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FACULTY OF ENGINEERING
AND ARCHITECTURE

DEPARTMENT OF ARCHITECTURE AND URBAN PLANNING
RESEARCH GROUP BUILDING PHYSICS AND CONSTRUCTION

THERMAL ANALYSIS OF CURTAIN WALL SYSTEMS – A PARAMETRIC STUDY

Prof. Nathan Van Den Bossche, Stephanie Van Goethem, Dr. Wahid Maref

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- **CONTEXT**
- SIMULATION METHOD
- MODEL
- 10 PARAMETERS
- CONCLUSIONS

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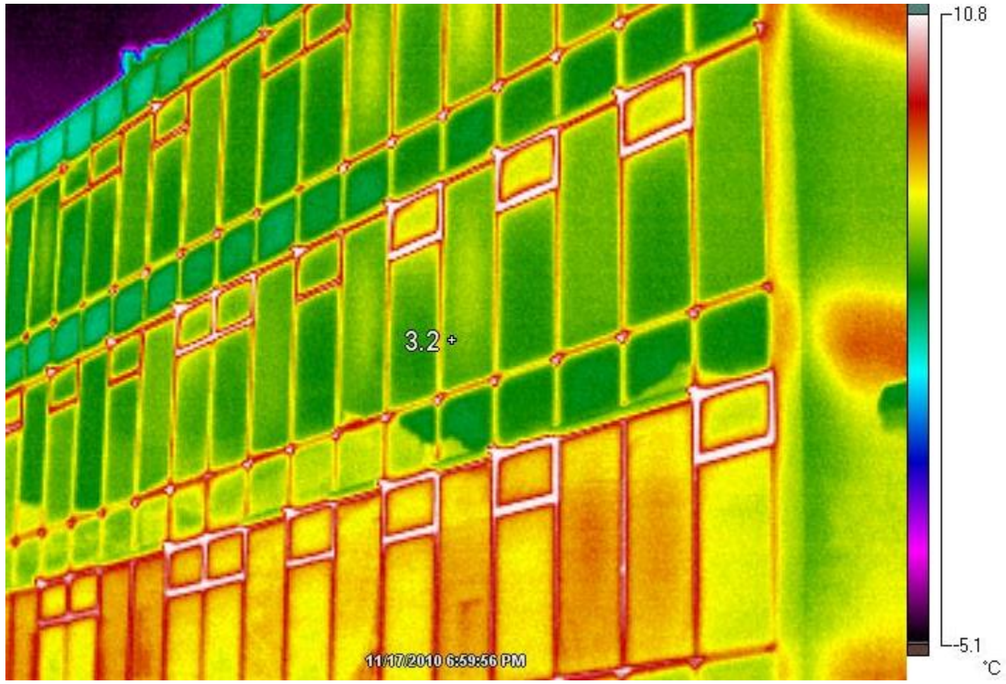
CONTEXT

- Windows and curtain walls: high U-values
- Calculation method well defined
- Software: available
- Industry: more ambition than knowledge
- No design guidelines in literature

GOAL

- Design guidelines



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CONTEXT

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 2500 – 2505

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Thermal optimization of window frames

Nathan Van Den Bossche[a,*], Lisa Buffel[a], Arnold Janssens[a]

[a] *Ghent University, Faculty of Engineering and Architecture, Sint-Pietersnieuwstraat 41, 9000 Ghent, Belgium*

Abstract

The thermal performance of window frames can easily be calculated using 2D numerical simulations. Several commercial software packages are available, and international standards provide a clear methodology to calculate the thermal transmittance. However, even though these methods are well known in academia and the research community in general, thermal optimization has not reached its full potential in the building industry yet and there is considerable margin for improvement. Specifically for small and medium size enterprises there is a lack of guidelines that are both generic enough to guarantee a wide-spread use, as well as specific enough to allow an easy and straightforward interpretation and implementation. In this research project, generic window sections were developed for vinyl, aluminium and wooden frames in collaboration with the building industry. Based on a market survey, typical approaches for improving the thermal performance for each type of window frame have been identified and described. Subsequently, the impact of separate improvements, as well as combined effects have been studied using both standardized and advanced calculation methods. For this, the heat transfer phenomena and the way these are modelled according to standard calculation procedures are discussed. Next to that, a number of secondary effect originating from standards are discussed, e.g. the thickness of the IGU, the depth of the window rebate, equivalent thermal conductivities and the impact of reduced heat transfer coefficients.

Aluminum

Vinyl

Wood

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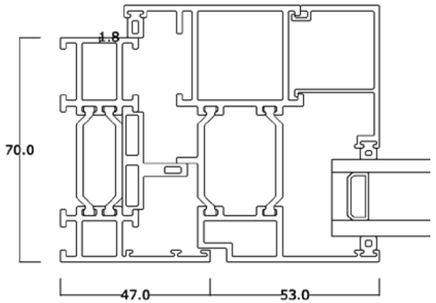
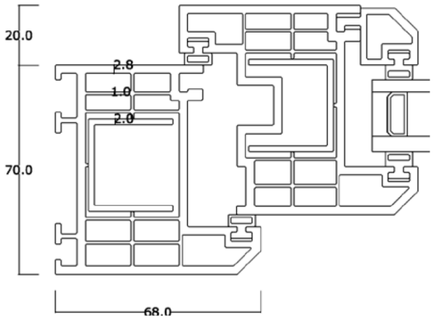
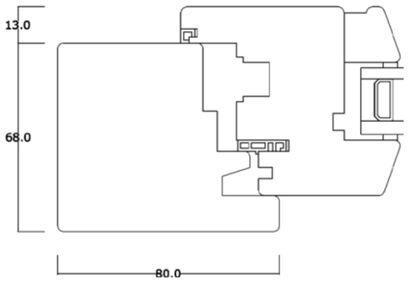


Aluminum



Vinyl



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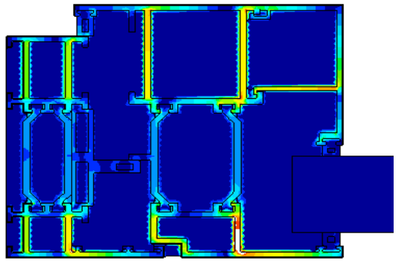
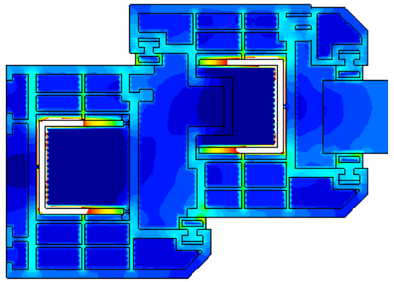
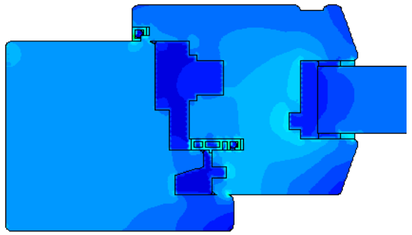


Aluminum



Vinyl



Wood

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- CONTEXT
- **SIMULATION METHOD**
- MODEL
- 10 PARAMETERS
- CONCLUSIONS

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SIMULATION METHOD

NFRC 100-2014

- Refers to ISO 15099 and ISO 10077-2
- Boundary conditions: T_{in} 21°C, T_{out} -18°C, wind speed 5.5m/s
- Indoor convective heat transfer coefficient is based on center-of-panel IGU surface temperature
- A cross-section should include at least 150mm of glazing section

- Correlation for convective heat transfer coefficient?
- Specific guidelines for curtain wall systems?

Therm 6.3 / Window 6.3 NFRC

- Screws: section at thermal bridge
- Adopt a surface area based thermal conductivity

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SIMULATION METHOD

ISO 12631

- Refers to ISO 15099 and ISO 10077-2
- Boundary conditions: T_{in} 20°C, T_{out} 0°C
- Interior surface resistance is 0.13 m²K/W in plane surfaces, and 0.20 m²K/W at edges or corners with reduced heat transfer.
- Exterior surface resistance is 0.04 m²K/W
- A cross-section should include at least 190mm of glazing section

- default ΔU is added to account for screws
  or adopt a surface area based thermal conductivity

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SIMULATION METHOD

NFRC 100-2014 *vs* ISO 12631

- Both refer to ISO 15099 and ISO 10077-2
- Small differences in boundary conditions and treatment of cavities
- Difference due to different convection correlations for cavities < 3% on U-value
- ISO 12631 was adopted here

- How to model screws?

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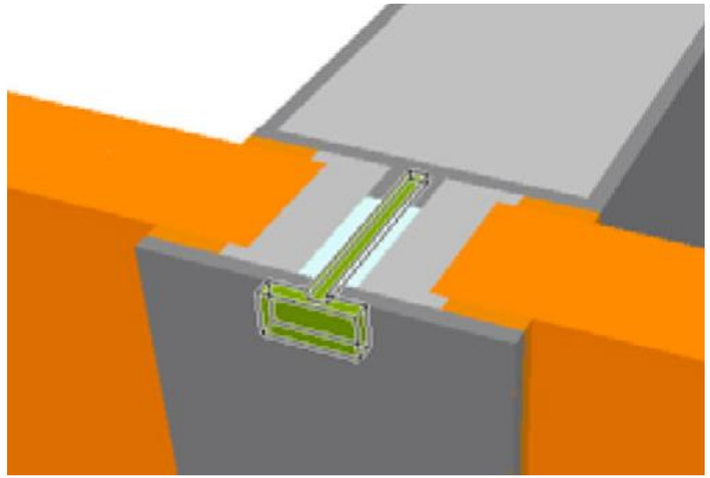
SIMULATION METHOD

		Q	Q	U_f	
		[W/m]	[W]	[W/m²K]	
Frame without screw					
	BISCO	8.3127		2.256	2D – triangular mesh
	TRISCO	8.3205		2.259	3D – orthogonal mesh
	SOLIDO	**8.3205**		**2.259**	**3D – node fitting mesh**



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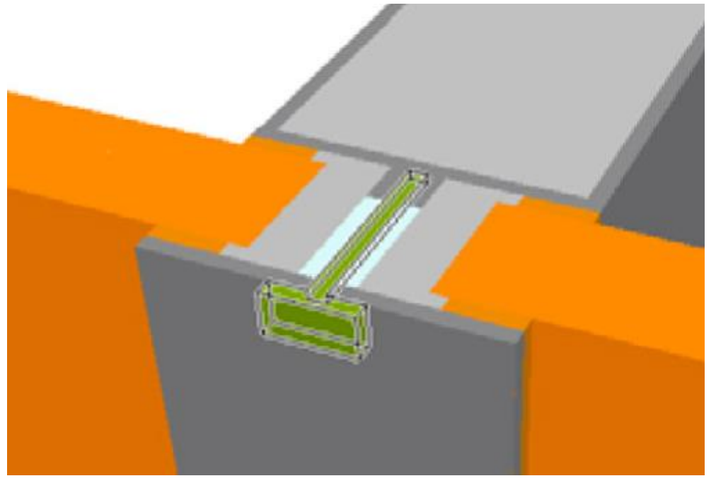
SIMULATION METHOD

		Q	Q	U_f	
		[W/m]	[W]	[W/m²K]	
Frame without screw					
	BISCO	8.3127		2.256	2D – triangular mesh
	TRISCO	8.3205		2.259	3D – orthogonal mesh
	SOLIDO	**8.3205**		**2.259**	**3D – node fitting mesh**
Frame with screw					
	SOLIDO		**1.1049**	**2.526**	**Reference**
	TRISCO		1.1141	2.564	+2



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SIMULATION METHOD

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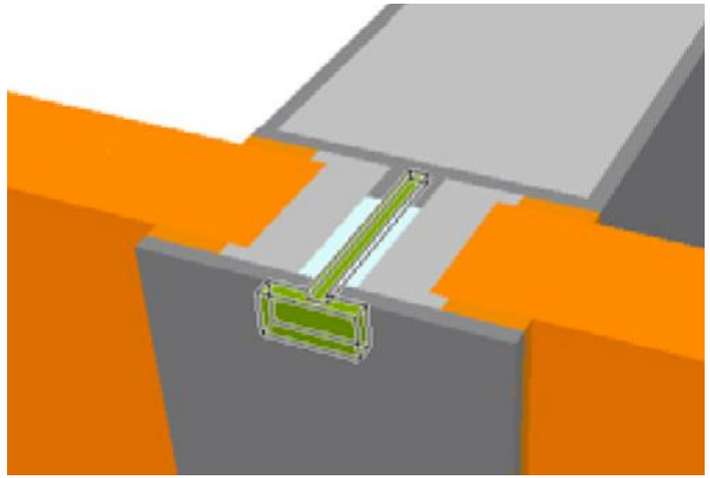
Smoothed lambda method (EN 13947)	BISCO	8.4918		2.363	-6



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SIMULATION METHOD

		Q	Q	U_f	
		[W/m]	[W]	[W/m²K]	
Frame without screw					
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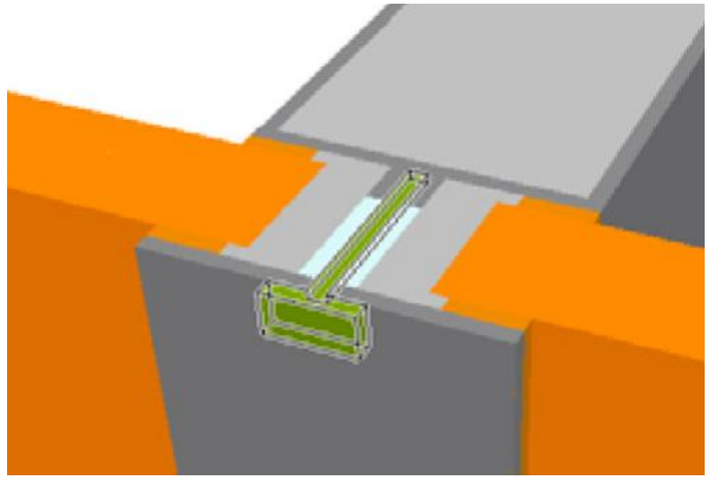
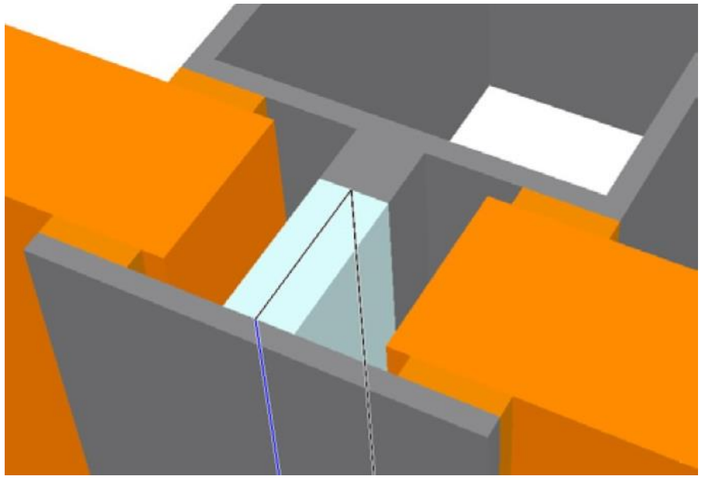
	TRISCO		1.1141	2.564	+2
Smoothed lambda method (EN 13947)	BISCO	8.4918		2.363	-6
Smoothed thickness method (EN 13947)	BISCO	8.9182		2.585	+2





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- CONTEXT
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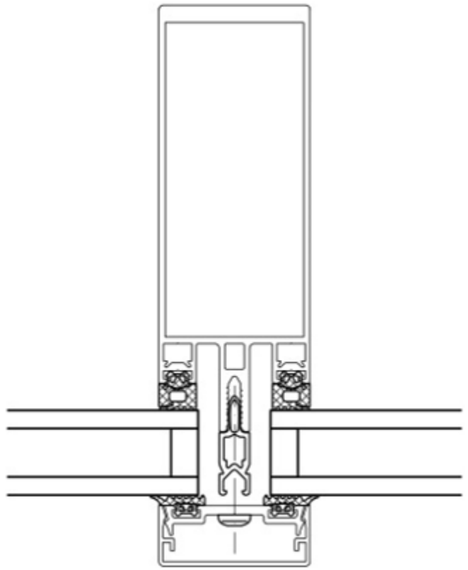
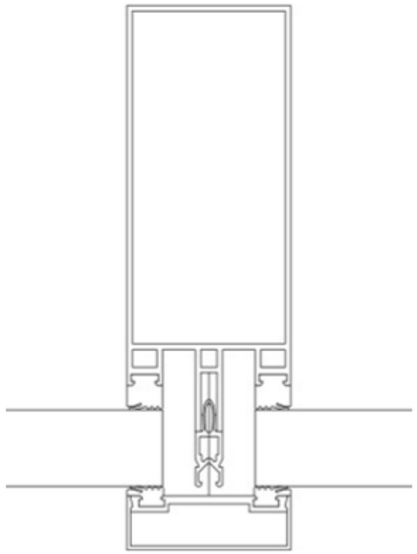
MODEL – EUROPEAN SECTIONS

SCHÜCO	SIMULATION MODEL	RESULTS
		$U_f = 4.203$ W/m²K $\Psi = 0.581$ W/mK I = 0.817

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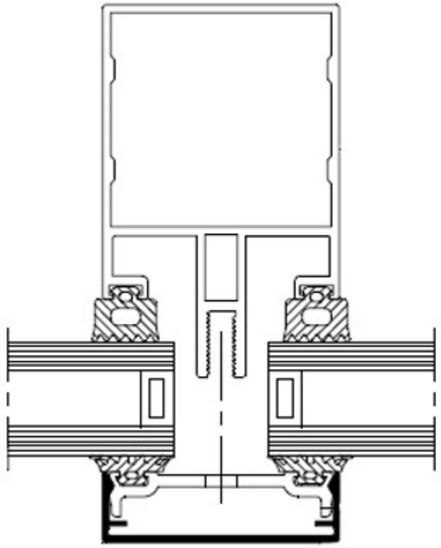
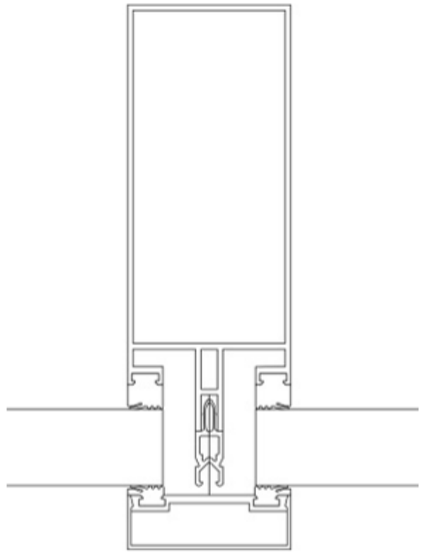
MODEL – EUROPEAN SECTIONS

REYNAERS	SIMULATION MODEL	RESULTS
		$U_f = 3.961$ W/m²K $\Psi = 0.567$ W/mK I = 0.818

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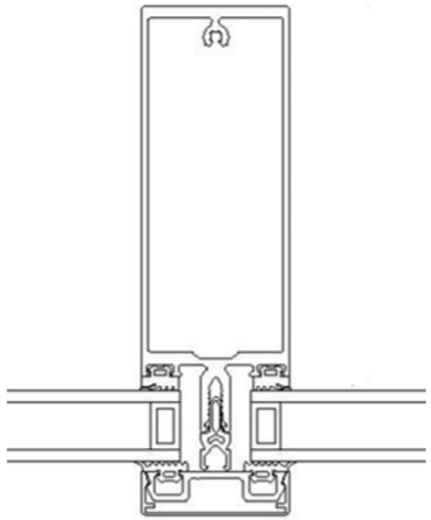
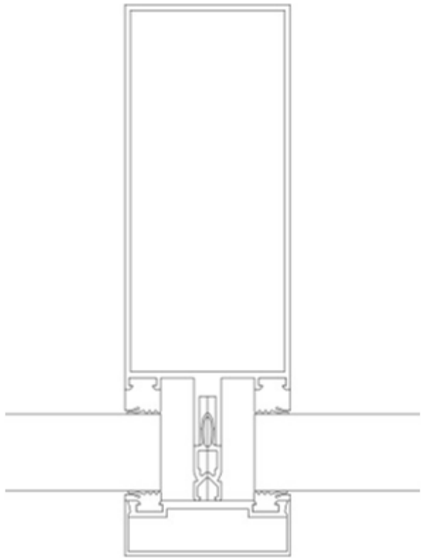
MODEL – EUROPEAN SECTIONS

HAKI	SIMULATION MODEL	RESULTS
		$U_f = 4.352$ W/m²K $\Psi = 0.590$ W/mK $I = 0.819$

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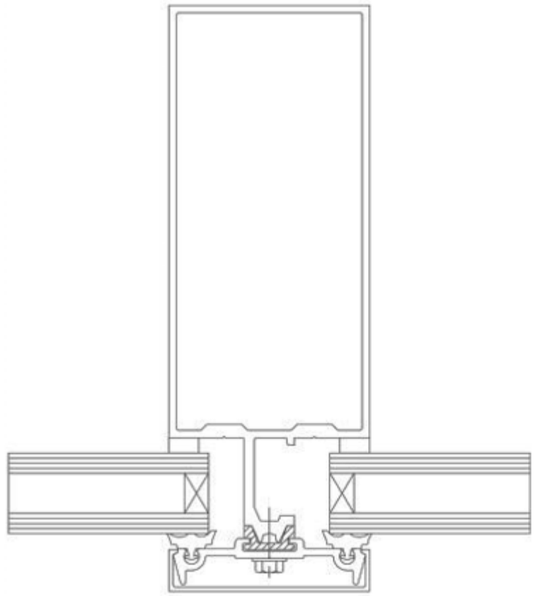
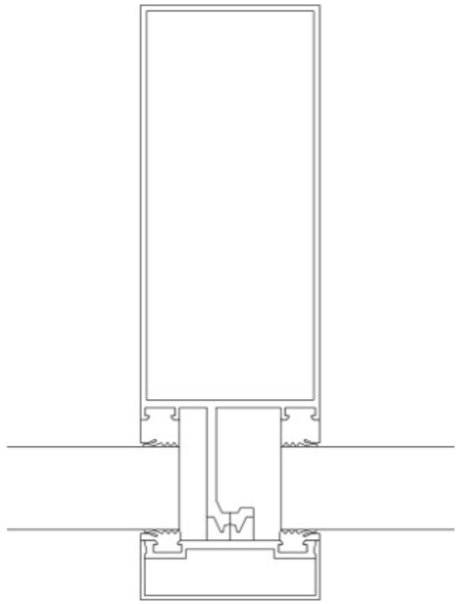
MODEL – NORTH AMERICAN SECTIONS

OLDCASTLE	SIMULATION MODEL	RESULTS
		$U_f = 7.344$ W/m²K $\Psi = 0.770$ W/mK I = 0.748

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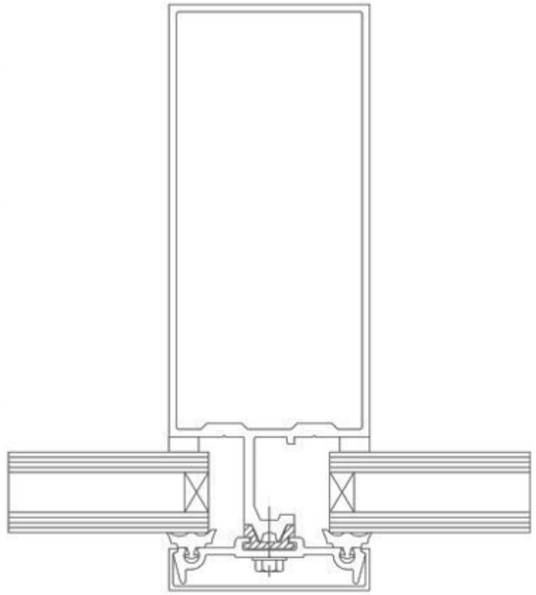
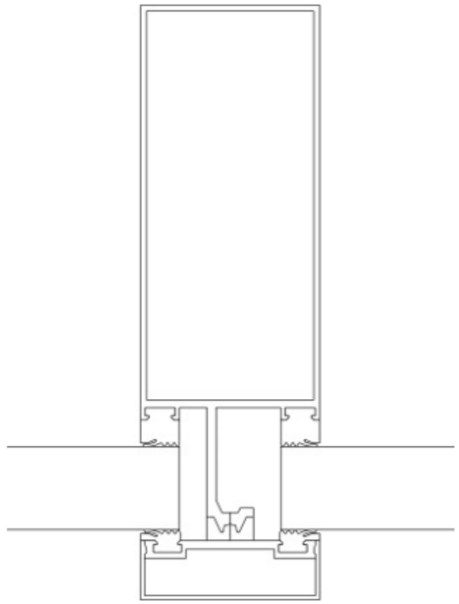
MODEL – NORTH AMERICAN SECTIONS

OLDCASTLE	SIMULATION MODEL	RESULTS
		$U_f = 7.344$ W/m²K $\Psi = 0.770$ W/mK I = 0.748

Addition of surface heat transfer resistance:

0.04 + 0.13 = 0.17 m²K/W

➡ **U = 5.88 W/m²K**

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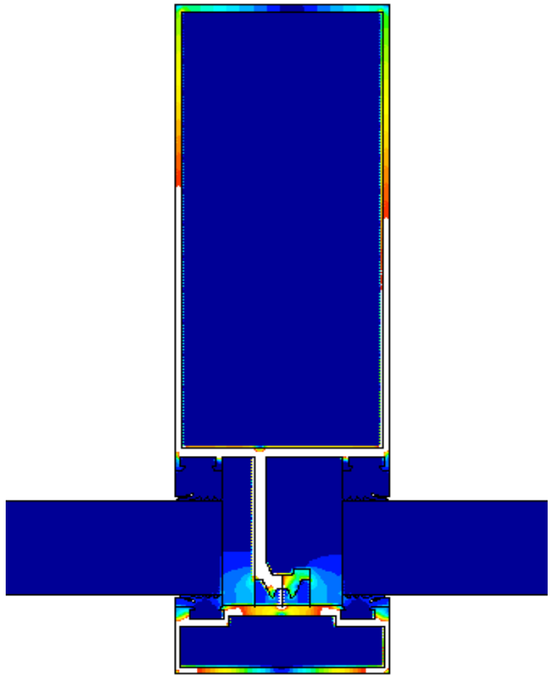
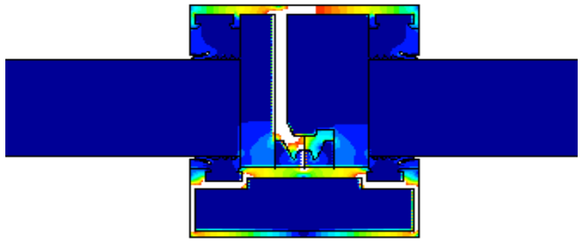
MODEL – NORTH AMERICAN SECTIONS



U = 7.344 W/m²K



U = 5.274 W/m²K

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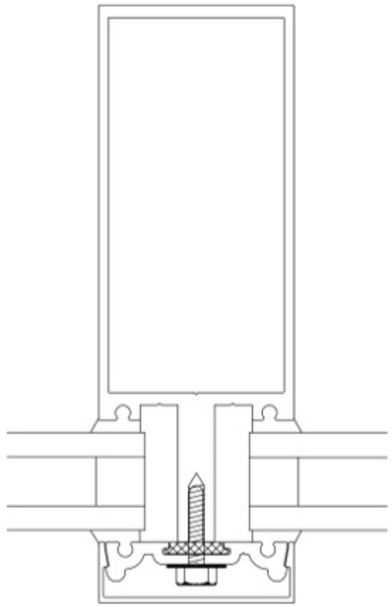
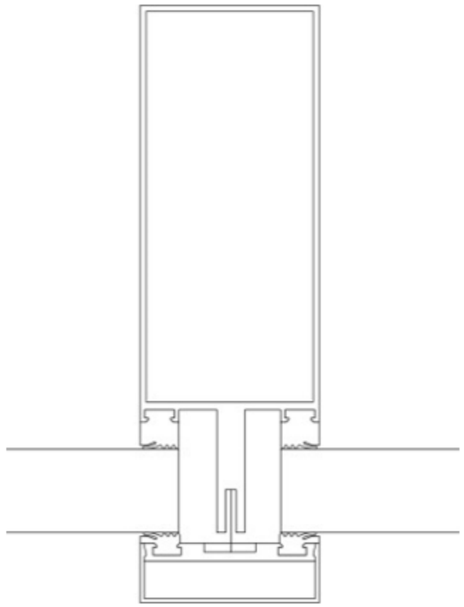
MODEL – NORTH AMERICAN SECTIONS

CAP	SIMULATION MODEL	RESULTS
		$U_f = 6.648$ W/m²K $\Psi = 0.728$ W/mK I = 0.774

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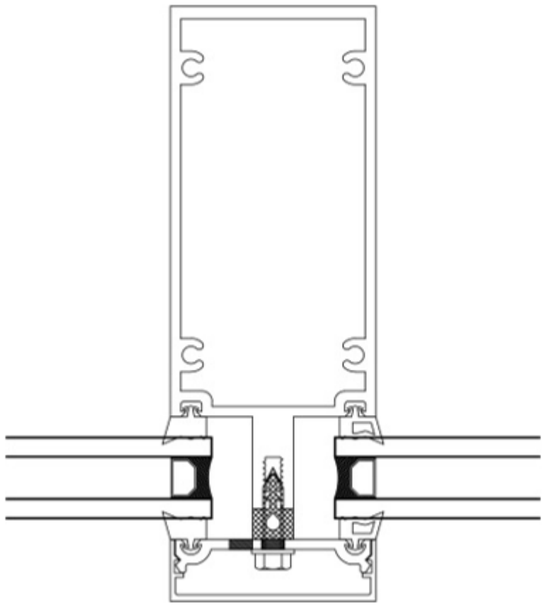
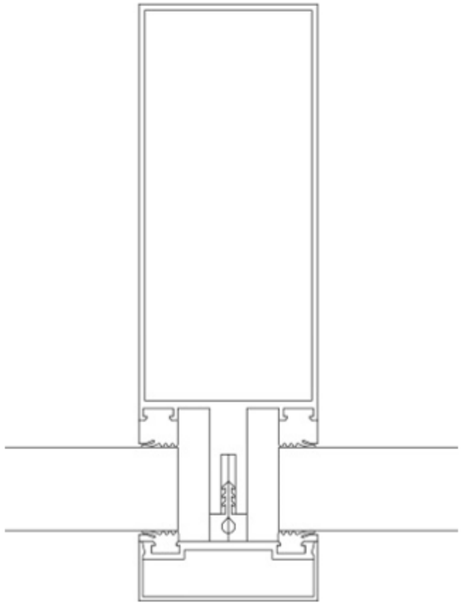
MODEL – NORTH AMERICAN SECTIONS

GRAHAM	SIMULATION MODEL	RESULTS
		$U_f = 7.453$ W/m²K $\Psi = 0.777$ W/mK I = 0.747

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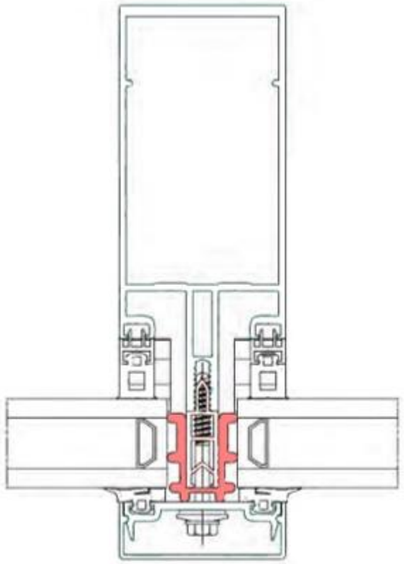
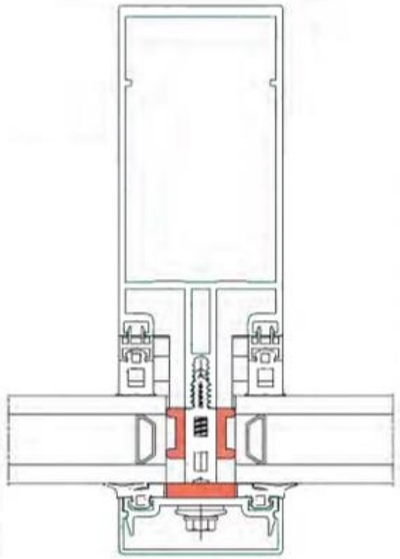
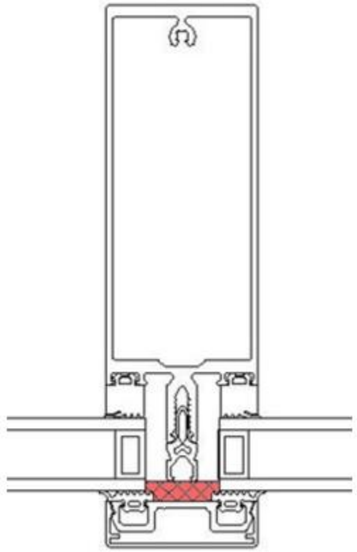
OPTIMIZATION

INSULATION INNER CAVITY		
		
Sapa/Schüco	Sapa/Schüco	Haki

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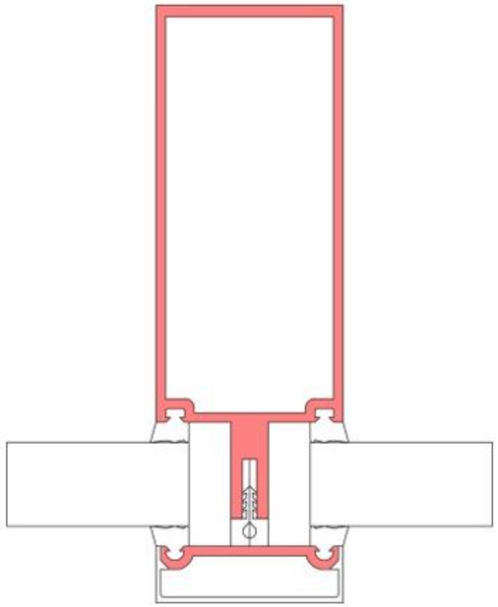
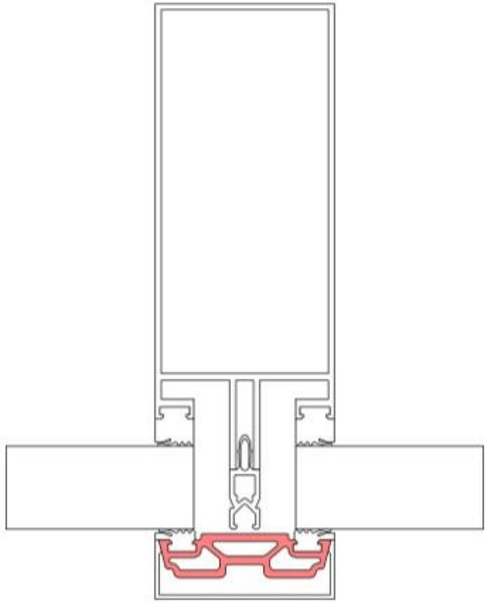
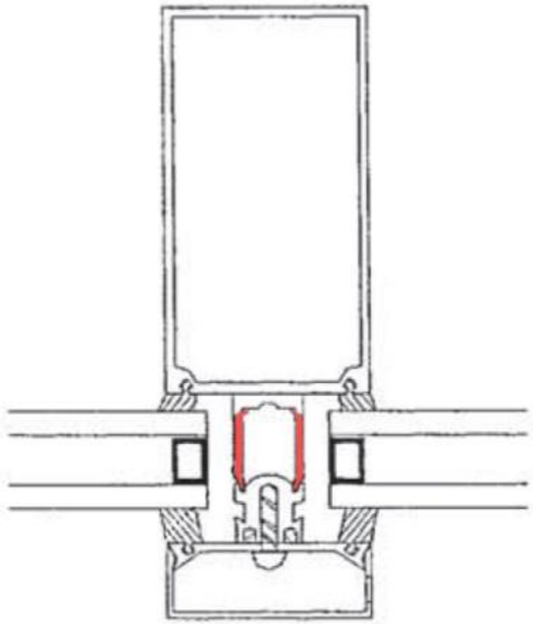
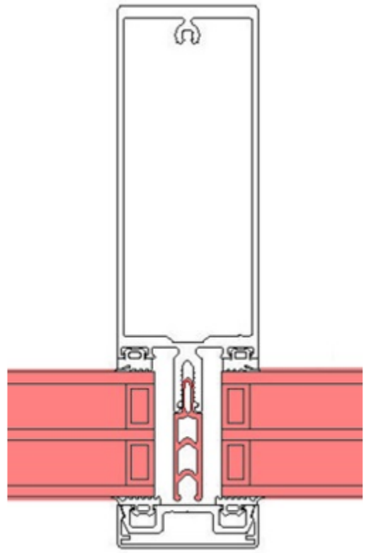
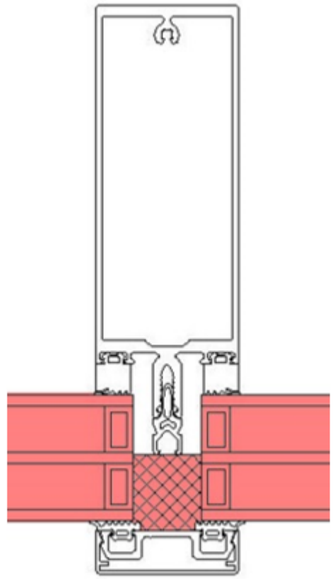
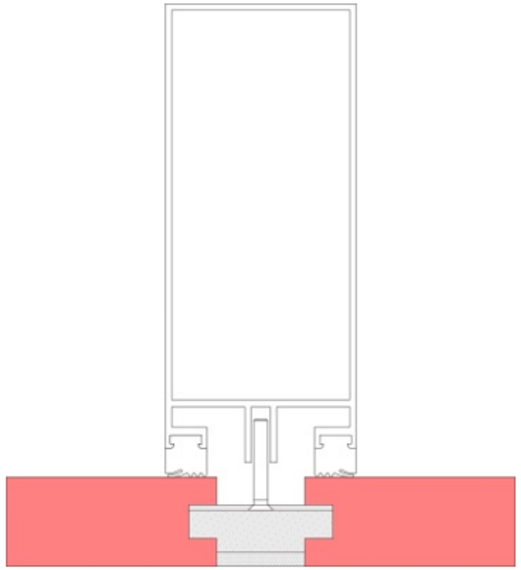
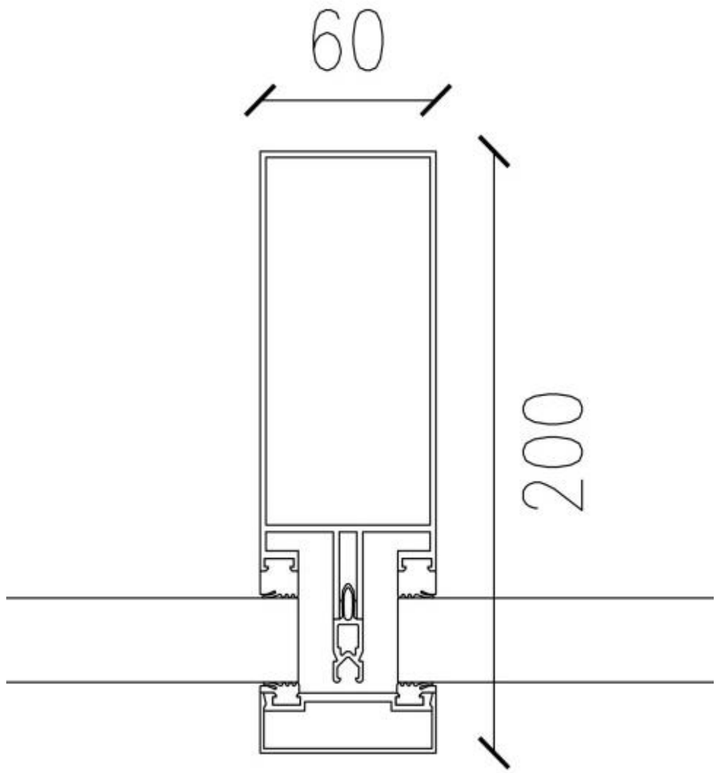
OPTIMIZATION

MATERIALIZATION FRAME		MATERIALIZATION SCREW FINS
		
Graham	Schüco	-

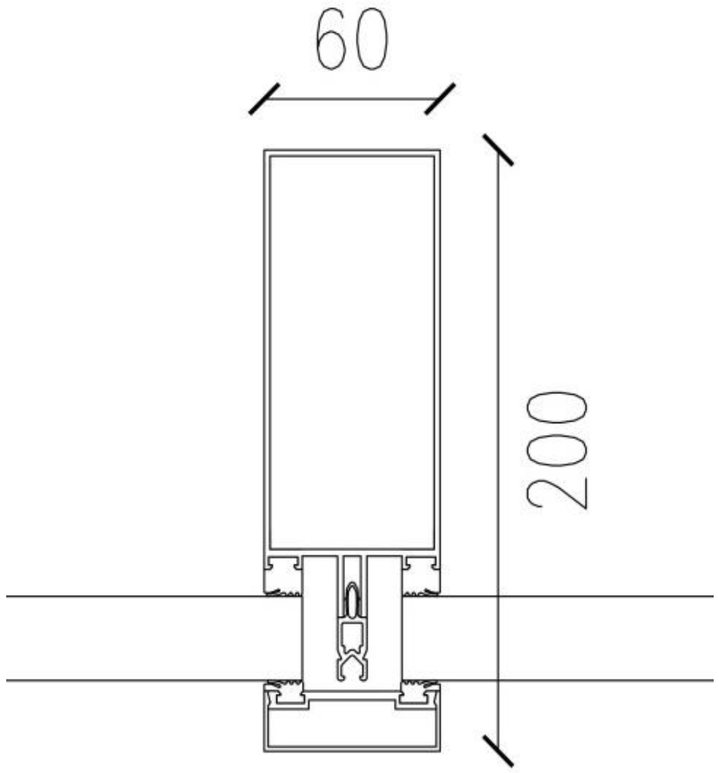
OPTIMIZATION

GLASS THICKNESS AND COMPARTMENTALIZATION PROFILE		SEMI-STRUCTURAL GLAZING
		
Haki	Haki	-

GENERIC PROFILES



Europe



North-America

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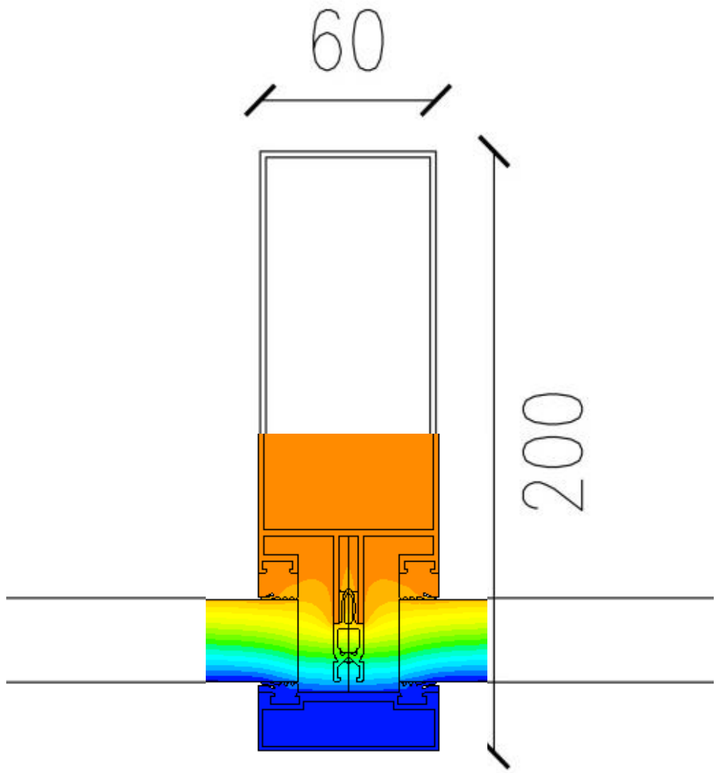
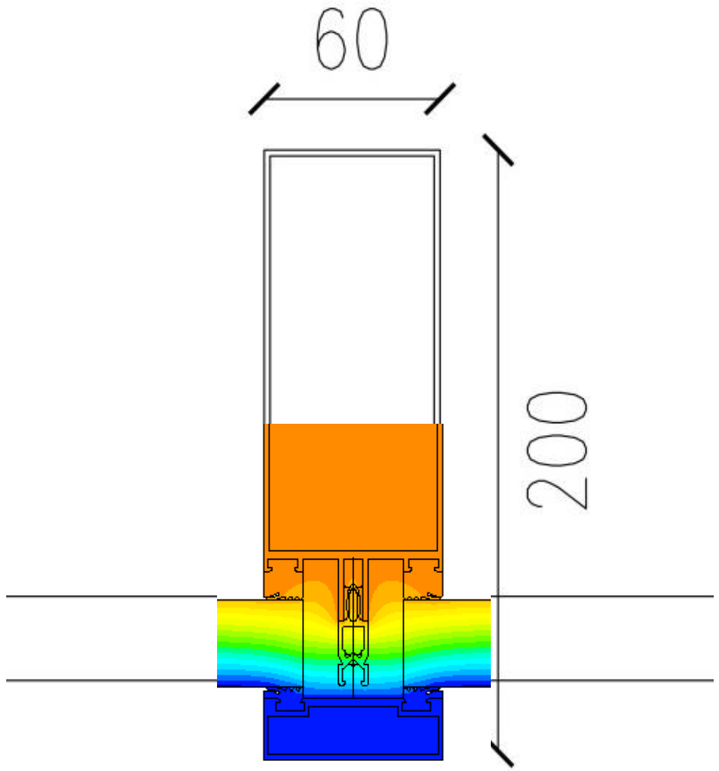
GENERIC PROFILES



Europe



North-America

	U_f [W/m²K]	Ψ [W/mK]	I [-]
Europe	3.947	0.566	0.818
North-America	3.792	0.557	0.817

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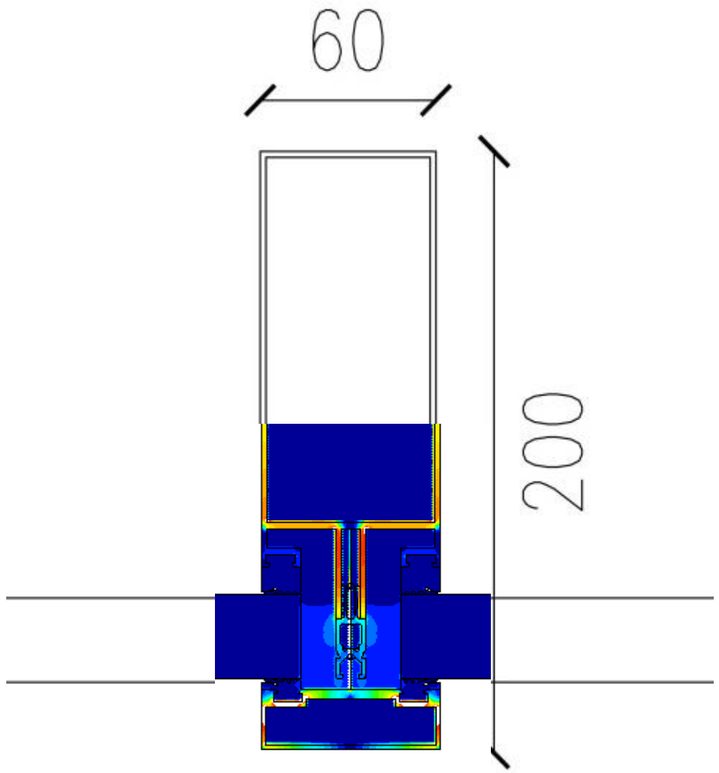
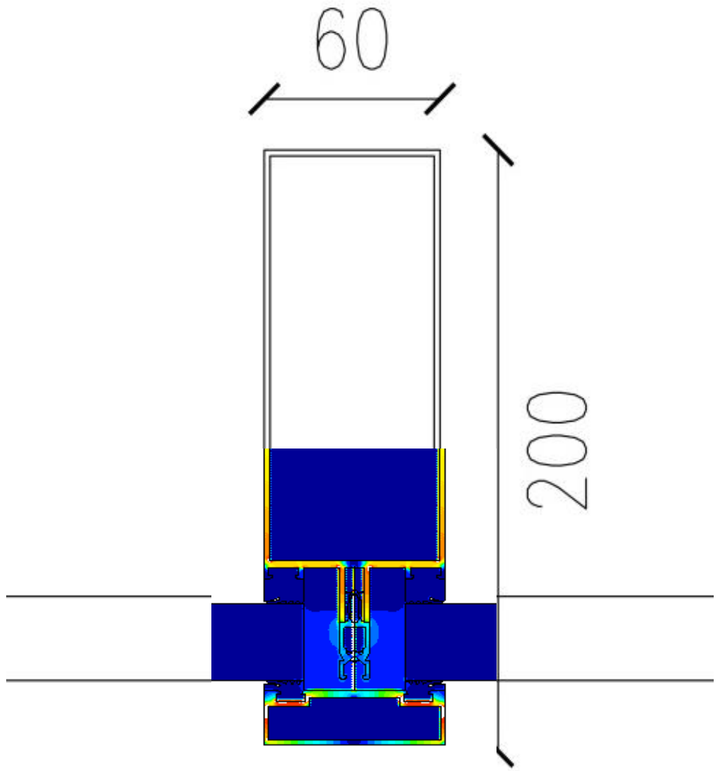
GENERIC PROFILES



Europe



North-America

	U_f [W/m²K]	Ψ [W/mK]	I [-]
Europe	3.947	0.566	0.818
North-America	3.792	0.557	0.817

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- CONTEXT
- SIMULATION METHOD
- MODEL
- **10 PARAMETERS**
- CONCLUSIONS

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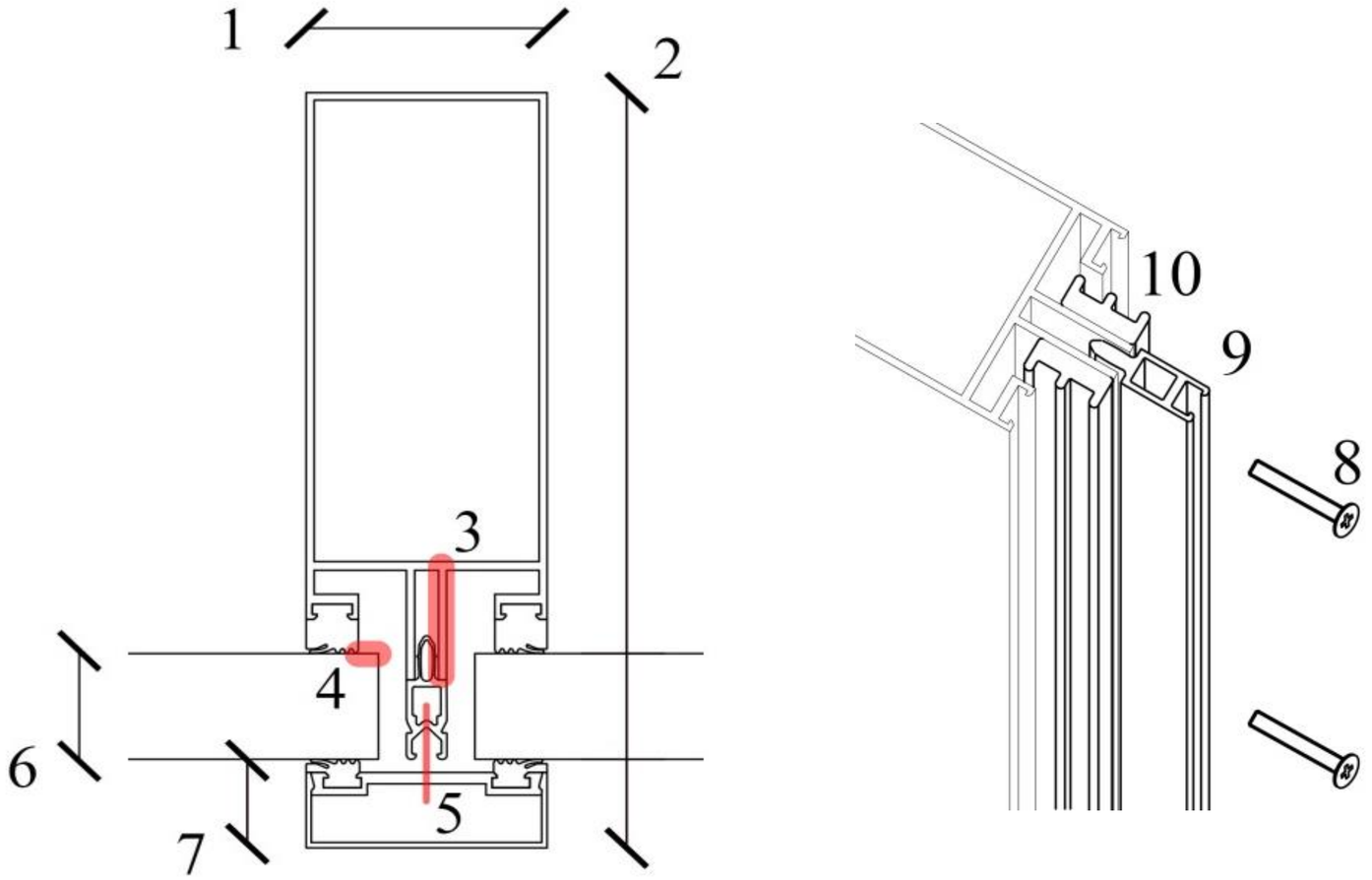
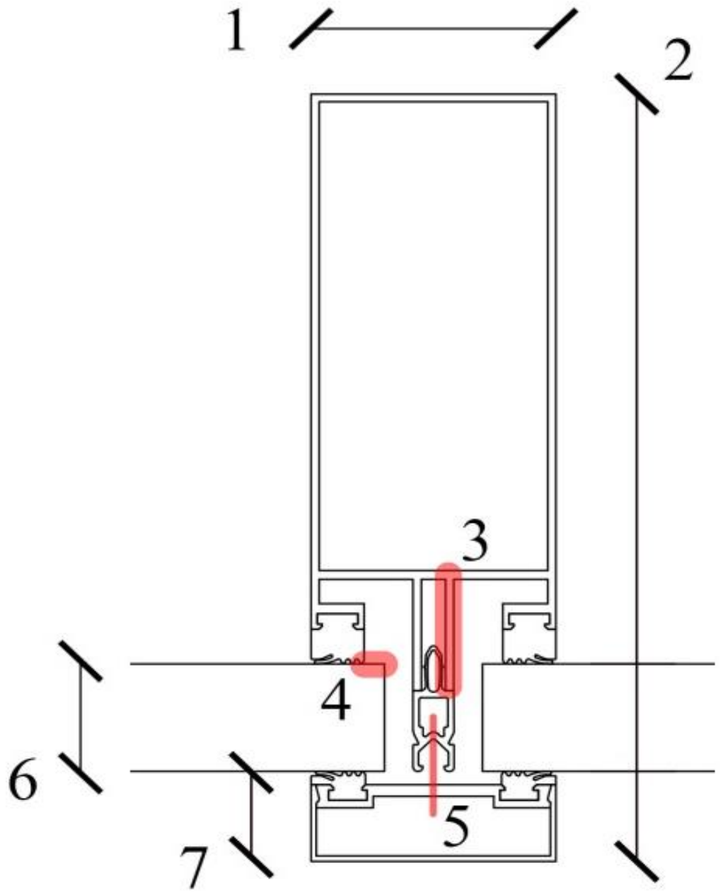
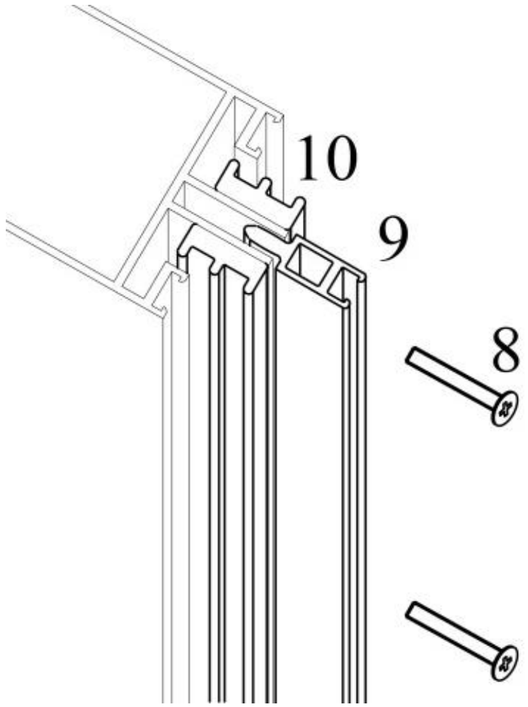
10 PARAMETERS



1	Profile width	6	Glass unit thickness
2	Profile length	7	Snap cover length
3	Length of the screw fins	8	λ-value of screws
4	Position of the IGU	9	λ-value of compartmentalization profile
5	Intermediate distance between mechanical fixings	10	Insulating interior gasket

10 PARAMETERS

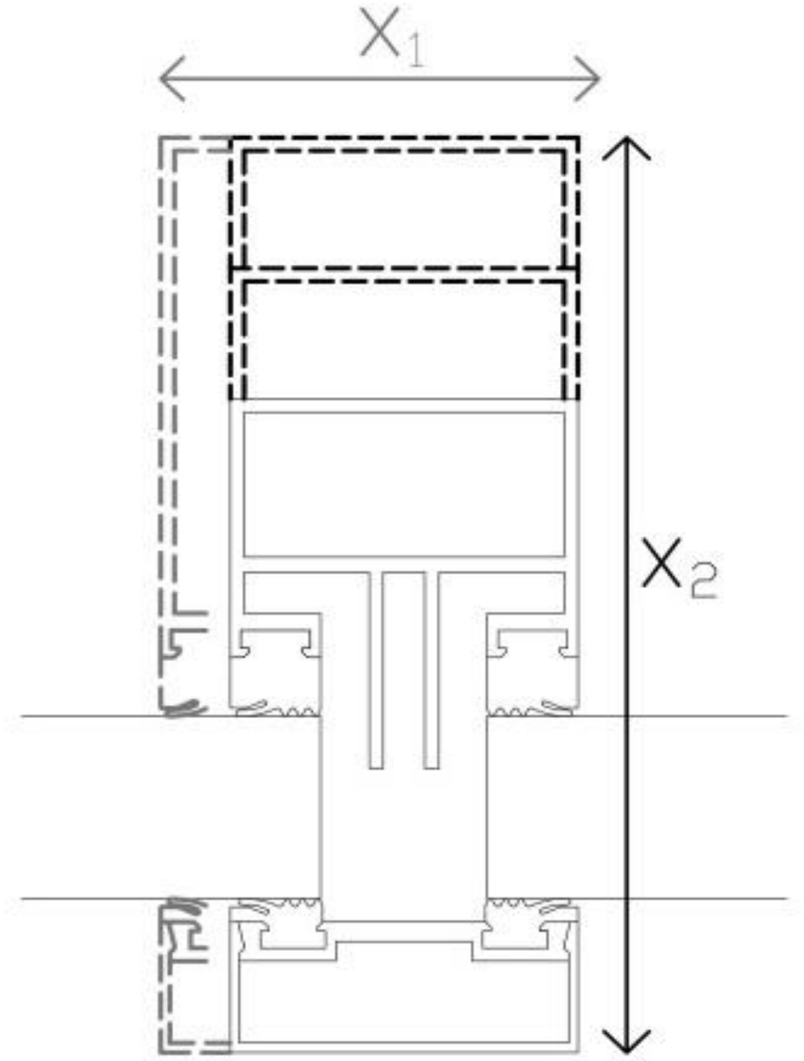


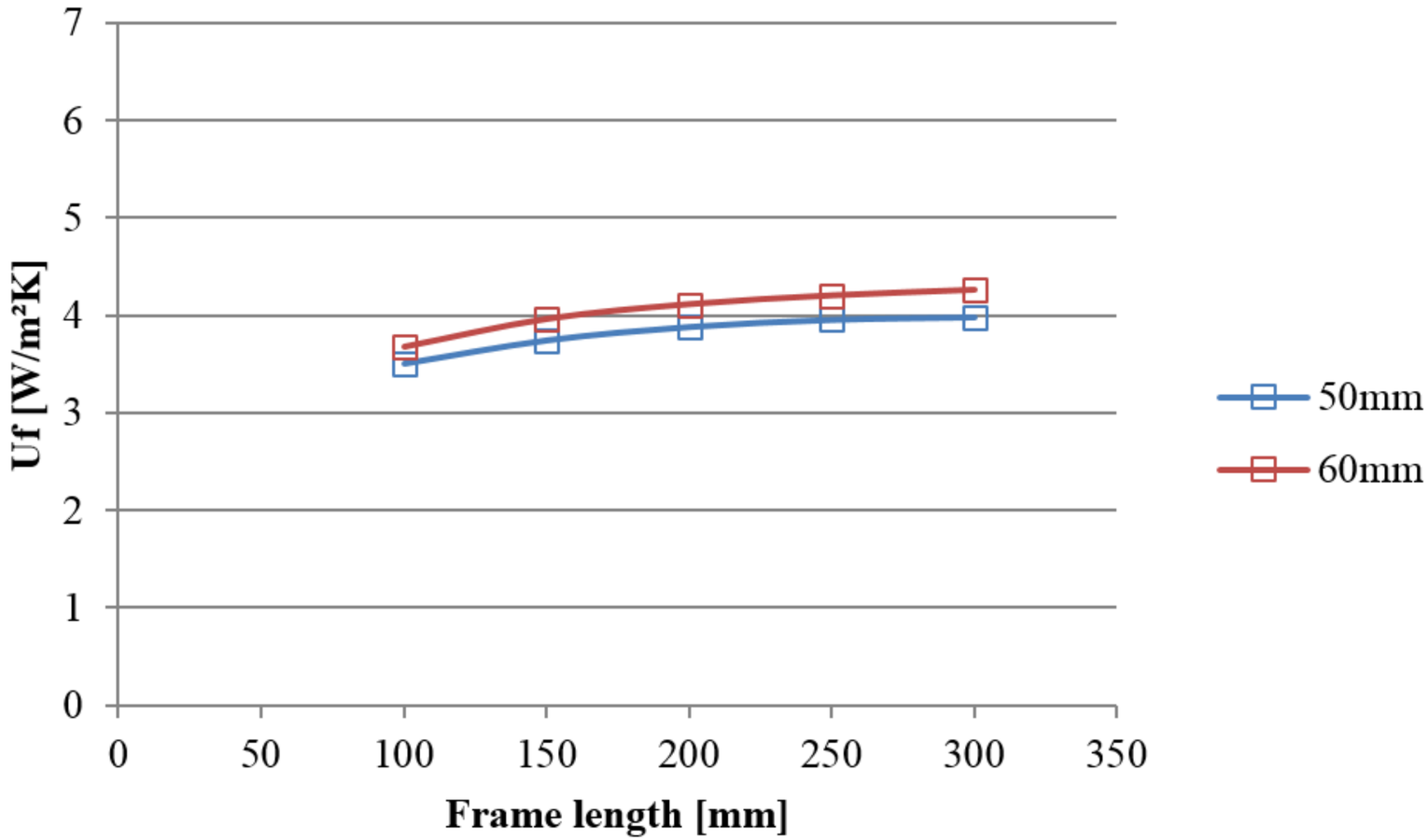


Material	λ [W/mK]
Aluminum frame	160
Insulation panel (glass)	0.035
EPDM gaskets	0.25
Fiber Reinforced Polyamid (compartmentalization profile)	0.3
Stainless steel (screw)	17

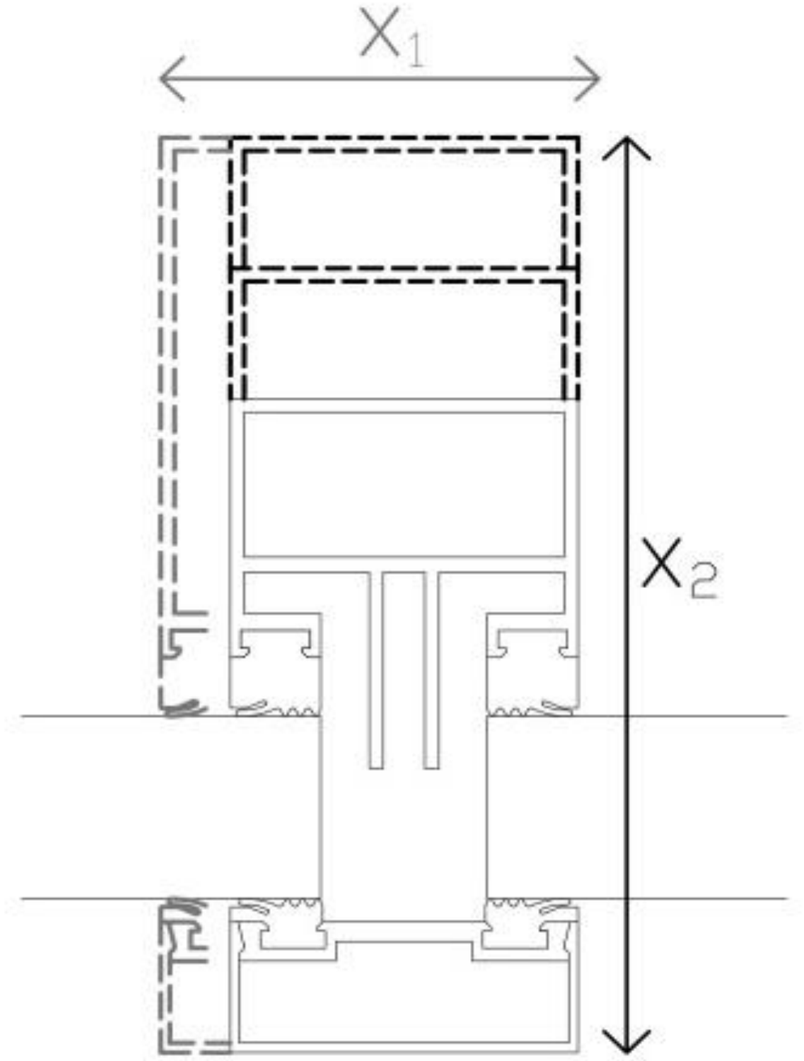
1	Profile width	6	Glass unit thickness
2	Profile length	7	Snap cover length
3	Length of the screw fins	8	λ-value of screws
4	Position of the IGU	9	λ-value of compartmentalization profile
5	Intermediate distance between mechanical fixings	10	Insulating interior gasket

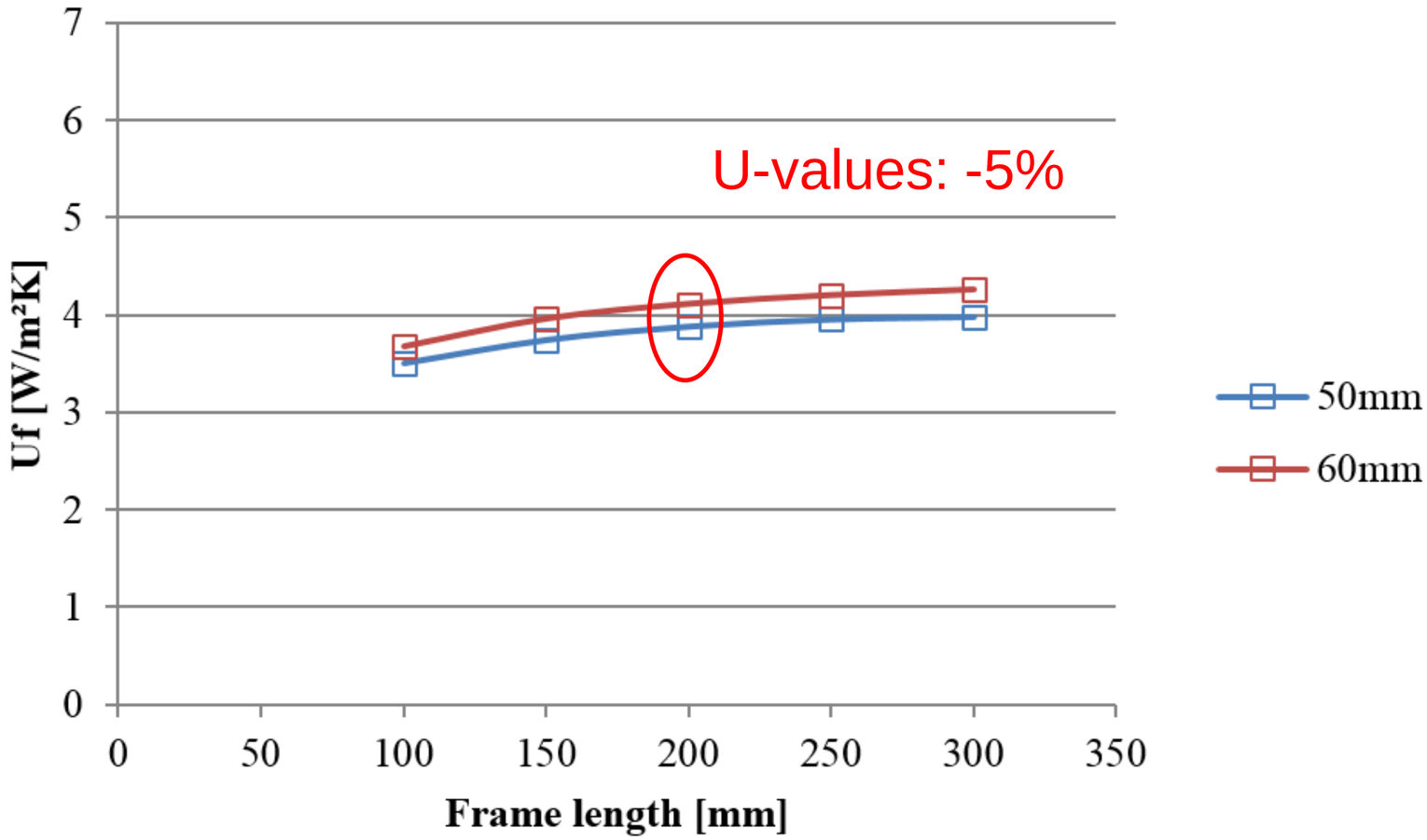
1 & 2. PROFILE WIDTH AND LENGTH



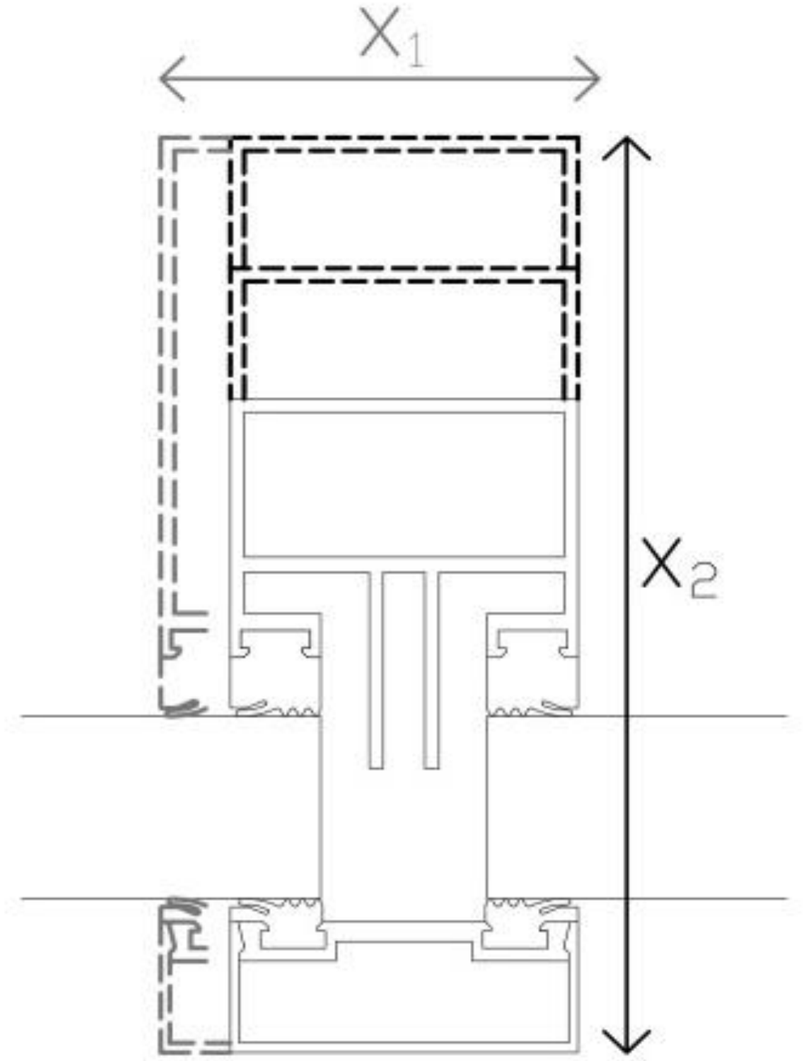


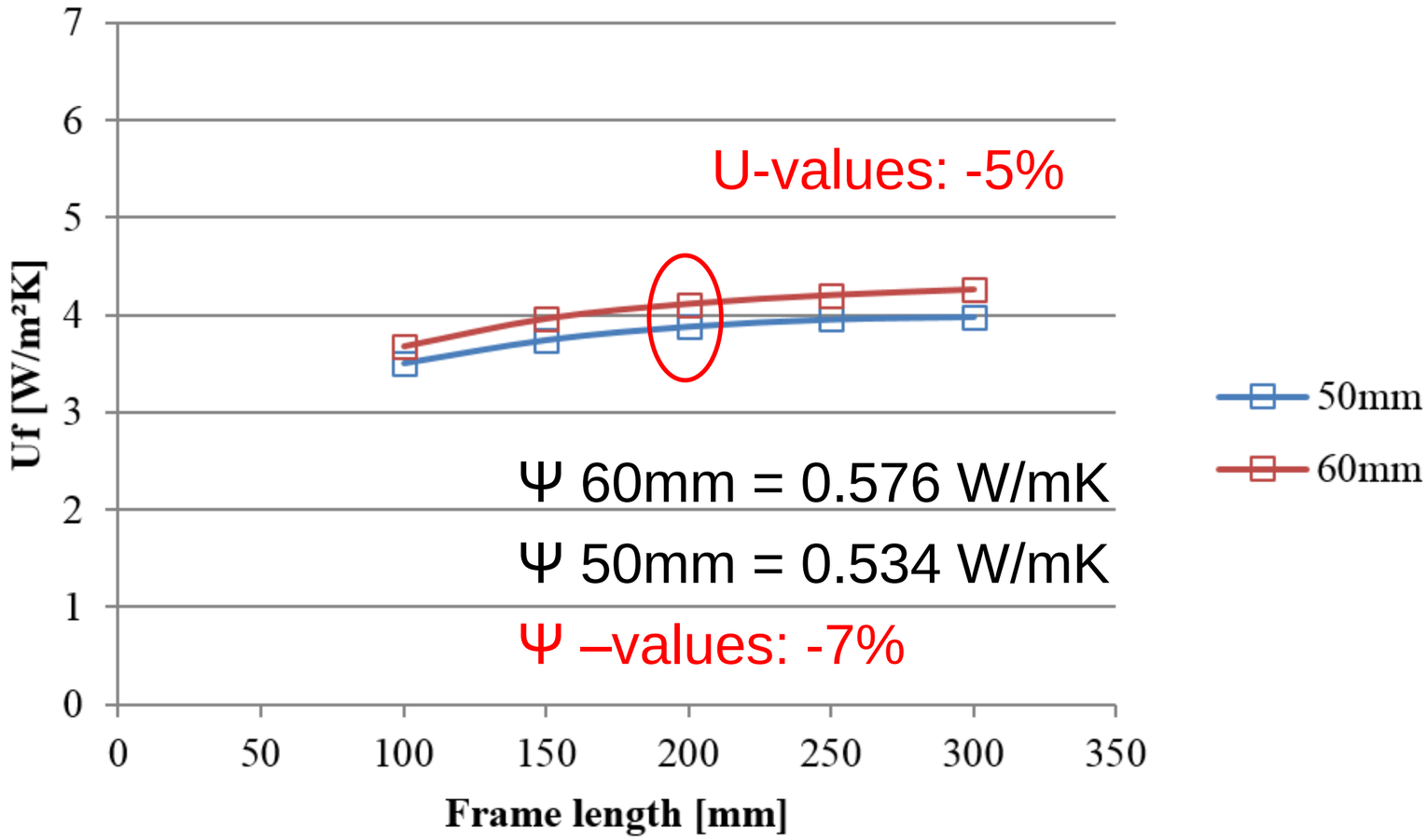
1 & 2. PROFILE WIDTH AND LENGTH



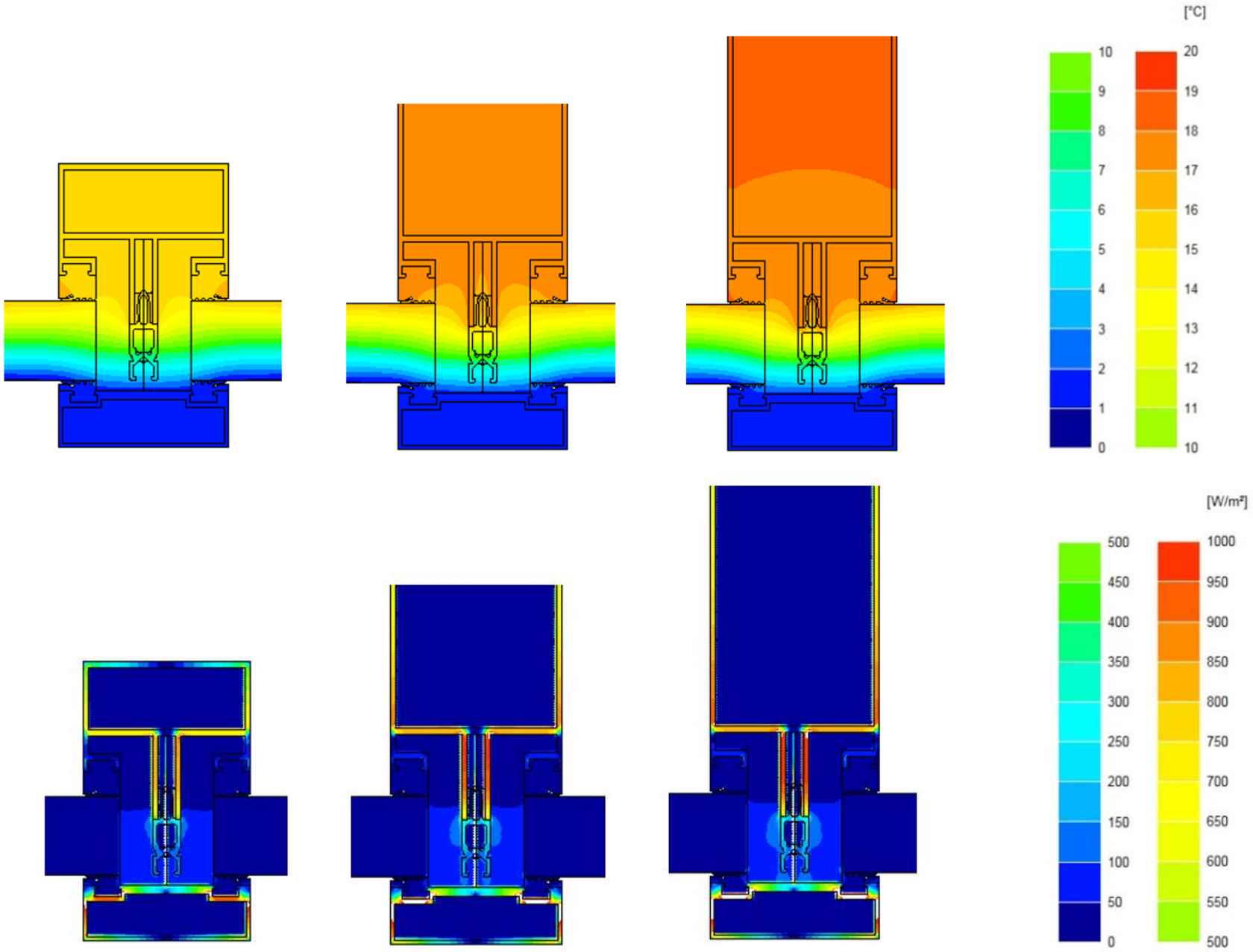


1 & 2. PROFILE WIDTH AND LENGTH





1 & 2. PROFILE WIDTH AND LENGTH



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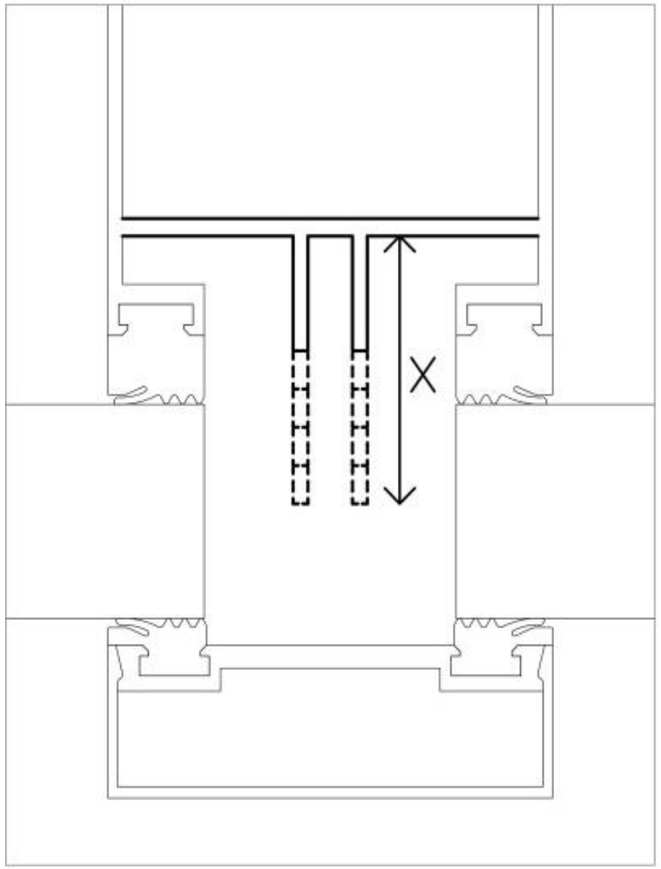
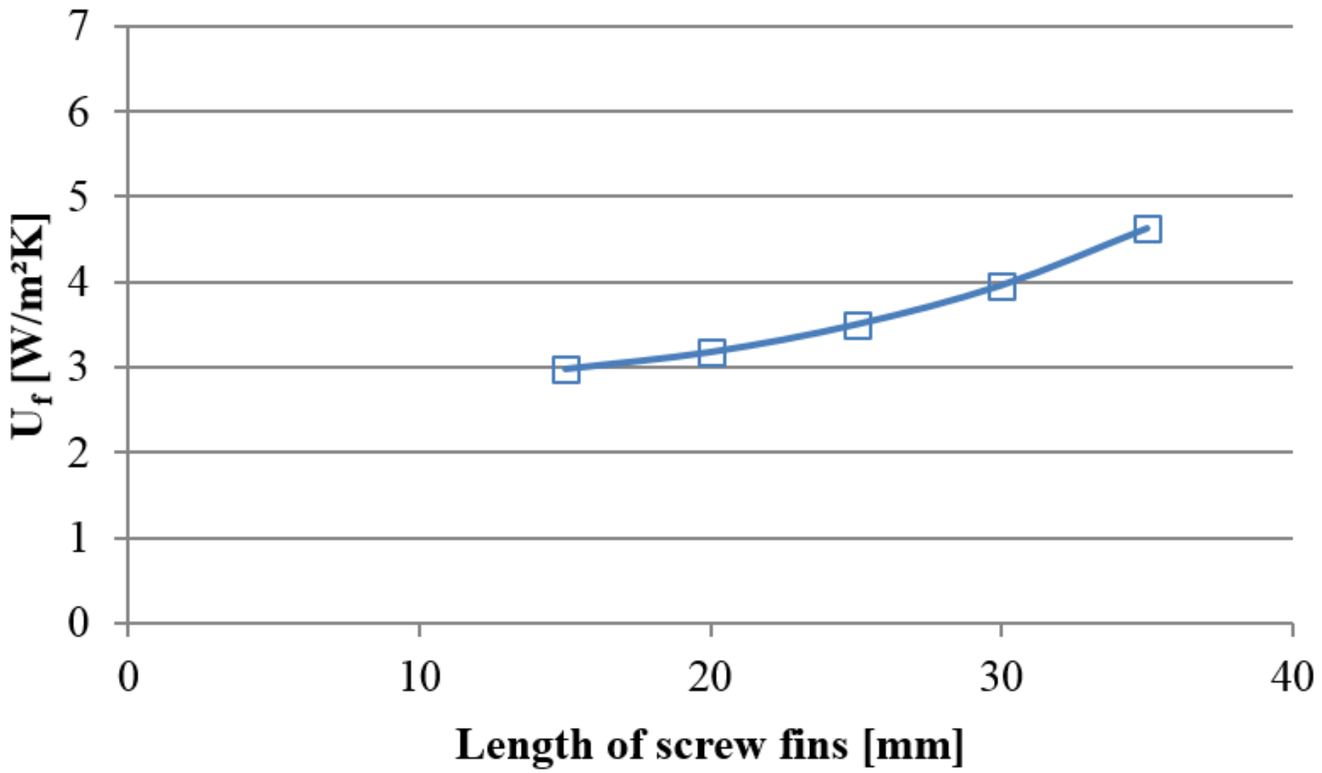
3. LENGTH OF SCREW FINS





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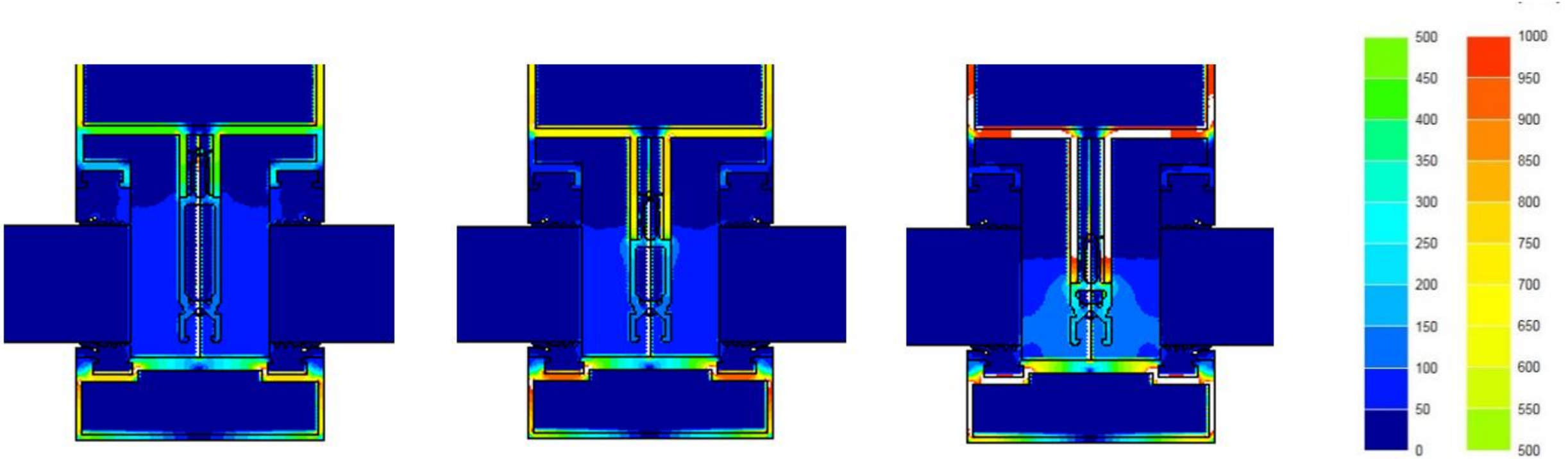
3. LENGTH OF SCREW FINS



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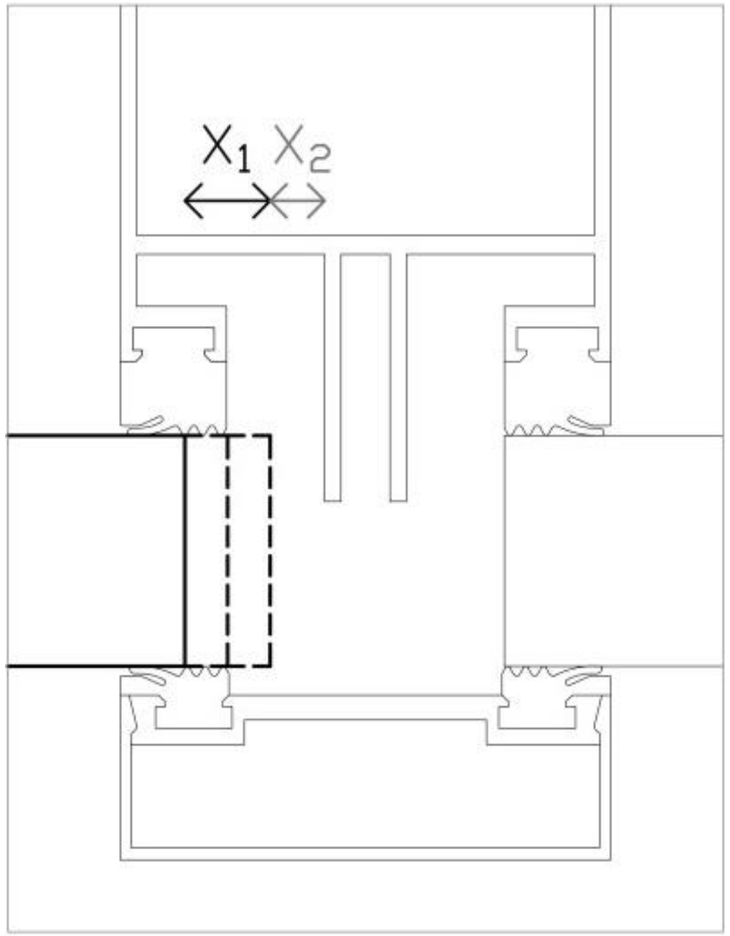
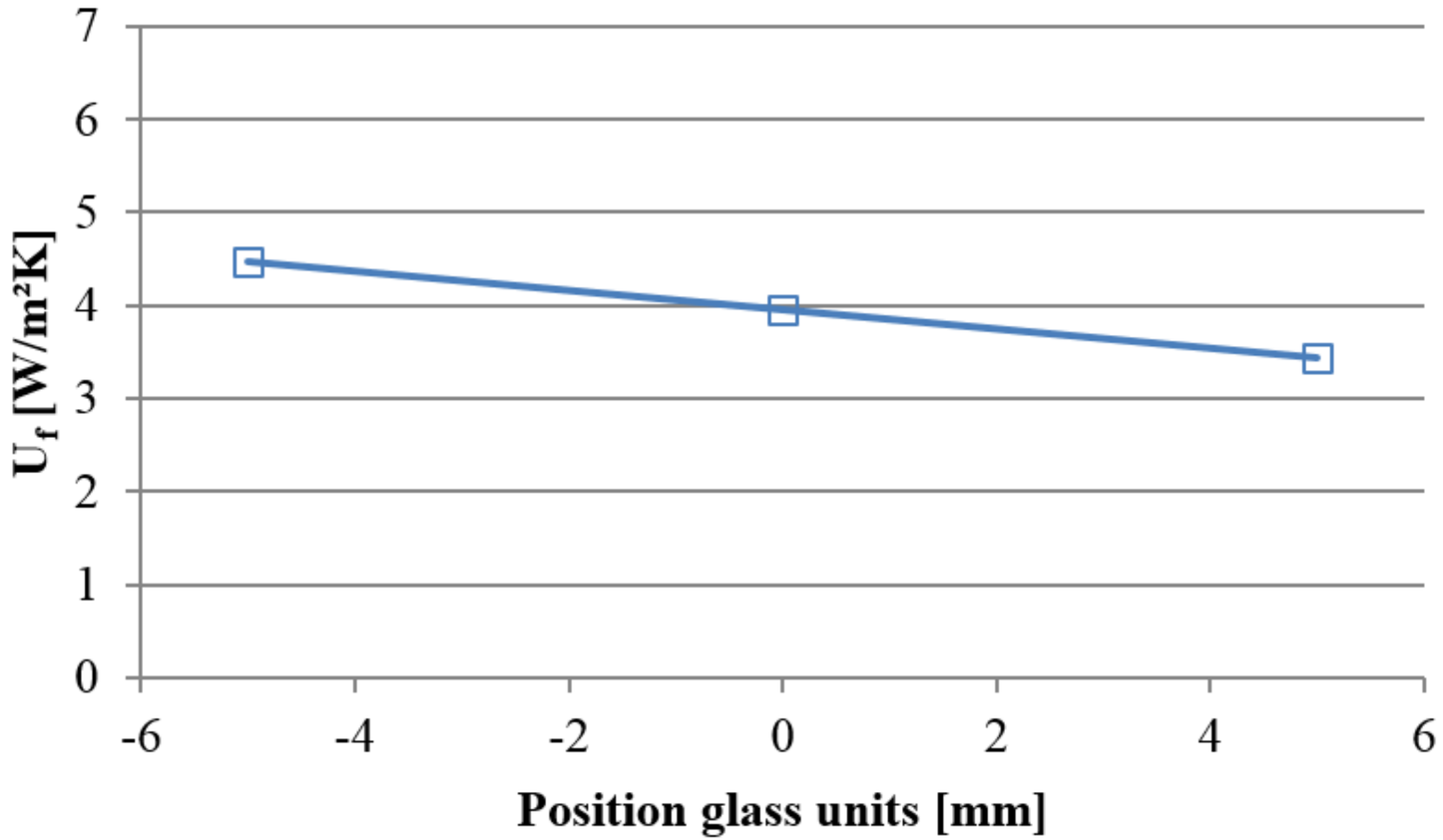
4. POSITION OF THE GLASS UNIT





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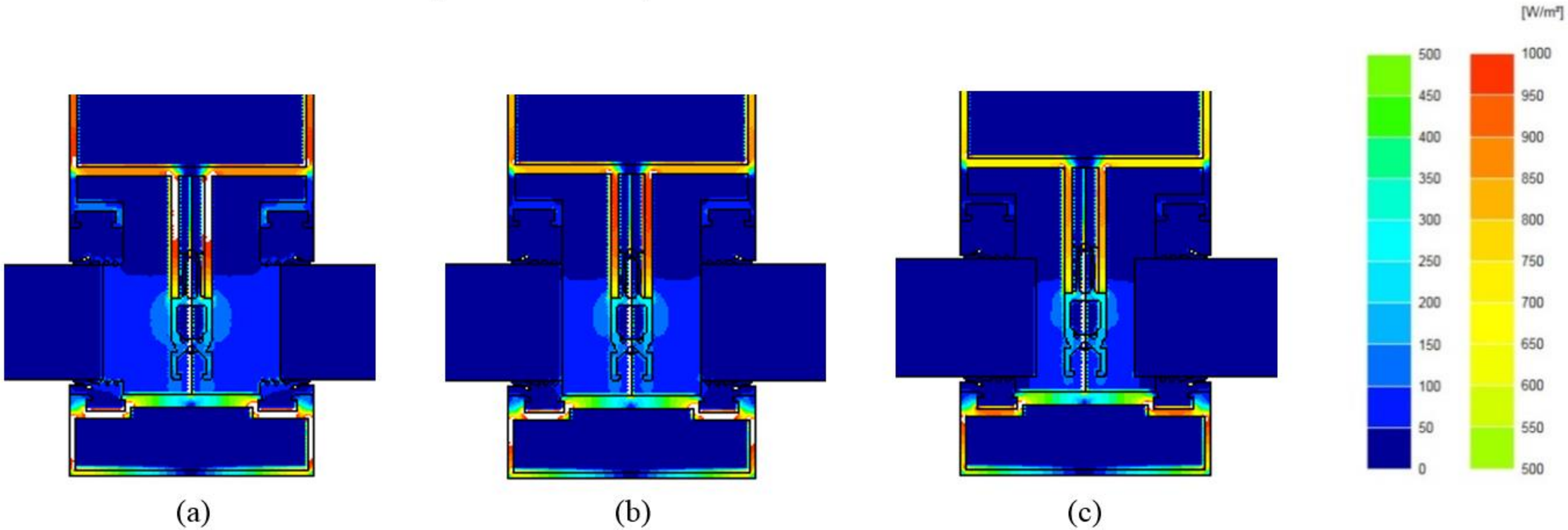
4. POSITION OF THE GLASS UNIT



(a) (b) (c)

	Configuration a	Configuration b	Configuration c
U_f [W/m²K]	4.481	3.958	3.434

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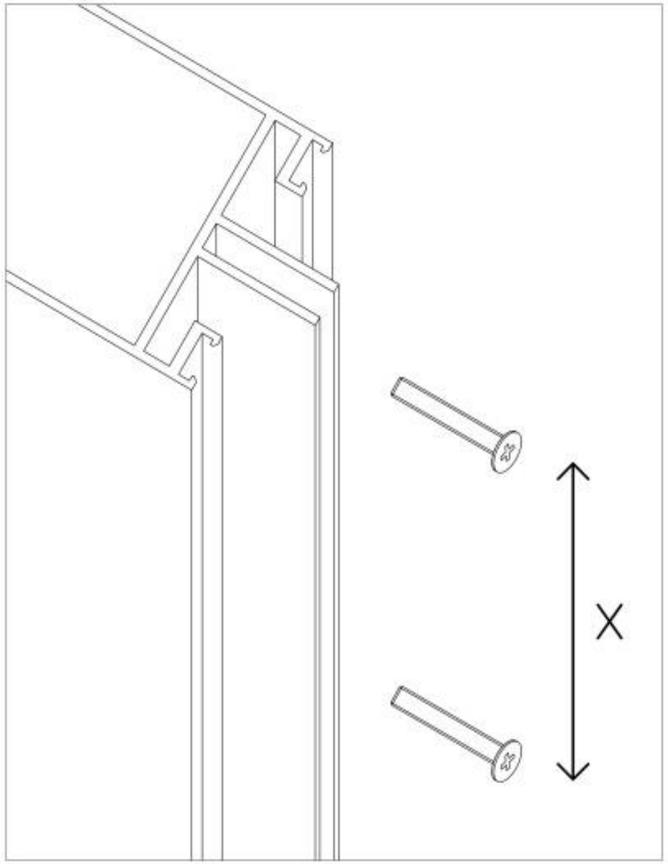
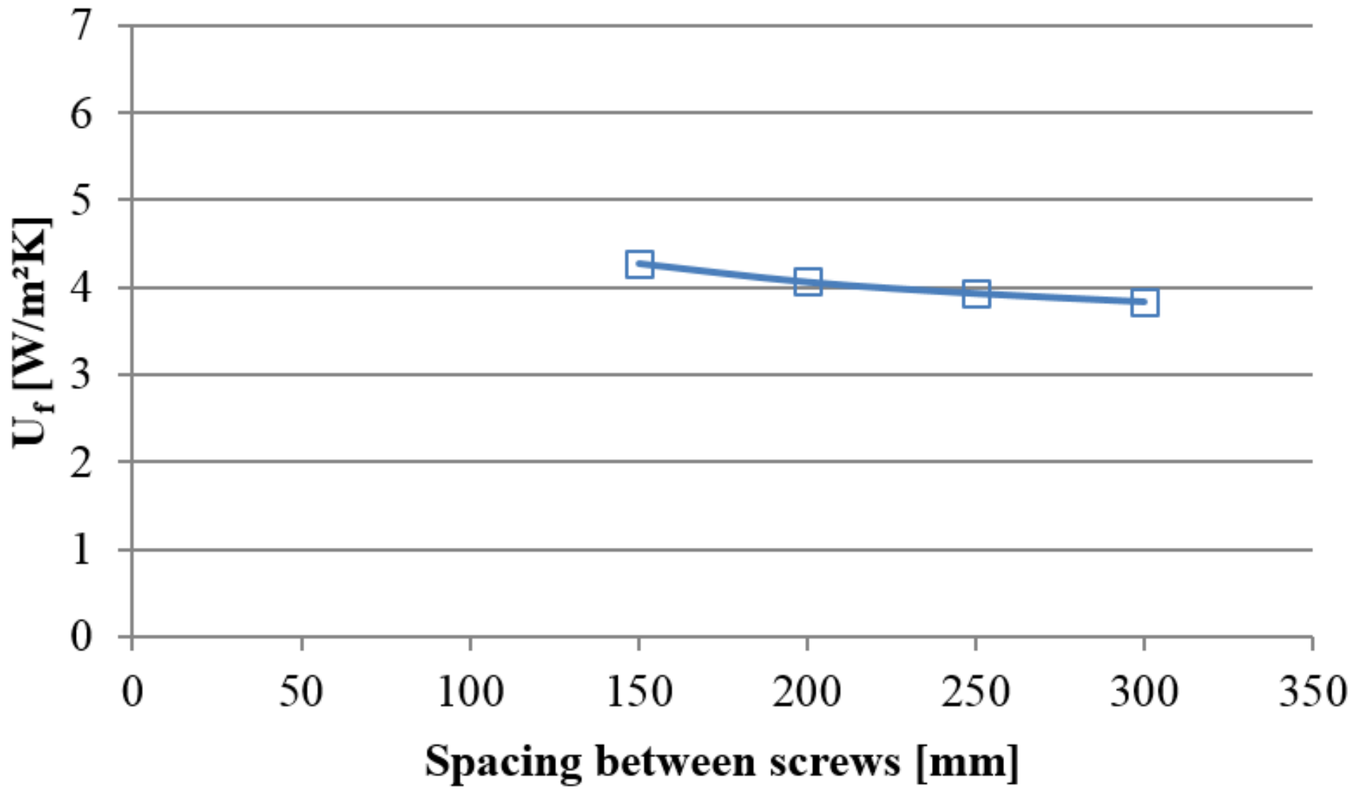
5. SPACING BETWEEN SCREWS





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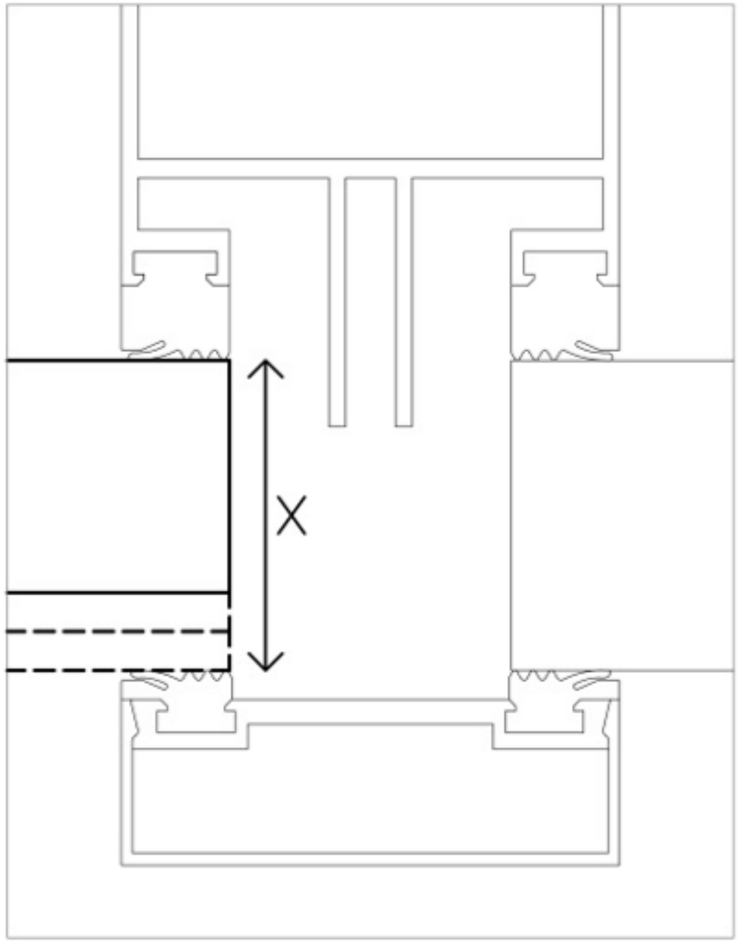
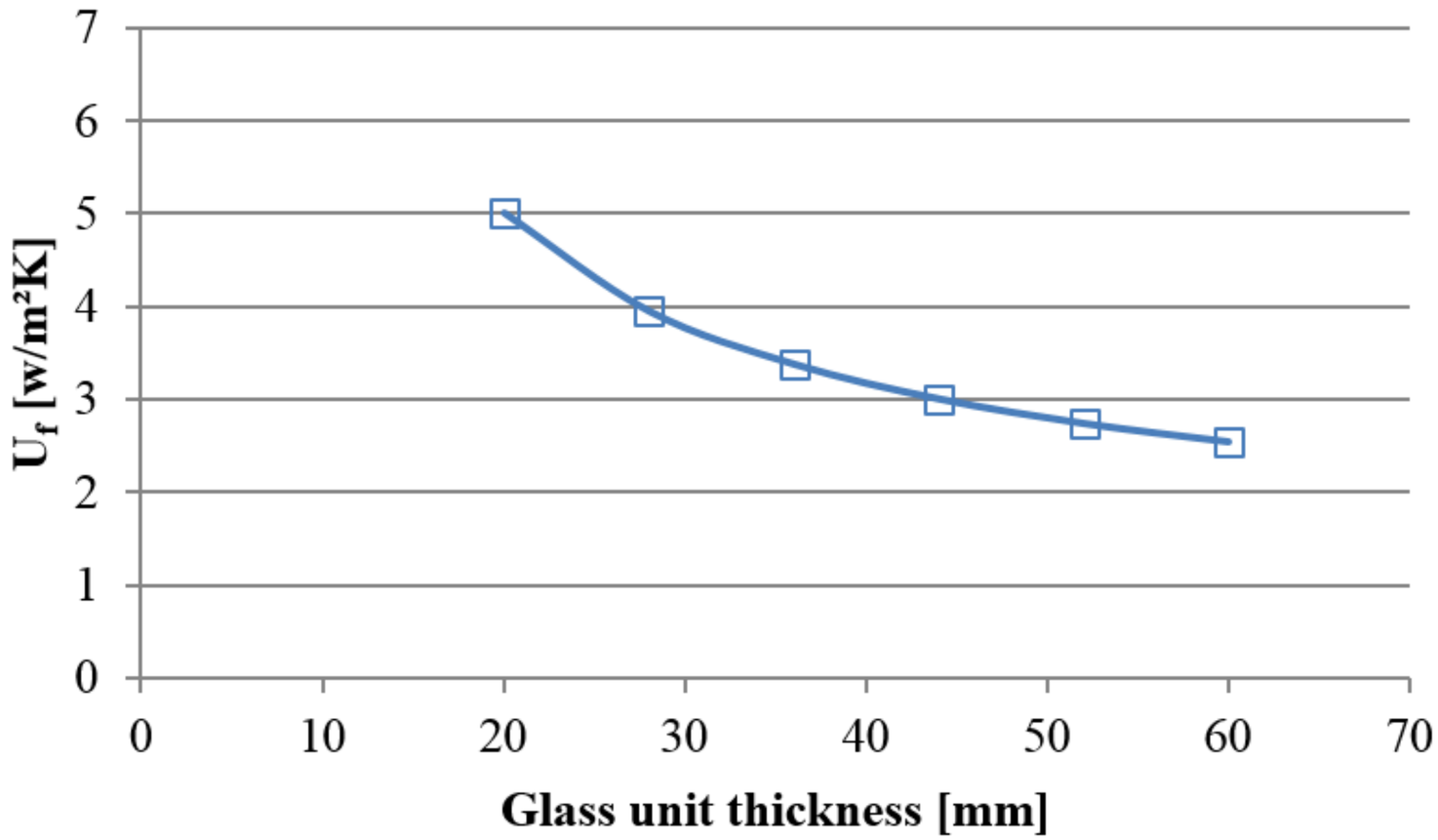
6. GLASS UNIT THICKNESS





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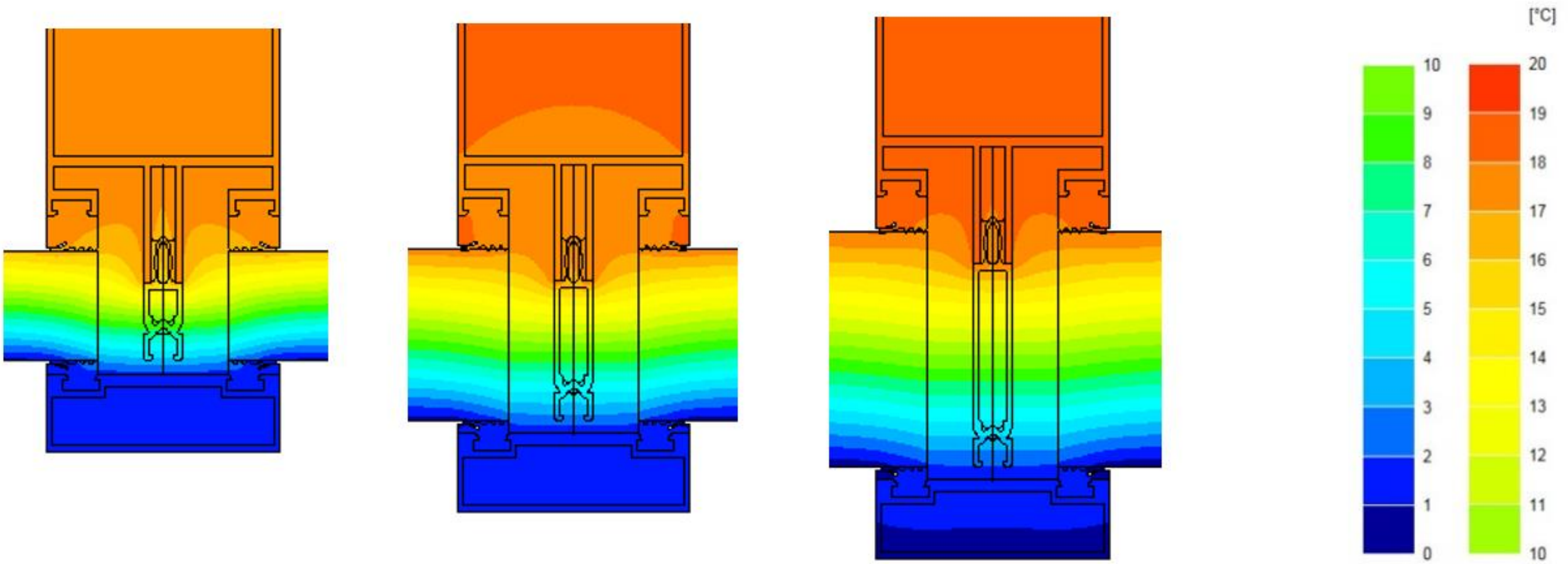
6. GLASS UNIT THICKNESS



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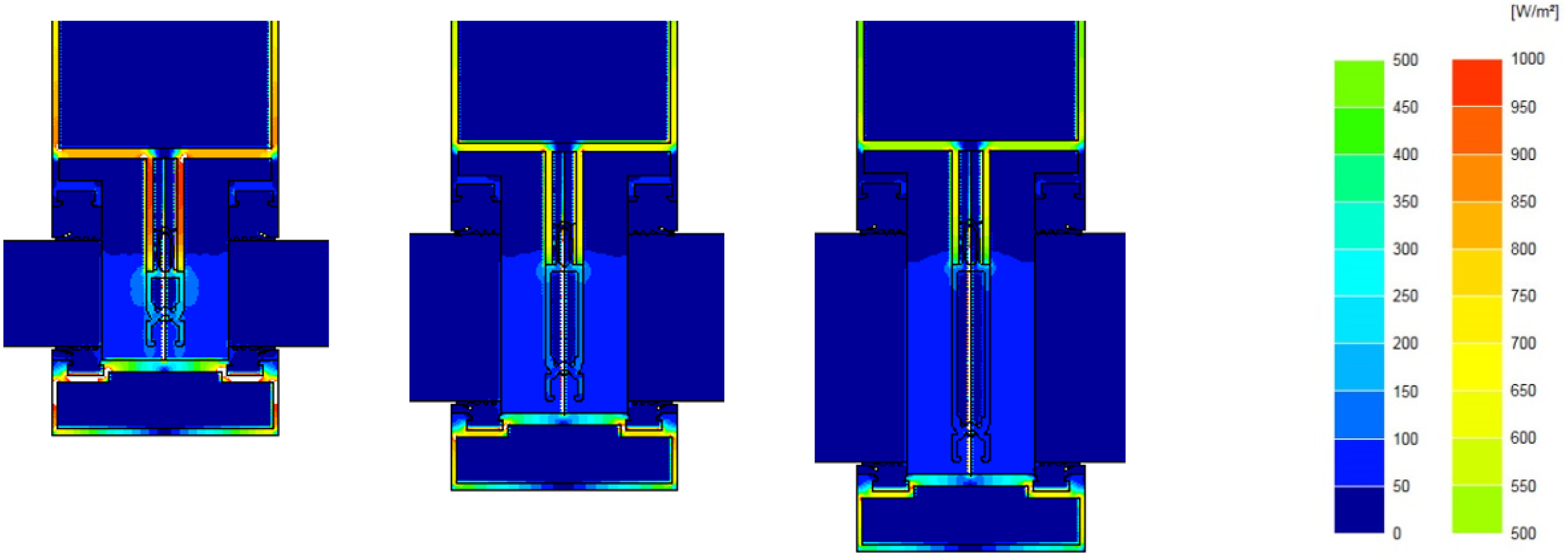
6. GLASS UNIT THICKNESS



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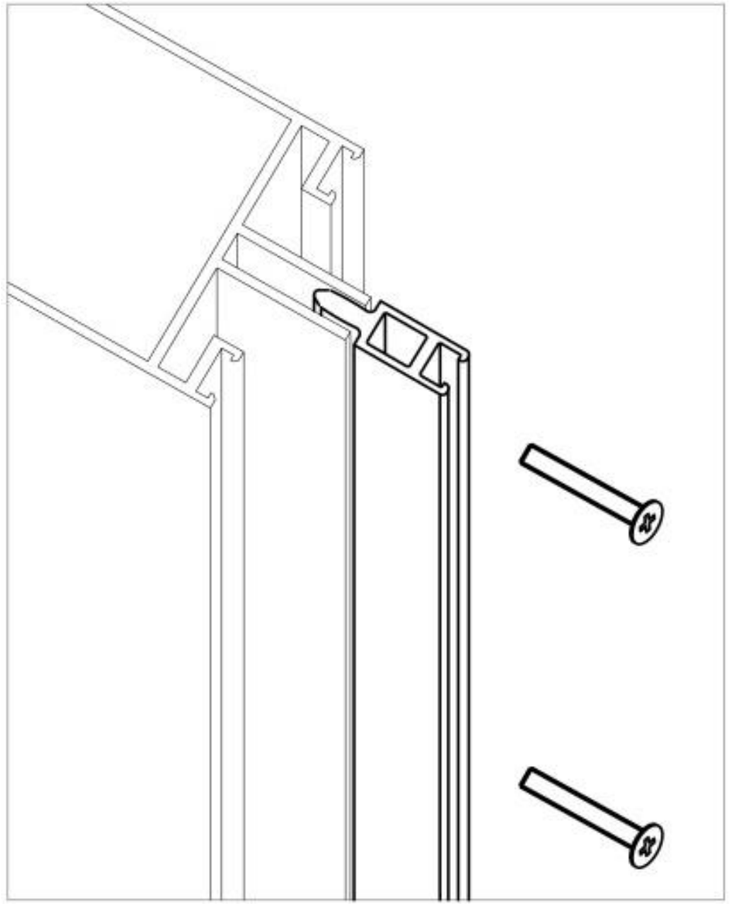
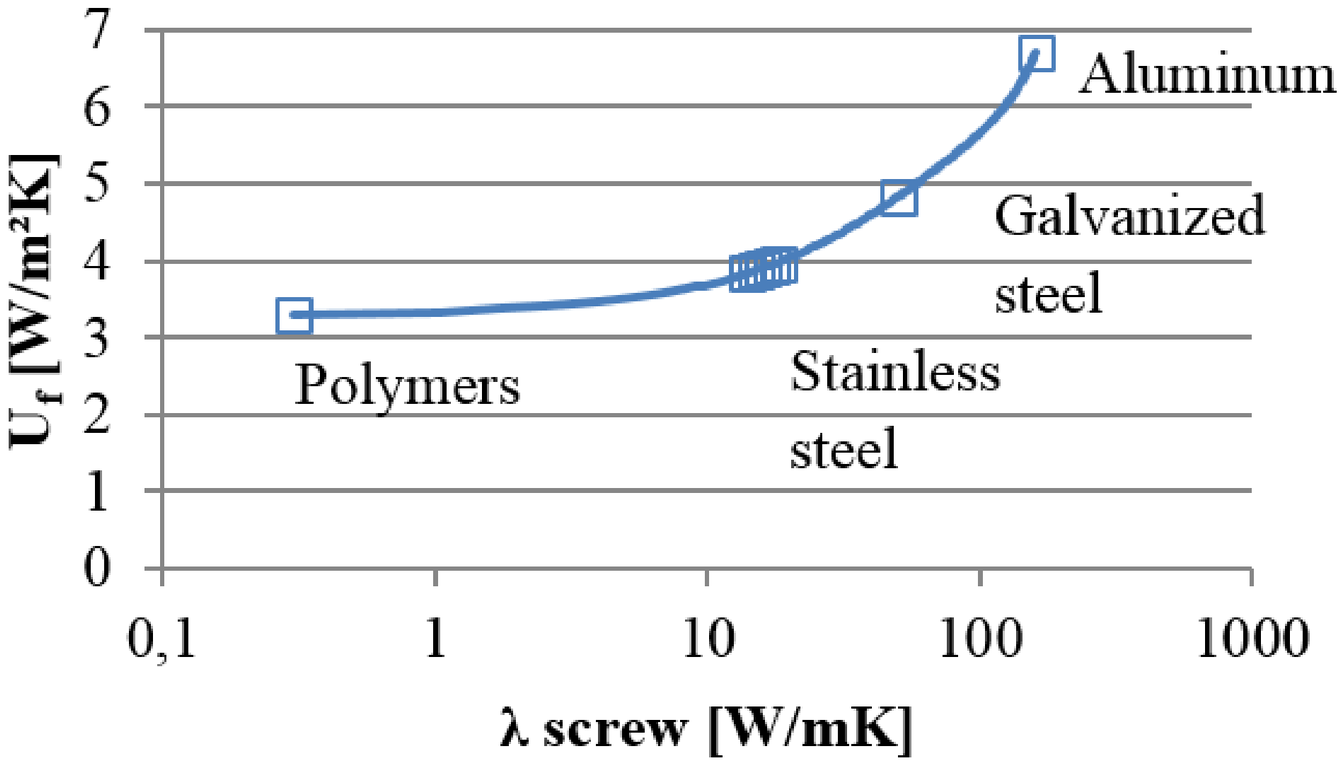
7. λ -VALUE OF SCREWS





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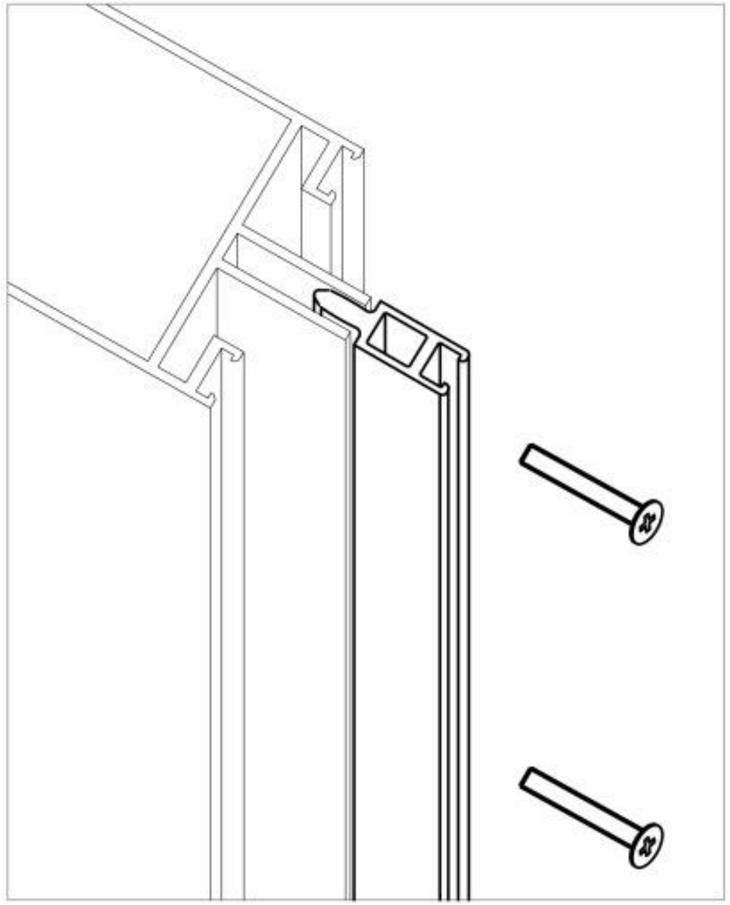
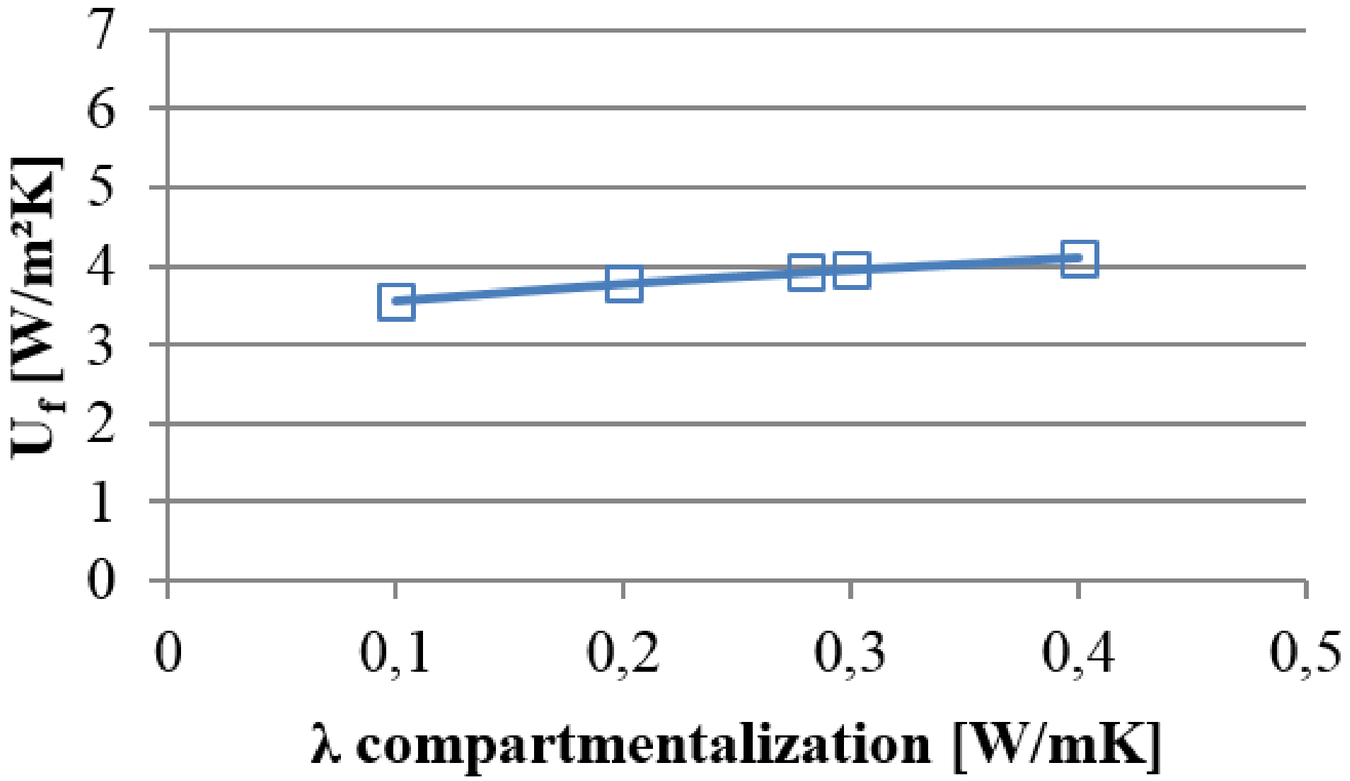
8. λ -VALUE OF COMPARTMENTALIZATION





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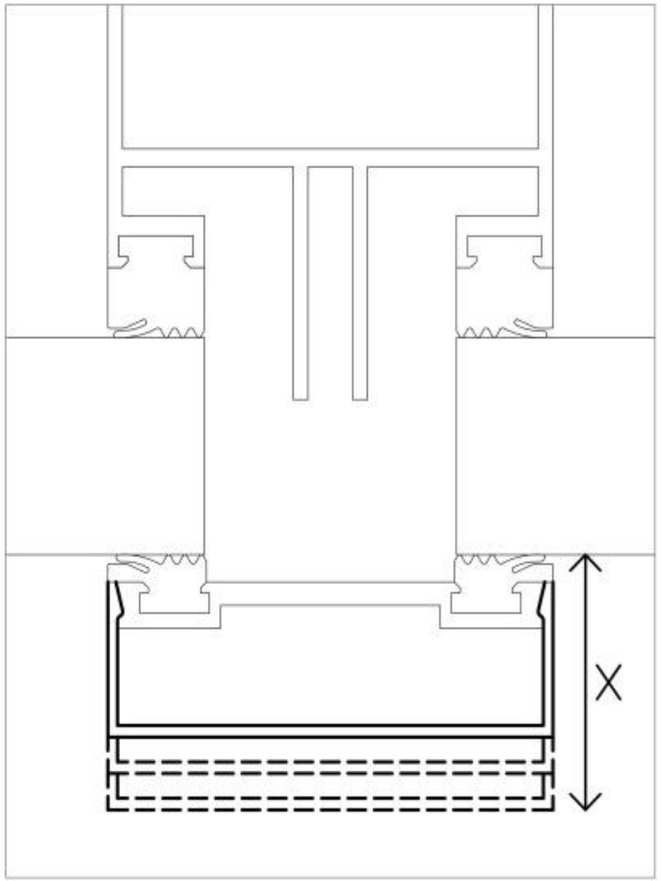
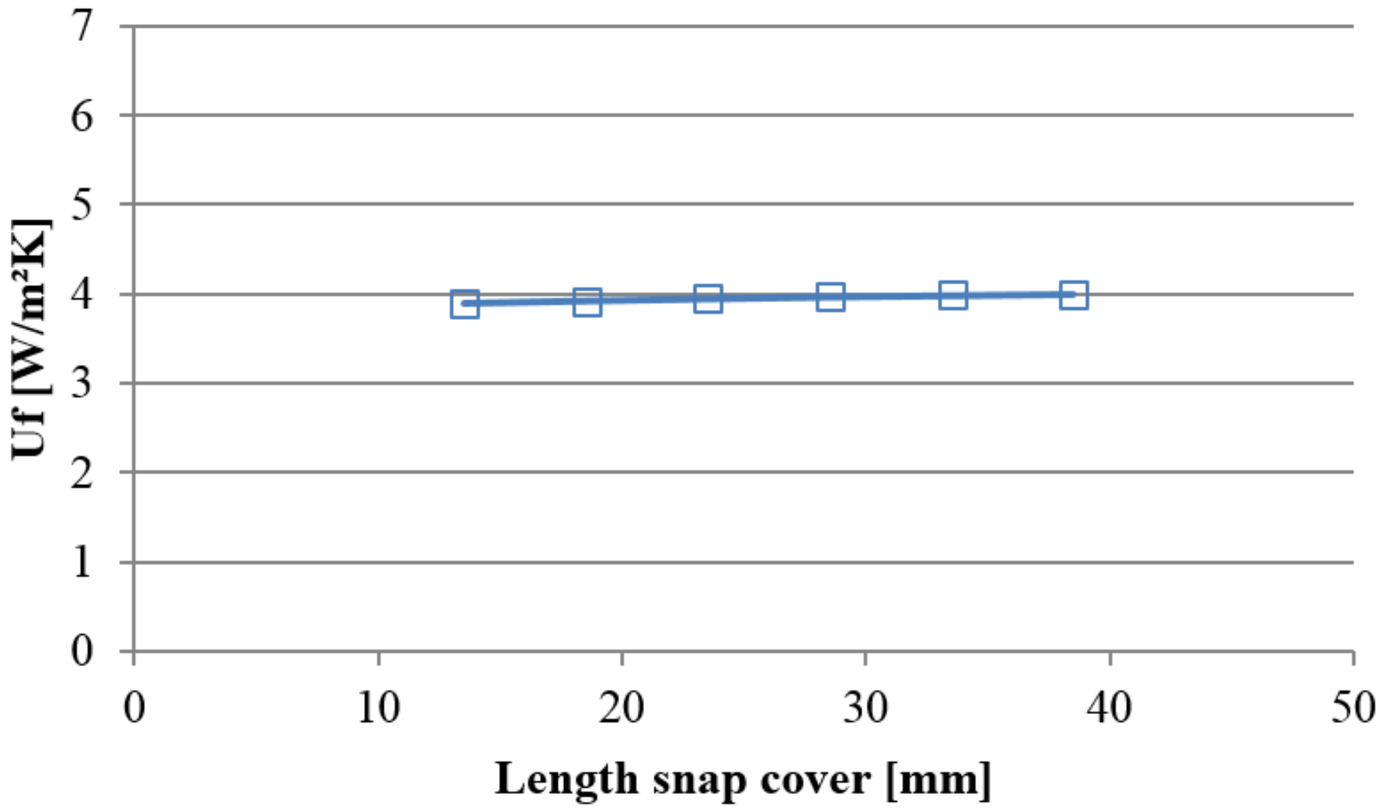
9. SNAP COVER LENGTH





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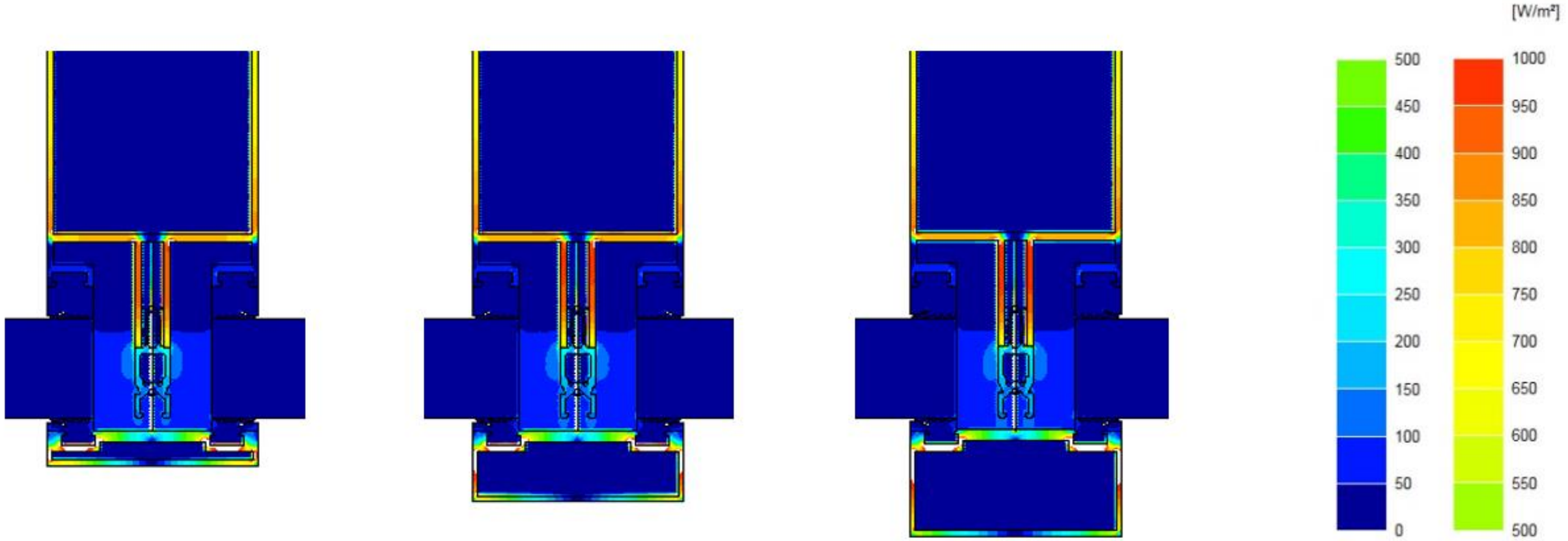
9. SNAP COVER LENGTH



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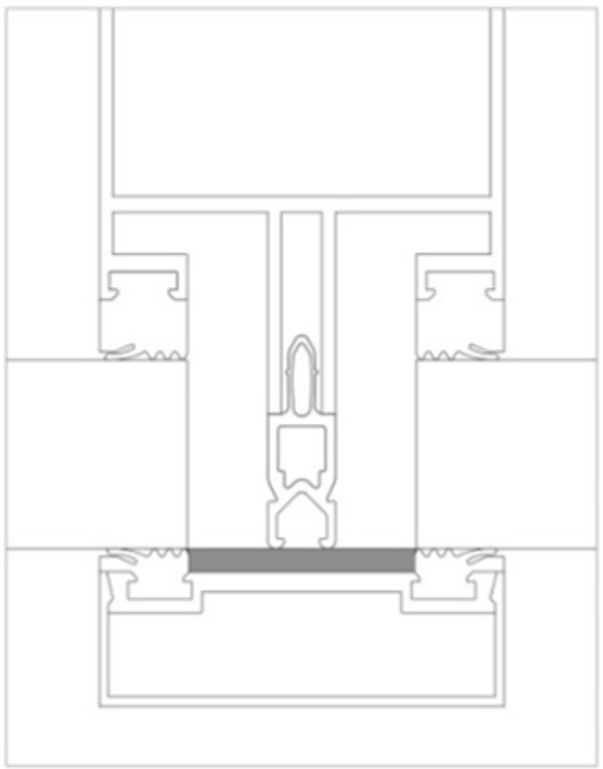
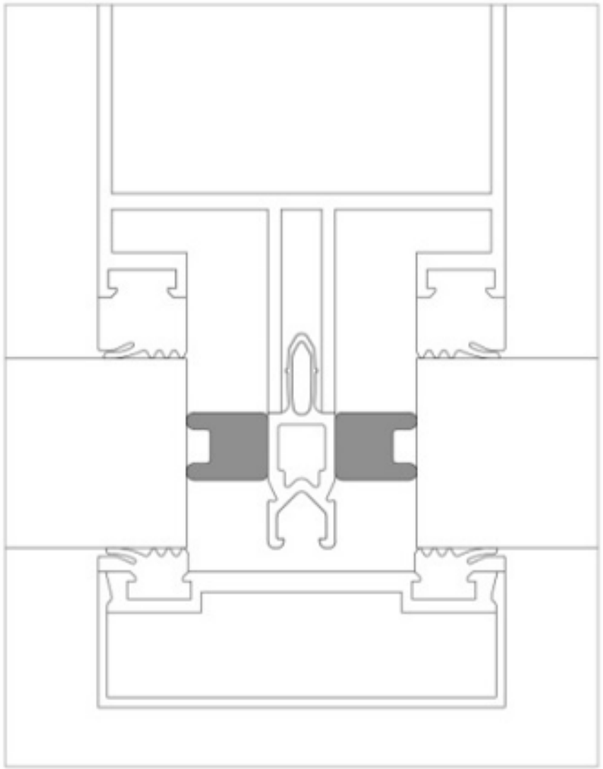
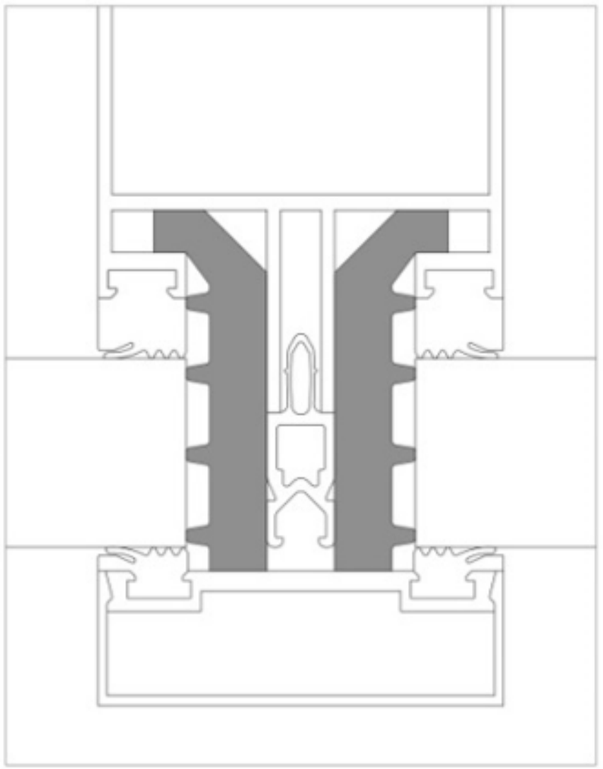
10. ADDITIONAL INSULATION



(a)



(b)



(c)

	U_f [W/m²K]	Ψ [W/mK]	I [-]
Reference frame	3.947	0.566	0.818
Option (a)	3.046	0.512	0.821
Option (b)	2.634	0.487	0.819
Option (c)	2.497	0.479	0.819

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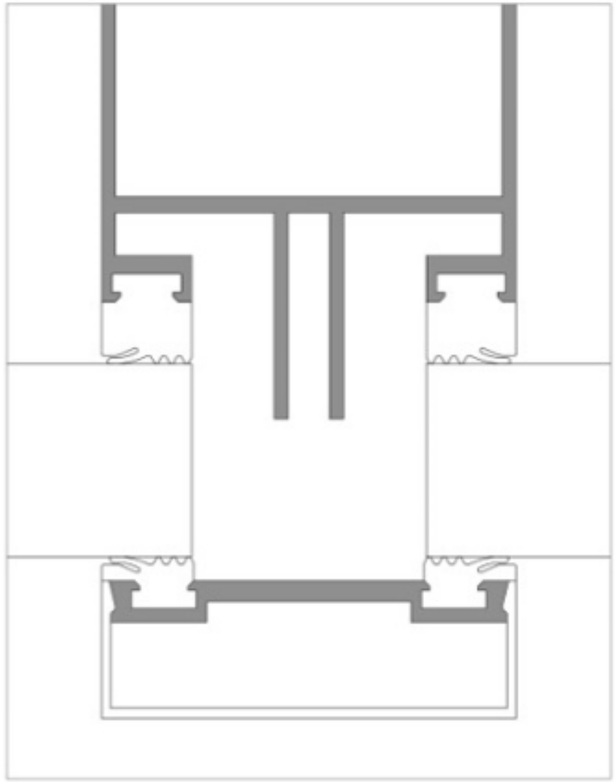
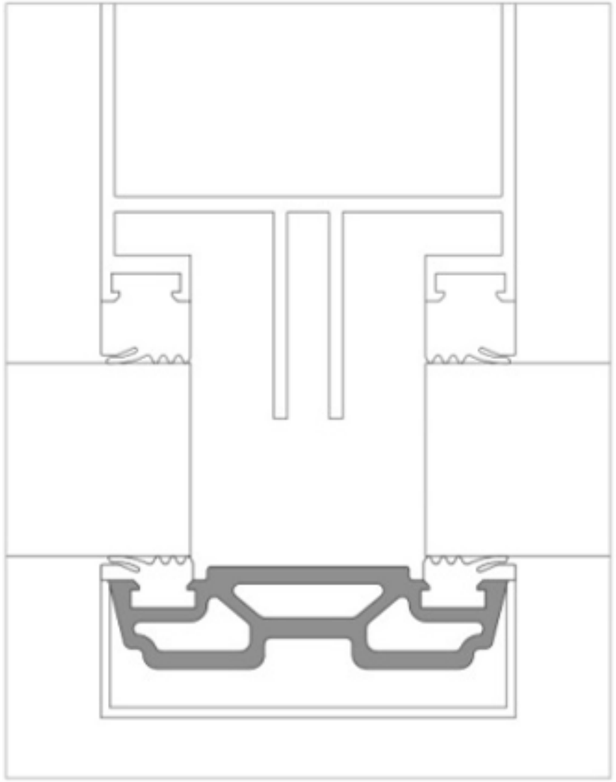
10. ADDITIONAL INSULATION

GFRP frame



(a)



(b)

Polymer pressure plate

	U_f [W/m²K]	Ψ [W/mK]	I [-]
Reference frame	3.947	0.566	0.818
GFRP frame	2.105	0.455	0.792
Polymer pressure plate	2.788	0.496	0.822

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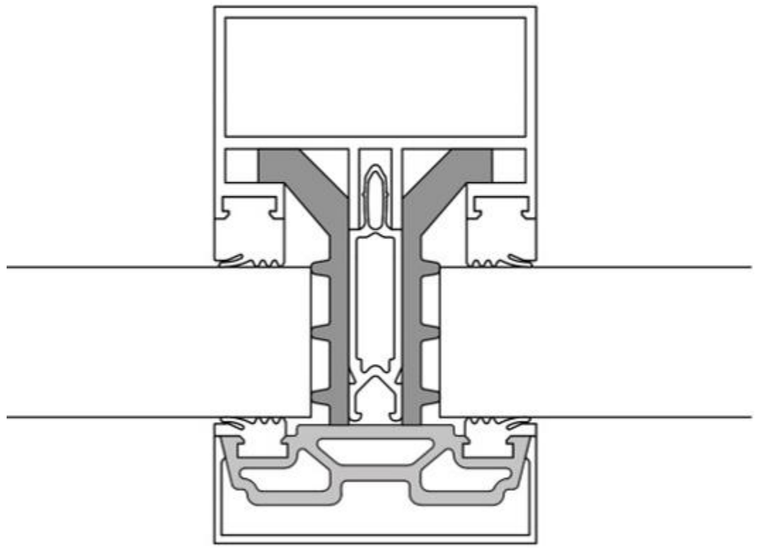
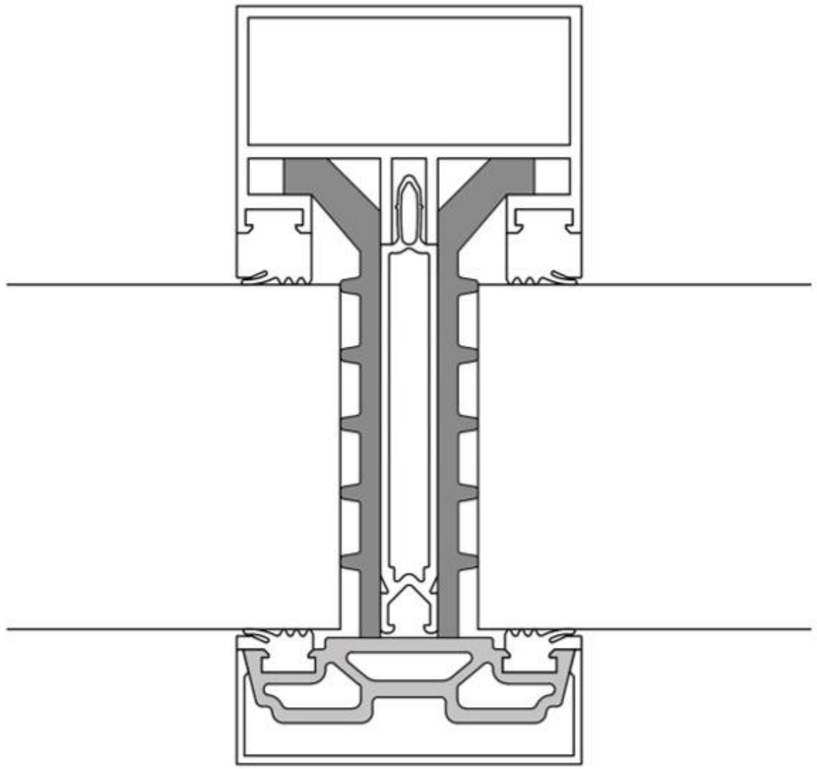
10. ADDITIONAL INSULATION



(a)



(b)

	U_f [W/m²K]	Ψ [W/mK]	I [-]
Reference frame	3.947	0.566	0.818
Combination (a)	1.524	0.420	0.817
Combination (b)	1.485	0.418	0.817

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- CONTEXT
- SIMULATION METHOD
- MODEL
- 10 PARAMETERS
- **CONCLUSIONS**

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CONCLUSIONS

Some parameters are taken into account in standard calculations

Following are typically not:

- Depth of the frame
- Position of IGU
- Thickness of IGU
- Spacing between screws

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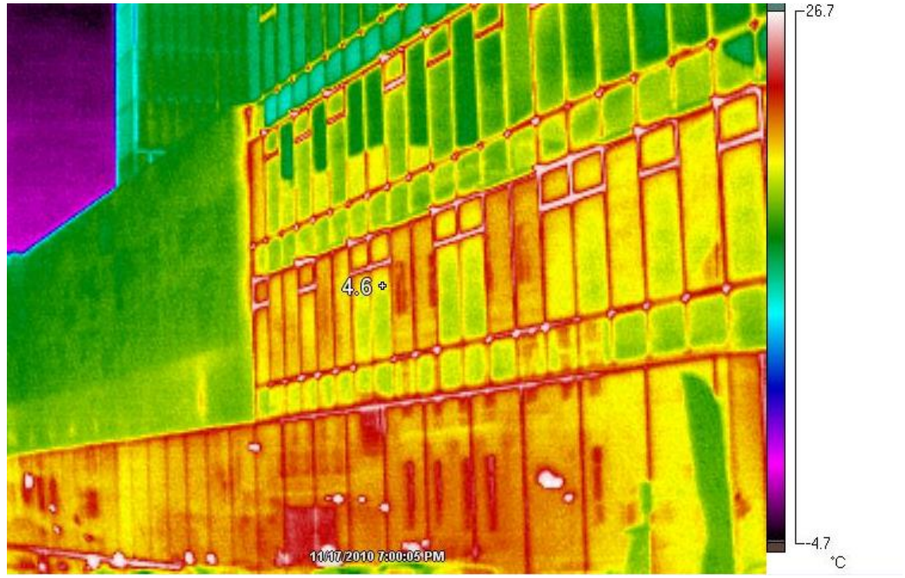
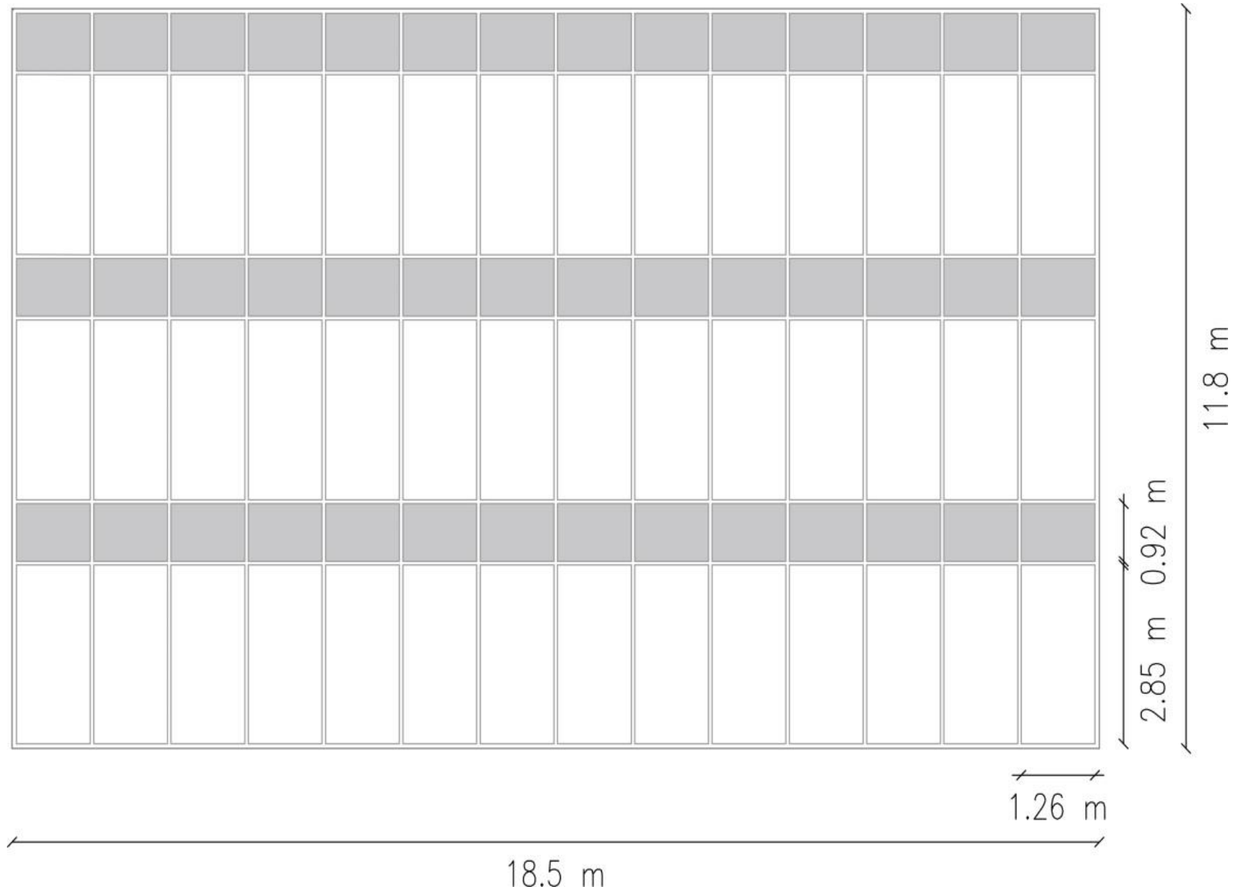
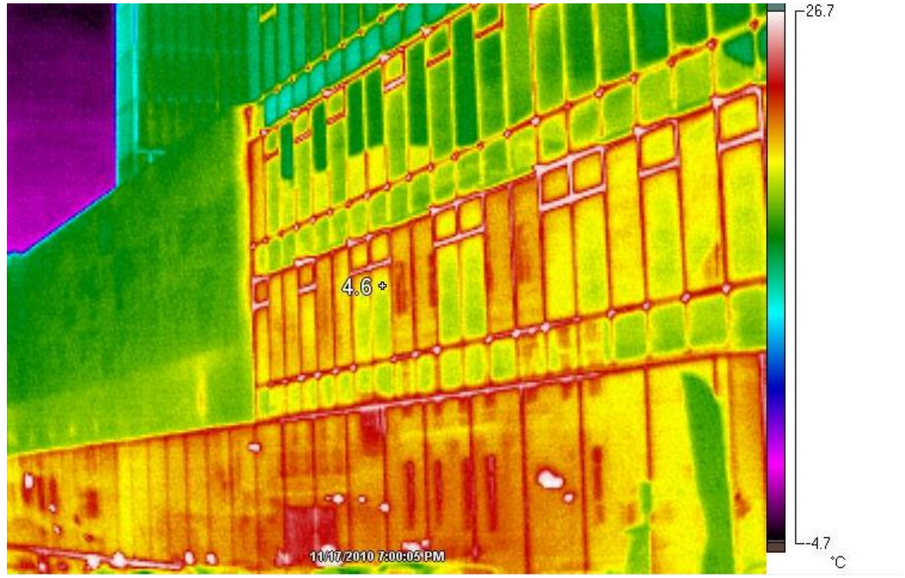
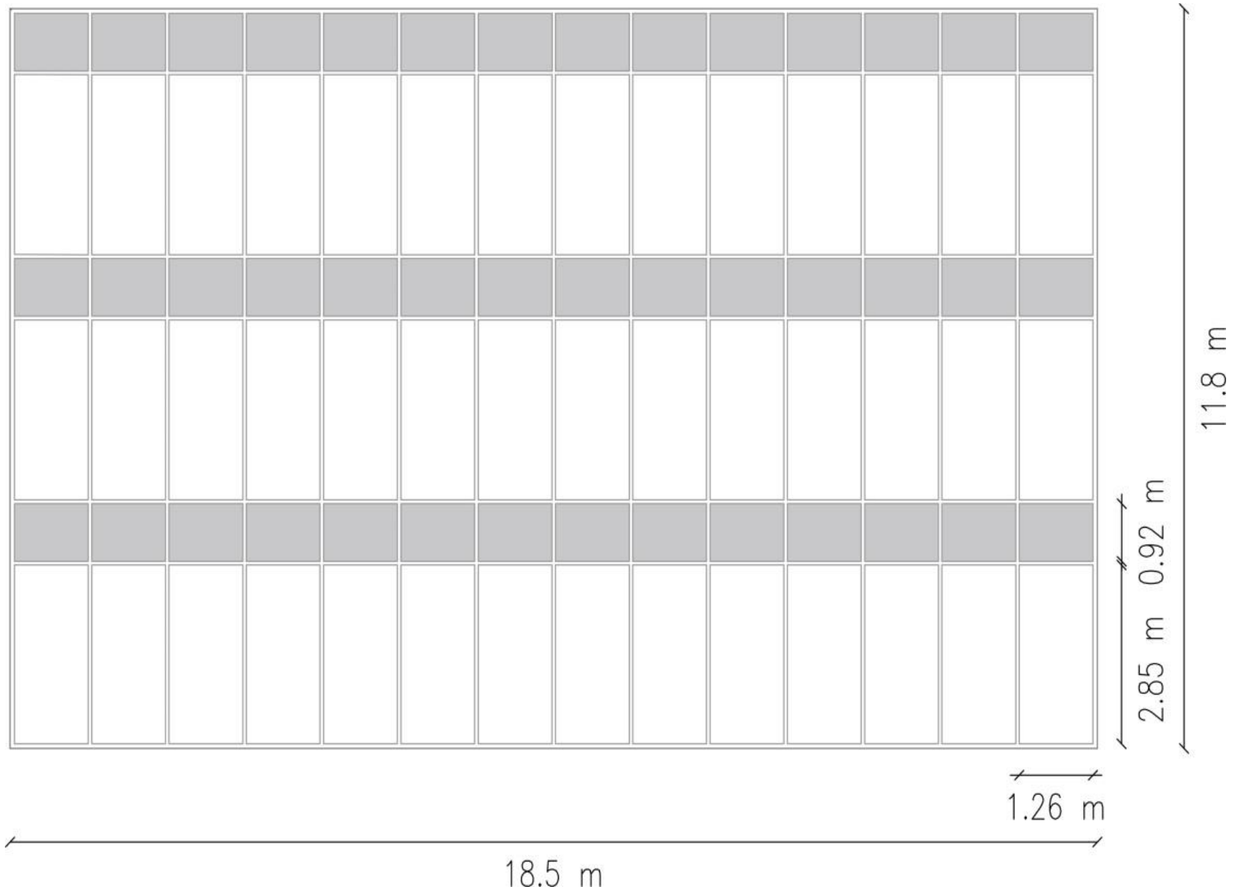
IMPACT





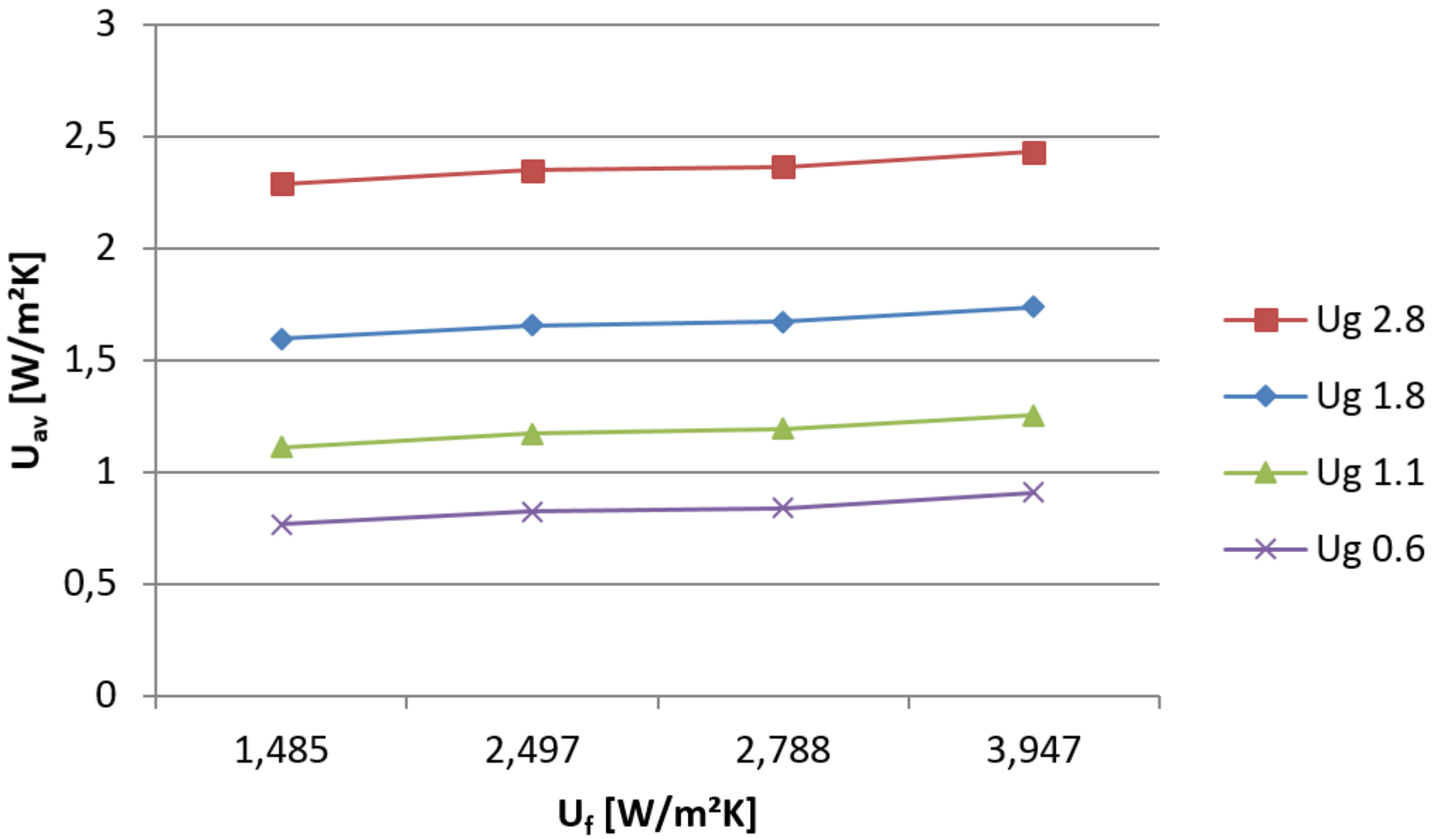
IMPACT





	Variation 1	Variation 2	Variation 3	Variation 4
U_{glass} (U_g)	2,8	1,8	1,1	0,6
$U_{spandrel}$ (U_s)	0,296	0,296	0,296	0,296
U_{frame} (U_f)	3,947	2,788	2,497	1,485
φ_{glass} (φ_g)	0,11	0,08	0,06	0,05
$\varphi_{spandrel}$ (φ_s)	0.004	0,038	0,047	0,077

IMPACT



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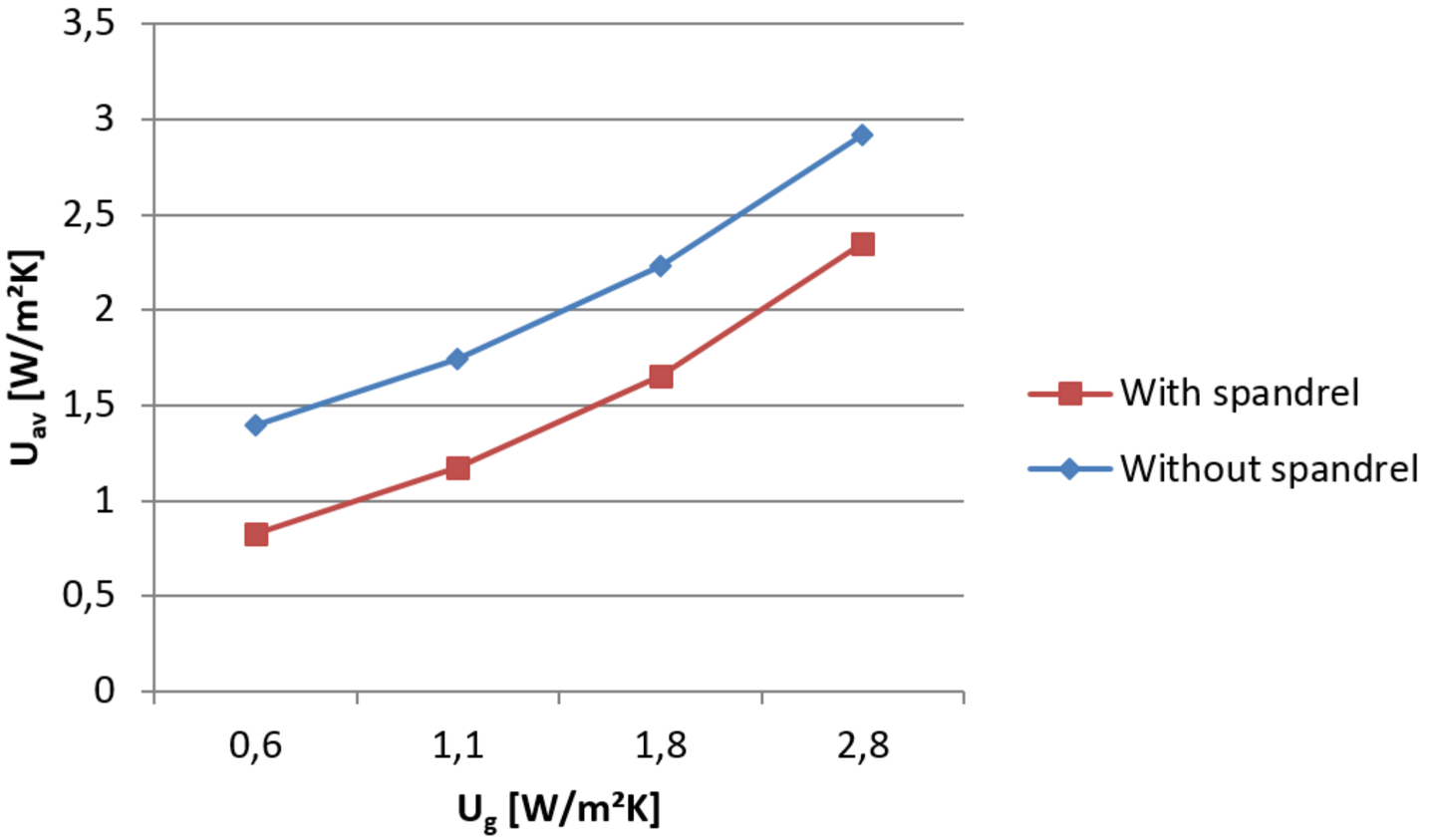
IMPACT



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Thank you for your attention!