7417	0.8979	0.5435

3. TARCOG VERIFICATION RESULTS

Results of TARCOG thermal properties calculations were compared against results obtained using WIS 3.0 program. Both WinCOG test program and WINDOW 6 program were used in this verification. Versions used: WinCOG v6.0.29, TARCOG v6.0.15. WINDOW 6 0.19

3.1. Test results – W6/TARCOG vs. WIS

After defining test glazing system configurations (IGUs), following testing procedure was carried out:

1. Test IGU configurations were created using WIS program and all simulations were performed using that program,
2. Same test IGU configurations were modeled in W6 program. All simulations were performed using boundary conditions which correspond to those used in WIS simulations, and using ASHRAE/NFRC boundary conditions.
3. WinCOG test simulations were ran, using input data extracted from W6 debug output file (which records all arguments from TARCOG function calls)
4. Results were extracted from WIS report files, W6 report files and WinCOG output/debug files
5. Results were tabulated and two methodologies were compared.

Environmental conditions used in the testing (labeled WIS boundary conditions) correspond to the typical CEN standard conditions:

- T_e = 0 °C

- T_i = 20 °C
- I = 500 W/m^2
- h_e = 15.0 W/(m^2·K)
- h_i = 3.0 W/(m^2·K)

IGUs considered in this verification work consisted of a single, double clear and double low-e glazing with Venetian shading device at the outdoor or indoor side, or between the two glass panes, when applicable (i.e., for double glazed units).

Details of the glasses/blinds used in this verification work are presented in the following tables. Note the difference between properties of the clear glass used in W6 and WIS. These differences can account to a very small difference in calculated U, SHGC values.

Table 3-1: Glass Selection – basic properties of slected glasses

Glass type		Name	Width [mm]	IR transm.	Front emissivity	Back emissivity	Thermal conductivity
clear	WIS	OpCl_4.pgl	4	0	0.837	0.837	1
	W6	Clear4.pgl	3.87	0	0.84	0.84	1
low-e	WIS	OptitSN4.pgl	4	0	0.048	0.837	1
	W6	OptitSN4.pgl	4	0	0.048	0.837	1

Solar optical properties of slat material and of venetian blinds, calculated by Window 6 program (using Venetian module) and WIS program, are given in Table 2-1 and Table 3-2.

Table 3-2**:** Venetian blind configurations and their bulk IR properties

Config ID	Slat type	Slat tilt [deg]	IR transmittance			IR emissivity external (front) side			IR emissivity internal (back) side		
			W6	WIS	Diff [%]	W6	WIS	Diff [%]	W6	WIS	Diff [%]
A0	A	0	0.3614	0.348	-3.7%	0.6175	0.631	2.2%	0.6175	0.631	2.2%
A45		45	0.2266	0.227	0.2%	0.7292	0.729	0.0%	0.7292	0.729	0.0%
A90		90	1E-06	1E-07	-	0.904	0.905	0.1%	0.904	0.905	0.1%
B0	B	0	0.3614	0.348	-3.7%	0.6175	0.631	2.2%	0.6175	0.631	2.2%
B45		45	0.2266	0.227	0.2%	0.7292	0.729	0.0%	0.7292	0.729	0.0%
B90		90	1E-06	1E-07	-	0.904	0.905	0.1%	0.904	0.905	0.1%
C0	C	0	0.3614	0.348	-3.7%	0.6175	0.631	2.2%	0.6175	0.631	2.2%
C45		45	0.2266	0.227	0.2%	0.7292	0.729	0.0%	0.7292	0.729	0.0%
C80		80	0.0288	0.0245	-	0.8851	0.89	0.6%	0.8851	0.89	0.6%
C90		90	1E-06	1E-07	-	0.904	0.905	0.1%	0.904	0.905	0.1%
D45	D	45	0.3866	0.385	-0.4%	0.532	0.536	0.8%	0.532	0.536	0.8%
D90		90	0.3242	0.32	-1.3%	0.6234	0.628	0.7%	0.6234	0.628	0.7%

Table 3-3 presents details of glazing configurations used. Gap is the distance between two glass panes (in double glazing cases) and external SD distance is the distance between the outdoor/indoor glass surface and the center plane of the SD, in IGUs with external (outdoor or indoor) SD configurations. Table 3-4 presents free ventilation parameters, used in Window 6 and WIS simulations. Table 3-5 shows indicators of SD position within the glazing system, which are used in configuration names.

Table 3-3: Glazing Configuration

	Glass 1	**Gap [mm]**	**Gap gas**	**Glass2**	**External SD distance [mm]**
Single	clear	-	-	-	**10**
Double clear	clear	**20**	air	clear	**10**
Double Low-E	low-e	**20**	10 % argon	clear	**10**

Table 3-4: Free ventilation parameters (hole areas)

W6 / WinCOG				**WIS**			
Dtop [mm]	**Dbot [mm]**	**Dleft [mm]**	**Dright [mm]**	**Hole frct.**	**d1 [mm]**	**d2 [mm]**	**d3 [mm]**
0.04	**0.04**	**0.00**	**0.00**	**0.05**	**40**	**40**	**40**

Table 3-5: Nomenclature – SD position

SD position	
i	indoor
b	in between
o	outdoor

Table 3-6 presents details for the full set of test configurations: type of SD used, type(s) of glasses used, ordering of glazing/shading layers, gas mixtures and dimensions.

Table 3-6: Test configurations for Window 6 vs. WIS 3 test runs

Num.	Config ID	Glazing type	Venetian blind				Forced air velocity	Glazing system configuration										
			SD type	Slat tilt angle	Slat Width	SD position		Layer1	Layer1 thickness	Gap1	Gap1 width	Layer2	Layer2 thickness	Gap2	Gap2 width	Layer3	Layer3 thickness	Total thickness
1	ww_sc_A0_i_0	Single clear	A	0	16.00	i	0		4		2		16.00					22.00
2	ww_sc_A0_i_2						2											
3	ww_sc_A0_o_0					o	0		16.00		2		4					22.00
4	ww_sc_A0_o_2						2											
5	ww_sc_A45_i_0			45	11.31	i	0		4		4.34		11.31					19.66
6	ww_sc_A45_i_2						2											
7	ww_sc_A45_o_0					o	0		11.31		4.34		4					19.66
8	ww_sc_A45_o_2						2											
9	ww_sc_A90_i_0			90	0.60	i	0		4		9.7		0.60					14.30
10	ww_sc_A90_i_2						2											
11	ww_sc_A90_o_0					o	0		0.60		9.7		4					14.30
12	ww_sc_A90_o_2						2											
13	ww_dc_A0_i_0	Double clear	A	0	16.00	i	0		4		20		4		2		16.00	46.00
14	ww_dc_A0_i_2						2											
15	ww_dc_A0_b_0					b	0		4		2		16.00		2		4	28.00
16	ww_dc_A0_b_2						2											
17	ww_dc_A0_o_0					o	0		16.00		2		4		20		4	46.00
18	ww_dc_A0_o_2						2											
19	ww_dc_A45_i_0			45	11.31	i	0		4		20		4		4.34		11.31	43.66
20	ww_dc_A45_i_2						2											
21	ww_dc_A45_b_0					b	0		4		4.34		11.31		4.34		4	28.00
22	ww_dc_A45_b_2						2											
23	ww_dc_A45_o_0					o	0		11.31		4.34		4		20		4	43.66
24	ww_dc_A45_o_2						2											
25	ww_dc_A90_i_0			90	0.60	i	0		4		20		4		9.7		0.60	38.30
26	ww_dc_A90_i_2						2											
27	ww_dc_A90_b_0					b	0		4		9.7		0.60		9.7		4	28.00
28	ww_dc_A90_b_2						2											
29	ww_dc_A90_o_0					o	0		0.60		9.7		4		20		4	38.30
30	ww_dc_A90_o_2						2											
31	ww_dc_B0_i_0		B	0	16.00	i	0		4		20		4		2		16.00	46.00
32	ww_dc_B0_b_0					b	0		4		2		16.00		2		4	28.00
33	ww_dc_B0_o_0					o	0		16.00		2		4		20		4	46.00
34	ww_dc_B45_i_0			45	11.31	i	0		4		20		4		4.34		11.31	43.66
35	ww_dc_B45_b_0					b	0		4		4.34		11.31		4.34		4	28.00
36	ww_dc_B45_o_0					o	0		11.31		4.34		4		20		4	43.66
37	ww_dc_B90_i_0			90	0.60	i	0		4		20		4		9.7		0.60	38.30
38	ww_dc_B90_b_0					b	0		4		9.7		0.60		9.7		4	28.00
39	ww_dc_B90_o_0					o	0		0.60		9.7		4		20		4	38.30

Table 3-6 - continued

Num.	Config ID	Glazing type	Venetian blind				Forced air velocity	Glazing system configuration										
			SD type	Slat tilt angle	Slat Width	SD position		Layer1	Layer1 thickness	Gap1	Gap1 width	Layer2	Layer2 thickness	Gap2	Gap2 width	Layer3	Layer3 thickness	Total thickness
40	ww_le_C0_i_0	Double Low-E	C	0	16.00	i	0		4		20		4		2		16.00	46.00
41	ww_le_C0_b_0					b	0		4		2		16.00		2		4	28.00
42	ww_le_C0_o_0					o	0		16.00		2		4		20		4	46.00
43	ww_le_C45_i_0			45	11.31	i	0		4		20		4		4.34		11.31	43.66
44	ww_le_C45_b_0					b	0		4		4.34		11.31		4.34		4	28.00
45	ww_le_C45_o_0					o	0		11.31		4.34		4		20		4	43.66
46	ww_le_C80_i_0			80	2.78	i	0		4		20		4		8.61		2.78	39.39
47	ww_le_C80_b_0					b	0		4		8.61		2.78		8.61		4	28.00
48	ww_le_C80_o_0					o	0		2.78		8.61		4		20		4	39.39
49	ww_le_C90_i_0			90	0.60	i	0		4		20		4		9.7		0.60	38.30
50	ww_le_C90_b_0					b	0		4		9.7		0.60		9.7		4	28.00
51	ww_le_C90_o_0					o	0		0.60		9.7		4		20		4	38.30
52	ww_le_D45_i_0		D	45	11.31	i	0		4		20		4		4.34		11.31	43.66
53	ww_le_D45_b_0					b	0		4		4.34		11.31		4.34		4	28.00
54	ww_le_D45_o_0					o	0		11.31		4.34		4		20		4	43.66
55	ww_le_D90_i_0			90	0.60	i	0		4		20		4		9.7		0.60	38.30
56	ww_le_D90_b_0					b	0		4		9.7		0.60		9.7		4	28.00
57	ww_le_D90_o_0					o	0		0.60		9.7		4		20		4	38.30

Legend:		-	Clear glass
		-	Low-E glass
		-	Venetian blind
		-	Air
		-	10% Argon

Table 3-7 and Table 3-8 present results of Window 6 and WIS test runs.

Table 3-7: Comparison of results (U factors) of W6 and WIS test runs.

Num.	Config ID	Results				
		U value				
		W6B19	WIS	DIFF [%]	W6B19 (NFRC BC)	DIFF [%]
1	ww_sc_A0_i_0	4.561	4.5552	-0.1%	4.958	8.7%
2	ww_sc_A0_i_2		6.4210	-		-
3	ww_sc_A0_o_0	4.152	4.1407	-0.3%	4.390	5.7%
4	ww_sc_A0_o_2		4.7073	-		-
5	ww_sc_A45_i_0	3.872	3.9565	2.2%	4.090	5.6%
6	ww_sc_A45_i_2		7.1105	-		-
7	ww_sc_A45_o_0	3.555	3.5662	0.3%	3.653	2.8%
8	ww_sc_A45_o_2		4.6915	-		-
9	ww_sc_A90_i_0	3.091	3.6800	19.1%	3.310	7.1%
10	ww_sc_A90_i_2		7.3886	-		-
11	ww_sc_A90_o_0	2.966	3.1383	5.8%	3.067	3.4%
12	ww_sc_A90_o_2		4.6715	-		-
13	ww_dc_A0_i_0	2.421	2.3825	-1.6%	2.551	5.4%
14	ww_dc_A0_i_2		2.8252	-		-
15	ww_dc_A0_b_0	3.269	3.2609	-0.2%	3.406	4.2%
16	ww_dc_A0_b_2		3.6135	-		-
17	ww_dc_A0_o_0	2.293	2.2595	-1.5%	2.361	3.0%
18	ww_dc_A0_o_2		2.4278	-		-
19	ww_dc_A45_i_0	2.203	2.1872	-0.7%	2.294	4.1%
20	ww_dc_A45_i_2		2.9594	-		-
21	ww_dc_A45_b_0	2.623	2.6216	-0.1%	2.645	0.8%
22	ww_dc_A45_b_2		3.3813	-		-
23	ww_dc_A45_o_0	2.090	2.0662	-1.1%	2.117	1.3%
24	ww_dc_A45_o_2		2.4238	-		-
25	ww_dc_A90_i_0	1.903	2.0179	6.0%	1.985	4.3%
26	ww_dc_A90_i_2		3.0130	-		-
27	ww_dc_A90_b_0	2.018	2.0638	2.3%	2.009	-0.4%
28	ww_dc_A90_b_2		3.1615	-		-
29	ww_dc_A90_o_0	1.858	1.8849	1.5%	1.881	1.2%
30	ww_dc_A90_o_2		2.4179	-		-
31	ww_dc_B0_i_0	2.421	2.3825	-1.6%	2.551	5.4%
32	ww_dc_B0_b_0	3.269	3.2609	-0.2%	3.406	4.2%
33	ww_dc_B0_o_0	2.293	2.2595	-1.5%	2.361	3.0%
34	ww_dc_B45_i_0	2.203	2.1872	-0.7%	2.294	4.1%
35	ww_dc_B45_b_0	2.623	2.6216	-0.1%	2.645	0.8%
36	ww_dc_B45_o_0	2.090	2.0662	-1.1%	2.117	1.3%
37	ww_dc_B90_i_0	1.903	2.0179	6.0%	1.985	4.3%
38	ww_dc_B90_b_0	2.018	2.0638	2.3%	2.009	-0.4%
39	ww_dc_B90_o_0	1.858	1.8849	1.5%	1.881	1.2%

Table 3-7 - continued

Num.	Config ID	Results				
		U value				
		W6B19	WIS	DIFF [%]	W6B19 (NFRC BC)	DIFF [%]
40	**ww_le_C0_i_0**	1.207	1.1316	-6.2%	1.465	21.4%
41	**ww_le_C0_b_0**	2.618	2.6181	0.0%	2.681	2.4%
42	**ww_le_C0_o_0**	1.162	1.0933	-5.9%	1.367	17.6%
43	**ww_le_C45_i_0**	1.144	1.0784	-5.7%	1.372	19.9%
44	**ww_le_C45_b_0**	1.837	1.8428	0.3%	1.839	0.1%
45	**ww_le_C45_o_0**	1.095	1.0353	-5.5%	1.262	15.3%
46	**ww_le_C80_i_0**	1.060	1.0164	-4.1%	1.257	18.6%
47	**ww_le_C80_b_0**	1.304	1.3579	4.1%	1.326	1.7%
48	**ww_le_C80_o_0**	1.023	0.9770	-4.5%	1.167	14.1%
49	**ww_le_C90_i_0**	1.046	1.0110	-3.3%	1.241	18.6%
50	**ww_le_C90_b_0**	1.233	1.3060	5.9%	1.270	3.0%
51	**ww_le_C90_o_0**	1.012	0.9698	-4.2%	1.153	13.9%
52	**ww_le_D45_i_0**	1.159	1.0910	-5.9%	1.394	20.3%
53	**ww_le_D45_b_0**	1.816	1.8224	0.4%	1.817	0.1%
54	**ww_le_D45_o_0**	1.101	1.0406	-5.5%	1.265	14.9%
55	**ww_le_D90_i_0**	1.113	1.0624	-4.5%	1.339	20.3%
56	**ww_le_D90_b_0**	1.240	1.3126	5.9%	1.275	2.8%
57	**ww_le_D90_o_0**	1.039	0.9918	-4.5%	1.174	13.0%

Notes:

- Unless indicated otherwise, runs are done using default WIS BC, so to accomplish appropriate comparison.
- Comparison between W6 and WINCOG results was not included here, because they were identical throughout.

Table 3-8: Comparison of results (SHGC) of W6 and WIS test runs.

Num.	Config ID	Results				
		SHGC				
		W6B19	WIS	DIFF [%]	W6B19 (NFRC BC)	DIFF [%]
1	ww_sc_A0_i_0	0.845	0.8474	0.3%	0.844	-0.1%
2	ww_sc_A0_i_2		0.8581	-		-
3	ww_sc_A0_o_0	0.864	0.8663	0.3%	0.864	0.0%
4	ww_sc_A0_o_2		0.8586	-		-
5	ww_sc_A45_i_0	0.397	0.4081	2.8%	0.401	1.0%
6	ww_sc_A45_i_2		0.4871	-		-
7	ww_sc_A45_o_0	0.237	0.2347	-1.0%	0.237	0.0%
8	ww_sc_A45_o_2		0.2091	-		-
9	ww_sc_A90_i_0	0.194	0.2429	25.2%	0.192	-1.0%
10	ww_sc_A90_i_2		0.3204	-		-
11	ww_sc_A90_o_0	0.040	0.0413	3.2%	0.049	22.5%
12	ww_sc_A90_o_2		0.0243	-		-
13	ww_dc_A0_i_0	0.741	0.7443	0.4%	0.742	0.1%
14	ww_dc_A0_i_2		0.7559	-		-
15	ww_dc_A0_b_0	0.743	0.7460	0.4%	0.743	0.0%
16	ww_dc_A0_b_2		0.7440	-		-
17	ww_dc_A0_o_0	0.761	0.7638	0.4%	0.761	0.0%
18	ww_dc_A0_o_2		0.7559	-		-
19	ww_dc_A45_i_0	0.444	0.4592	3.4%	0.449	1.1%
20	ww_dc_A45_i_2		0.5263	-		-
21	ww_dc_A45_b_0	0.314	0.3160	0.6%	0.316	0.6%
22	ww_dc_A45_b_2		0.3102	-		-
23	ww_dc_A45_o_0	0.191	0.1849	-3.2%	0.191	0.0%
24	ww_dc_A45_o_2		0.1660	-		-
25	ww_dc_A90_i_0	0.249	0.3028	21.6%	0.234	-6.0%
26	ww_dc_A90_i_2		0.3849	-		-
27	ww_dc_A90_b_0	0.142	0.1462	3.0%	0.142	0.0%
28	ww_dc_A90_b_2		0.1436	-		-
29	ww_dc_A90_o_0	0.026	0.0263	1.0%	0.031	19.2%
30	ww_dc_A90_o_2		0.0139	-		-
31	ww_dc_B0_i_0	0.741	0.7443	0.4%	0.742	0.1%
32	ww_dc_B0_b_0	0.743	0.7460	0.4%	0.743	0.0%
33	ww_dc_B0_o_0	0.761	0.7638	0.4%	0.761	0.0%
34	ww_dc_B45_i_0	0.470	0.4868	3.6%	0.478	1.7%
35	ww_dc_B45_b_0	0.319	0.3206	0.5%	0.321	0.6%
36	ww_dc_B45_o_0	0.165	0.1607	-2.6%	0.165	0.0%
37	ww_dc_B90_i_0	0.307	0.3740	21.8%	0.291	-5.2%
38	ww_dc_B90_b_0	0.189	0.1933	2.3%	0.191	1.1%
39	ww_dc_B90_o_0	0.034	0.0345	1.6%	0.042	23.5%

Table 3-8 - continued

Num.	Config ID	Results				
		SHGC				
		W6B19	WIS	DIFF [%]	W6B19 (NFRC BC)	DIFF [%]
40	**ww_le_C0_i_0**	0.561	0.5831	3.9%	0.558	-0.5%
41	**ww_le_C0_b_0**	0.564	0.5869	4.1%	0.563	-0.2%
42	**ww_le_C0_o_0**	0.576	0.5982	3.9%	0.570	-1.0%
43	**ww_le_C45_i_0**	0.394	0.4192	6.4%	0.405	2.8%
44	**ww_le_C45_b_0**	0.292	0.2998	2.7%	0.297	1.7%
45	**ww_le_C45_o_0**	0.114	0.1143	0.2%	0.110	-3.5%
46	**ww_le_C80_i_0**	0.265	0.3186	20.2%	0.258	-2.6%
47	**ww_le_C80_b_0**	0.195	0.2009	3.0%	0.200	2.6%
48	**ww_le_C80_o_0**	0.024	0.0243	1.3%	0.022	-8.3%
49	**ww_le_C90_i_0**	0.237	0.3017	27.3%	0.226	-4.6%
50	**ww_le_C90_b_0**	0.176	0.1829	3.9%	0.180	2.3%
51	**ww_le_C90_o_0**	0.016	0.0158	-1.0%	0.015	-6.3%
52	**ww_le_D45_i_0**	0.408	0.4276	4.8%	0.411	0.7%
53	**ww_le_D45_b_0**	0.348	0.3546	1.9%	0.348	0.0%
54	**ww_le_D45_o_0**	0.263	0.2661	1.2%	0.257	-2.3%
55	**ww_le_D90_i_0**	0.349	0.3842	10.1%	0.339	-2.9%
56	**ww_le_D90_b_0**	0.302	0.3105	2.8%	0.302	0.0%
57	**ww_le_D90_o_0**	0.217	0.2234	3.0%	0.213	-1.8%

- Unless indicated otherwise, runs are done using default WIS BC, so to accomplish appropriate comparison.
- Comparison between W6 and WINCOG results was not included here, because they were identical throughout.

Table 3-9 presents comparison of solar-optical properties calculated by W6 and WIS.

Table 3-9: Comparison of results (solar-optical properties) of W6 and WIS test runs.

Num.	Config ID	Itemized Solar-Optical Results											
		TotSol			Asol 1			Asol 2			Asol 3		
		W6 B19	WIS	Diff [%]	W6 B19	WIS	Diff [%]	W6 B19	WIS	Diff [%]	W6 B19	WIS	Diff [%]
1	ww_sc_A0_i_0	0.8187	0.8230	0.5%	0.1055	0.1010	-4.3%	0.0016	0.0000	-			
2	ww_sc_A0_i_2		0.8230	-		0.1010	-		0.0000	-			
3	ww_sc_A0_o_0	0.8187	0.8230	0.5%	0.0020	0.0000	-	0.1053	0.1010	-4.1%			
4	ww_sc_A0_o_2		0.8230	-		0.0000	-		0.1010	-			
5	ww_sc_A45_i_0	0.1753	0.1800	2.7%	0.1450	0.1400	-3.4%	0.3493	0.3520	0.8%			
6	ww_sc_A45_i_2		0.1800	-		0.1400	-		0.3520	-			
7	ww_sc_A45_o_0	0.1604	0.1580	-1.5%	0.4163	0.4170	0.2%	0.0235	0.0227	-3.4%			
8	ww_sc_A45_o_2		0.1580	-		0.4170	-		0.0227	-			
9	ww_sc_A90_i_0	0.0023	0.0028	-	0.1756	0.1700	-3.2%	0.2925	0.3050	4.3%			
10	ww_sc_A90_i_2		0.0028	-		0.1700	-		0.3050	-			
11	ww_sc_A90_o_0	0.0021	0.0026	-	0.3277	0.3350	2.2%	0.0003	0.0004	-			
12	ww_sc_A90_o_2		0.0026	-		0.3350	-		0.0004	-			
13	ww_dc_A0_i_0	0.6755	0.6810	0.8%	0.1119	0.1080	-3.5%	0.0870	0.0838	-3.7%	0.0013	0.0000	-
14	ww_dc_A0_i_2		0.6810	-		0.1080	-		0.0838	-		0.0000	-
15	ww_dc_A0_b_0	0.6755	0.6810	0.8%	0.1119	0.1080	-3.5%	0.0017	0.0000	-	0.0869	0.0838	-3.5%
16	ww_dc_A0_b_2		0.6810	-		0.1080	-		0.0000	-		0.0838	-
17	ww_dc_A0_o_0	0.6755	0.6810	0.8%	0.0021	0.0000	-	0.1117	0.1080	-3.3%	0.0869	0.0838	-3.5%
18	ww_dc_A0_o_2		0.6810	-		0.0000	-		0.1080	-		0.0838	-
19	ww_dc_A45_i_0	0.1507	0.1570	4.2%	0.1377	0.1320	-4.1%	0.1233	0.1200	-2.7%	0.2943	0.3000	1.9%
20	ww_dc_A45_i_2		0.1570	-		0.1320	-		0.1200	-		0.3000	-
21	ww_dc_A45_b_0	0.1422	0.1430	0.6%	0.1456	0.1410	-3.2%	0.3566	0.3610	1.2%	0.0210	0.0207	-1.2%
22	ww_dc_A45_b_2		0.1430	-		0.1410	-		0.3610	-		0.0207	-
23	ww_dc_A45_o_0	0.1306	0.1260	-3.5%	0.4209	0.4230	0.5%	0.0260	0.0257	-1.3%	0.0189	0.0181	-4.3%
24	ww_dc_A45_o_2		0.1260	-		0.4230	-		0.0257	-		0.0181	-
25	ww_dc_A90_i_0	0.0020	0.0025	-	0.1588	0.1530	-3.7%	0.1531	0.1510	-1.4%	0.2530	0.2680	5.9%
26	ww_dc_A90_i_2		0.0025	-		0.1530	-		0.1510	-		0.2680	-
27	ww_dc_A90_b_0	0.0019	0.0023	-	0.1756	0.1700	-3.2%	0.2926	0.3050	4.2%	0.0003	0.0004	-
28	ww_dc_A90_b_2		0.0023	-		0.1700	-		0.3050	-		0.0004	-
29	ww_dc_A90_o_0	0.0017	0.0021	-	0.3278	0.3350	2.2%	0.0004	0.0005	-	0.0003	0.0003	-
30	ww_dc_A90_o_2		0.0021	-		0.3350	-		0.0005	-		0.0003	-
31	ww_dc_B0_i_0	0.6755	0.6810	0.8%	0.1119	0.1080	-3.5%	0.0870	0.0838	-3.7%	0.0013	0.0000	-
32	ww_dc_B0_b_0	0.6755	0.6810	0.8%	0.1119	0.1080	-3.5%	0.0017	0.0000	-	0.0869	0.0838	-3.5%
33	ww_dc_B0_o_0	0.6755	0.6810	0.8%	0.0021	0.0000	-	0.1117	0.1080	-3.3%	0.0869	0.0838	-3.5%
34	ww_dc_B45_i_0	0.1107	0.1150	3.9%	0.1309	0.1260	-3.8%	0.1138	0.1110	-2.5%	0.3952	0.4020	1.7%
35	ww_dc_B45_b_0	0.1044	0.1050	0.6%	0.1351	0.1300	-3.8%	0.4785	0.4830	0.9%	0.0151	0.0149	-1.5%
36	ww_dc_B45_o_0	0.0968	0.0940	-2.9%	0.5694	0.5710	0.3%	0.0188	0.0185	-1.7%	0.0138	0.0132	-4.3%
37	ww_dc_B90_i_0	0.0006	0.0008	-	0.1476	0.1420	-3.8%	0.1372	0.1340	-2.4%	0.3556	0.3710	4.3%
38	ww_dc_B90_b_0	0.0006	0.0007	-	0.1594	0.1530	-4.0%	0.4158	0.4280	2.9%	0.0001	0.0001	-
39	ww_dc_B90_o_0	0.0005	0.0006	-	0.4746	0.4810	1.3%	0.0001	0.0001	-	0.0001	0.0001	-

Table 3-9 - continued.

Num.	Config ID	Itemized Solar-Optical Results											
		TotSol			Asol 1			Asol 2			Asol 3		
		W6 B19	WIS	Diff [%]	W6 B19	WIS	Diff [%]	W6 B19	WIS	Diff [%]	W6 B19	WIS	Diff [%]
40	ww_le_C0_i_0	0.4945	0.5180	4.8%	0.2023	0.2000	-1.2%	0.0637	0.0638	0.1%	0.0009	0.0000	-
41	ww_le_C0_b_0	0.4945	0.5180	4.8%	0.2023	0.2000	-1.1%	0.0012	0.0000	-	0.0636	0.0638	0.3%
42	ww_le_C0_o_0	0.4945	0.5180	4.8%	0.0024	0.0000	-	0.2019	0.2000	-1.0%	0.0636	0.0638	0.3%
43	ww_le_C45_i_0	0.0930	0.0987	6.1%	0.2279	0.2240	-1.7%	0.0934	0.0933	-0.1%	0.2611	0.2730	4.6%
44	ww_le_C45_b_0	0.0894	0.0912	2.1%	0.2358	0.2310	-2.0%	0.3196	0.3310	3.6%	0.0131	0.0131	0.3%
45	ww_le_C45_o_0	0.0725	0.0748	3.1%	0.5006	0.5000	-0.1%	0.0359	0.0332	-7.4%	0.0103	0.0105	1.6%
46	ww_le_C80_i_0	0.0133	0.0109	-18.1%	0.2502	0.2450	-2.1%	0.1191	0.1190	-0.1%	0.2179	0.2340	7.4%
47	ww_le_C80_b_0	0.0107	0.0097	-	0.2694	0.2620	-2.8%	0.2645	0.2760	4.4%	0.0021	0.0015	-
48	ww_le_C80_o_0	0.0051	0.0057	-	0.3603	0.3680	2.1%	0.0028	0.0028	-	0.0008	0.0009	-
49	ww_le_C90_i_0	0.0004	0.0005	-	0.2546	0.2490	-2.2%	0.1242	0.1240	-0.2%	0.2065	0.2210	7.0%
50	ww_le_C90_b_0	0.0004	0.0005	-	0.2761	0.2680	-2.9%	0.2480	0.2590	4.4%	0.0001	0.0001	-
51	ww_le_C90_o_0	0.0003	0.0004	-	0.3321	0.3400	2.4%	0.0002	0.0002	-	0.0000	0.0001	-
52	ww_le_D45_i_0	0.2477	0.2610	5.4%	0.2319	0.2280	-1.7%	0.0980	0.0978	-0.2%	0.0842	0.0879	4.5%
53	ww_le_D45_b_0	0.2420	0.2460	1.7%	0.2444	0.2400	-1.8%	0.1064	0.1110	4.3%	0.0366	0.0368	0.6%
54	ww_le_D45_o_0	0.2088	0.2140	2.5%	0.1686	0.1680	-0.4%	0.1107	0.1000	-9.7%	0.0310	0.0318	2.7%
55	ww_le_D90_i_0	0.2030	0.2160	6.4%	0.2416	0.2370	-1.9%	0.1093	0.1090	-0.2%	0.0753	0.0790	4.9%
56	ww_le_D90_b_0	0.1992	0.2050	2.9%	0.2584	0.2520	-2.5%	0.0949	0.0987	4.0%	0.0307	0.0313	2.0%
57	ww_le_D90_o_0	0.1709	0.1790	4.8%	0.1419	0.1430	0.8%	0.0939	0.0862	-8.2%	0.0259	0.0273	5.6%

Table 3-10 presents details of purely specular single- and double glazing test configurations. Glazing systems 1-3 are single glazing configurations. Glazing system 1 has coating on surface 1, while glazing system 2 has coating on surface 2. Glazing systems 4-6 are double glazing configurations. Glazing system 4 has coating on surface 2, while glazing system 5 has coating on surface 3

Table 3-10: Purely specular test configurations.

Num.	Config ID	Glazing type	Glazing system configuration						
			Layer1	Layer1 thickness	Gap1	Gap1 width	Layer2	Layer2 thickness	Total thickness
1	Pilkington_LowE	Single		4					4.00
2	Pilkington_LowE2			4					4.00
3	Pilkington_Clr			4					4.00
4	Pilkington_dLowE	Double		4		12.7		4	20.70
5	Pilkington_dLowE2			4		12.7		4	20.70
6	Pilkington_dClr			4		12.7		4	20.70

Legend:			
		-	Clear glass
		-	Low-E glass
		-	Air
		-	10% Argon

Table 3-11 and Table 3-12 show results of test runs conducted for several purely specular glazing systems. Table 3-11 also includes results of WinCOG runs obtained using EN673 method, as given in EN673 (1997) standard and ISO10292 (1994) standard.

Table 3-11: Comparison of results (U factor) of W6, WinCOG and WIS test runs for purely specular glazing systems.

Num.	Config ID	Results						
		U value						
		W6B19	WIS	DIFF [%]	WinCOG, EN673	DIFF [%]	W6B19 (NFRC BC)	DIFF [%]
1	Pilkington_LowE	4.913	4.9099	-0.1%	5.7896	17.8%	5.937	20.8%
2	Pilkington_LowE2	2.744	2.7437	0.0%	3.2560	18.7%	3.354	22.2%
3	Pilkington_Clr	5.250	5.2338	-0.3%	5.8022	10.5%	6.060	15.4%
4	Pilkington_dLowE	1.277	1.2420	-2.7%	1.2687	-0.6%	1.441	12.8%
5	Pilkington_dLowE2	1.276	1.2420	-2.7%	1.2683	-0.6%	1.440	12.9%
6	Pilkington_dClr	2.704	2.6891	-0.6%	2.8406	5.1%	2.754	1.8%

Table 3-12: Comparison of results (SHGC) of W6 and WIS test runs for purely specular glazing systems.

Num.	Config ID	Results				
		SHGC				
		W6B19	WIS	DIFF [%]	W6B19 (NFRC BC)	DIFF [%]
1	Pilkington_LowE	0.628	0.6638	5.7%	0.627	-0.2%
2	Pilkington_LowE2	0.614	0.6468	5.3%	0.612	-0.3%
3	Pilkington_Clr	0.850	0.8511	0.1%	0.849	-0.1%
4	Pilkington_dLowE	0.552	0.5812	5.3%	0.551	-0.2%
5	Pilkington_dLowE2	0.596	0.6306	5.8%	0.596	0.0%
6	Pilkington_dClr	0.749	0.7517	0.4%	0.748	-0.1%

4. REFERENCES

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