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1. Introduction

This report presents findings of the thermal performance and condensation risk analysis for the curtain wall covering thermal breaks for all junctions including junctions with aluminium frames.

The aim of the analysis is to confirm the thermal bridging values to be equal or better than are set out in Façade performance specification as well as confirm surface condensation is avoided.

1.1 Exterior wall thermal requirements

Condensation assessment under the following boundary conditions: T_e=-4^{o}C; T_i=+20^{o}C; R. H.=50%.

Curtain wall vision U-value= 1.40 W/m^{2}K.

Curtain wall opaque U-value= 1.2 W/m^{2}K.

2. Thermal transmittance

2.1 Methodology and assumptions

In order to assess the overall thermal transmittance of the cladding and glazing areas, the heat flow through the cladding, infill elements and framing were considered.

Thermal transmittance of all configurations have been calculated by implementing material assumptions, boundary conditions (listed below) and combined to obtain the weighted average thermal transmittance.

Aluminium systems:

Curtain wall system – Schueco FWS 35 PD;

Door system – Schueco ADS 75 HD.HI;

Window system – Schueco AWS 114.

2.1.1 Methodology

Details were analysed using the software Flixo Pro. Flixo is a validated thermal bridge program according to standards EN ISO 10211 an EN ISO 10077-2. All important thermal characteristics of facades can be calculated easily according to EN ISO 1077-2 and EN ISO 12631.

In order to assess the overall thermal transmittance of the external envelope, the heat flow through all of the corresponding elements were considered and weighted average U-value for studied sections calculated.

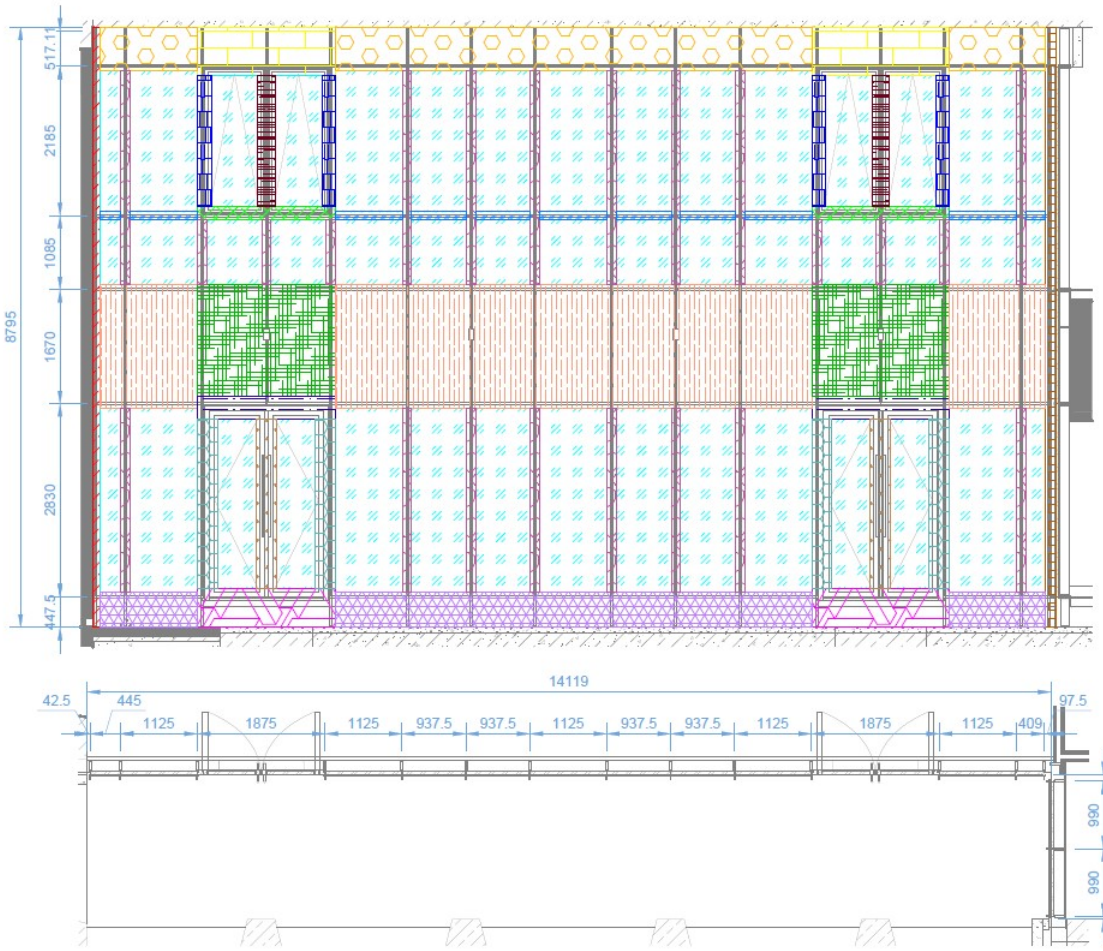
The linear thermal transmittance Psi (ψj) value includes junctions present at the sections considered.

3. Overall thermal value calculation

Objective is to meet the thermal transmittance value as set out by the specification in order to achieve the weighted average U-value.

3.1 Calculated U-value as per specification

Given the specification for the project which outlines thermal transmittance values for individual elements, weighted average is calculated by considering all of the elements present.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2185
1085
1670
2830
447.5
14119
42.5
445
1125
1875
1125
937.5
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1125
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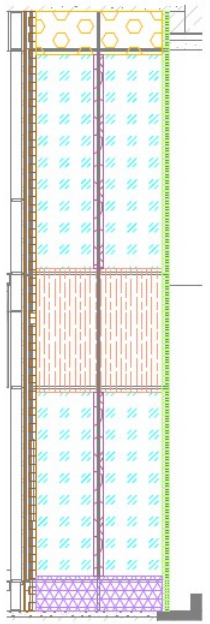
937.5
1125
1875
1125
409
97.5
97.5
990
990
2120
42



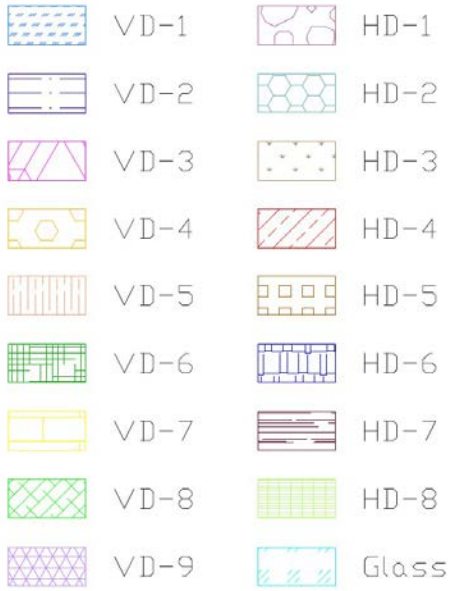

VD-1
VD-2
VD-3
VD-4
VD-5
VD-6
VD-7
VD-8
VD-9
HD-1
HD-2
HD-3
HD-4
HD-5
HD-6
HD-7
HD-8
Glass

Table1. Summary of project specific U-values

Detail/Area	Discription	U-value, W/m^{2}K	Area, m^2	Thermal Conductance, W/K	
Glass	GL_01	1.400	73.637	103.092	Vision area
HD-1	Horizontal detail A	1.400	7.849	10.989	
HD-2	Door horizontal detail-1	1.400	2.911	4.075	
HD-3	Door horizontal detail-2	1.400	1.49	2.086	
HD-4	Jamb detail A	1.400	0.963	1.348	
HD-8	Jamb detail B	1.400	0.967	1.354	
HD-5	Corner detail A	1.400	2.898	4.057	
HD-6	Window horizontal detail-1	1.400	1.508	2.111	
HD-7	Window horizontal detail-2	1.400	0.987	1.382	
VD-1	Vertical detail A	1.400	1.18	1.652	
VD-2	Door vertical detail-1	1.400	1.379	1.931	
VD-3	Door vertical detail-2	1.400	2.316	3.242	
VD-7	Window vertical detail-1	1.400	2.836	3.970	
VD-8	Window vertical detail-2	1.400	0.786	1.100	
VD-4	Head detail A	1.200	7.528	9.034	Solid area
VD-5	Slab detail A	1.200	21.064	25.277	
VD-6	Vertical detail B	1.200	6.517	7.820	
VD-9	Foot detail	1.200	6.01	7.212	
Total:		**1.342**	142.826	191.733	

Table2.Summary of U-values from thermal analysis

Detail/Area	Discription	U-value, W/m^{2}K	Area, m^2	Thermal Conductance, W/K	
Glass	GL_01	1.000	73.637	73.637	Vision area
HD-1	Horizontal detail A	2.850	7.849	22.373	
HD-2	Door horizontal detail-1	2.540	2.911	7.393	
HD-3	Door horizontal detail-2	2.020	1.49	3.01	
HD-4	Jamb detail A	2.890	0.963	2.783	
HD-8	Jamb detail B	2.970	0.967	2.873	
HD-5	Corner detail A	4.210	2.898	12.201	
HD-6	Window horizontal detail-1	2.440	1.508	3.679	
HD-7	Window horizontal detail-2	2.200	0.987	2.171	
VD-1	Vertical detail A	2.820	1.18	3.329	
VD-2	Door vertical detail-1	1.330	1.379	1.834	
VD-3	Door vertical detail-2	1.020	2.316	2.362	
VD-7	Window vertical detail-1	1.440	2.836	4.083	
VD-8	Window vertical detail-2	2.380	0.786	1.87	
VD-4	Head detail A	0.856	7.528	6.444	Solid area
VD-5	Slab detail A	0.579	21.064	12.196	
VD-6	Vertical detail B	0.693	6.517	4.516	
VD-9	Foot detail	1.360	6.01	8.173	
Total:		**1.225**	142.826	174.927	

Average U-values to compare with project specified U-values:
Personnel doors U-value= **1.803 W/m^{2}K** (1.4 W/m^{2}K).
Personnel windows U-value = **1.930 W/m^{2}K** (1.4 W/m^{2}K).
Curtain wall vision U-value= **1.339 W/m^{2}K** (1.4 W/m^{2}K).
Curtain wall opaque U-value= **0.762 W/m^{2}K** (1.2 W/m^{2}K).

Final row in Table 2 gives the total values of each parameter. U-value is calculated backwards by summing values of the thermal conductance and dividing with the total area. Final value gives the weighted average thermal transmittance as specified for the project.

4. Surface condensation

4.1 Methodology

Details were analysed in the software Flixo Pro in accordance to BS EN 13788 and CWCT guidelines. Thermal analysis models in Appendix A shows isotherm lines produced form the simulation. Dew point temperature's isotherm line is highlighted.

4.2 Boundary conditions

The following boundary conditions were used for the modelling:

	Θ (°C)	R[(m²K)/W]	ε	Relative humidity [%]
Epsilon			0.900	
Exterior, frame	-4.00	0.040		80%
Interior, frame, normal	+20.00	0.130		50%
Interior, frame, reduced	+20.00	0.200		50%

Assuming an internal temperature T_i=+20°C and relative humidity R. H.=50% the calculated dew point temperature is T_{dp}=9.3°C.

4.3 Summary of results – surface condensation

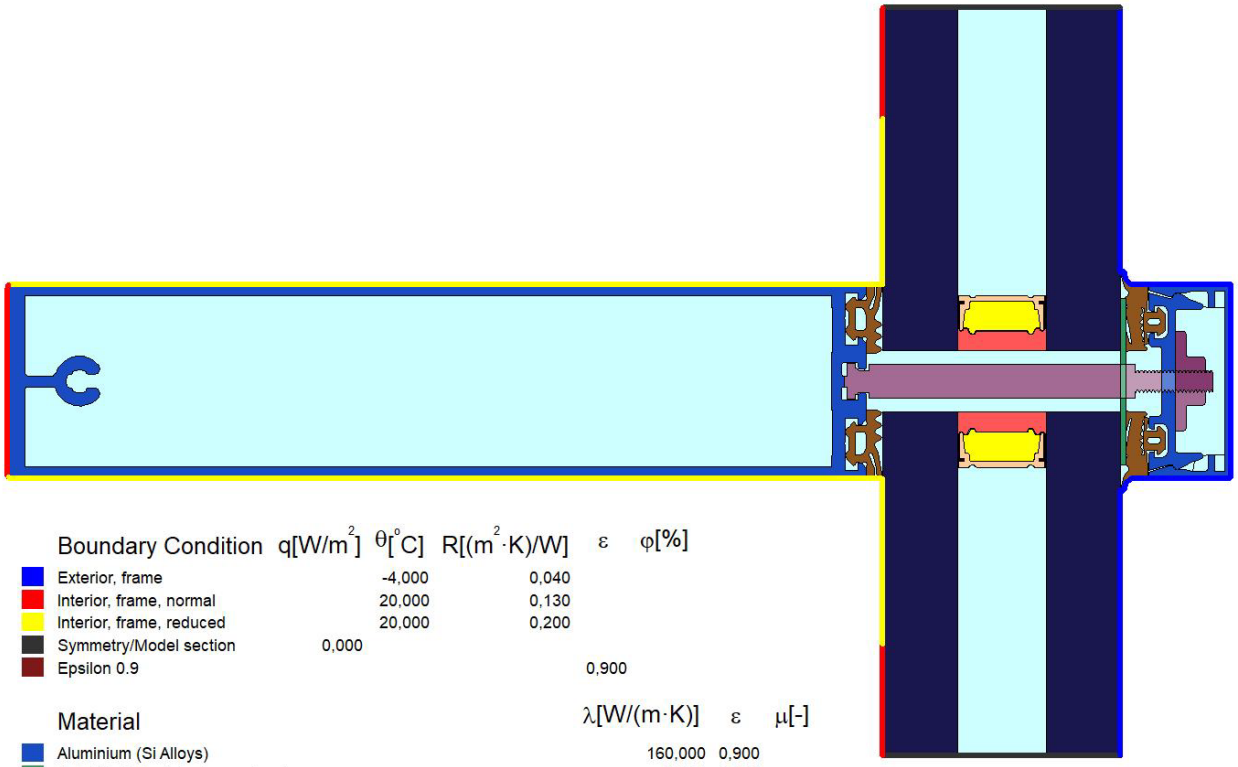
The following table shows the minimum internal surface temperature which, according to boundary conditions, must be above the calculated dew point temperature to avoid surface condensation. From the table below minimum temperature is found to be 10.98 higher T_{dp}.

Detail	Lowest surface temperature @ 20 °C	Equivalent RH at which condensation may occur
HD-1	13.24 °C	77 %
HD-2	11.18 °C	88 %
HD-3	11.09 °C	89 %
HD-4	11.37 °C	87 %
HD-5	11.72 °C	85 %
HD-6	11.83 °C	84 %
HD-7	10.98 °C	89 %
HD-8	11.37 °C	87 %
VD-1	11.78 °C	85 %
VD-2	12.90 °C	79 %
VD-3	12.33 °C	82 %
VD-4	12.10 °C	83 %
VD-5	12.41 °C	81 %
VD-6	12.34 °C	82 %
VD-7	11.36 °C	87 %
VD-8	11.33 °C	87 %
VD-9	12.45 °C	81 %

Appendix A

Thermal analysis models

VD-1

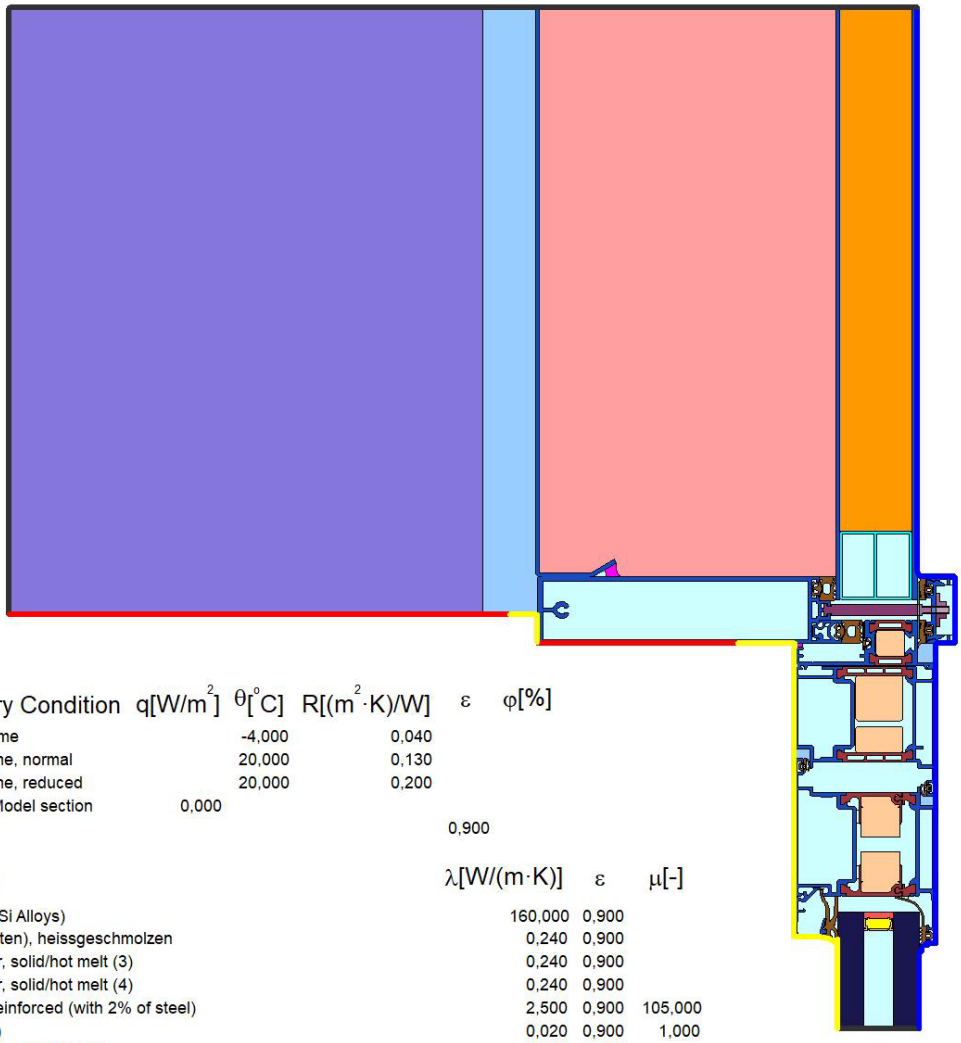


Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Gasfilling(1)	0,020	0,900	1,000
Gasfilling(2)	0,020	0,900	1,000
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
Polysulfide (1)	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,205	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,063	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop

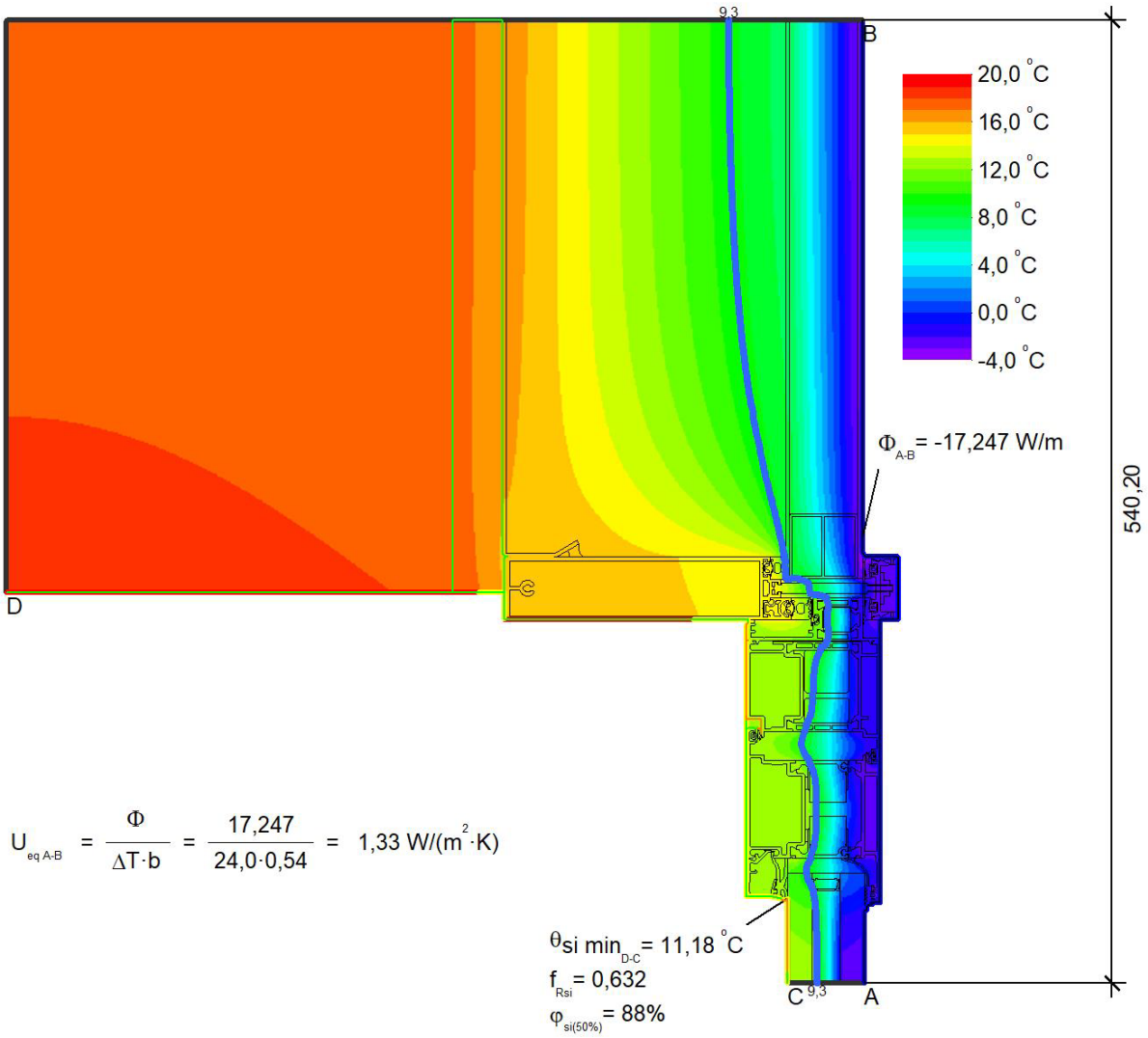
VD-2



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

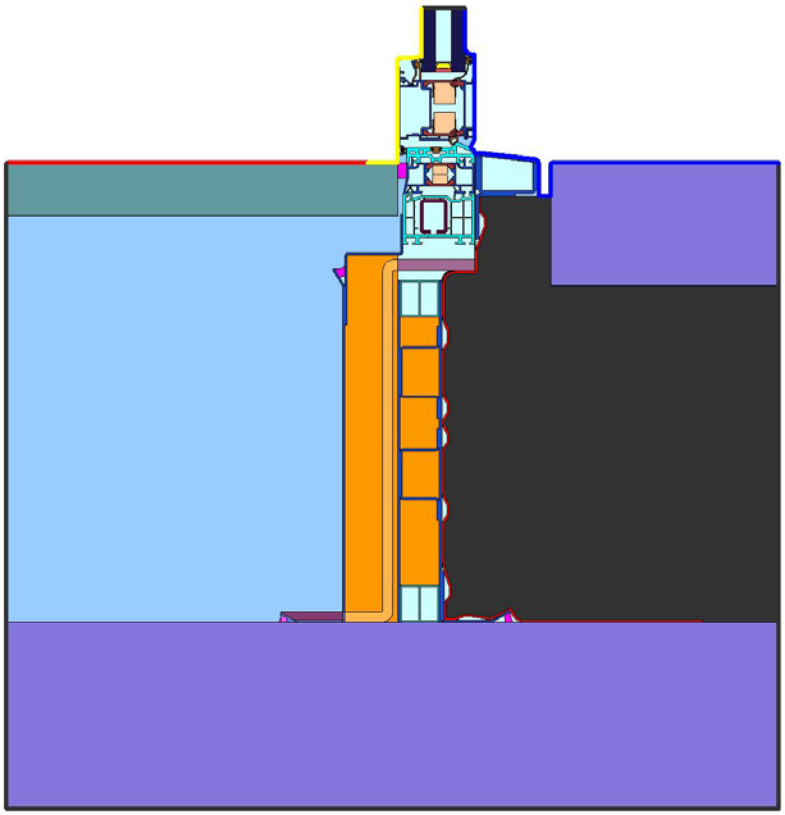
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Gasfilling(1)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide (1)	0,400	0,900	
SIDERISE Fire Stop	0,039	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 9-350	1,195	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{17{,}247}{24{,}0 \cdot 0{,}54} = 1{,}33\ W/(m^2 \cdot K)$$

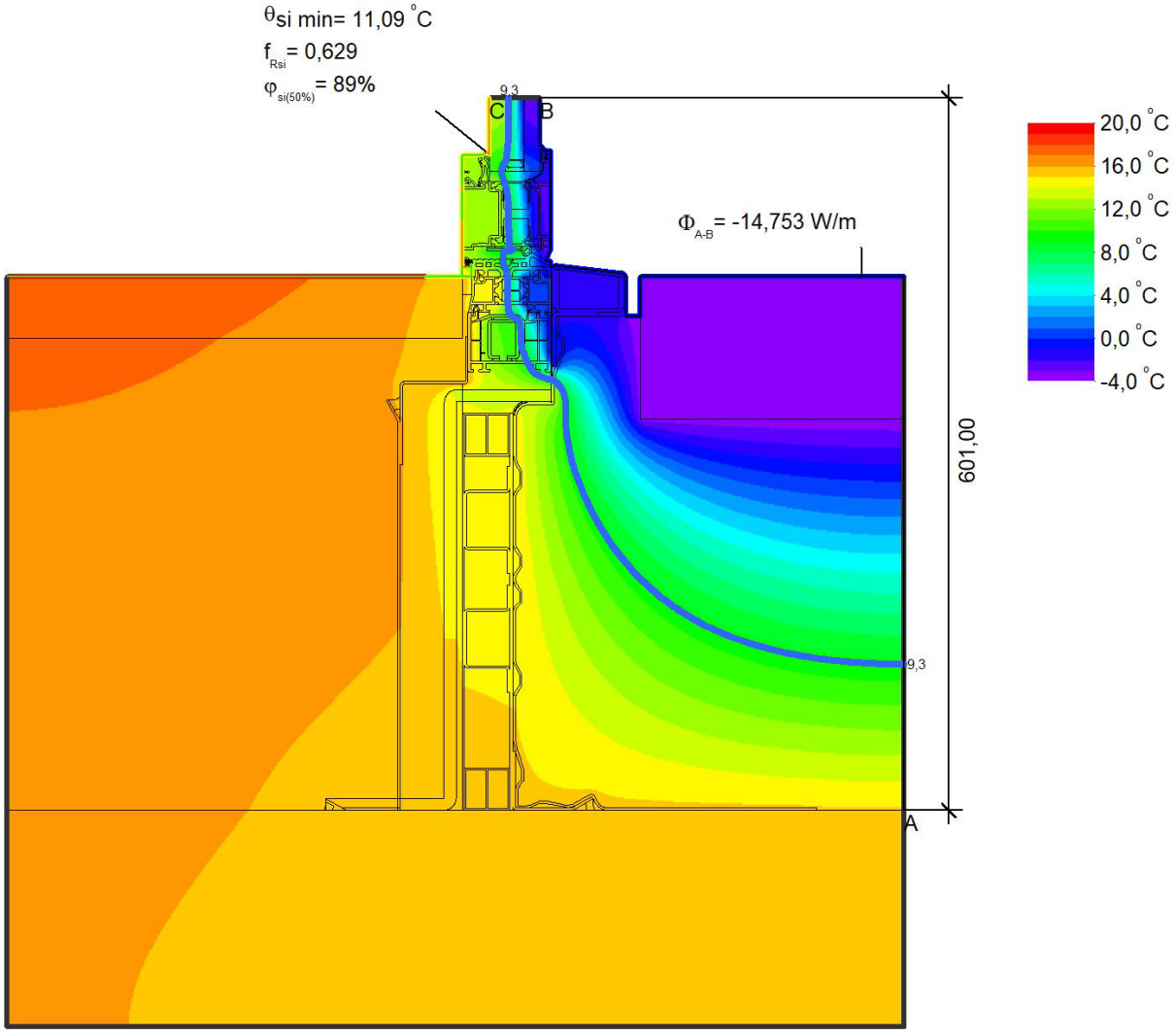
VD-3



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

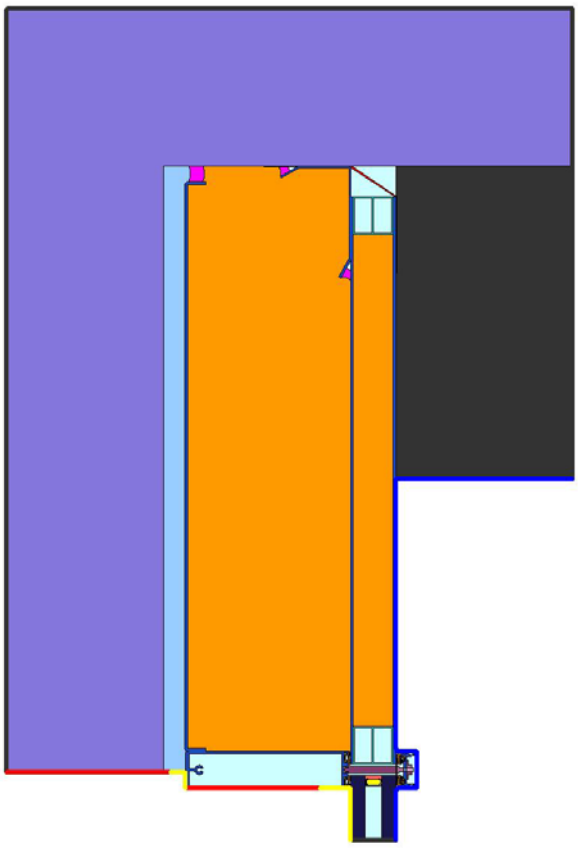
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl rubber, solid/hot melt (5)	0,240	0,900	
Butyl rubber, solid/hot melt (6)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Floor finishing	2,800	0,900	10000,000
Gasfilling(2)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
Insulation by other	0,035	0,900	
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide (2)	0,400	0,900	
SIKA Membrane Universal	0,250	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant) (2)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent R 100-300(5)	123,333	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent R 100-300(6)	123,333	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent R 100-300(7)	123,333	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent R 100-300(8)	123,333	0,900	
Steel / Insulation Knauf Unifit 035, 3D equivalent R 100-300(2)	16,690	0,900	
Steel / Silicone, 3D equivalent R 100-300(2)	17,000	0,900	
Steel / Slightly ventilated air cavity, 3D equivalent R1 100-300	17,000	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent R2 100-300	16,867	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{14{,}753}{24{,}0 \cdot 0{,}601} = 1{,}02\ W/(m^2 \cdot K)$$

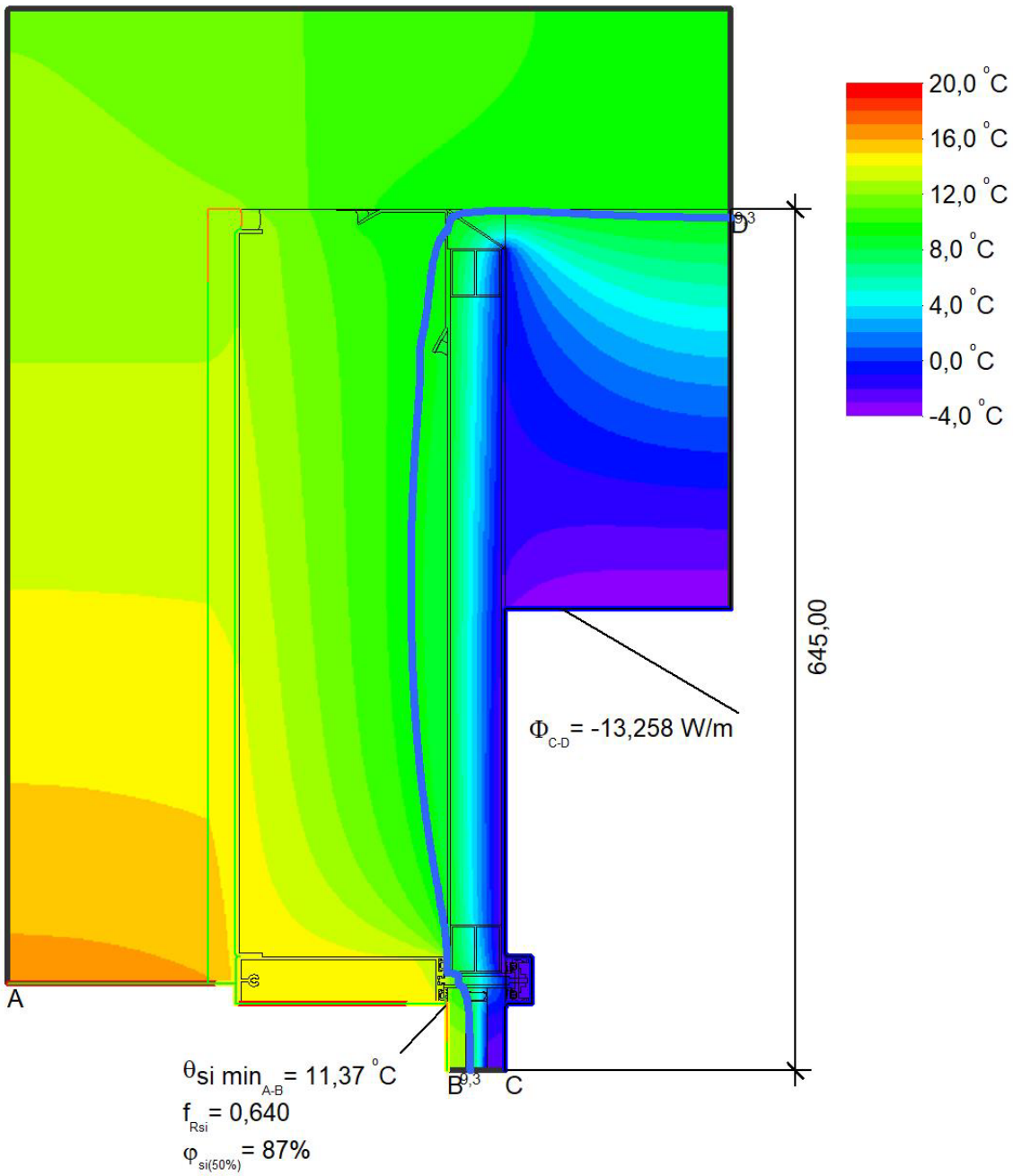
VD-4



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

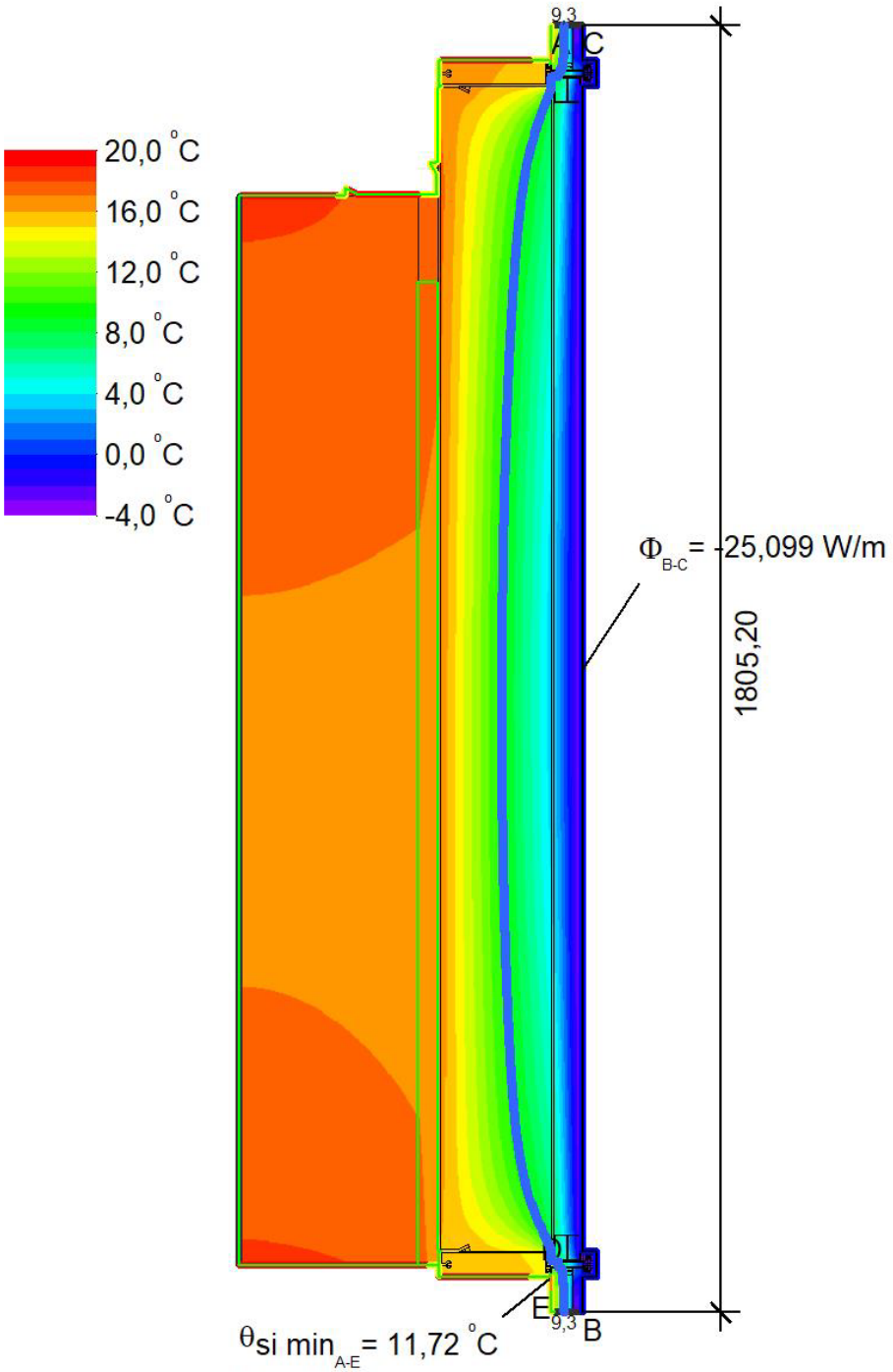
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Gasfilling(1)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
Insulation by other	0,035	0,900	
PVC	0,170	0,900	
Polycarbonat	0,240	0,900	
Polysulfide (1)	0,400	0,900	
SIKA Membrane Universal	0,250	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 9-350	1,198	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,062	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



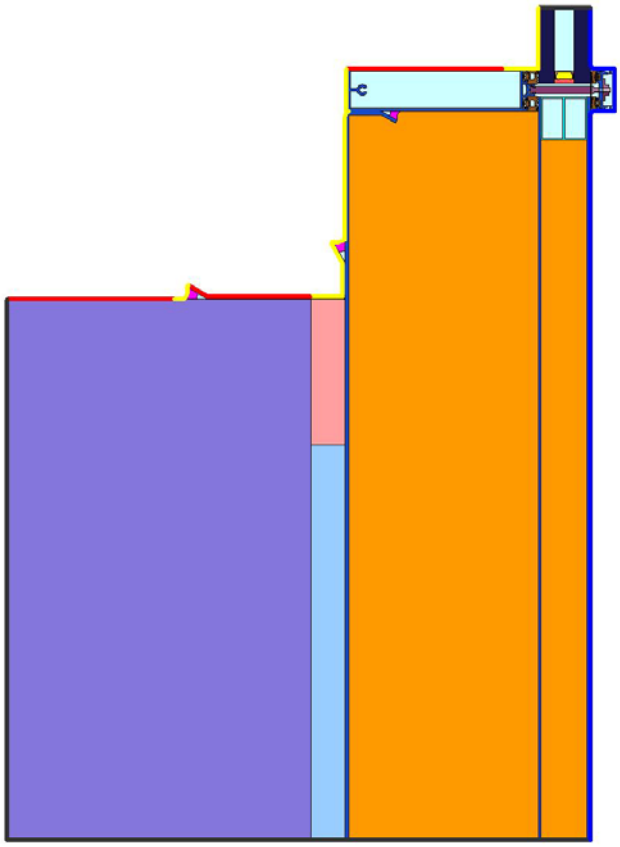
$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{13{,}258}{24{,}0 \cdot 0{,}645} = 0{,}856\ W/(m^2 \cdot K)$$

VD-5



$$U_{eq\ B\text{-}C} = \frac{\Phi}{\Delta T \cdot b} = \frac{25{,}099}{24{,}0 \cdot 1{,}805} = 0{,}579\ W/(m^2 \cdot K)$$

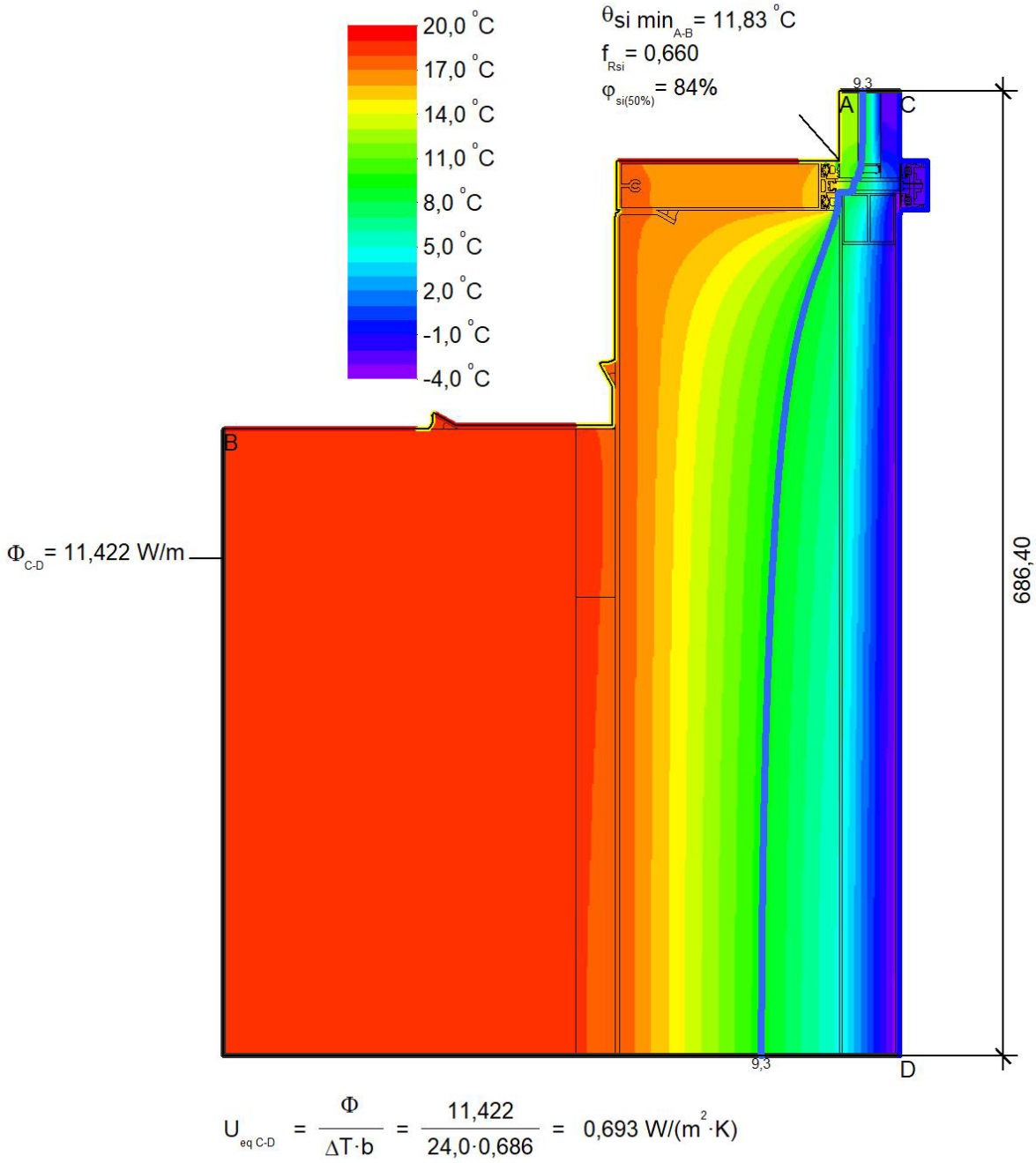
VD-6



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

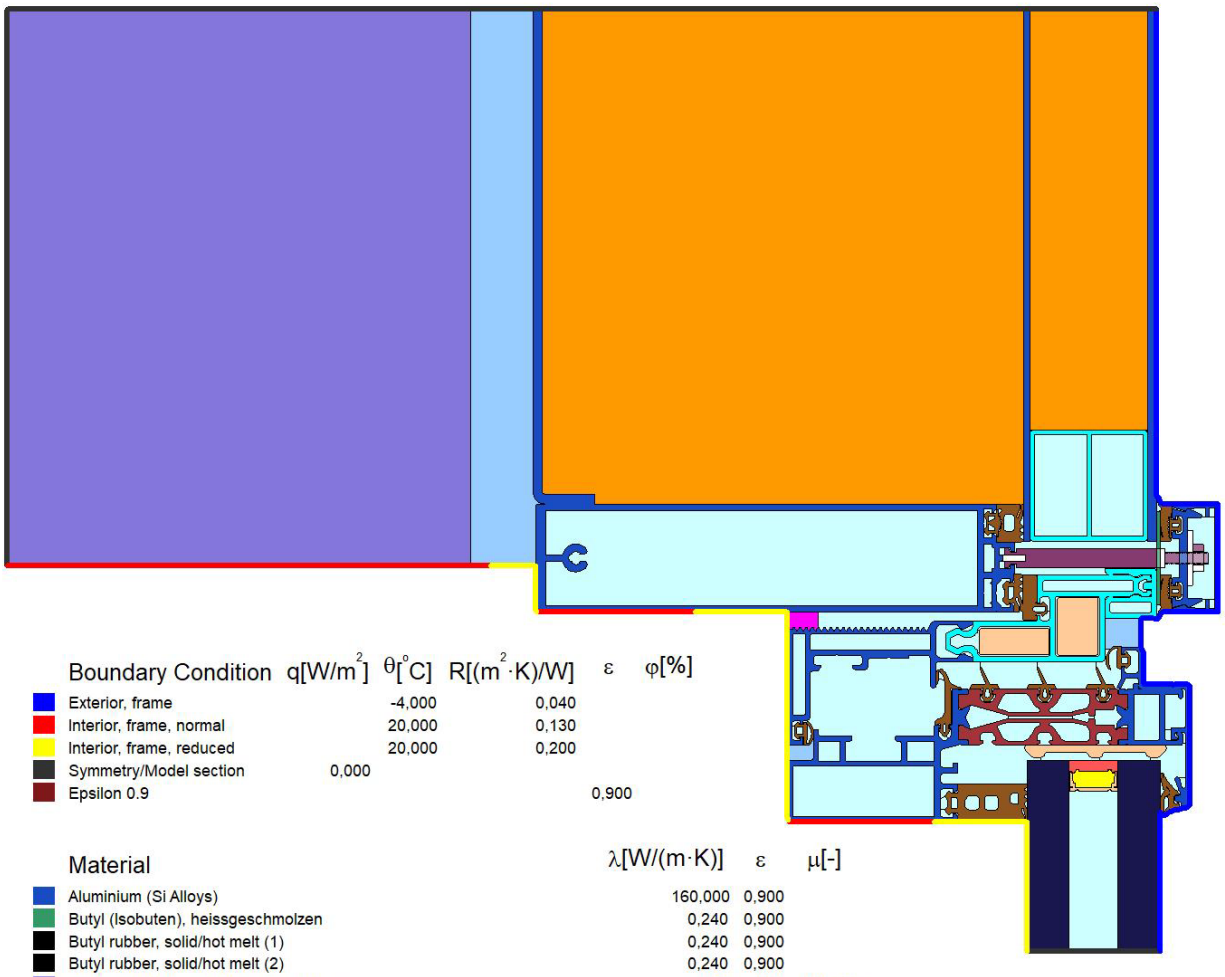
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Gasfilling(1)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
PVC	0,170	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
SIDERISE Fire Stop	0,039	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 9-350	1,203	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,062	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{11{,}422}{24{,}0 \cdot 0{,}686} = 0{,}693\ W/(m^2 \cdot K)$$

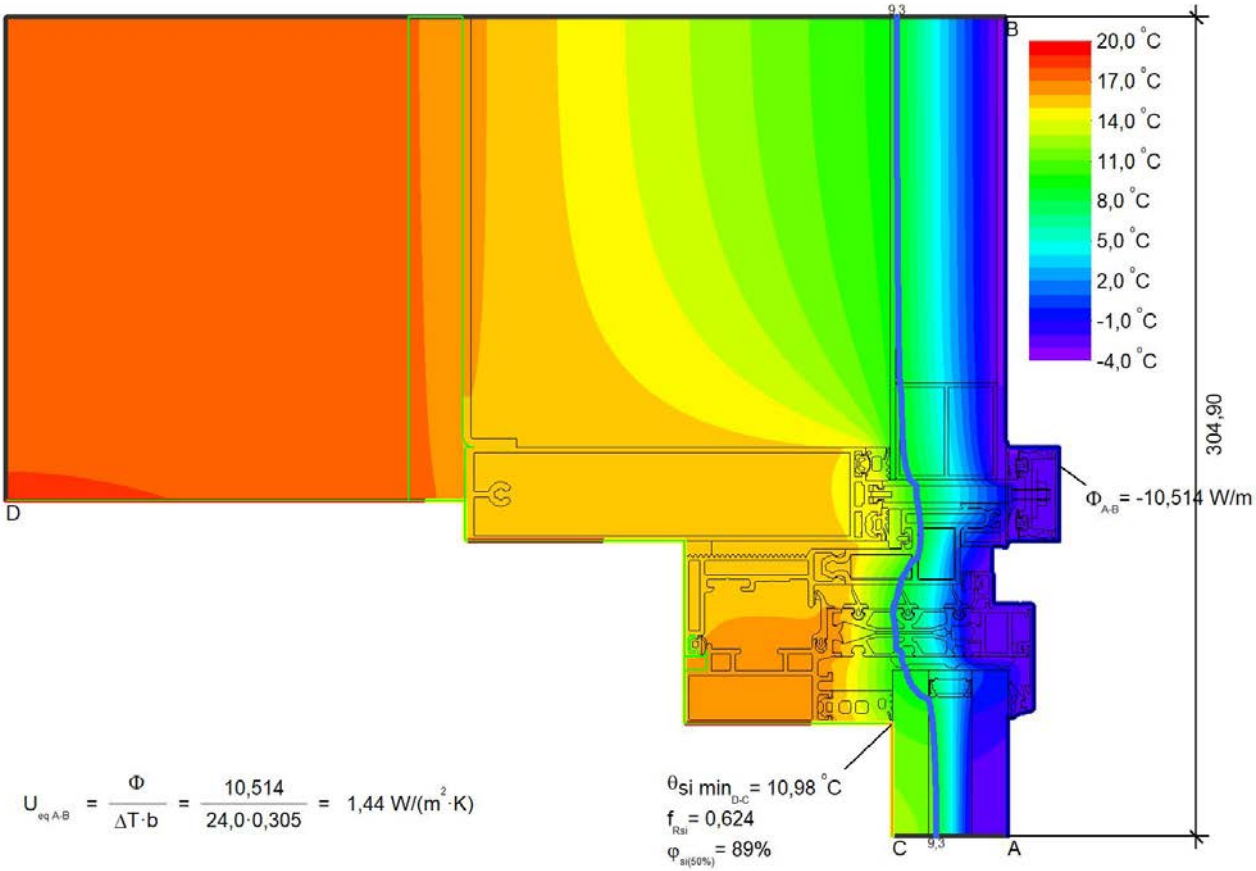
VD-7



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

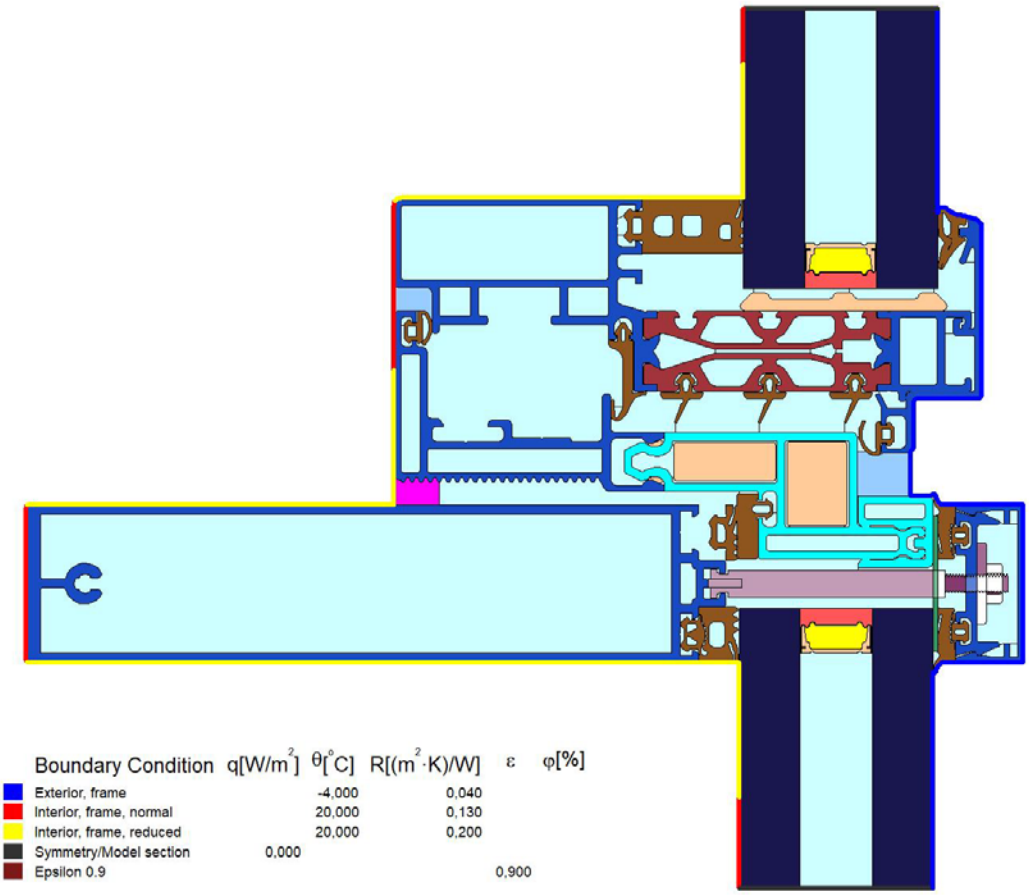
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Gasfilling(10)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350(5)	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350(5)	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 9-350	1,184	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,062	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,087	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,044	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,043	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 18-350	2,049	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,095	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\,A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{10{,}514}{24{,}0 \cdot 0{,}305} = 1{,}44\ W/(m^2 \cdot K)$$

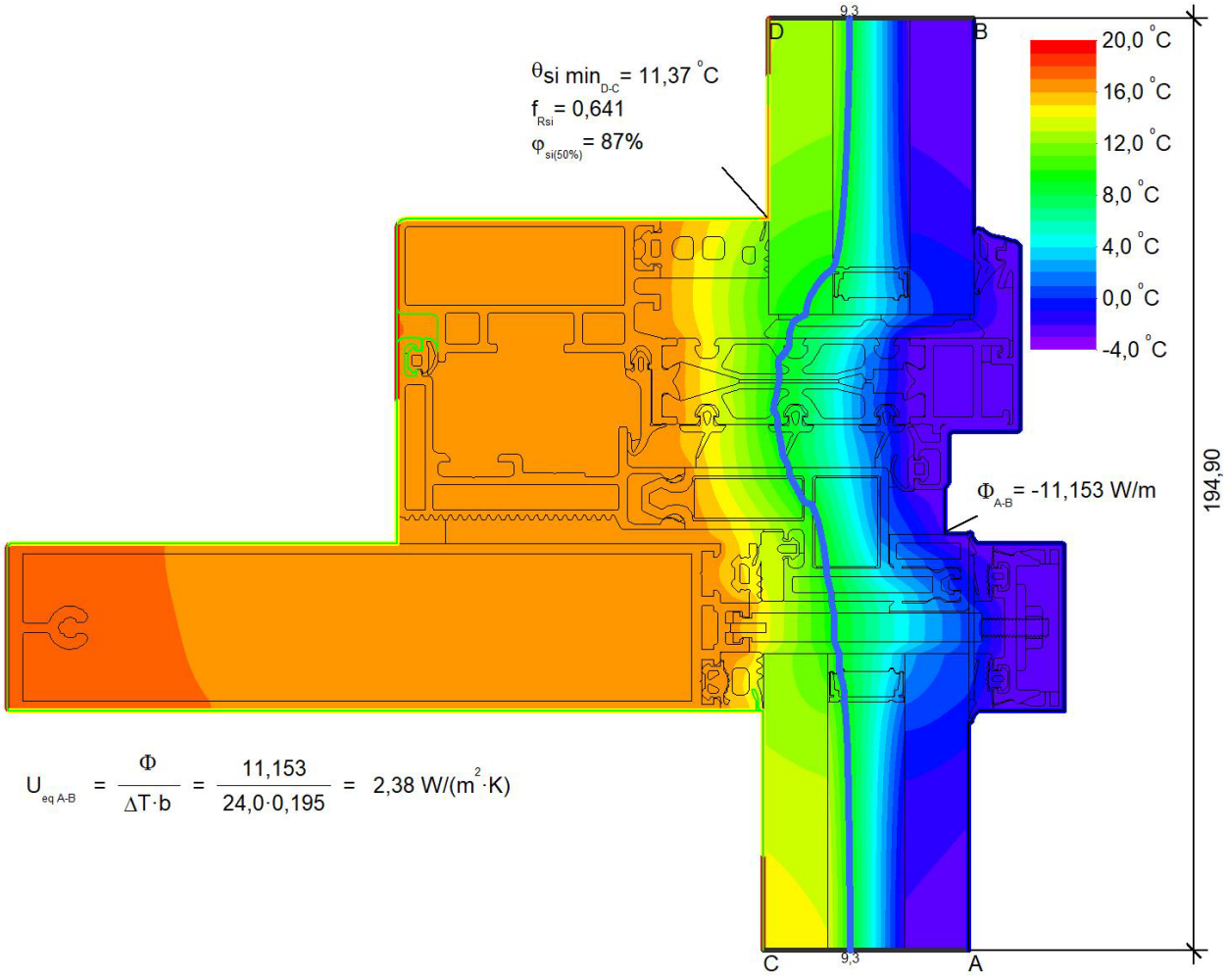
VD-8



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

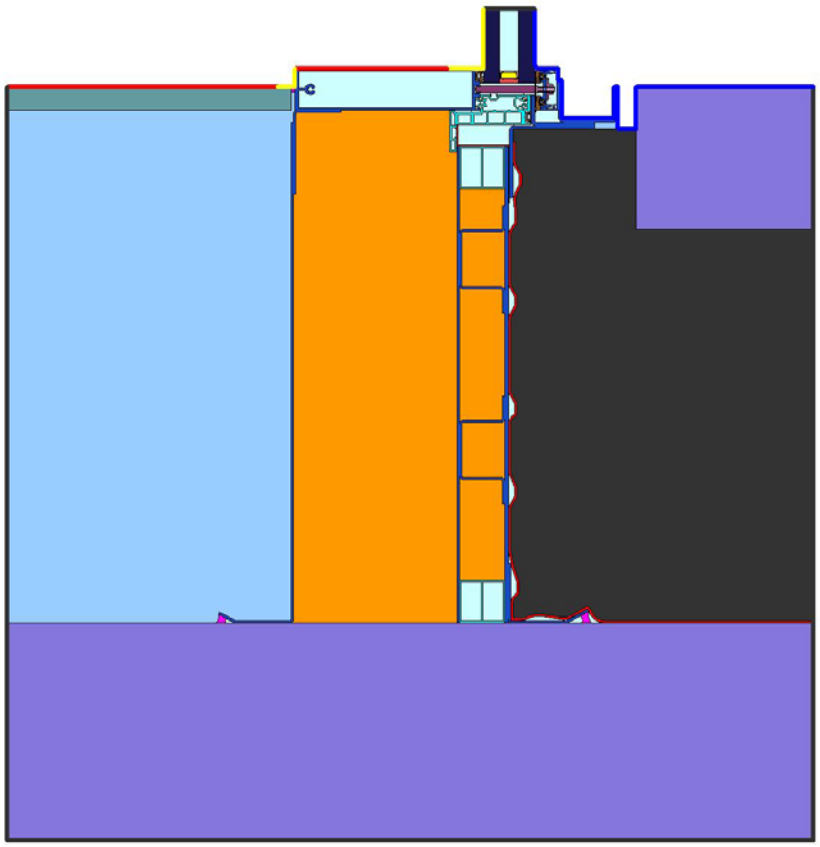
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (SI Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Butyl rubber, solid/hot melt (5)	0,240	0,900	
Butyl rubber, solid/hot melt (6)	0,240	0,900	
Gasfilling(11)	0,020	0,900	1,000
Gasfilling(12)	0,020	0,900	1,000
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide (1)	0,400	0,900	
Polysulfide (2)	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Silica gel (desiccant) (2)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (SI Alloys), 3D equivalent C 9-350(6)	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350(6)	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,049	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 18-350	2,096	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,196	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,196	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,062	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 9-350	1,087	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{11{,}153}{24{,}0 \cdot 0{,}195} = 2{,}38\ W/(m^2 \cdot K)$$

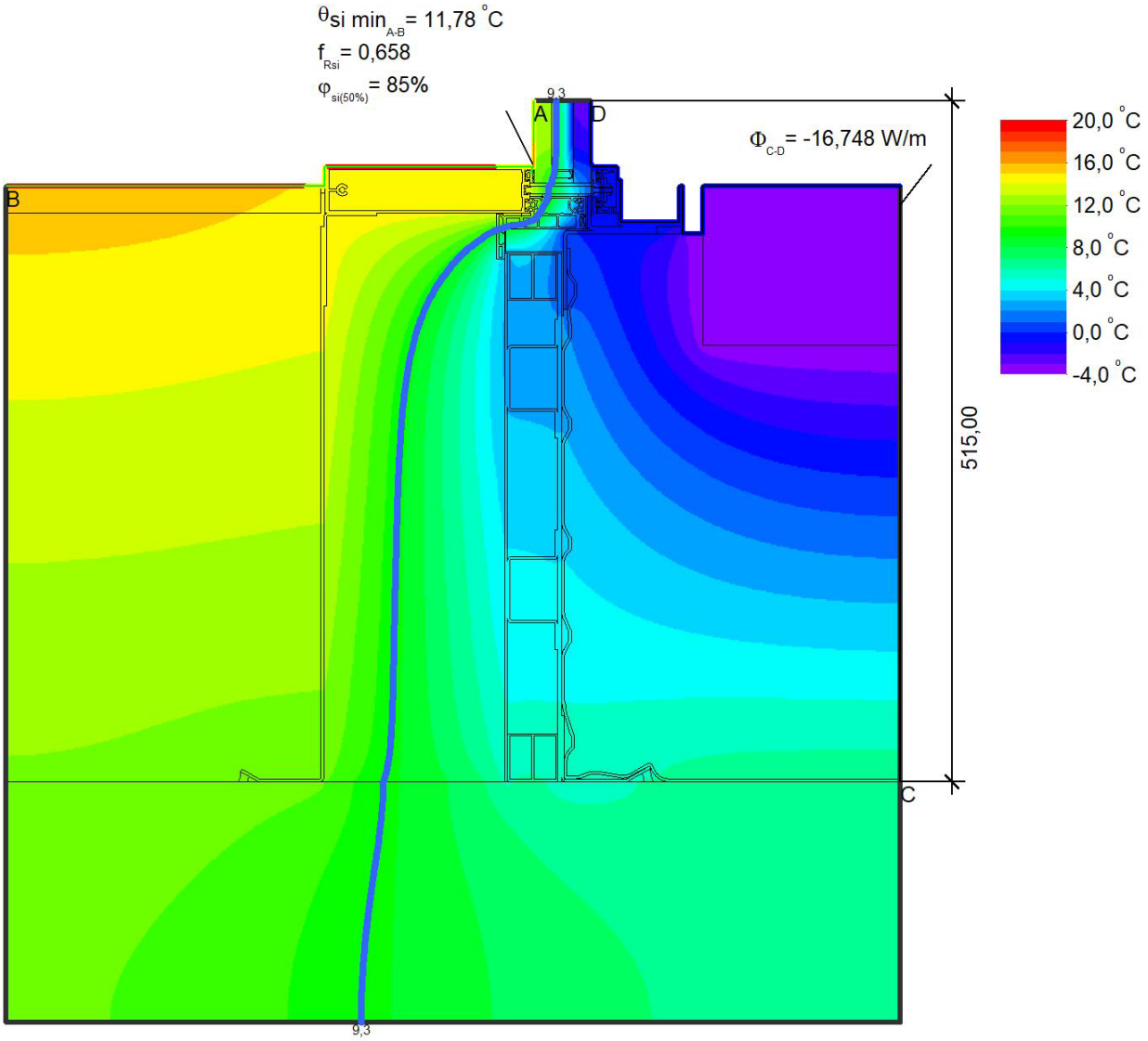
VD-9



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

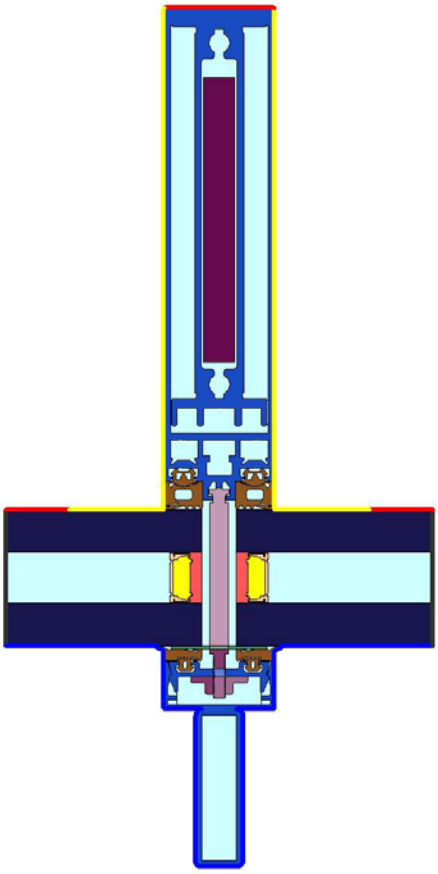
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Floor finishing	2,800	0,900	10000,000
Gasfilling(1)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
Insulation by other	0,035	0,900	
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
SIKA Membrane Universal	0,250	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 9-350	1,182	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,063	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,091	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 18-350	2,099	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,099	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{16{,}748}{24{,}0 \cdot 0{,}515} = 1{,}36\ W/(m^2 \cdot K)$$

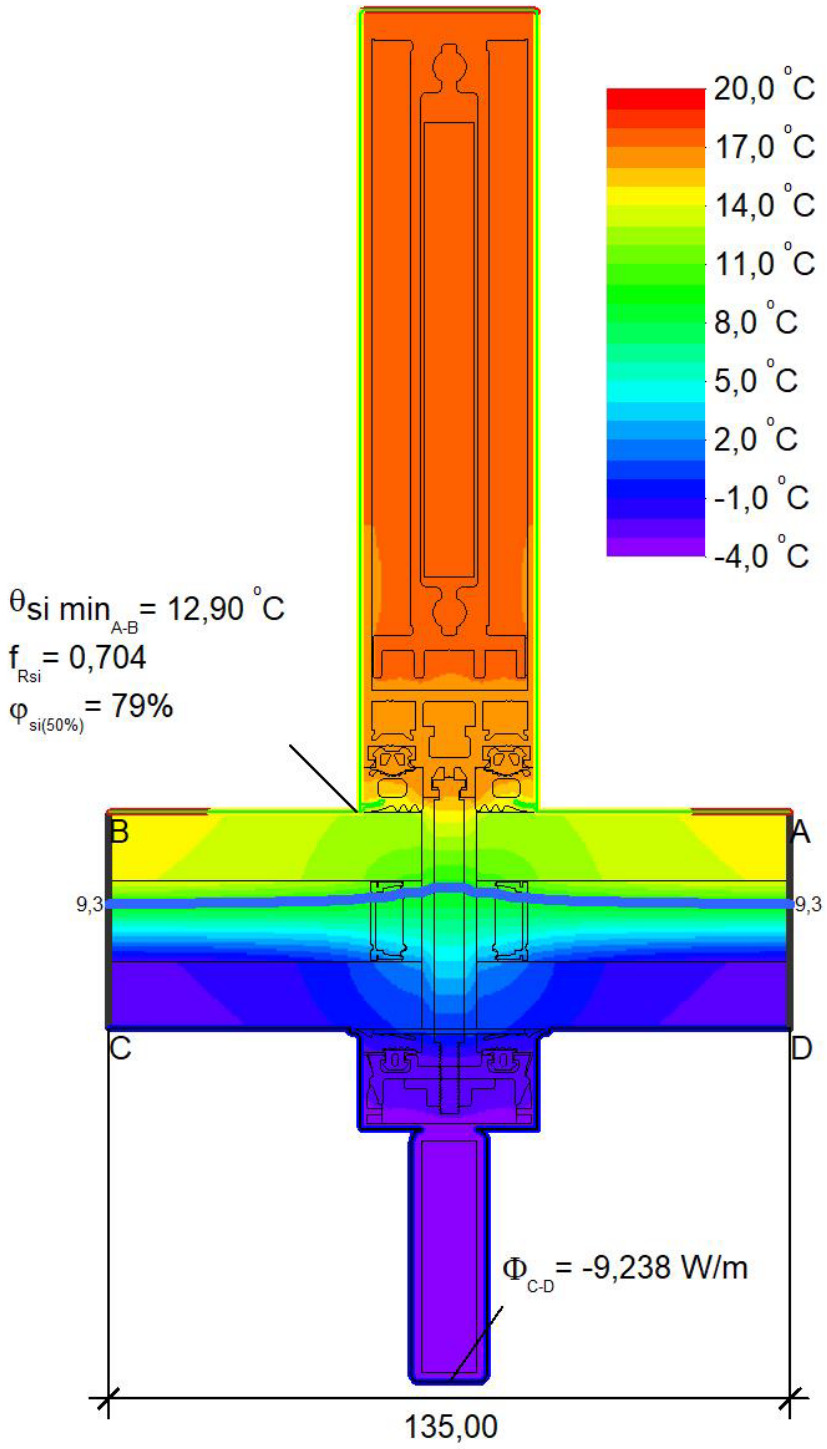
HD-1



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

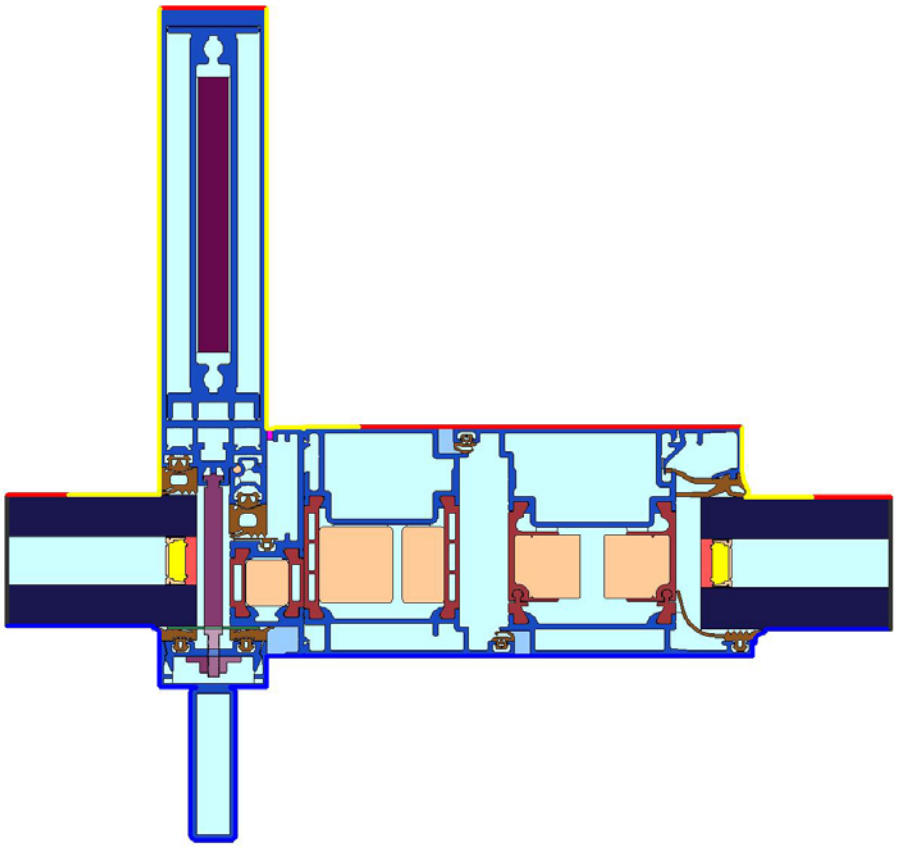
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Gasfilling(1)	0,020	0,900	1,000
Gasfilling(2)	0,020	0,900	1,000
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
Polysulfide (1)	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,209	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,062	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{9{,}238}{24{,}0 \cdot 0{,}135} = 2{,}85\ W/(m^2 \cdot K)$$

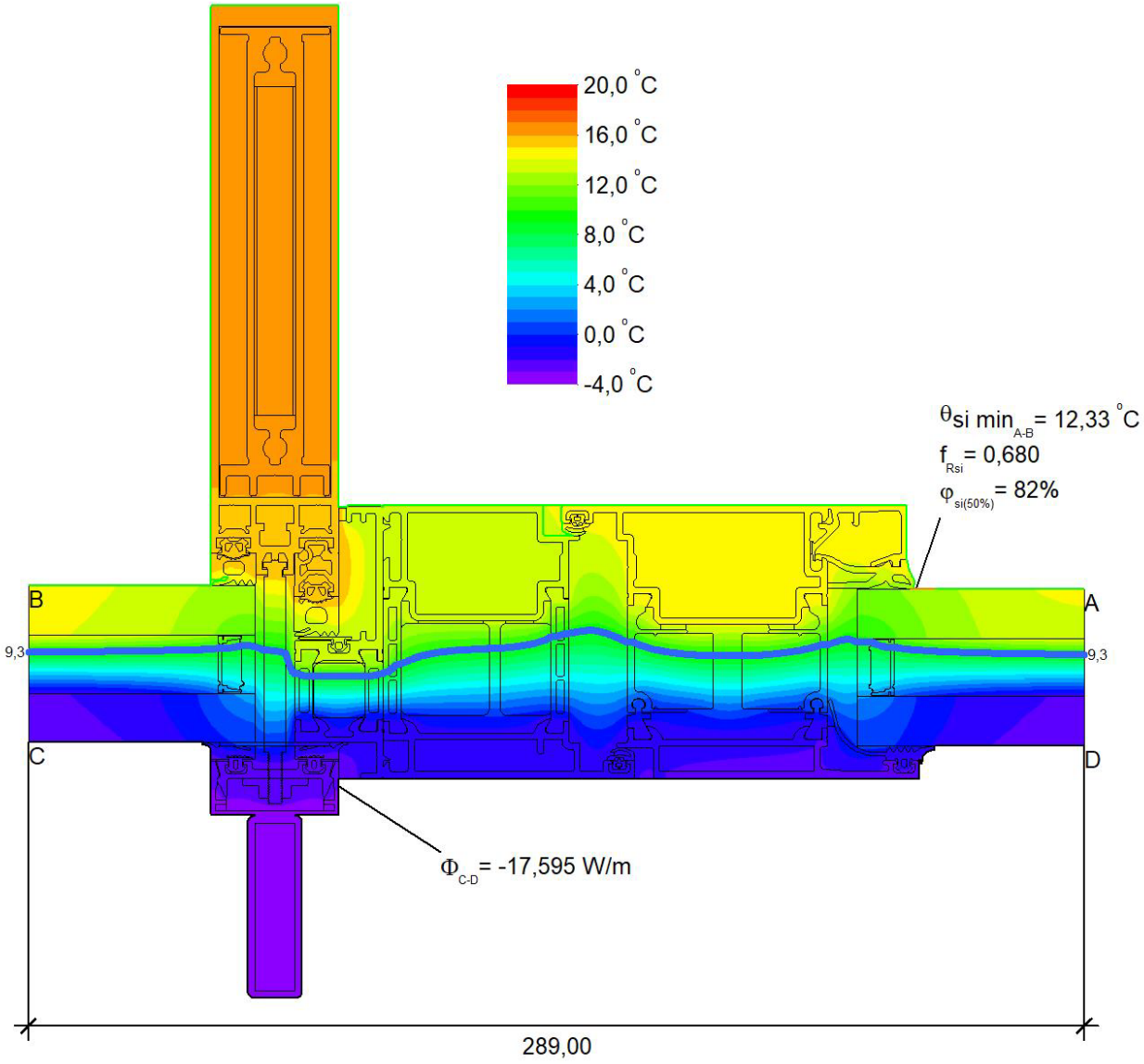
HD-2



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Gasfilling(1)	0,020	0,900	1,000
Gasfilling(2)	0,020	0,900	1,000
PET-Shaum	0,035	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
Polysulfide (1)	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,201	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

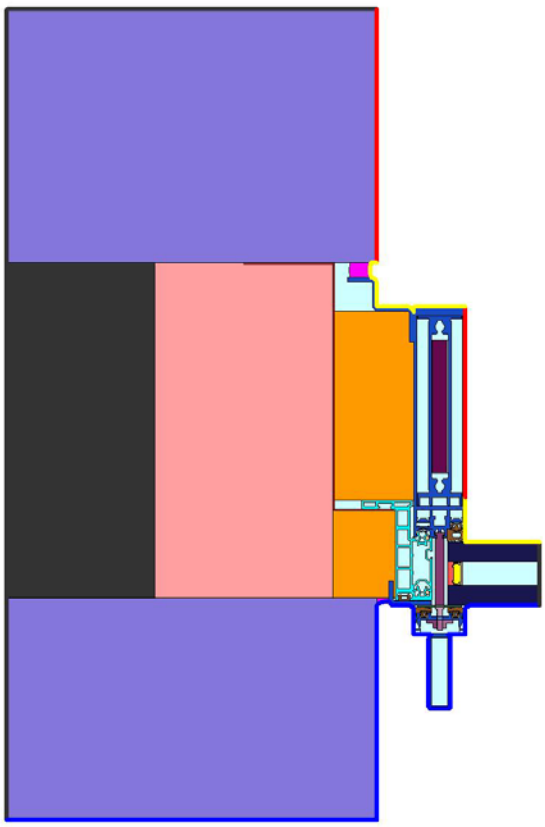
* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{17{,}595}{24{,}0 \cdot 0{,}289} = 2{,}54\ W/(m^2 \cdot K)$$

HD-3

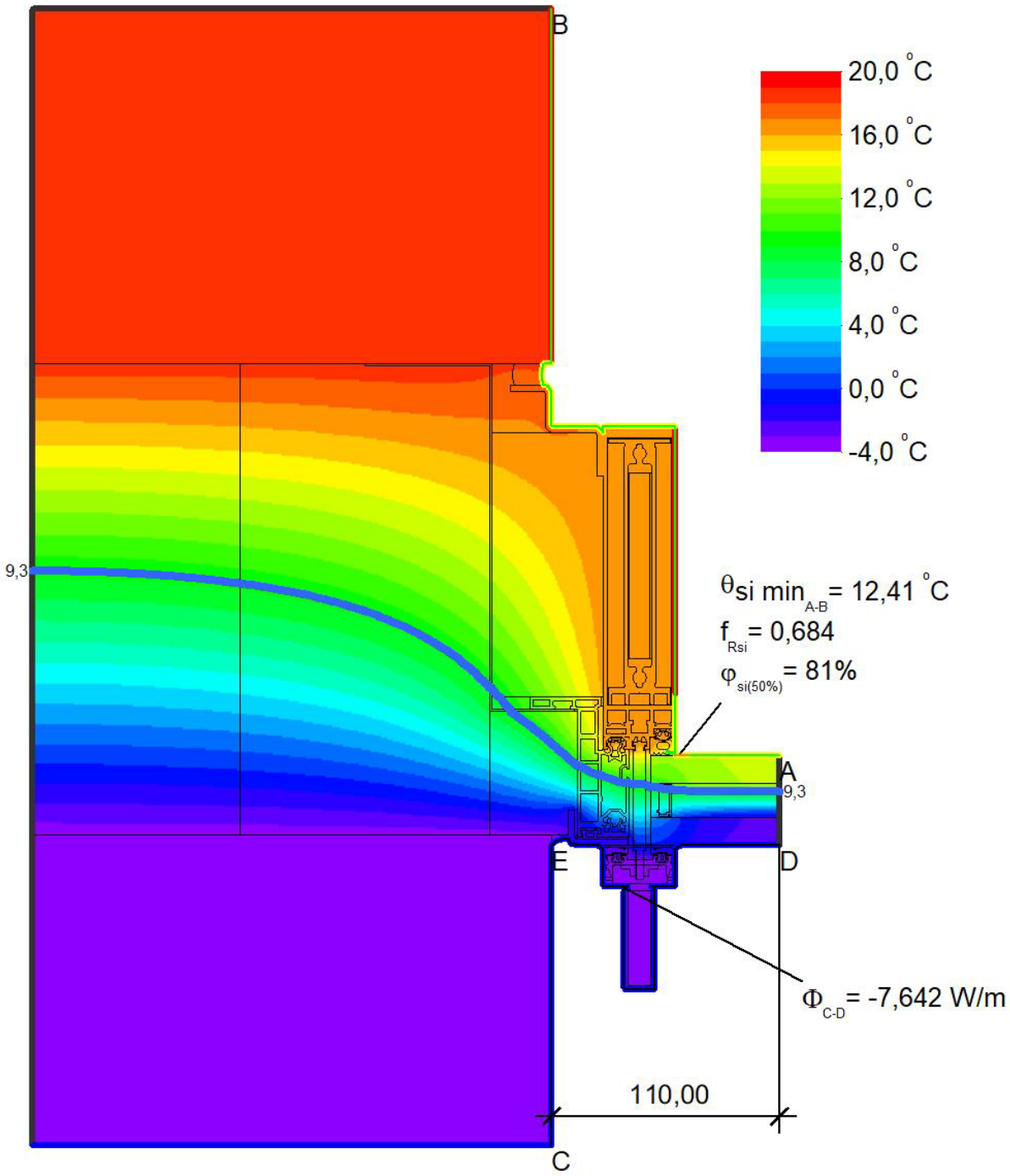
HD-4



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Edelstahl, Fa. SGG	15,000	0,900	1,000
Gasfilling(1)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
Insulation by other	0,035	0,900	
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
SIDERISE Fire Stop	0,039	0,900	
SIKA Membrane Universal	0,250	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,089	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,194	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Unventilated air cavity *			1,000

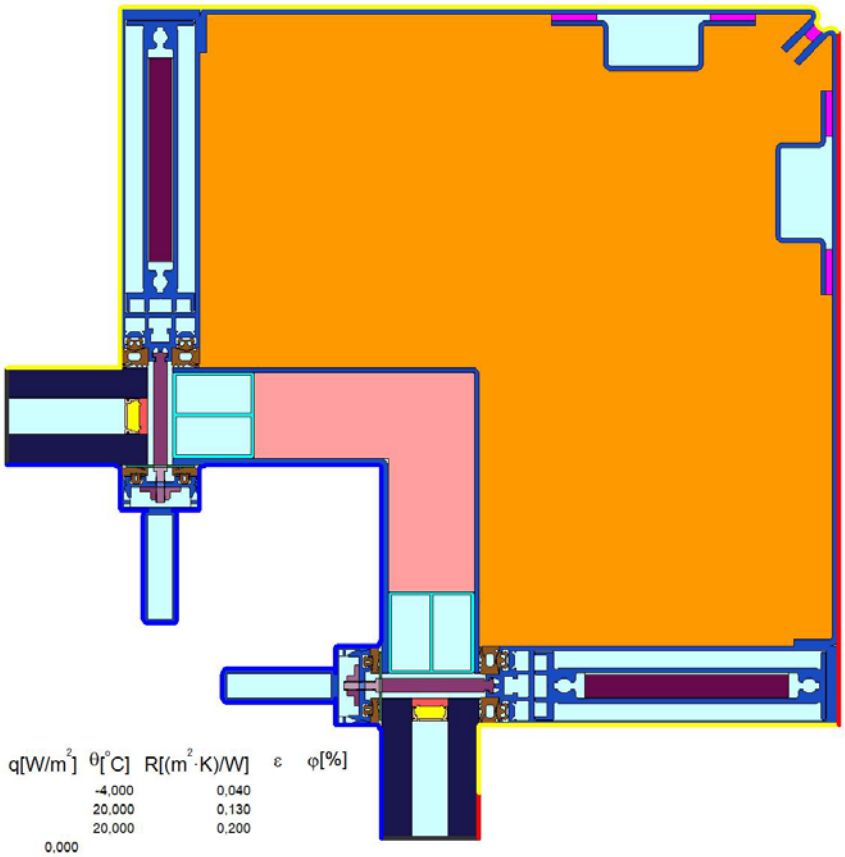
* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{7{,}642}{24{,}0 \cdot 0{,}11} = 2{,}89\ W/(m^2 \cdot K)$$

Section heat flux: 9,1%

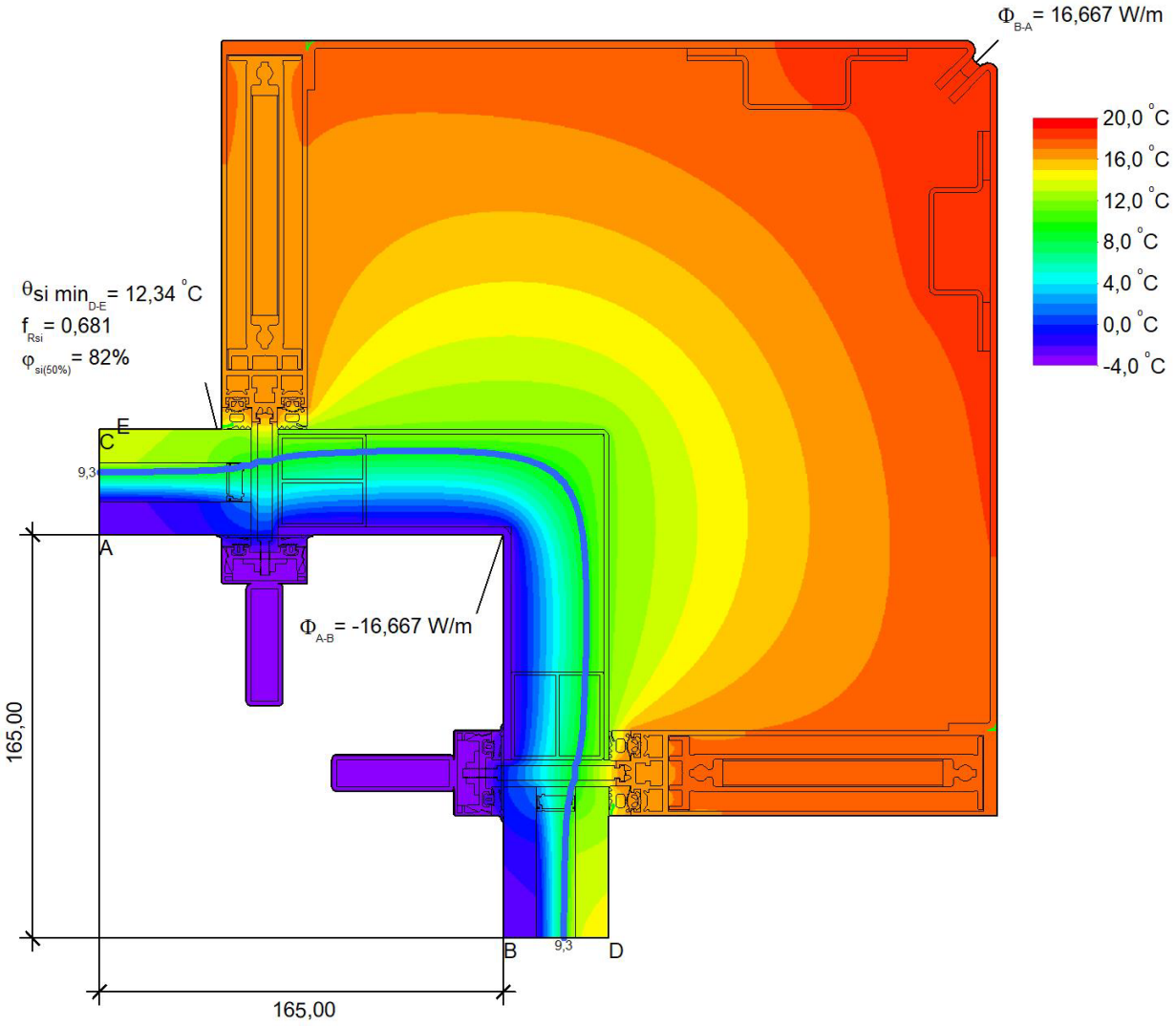
HD-5



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

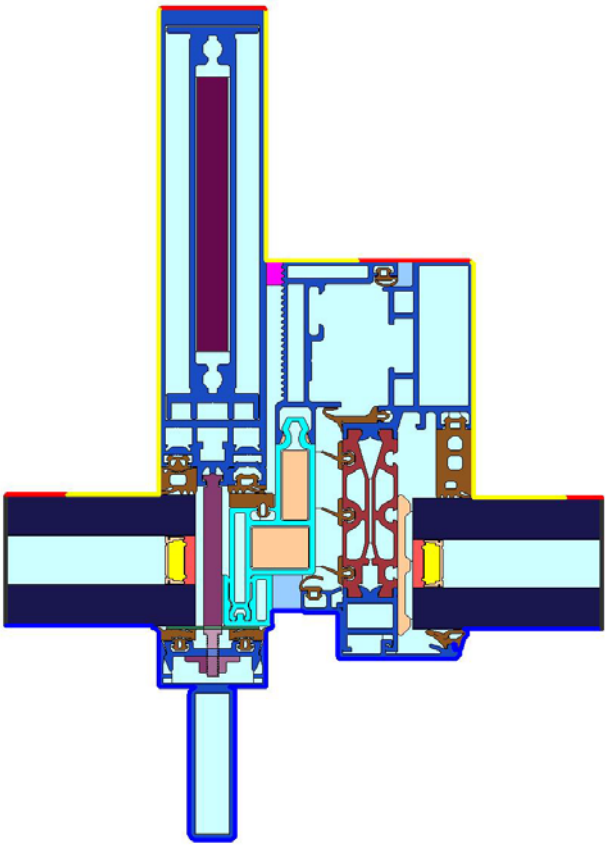
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (5)	0,240	0,900	
Butyl rubber, solid/hot melt (6)	0,240	0,900	
Butyl rubber, solid/hot melt (7)	0,240	0,900	
Butyl rubber, solid/hot melt (8)	0,240	0,900	
Gasfilling(1)	0,020	0,900	1,000
Gasfilling(2)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
PVC	0,170	0,900	
Polycarbonat	0,240	0,900	
Polysulfide (2)	0,400	0,900	
Polysulfide (3)	0,400	0,900	
SIDERISE Fire Stop	0,039	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant) (2)	0,130	0,900	
Silica gel (desiccant) (3)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C10 9-350	1,208	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,089	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,207	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C6 9-350	1,089	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C7 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C8 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C9 9-350	1,065	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{16{,}667}{24{,}0 \cdot 0{,}165} = 4{,}21\ W/(m^2 \cdot K) \qquad U_{eq\ B\text{-}A} = \frac{\Phi}{\Delta T \cdot b} = \frac{16{,}667}{24{,}0 \cdot 0{,}165} = 4{,}21\ W/(m^2 \cdot K)$$

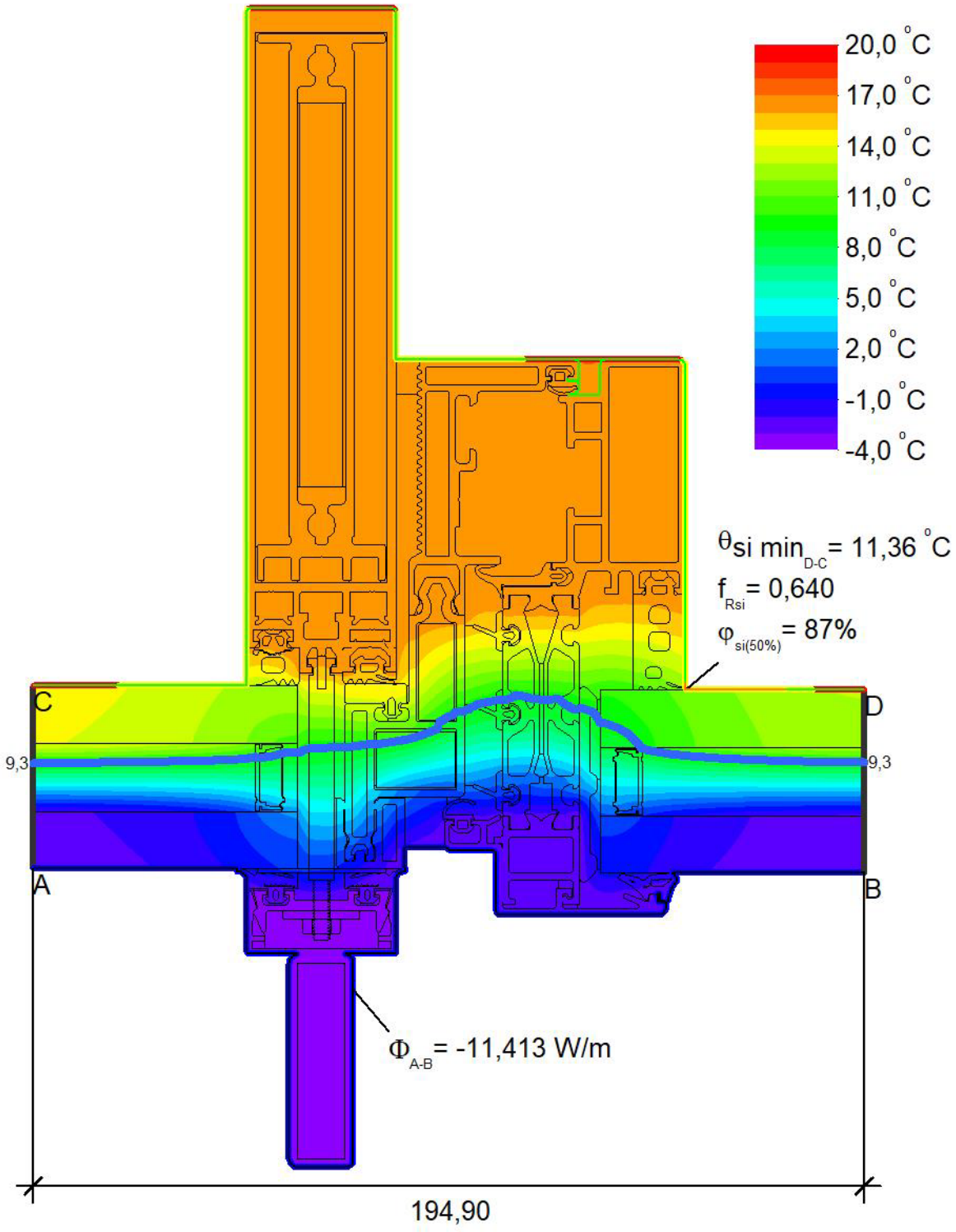
HD-6



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

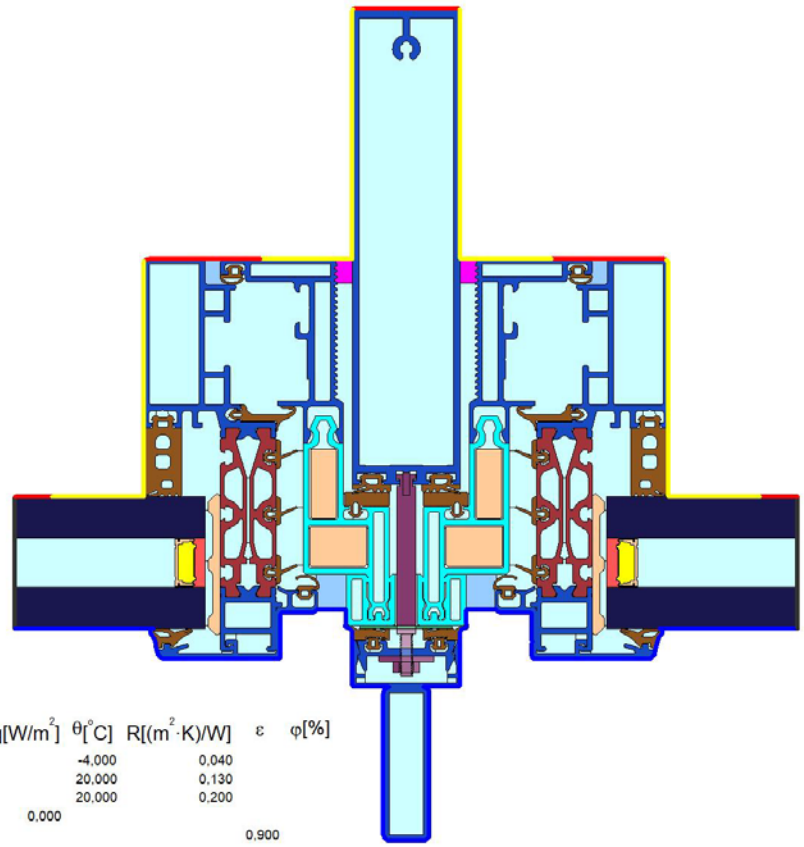
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Butyl rubber, solid/hot melt (3)	0,240	0,900	
Butyl rubber, solid/hot melt (4)	0,240	0,900	
Gasfilling(14)	0,020	0,900	1,000
Gasfilling(15)	0,020	0,900	1,000
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
Polysulfide (1)	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silica gel (desiccant) (1)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,090	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,202	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{11{,}413}{24{,}0 \cdot 0{,}195} = 2{,}44\ W/(m^2 \cdot K)$$

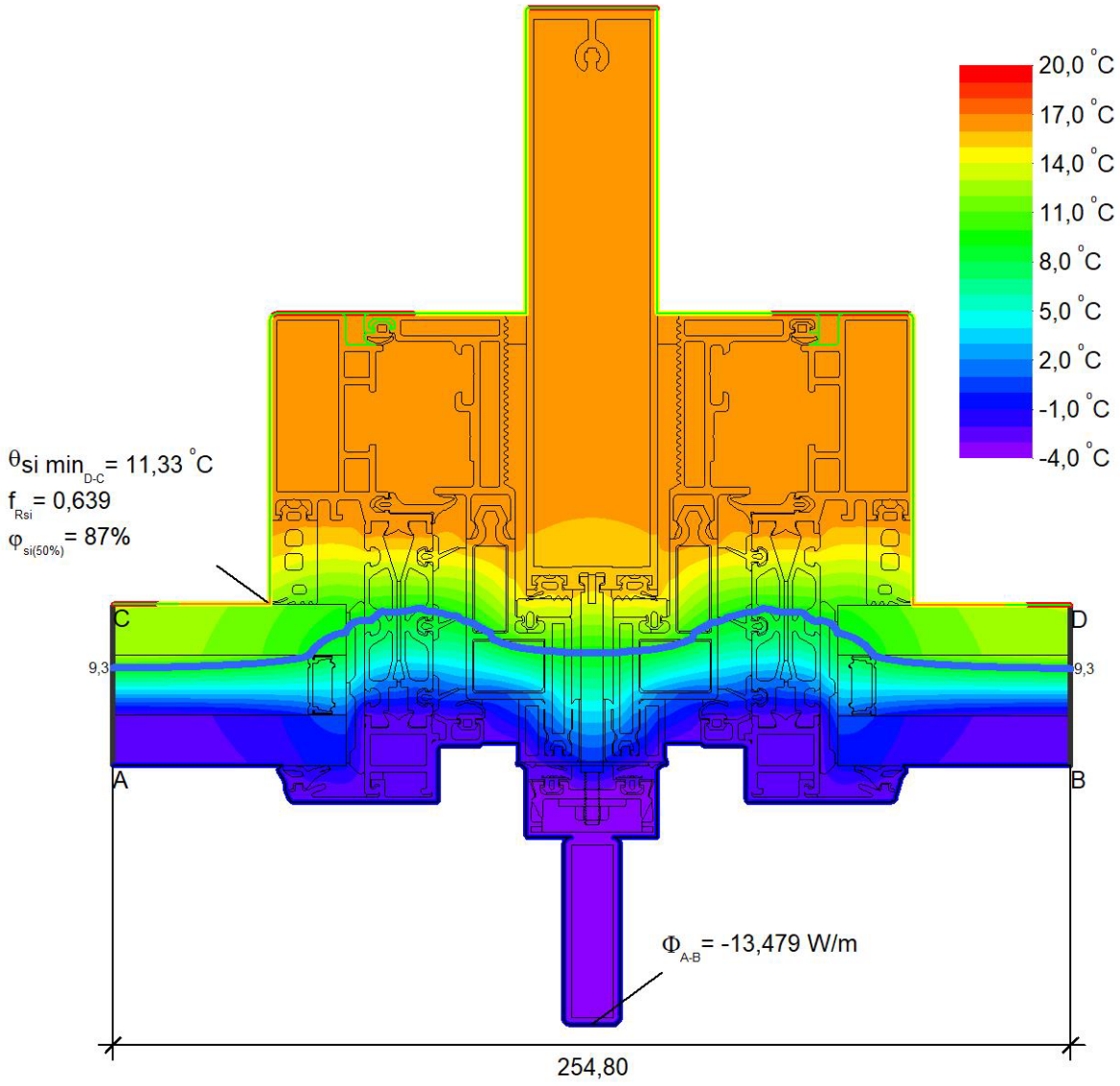
HD-7



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

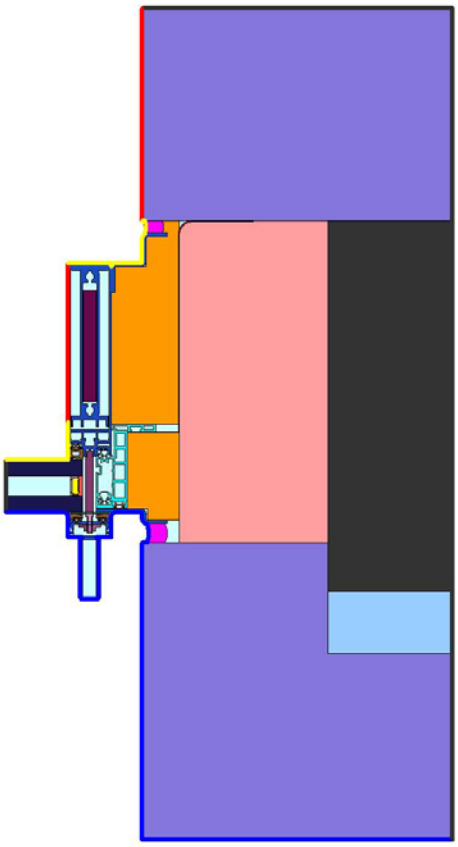
Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (5)	0,240	0,900	
Butyl rubber, solid/hot melt (6)	0,240	0,900	
Butyl rubber, solid/hot melt (7)	0,240	0,900	
Butyl rubber, solid/hot melt (8)	0,240	0,900	
Gasfilling(16)	0,020	0,900	1,000
Gasfilling(17)	0,020	0,900	1,000
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polyamid 6.6 with 25% glass fibre	0,300	0,900	
Polycarbonat	0,240	0,900	
Polysulfide (2)	0,400	0,900	
Polysulfide (3)	0,400	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant) (2)	0,130	0,900	
Silica gel (desiccant) (3)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350(4)	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350(4)	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,049	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,095	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,095	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,087	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,044	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,043	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,065	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,192	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,192	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,095	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,095	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,095	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ A\text{-}B} = \frac{\Phi}{\Delta T \cdot b} = \frac{13{,}479}{24{,}0 \cdot 0{,}255} = 2{,}20\ W/(m^2 \cdot K)$$

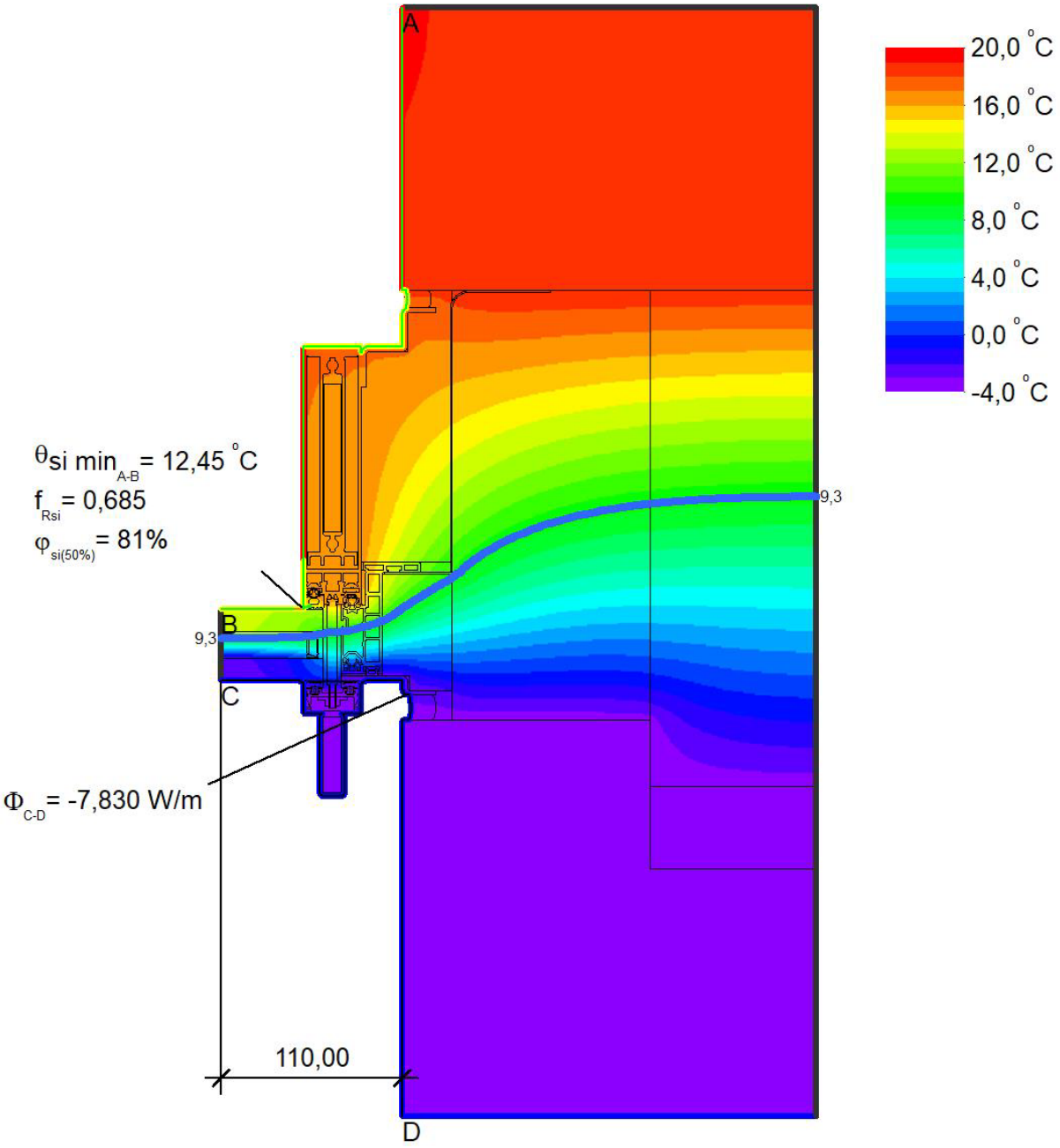
HD-8



Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]	ε	φ[%]
Exterior, frame		-4,000	0,040		
Interior, frame, normal		20,000	0,130		
Interior, frame, reduced		20,000	0,200		
Symmetry/Model section	0,000				
Epsilon 0.9				0,900	

Material	λ[W/(m·K)]	ε	μ[-]
Aluminium (Si Alloys)	160,000	0,900	
Butyl (Isobuten), heissgeschmolzen	0,240	0,900	
Butyl rubber, solid/hot melt (1)	0,240	0,900	
Butyl rubber, solid/hot melt (2)	0,240	0,900	
Concrete, reinforced (with 2% of steel)	2,500	0,900	105,000
Edelstahl, Fa. SGG	15,000	0,900	1,000
Gasfilling(1)	0,020	0,900	1,000
Insulation Knauf Unifit 035	0,035	0,900	
Insulation by other	0,035	0,900	
PET-Shaum	0,035	0,900	
PVC	0,170	0,900	
Polycarbonat	0,240	0,900	
Polysulfide	0,400	0,900	
SIDERISE Fire Stop	0,039	0,900	
SIKA Membrane Universal	0,250	0,900	
Schuco Gasket	0,250	0,900	
Silica gel (desiccant)	0,130	0,900	
Silicone	0,500	0,900	
Soda lime glass	1,000	0,900	
Stainless steel	17,000	0,900	
Steel	50,000	0,900	
Steel / Aluminium (Si Alloys), 3D equivalent C 9-350	157,778	0,900	
Steel / Butyl (Isobuten), heissgeschmolzen, 3D equivalent C 9-350	1,245	0,900	
Steel / Unventilated air cavity, 3D equivalent C1 18-350	2,098	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C2 9-350	1,089	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C3 9-350	1,062	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C4 9-350	1,195	0,900	1,000
Steel / Unventilated air cavity, 3D equivalent C5 18-350	2,098	0,900	1,000
Slightly ventilated air cavity *			1,000
Unventilated air cavity *			1,000

* EN ISO 10077-2:2017, 6.4.3/anisotrop



$$U_{eq\ C\text{-}D} = \frac{\Phi}{\Delta T \cdot b} = \frac{7,83}{24,0 \cdot 0,11} = 2,97\ W/(m^2 \cdot K)$$