CEN/TC 129/WG 9 "Light and energy transmission, thermal insulation"
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Round robin programme on the calculation of light solar and thermal properties in accordance with EN 410 and EN 673

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Description

Report on the results of the round robin programme on the calculation of light solar and thermal properties in accordance with EN 410 and EN 673

<u>Round robin programme on the calculation of light, solar and thermal properties in accordance with EN 410 and EN 673</u>

REPORT

1. Introduction

To fill a gap in the framework of European Standardisation, CEN/TC129/WG9 (Glass in building – Light and solar transmission, thermal insulation) has developed a European Standard, *Glass in building — Spectrophotometric characteristics of glass products — Validation procedure for calculation tool*. This standard provides a procedure to validate calculation programs of spectrophotometric and thermal characteristics of the glass products following EN 410 or EN 673, including light transmittance, light reflectance, solar direct transmittance, solar direct reflectance, total solar energy transmittance (solar factor or g value) and thermal transmittance (U value) in the vertical position.

In support of this development, members of CEN/TC129/WG9 and International Commission on Glass (ICG) Technical Committee (TC) 10 (Optical properties) participated in a round robin calculation program to establish and confirm the acceptable limits for the difference criteria between the results of the validator and the applicant.

This report summarises the results of the round robin calculation programme.

2. Normative references

EN 410: 2011:	Glass in building - Determination of luminous and solar characteristics of glazing
EN 673: 2011:	Glass in building - Determination of thermal transmittance (U value) - Calculation method
EN 12898: 2019:	Glass in building - Determination of the emissivity

3. Methodology

Using identical reference spectral data, several members of CEN/TC129/WG9 and ICG TC 10 calculated agreed light, solar and thermal properties of the glass configurations in accordance with the following tasks stated in Table 1 (based on the aforementioned standard).

<u>Table 1. Tasks undertaken during the round robin calculation program</u>

Task number	Task description	Example	EN410 calculation (τ_v, ρ_v, ρ'_v, τ_e, ρ_e, ρ'_e, g)	EN673 calculation (U value)
Single glazing				
1	Check calculation for uncoated float glass	4mm uncoated basic soda lime silicate float glass	✓	✓
2	Change thickness of uncoated glass	4mm uncoated glass to 6mm uncoated glass	✓	✓
3	Change thickness of coated glass based on the same substrate	4mm coated glass to 6mm coated glass	✓	✓

4	Change substrate of coated glass from clear float to tinted	4mm coated clear float to 4mm coated green tinted glass – but not vice versa (i.e. not from low transmission glass to higher transmission glass)	✓	✗
Double glazing				
5	Check double glazing with solar control outer pane	6mm solar control coated #2 outer pane and 4mm uncoated inner pane	✓	✓
6	Check double glazing with low-e inner pane	4mm uncoated outer pane and 4mm low-e coated #3 inner pane (with 8mm argon, 16mm argon, 20mm argon, 8mm krypton, 16mm 45% argon, 45% krypton and 10% air)	✓	✓
7	Check double glazing with both panes coated (surfaces 2 and 3)	6mm solar control coated #2 outer pane and 4mm low-e coated #3 inner pane	✓	✓
8	Check double glazing with two coatings, one of which is on surface 4	4mm uncoated outer pane and 4mm low-e double coated #3 and #4 inner pane <u>or</u> 4mm coated #2 outer pane and monolithic low-e coated #4 inner pane	✗	✓
9	Check double glazing with coated laminated inner pane (coating facing the cavity)	4mm uncoated outer pane and 8.8mm (44.2) coated laminated glass #3 inner pane	✓	✓
Triple glazing				
10	Check triple glazing with solar control outer pane and low-e inner pane	6mm solar control coated #2 outer pane, 4mm uncoated glass mid-pane and 4mm low-e coated #5 inner pane	✓	✓
11	Check triple glazing with two panes of low-e glass	4mm uncoated glass outer pane, 4mm low e coated #3 mid-pane and 4mm low-e coated #5 inner pane (with 8mm argon, 12mm argon, 16mm argon and 8mm krypton)	✓	✓

12	Check with triple glazing with two panes of uncoated laminated glass	8.8mm (44.2) uncoated laminated glass outer pane, 4mm uncoated glass mid-pane and 8.8mm (44.2) uncoated laminated glass inner pane	✓	✓
Additional calculations				
13	Check laminated glass with thick interlayer (EN 410 2011 Annex B)	Laminated glass with configuration of 4mm uncoated glass / 3.04mm clear interlayer / 4mm uncoated glass)	✓	✓
14	Check laminated glass with an absorbing coating between the interlayer and the second glass pane with the external surfaces uncoated (EN 410 2011 Annex B example 2)	From 8.8mm (44.2) laminated glass (with coating against interlayer) to 12.8mm (66.2) laminated glass (with coating against interlayer)	✓	✓

Notes

Table 1 is based on an earlier draft of the standard at the time the round robin calculation programme commenced. Some of the tasks in Table 1 have been changed in the final draft version of the standard.

Not all tasks were undertaken by all participants, dependent upon the scope of the calculator used.

For the calculation of the U value, participants determined the corrected emissivity from the normal emissivity in accordance with EN 12898: 2019

4. Results

The results of the round robin calculation programme are presented in Table 2.

Table 2. Summary of results of round robin calculation programme

Task number	Participant	Light transmittance	Light reflectance outside	Light reflectance inside	Solar transmittance	Solar reflectance outside	Solar reflectance inside	Solar factor	Ug value	Remarks
1	A	0.906	0.081	0.081	0.866	0.077	0.077	0.880	5.751	
	B	0.906	0.082	0.082	0.866	0.078	0.078	0.880	5.751	
	C	0.906	0.082	0.082	0.866	0.078	0.078	0.880	5.753	
	D	0.906	0.082	0.082	0.867	0.078	0.078	0.880	5.751	
	F	0.906	0.082	0.082	0.866	0.078	0.078	0.880	5.752	
	G	0.906	0.082	0.082	0.866	0.078	0.078	0.879	------	Tool 1
	G	0.906	0.082	0.082	0.867	0.078	0.078	0.880	5.751	Tool 2
	E	0.906	0.082	0.082	0.866	0.078	0.078	0.880	5.751	
2	A	0.901	0.081	0.081	0.845	0.076	0.076	0.864	5.686	
	B	0.901	0.081	0.081	0.844	0.076	0.076	0.862	5.686	
	C	0.901	0.081	0.081	0.844	0.076	0.076	0.863	5.687	
	D	0.900	0.082	0.082	0.843	0.076	0.076	0.862	5.686	
	F	0.901	0.082	0.082	0.844	0.076	0.076	0.862	5.687	
	G	------	------	------	------	------	------	------	------	Tool 1
	G	0.901	0.082	0.082	0.844	0.076	0.076	0.863	5.686	Tool 2
	E	0.901	0.082	0.082	0.844	0.076	0.076	0.863	5.686	
3	A	0.759	0.175	0.142	0.486	0.356	0.407	0.506	3.173	
	B	0.759	0.175	0.142	0.485	0.354	0.407	0.506	3.173	
	C	0.759	0.175	0.142	0.485	0.354	0.407	0.506	3.173	
	D	0.759	0.175	0.142	0.485	0.354	0.407	0.505	3.173	
	F	0.759	0.175	0.142	0.485	0.354	0.407	0.506	3.173	
	G	------	------	------	------	------	------	------	------	Tool 1
	G	0.759	0.175	0.142	0.485	0.354	0.406	0.506	3.173	Tool 2
	E	0.759	0.175	0.142	0.485	0.354	0.407	0.506	3.173	

4	A	0.523	0.107	0.128	0.260	0.097	0.398	0.343	3.193	
	B	0.523	0.107	0.128	0.260	0.097	0.398	0.343	3.193	
	C	0.522	0.107	0.128	0.260	0.097	0.398	0.343	3.194	
	D	0.522	0.107	0.128	0.260	0.097	0.398	0.343	3.193	
	F	0.523	0.107	0.128	0.260	0.097	0.398	0.343	3.193	
	G	------	------	------	------	------	------	------	------	Tool 1
	G	0.523	0.107	0.128	0.260	0.097	0.398	0.343	------	Tool 2
	E	0.523	0.107	0.128	0.260	0.097	0.398	0.343	3.193	
5	A	0.502	0.261	0.226	0.302	0.400	0.419	0.326	1.154	
	B	0.502	0.261	0.227	0.302	0.398	0.420	0.325	1.154	
	C	0.502	0.261	0.227	0.302	0.398	0.420	0.325	1.154	
	D	0.502	0.262	0.227	0.302	0.398	0.420	0.325	1.153	
	F	0.502	0.261	0.227	0.302	0.398	0.420	0.325	1.154	
	G	0.502	0.262	------	0.301	0.398	------	0.325	1.154	Tool 1
	G	0.502	0.262	0.227	0.302	0.398	0.420	0.325	1.154	Tool 2
	E	0.502	0.262	0.227	0.302	0.398	0.420	0.325	1.154	
6a	A	0.700	0.199	0.225	0.446	0.386	0.403	0.519	1.646	
	B	0.700	0.200	0.225	0.446	0.387	0.403	0.518	1.646	
	C	0.700	0.200	0.225	0.446	0.387	0.403	0.518	1.646	
	D	0.700	0.200	0.226	0.446	0.387	0.403	0.518	1.646	
	F	0.700	0.200	0.225	0.446	0.387	0.403	0.518	1.645	
	G	0.700	0.200	------	0.445	0.387	------	0.518	1.646	Tool 1
	G	0.700	0.200	0.225	0.446	0.387	0.403	0.518	1.645	Tool 2
	E	0.700	0.200	0.225	0.446	0.387	0.403	0.518	1.646	
6b	A	0.700	0.199	0.225	0.446	0.386	0.403	0.523	1.081	
	B	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.082	
	C	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.082	
	D	0.700	0.200	0.226	0.446	0.387	0.403	0.523	1.081	
	F	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.081	
	G	0.700	0.200	------	0.445	0.387	------	0.522	1.081	Tool 1
	G	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.081	Tool 2
	E	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.081	

6c	A	0.700	0.199	0.225	0.446	0.386	0.403	0.523	1.107	
	B	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.107	
	C	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.107	
	D	0.700	0.200	0.226	0.446	0.387	0.403	0.523	1.107	
	F	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.106	
	G	0.700	0.200	------	0.445	0.387	------	0.518	1.107	Tool 1
	G	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.106	Tool 2
	E	0.700	0.200	0.225	0.446	0.387	0.403	0.523	1.106	
6d	A	0.700	0.199	0.225	0.446	0.386	0.403	0.522	1.150	
	B	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.150	
	C	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.150	
	D	0.700	0.200	0.226	0.446	0.387	0.403	0.522	1.149	
	F	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.149	
	G	0.700	0.200	------	0.445	0.387	------	0.522	1.150	Tool 1
	G	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.149	Tool 2
	E	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.149	
6e	A	0.700	0.199	0.225	0.446	0.386	0.403	0.523	1.132	
	B	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.132	
	C	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.132	
	D	0.700	0.200	0.226	0.446	0.387	0.403	0.523	1.131	
	F	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.131	
	G	0.700	0.200	------	0.445	0.387	------	0.522	1.132	Tool 1
	G	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.131	Tool 2
	E	0.700	0.200	0.225	0.446	0.387	0.403	0.522	1.130	
7	A	0.428	0.280	0.281	0.232	0.424	0.477	0.280	1.054	
	B	0.428	0.280	0.281	0.232	0.422	0.477	0.279	1.054	
	C	0.428	0.280	0.281	0.232	0.422	0.477	0.279	1.054	
	D	0.428	0.280	0.281	0.232	0.422	0.477	0.279	1.054	
	F	0.428	0.280	0.281	0.232	0.422	0.477	0.279	1.053	
	G	0.428	0.280	------	0.231	0.422	------	0.279	1.054	Tool 1
	G	0.428	0.280	0.281	0.232	0.422	0.477	0.279	1.053	Tool 2
	E	0.428	0.280	0.281	0.232	0.422	0.477	0.279	1.053	

8a	A	0.601	0.257	0.246	0.337	0.443	0.493	0.441	0.940	
	B	------	------	------	------	------	------	------	------	
	C	0.601	0.258	0.246	0.337	0.444	0.493	0.441	0.940	
	D	0.601	0.258	0.246	0.337	0.444	0.493	0.441	0.940	
	F	0.601	0.258	0.246	0.337	0.444	0.493	0.441	0.939	
	G	------	------	------	------	------	------	------	0.940	Tool 1
	G	------	------	------	------	------	------	------	0.939	Tool 2
	E	0.601	0.258	0.246	0.337	0.444	0.493	0.441	0.939	
8b	A	0.599	0.283	0.227	0.335	0.459	0.484	0.386	0.940	
	B	------	------	------	------	------	------	0.386	0.940	
	C	0.599	0.283	0.227	0.335	0.460	0.484	0.386	0.940	
	D	------	------	------	------	------	------	------	------	
	F	0.599	0.283	0.227	0.335	0.460	0.484	0.386	0.939	
	G	------	------	------	------	------	------	------	0.940	Tool 1
	G	------	------	------	------	------	------	------	0.939	Tool 2
	E	0.599	0.283	0.227	0.335	0.460	0.484	0.386	0.939	
9	A	0.680	0.198	0.214	0.405	0.385	0.305	0.519	1.073	
	B	0.681	0.199	0.215	0.405	0.386	0.306	0.518	1.073	
	C	0.681	0.199	0.215	0.405	0.386	0.306	0.519	1.073	
	D	0.681	0.199	0.215	0.405	0.386	0.306	0.519	1.072	
	E	0.681	0.199	0.215	0.405	0.386	0.306	0.518	1.072	
	G	------	------	------	------	------	------	------	1.150	Tool 1
	G	0.681	0.199	0.215	0.405	0.386	0.306	0.518	1.072	Tool 2
	E	0.681	0.199	0.215	0.405	0.386	0.306	0.518	1.072	
10	A	0.396	0.298	0.313	0.210	0.428	0.482	0.261	0.716	
	B	0.396	0.298	0.313	0.210	0.426	0.482	0.260	0.716	
	C	0.396	0.298	0.313	0.210	0.426	0.482	0.260	0.716	
	D	0.396	0.299	0.313	0.210	0.426	0.482	0.260	0.710	
	F	0.396	0.298	0.313	0.210	0.426	0.482	0.260	0.715	
	G	0.396	0.299	------	0.210	0.426	------	0.261	0.716	Tool 1
	G	0.396	0.299	0.313	0.210	0.426	0.482	0.260	0.715	Tool 2
	E	0.396	0.299	0.313	0.210	0.426	0.482	0.260	0.715	

11a	A	0.553	0.271	0.312	0.306	0.449	0.473	0.404	0.960	
	B	0.553	0.272	0.313	0.306	0.450	0.473	0.404	0.960	
	C	0.553	0.272	0.313	0.306	0.450	0.473	0.404	0.960	
	D	0.553	0.272	0.313	0.306	0.450	0.473	0.404	0.954	
	F	0.553	0.272	0.313	0.306	0.450	0.473	0.404	0.960	
	G	0.553	0.272	------	0.307	0.450	------	0.404	0.960	Tool 1
	G	0.553	0.272	0.313	0.306	0.450	0.473	0.404	0.960	Tool 2
	E	0.553	0.272	0.313	0.306	0.450	0.473	0.404	0.960	
11b	A	0.553	0.271	0.312	0.306	0.449	0.473	0.406	0.695	
	B	0.553	0.272	0.313	0.306	0.450	0.473	0.406	0.695	
	C	0.553	0.272	0.313	0.306	0.450	0.473	0.406	0.695	
	D	0.553	0.272	0.313	0.306	0.450	0.473	0.406	0.690	
	F	0.553	0.272	0.313	0.306	0.450	0.473	0.406	0.695	
	G	0.553	0.272	------	0.307	0.450	------	0.407	0.695	Tool 1
	G	0.553	0.272	0.313	0.306	0.450	0.473	0.406	0.695	Tool 2
	E	0.553	0.272	0.313	0.306	0.450	0.473	0.406	0.695	
11c	A	0.553	0.271	0.312	0.306	0.449	0.473	0.408	0.551	
	B	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.551	
	C	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.551	
	D	0.553	0.272	0.313	0.306	0.450	0.473	0.408	0.546	
	F	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.550	
	G	0.553	0.272	------	0.307	0.450	------	0.408	0.551	Tool 1
	G	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.550	Tool 2
	E	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.550	
11d	A	0.553	0.271	0.312	0.306	0.449	0.473	0.407	0.639	
	B	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.639	
	C	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.639	
	D	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.633	
	F	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.638	
	G	0.553	0.272	------	0.307	0.450	------	0.407	0.639	Tool 1
	G	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.638	Tool 2
	E	0.553	0.272	0.313	0.306	0.450	0.473	0.407	0.638	

12	A	0.716	0.195	0.196	0.536	0.153	0.153	0.627	1.713	
	B	0.716	0.196	0.196	0.537	0.154	0.154	0.628	1.713	
	C	0.716	0.196	0.196	0.537	0.154	0.154	0.628	1.714	
	D	0.716	0.196	0.196	0.537	0.154	0.154	0.628	1.687	
	F	0.716	0.196	0.196	0.537	0.154	0.154	0.628	1.713	
	G	------	------	------	------	------	------	------	------	Tool 1
	G	0.716	0.196	0.196	0.537	0.154	0.154	0.628	1.713	Tool 2
	E	0.716	0.196	0.196	0.537	0.154	0.154	0.628	1.713	
13	A	0.838	0.076	0.075	0.677	0.066	0.066	0.738	5.203	
	B	0.839	0.076	0.076	0.678	0.067	0.067	0.738	5.203	
	C	0.839	0.076	0.076	0.678	0.067	0.067	0.739	5.204	
	D	0.842	0.077	0.077	0.681	0.067	0.067	0.740	5.204	
	F	0.839	0.076	0.076	0.678	0.067	0.067	0.738	5.203	
	G	------	------	------	------	------	------	------	------	Tool 1
	G	0.839	0.077	0.077	0.678	0.067	0.067	0.738	5.202	Tool 2
	E	0.839	0.077	0.077	0.678	0.067	0.067	0.738	5.204	
14	A	0.521	0.136	0.075	0.395	0.116	0.075	0.510	5.392	coating on #2
	A	0.521	0.075	0.136	0.395	0.075	0.116	0.520	5.392	coating on #3
	B	0.521	0.136	0.075	0.395	0.117	0.075	0.510	5.392	coating on #2
	B	0.521	0.075	0.136	0.395	0.075	0.117	0.520	5.392	coating on #3
	C	0.521	0.075	0.136	0.395	0.075	0.117	0.520	5.393	coating on #3
	D	------	------	------	------	------	------	------	------	
	F	0.521	0.075	0.136	0.395	0.075	0.117	0.520	5.393	coating on #3
	G	------	------	------	------	------	------	------	------	Tool 1
	G	0.521	0.136	0.075	0.395	0.113	0.076	0.511	5.392	coating on #2
	E	------	------	------	------	------	------	------	------	

In Table 2, the names of the participants have been anonymised.

Several outliers were reported during the programme. In most cases, they were attributed to a lack of full clarity in the description of tasks or the relevant standard on which the calculations are based. For example, EN 673 does not make it explicit that the thermal conductivity of the interlayer should be taken into account when determining the U value of laminated glass. These findings will be used to inform future revisions of standards such as EN 673.

5. Conclusion

The results of the round robin calculation programme confirmed that the proposed maximum difference in calculation results as detailed in Table 3 are reasonable.

Table 3. Maximum difference in calculation results

Parameter	Maximum difference
τ_v, ρ_v, ρ'_v, τ_e, ρ_e, ρ'_e	±0.002
g	±0.002
U value	±0.01 W/m^{2}K

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On behalf of CEN/TC129/WG9

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