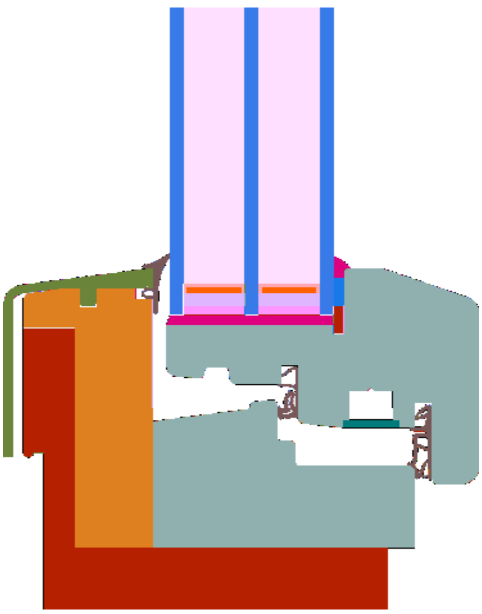
Passivhaus Institut

Thermal bridge calculation for the certification of the window frame PROGRESSION as a suitable component for Passive Houses

for
SLAVONA, s.r.o.
Stálkovská 258
Slavonice Czech Republic



Passivhaus Institut
Rheinstraße 44/46
D-64283 Darmstadt
Phone: +49 6151 82699 0
Fax: +49 6151 82699 11
mail@passiv.de www.passiv.de

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Author: Esther Gollwitzer

Table of contents

1. Introduction

Because a separate heating system is not necessarily required in Passive Houses, high demands are placed on the quality of the building components used. If no radiator under the windows is planned, the thermal transmittance U_W (U-value) of the window used may not exceed 0.80 W/(m²K), in order to prevent unpleasant radiant heat deprivation and cold air descent at the window. For a given quality of glazing, this results in restriction of the thermal bridge loss coefficient for window frames.
The following requirements for the certificate "Passive House suitable component" have been set by the PHI:

$$\mathbf{U_W \leq 0.80\ W/(m^2K)}$$

U_W is the average thermal transmittance for the whole window. The criterion must be met with U_g = 0.70 W/(m²K) and with a window size of 1.23 m x 1.48 m.

$$\mathbf{U_{W,installed} \leq 0.85\ W/(m^2K)}$$

$U_{W,installed}$ is the U-Value of the installed window. The criterion must be met in minimum three installation situations.

Also the hygiene criterion must be met. For reasons of hygiene, this criterion limits the minimum individual temperature on window surfaces to prevent mould growth. Criterion for cool, temperate climate is:

$$\mathbf{f_{Rsi\_0.25\ m^2K/W} \geq 0.70}$$

At -5°C ambient temperature, 20°C interior temperature and 50% relative humidity is the minimum temperature of the surface therefor is limited to 12.6 °C.

In addition, certified windows will be ranked by the thermal losses through the not transparent parts, aligned to Ψ_{opaque}. These efficiency classes include the U-Value of the frame, the frame width, the Ψ-Value of the Glass edge and the length of the Glass edge:

$$\Psi_{opaque} = \Psi_g + \frac{U_f \cdot A_f}{l_g}$$

Relevant for passive houses is the energy balance, the sum out of losses and gains. Because the solar gains are difficult to quote it is useful to rate the parts of the window, which do not allow solar gains. This does Ψ_{opaque}.

Table 1: Passive house efficency classes

Ψ_{opaque}	Passive house efficiency class	Name
≤ 0.110 W/(mK)	$_{ph}$**A**	Advanced component
≤ 0.155 W/(mK)	$_{ph}$**B**	Basic component
≤ 0.220 W/(mK)	$_{ph}$**C**	Certifiable component

2. Guidelines for thermal bridge calculation for windows

On behalf of the SLAVONA, s.r.o. company in Slavonice, the Passive House Institute has calculated the thermal characteristics for a window based on the regulation EN ISO 10077 (standard size 1.23 m * 1.48 m), with an insulated window frame PROGRESSION.
The calculations were carried out using the heat flow software Bisco by the Belgian company Physibel.

2.1 Description of the window frame

Timber frame (Spruce and Thermowood) with insulation (λ = 0,058W/mK). Used spacer: SwisspacerV.

2.2 Glass, Panel and Spacer

For triple glazing with low-e coating, generally a Glasss U-value of U_g = 0.7 W/(m²K) is assumed for the calculations in the course of certification. In order to meet the certification criterion U_W = 0.80 W/(m²K), a frame (including spacer and edge bond) with the corresponding thermal quality is necessary

Table 2: Properties of the glazing and the panel.

Properties of the glazing	Edge-bond	SwisspacerV	
	Number of panes	3	
	Thickness of the panes	4 / 4 / 4	mm
	Thickness of the gas gap	18	mm
	Glazing	48	mm
	Conductivity of gas gap	0,029	W/(mK)
	Additional air gap	-	mm
	Thickness of additional pane	-	mm
	conductivity of air gap	-	W/(mK)
	thickness of the total glazing	48	mm
	U-Value of the glazing	0,700	W/(m²K)
Properties of the panel	Conductivity of the panel	0,035	W/(mK)
	U-Value of the panel	0,649	W/(m²K)

In many edge bond constructions, very thin (about 0.025 to 0.1 mm) films are incorporated, the materials of which have a high thermal conductivity. The true-scale representation of the spacer in the calculation model could only be resolved with a very large numerical effort.
Instead of a high resolution representation of the spacer SwisspacerV a simplified, but thermally equivalent, replacement was therefore used. This allows a more coarse discretisation of the calculation model and therefore a viable computational effort.

2.3 Boundary conditions

The boundary conditions for the calculations were chosen to reflect the actual circumstances, i.e. with an external temperaure of –10℃, an interior temperature of +20℃ and the corresponding heat transfer coefficient at the surfaces (see table below). A reduced inner heat transfer coefficient of h_i = 5 W/(m²K) was assumed at the inner surfaces of the window corners, in accordance with DIN EN 10077-2.

Table 3: Heat transfer resistances and surface temperatures.

Surface	Temperature θ [℃]	Heat-transfer resistance R_{SI} [m²K/W]
to ambient	-10	0.04
to ambient with air gap		0.13
to interior	20	0.13
to interior in edges		0.20
to ambient for calculation of f_{Rsi}		0.04
to interior for calculation of f_{Rsi}		0.25

2.4 Used materials and thermal conductivities

In the following table the materials used in the calculation are listed with their thermal conductivities and the colours used to represent them. The thermal conductivities are based on information provided by the company or on established standards. The equivalent thermal conductivity of hollow spaces was determined in accordance with DIN EN 10077-2.

Table 4: Thermal conductivities and colours representing the materials used for the calculation model.

Farbe Coulour	λ W/mK	Description
	0,035	Insulation material
	0,040	Insulation material
	0,041	PE-Strip
	0,050	PU in-situ foam
	0,050	Soft wood fibre board
	0,058	Cork
	0,100	Molecular sieve
	0,110	Spruce
	0,116	Thermowood Pine
	0,130	Softwood ~500kg/m³, OSB ~650kg/m³
	0,180	Hardwood ~700kg/m³
	0,190	Swisspacer V replacement
	0,190	Glass fibre reinforced plastic
	0,230	Fiberglas
	0,250	Plasterboard
	0,250	EPDM
	0,289	Polybutyl
	0,290	2,2x Softwood ~500kg/m³ (heat flow in direction of fibres)
	0,350	Silicone
	0,400	Polysulphide
	0,510	Interior plaster/gypsum board
	0,700	Exterior plaster
	1,0	Sand-lime brick
	1,0	Glass
	2,3	Reinforced concrete
	3,5	Marble
	50	Steel
	160	Aluminium silicum alloy

3. Results of the heat-flow-calculation

The heat flow Q_{total} was calculated for each sectional drawing following DIN EN 10077–1 and 2 using the two-dimensional heat flow software programme Bisco. For each section, two calculations were carried out, one with the installed glazing and one with a calibration panel (lamda-value of 0,035 W/(m²K)) in place of the glazing. The depth of the edge and thickness of the calibration panel correspond with those of the glazing. Each of the calculated heat flow Q_{total} are documented with the respective dimensions of the sections in Table 3. These intermediate results form the basis for the calculation of the U-values and the Ψ-values.

The height of the calculation models is 0.4 m in models with one glazed part and 0.6 m in models with two glazed parts. For installation situations 1.41 m.

Table 5: Results of the heat flow calculations for all sections [W/m].

Name		Progression					
Frame with panel	bottom	8,3020					
	top	8,2779					
	side	8,2779					
	mullion	12,5111					
	-						
Edge bond		SwisspacerV					
Frame with glass	bottom	9,5165					
	top	9,5198					
	side	9,5198					
	mullion	14,7195					
	-						
EIFS	bottom	13,8335					
	top	13,4051					
	side	13,4051					
Timber constr. wall	bottom	14,0765					
	top	13,9064					
	side	13,9064					
Ventilated facing	bottom	13,7731					
	top	13,5421					
	side	13,5421					

4. Overview of calculation results

Table 6: Overview of calculation results.

Name		Progression					
frame width b_f [m]	bottom	0,109					
	top	0,089					
	side	0,089					
	mullion	0,164					
	-						
U-value of the frame U_f [W/(m²K)]	bottom	0,807					
	top	0,833					
	side	0,833					
	mullion	0,818					
	-						
Edge bond		SwisspacerV					
th. bridge of edge bond Ψ_g [W/(mK)]	bottom	0,0256					
	top	0,0255					
	side	0,0255					
	mullion	0,0256					
	-						
minimum temperature-factor $f_{Rsi=0,25}$	bottom	0,72					
	top	0,72					
	side	0,72					
	mullion	0,72					
	-						
Window-U-value U_W [W/(m²K)]		**0,798**					
Ψ_{opaque} [W/(mK)]		0,109					
Passive House Efficiency class		ph **A**					
Thermal installation bridge $\Psi_{install}$ [W/(mK)] und $U_{W,installed}$ [W/(m²K)]							
EIFS	bottom	0,0096					
	top	-0,0048					
	side	-0,0048					
	$U_{W,installed}$	**0,793**					
Timber constr. wall	bottom	0,0197					
	top	0,0139					
	side	0,0139					
	$U_{W,installed}$	**0,843**					
Ventilated facing	bottom	0,0076					
	top	-0,0003					
	side	-0,0003					
	$U_{W,installed}$	**0,802**					

5. Certified window construction

In the following figures, the calculation models are shown on the left. The respective isothermal figures are shown on the right. The heat flows perpendicular to the isotherms in colour, as indicated by the black lines. The heat flow rate between the lines is 0.1 W/m. In order to better represent the details, only relevant sections of the calculation model are shown.
Figure 1 shows the sections 'top/side' und ‘bottom‘ of the certified window with a 48 mm wide glazing (4/18/4/18/4) and the spacer SwisspacerV.

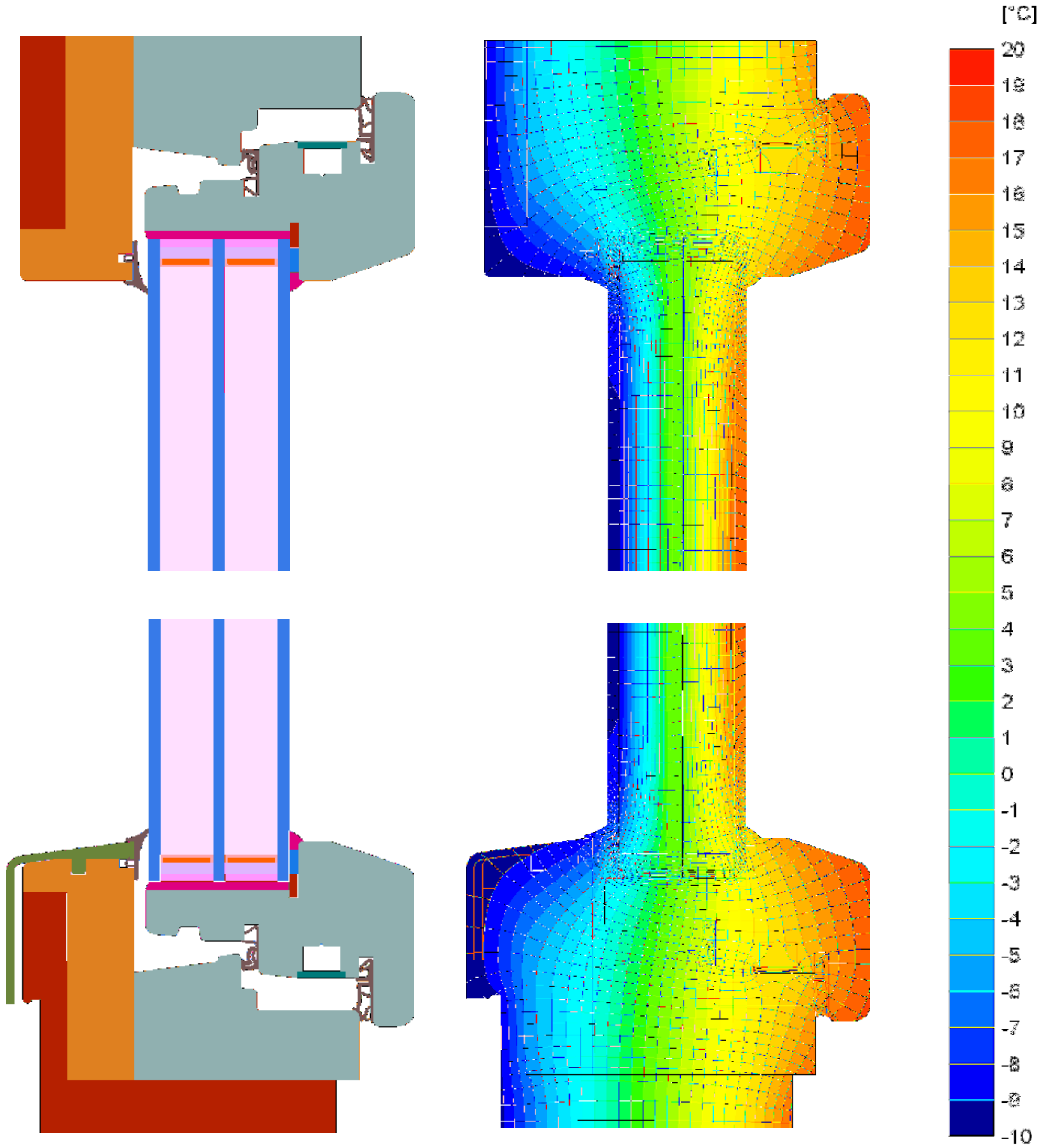


Figure 1: Progression: Section 'side/top' and bottom' with the respective isothermal- and heat flux graphic.

5.1 Mullion

Figure 2 shows the section of a mullion of the certified window system with a 48 mm wide glazing (4/18/4/18/4) and the spacer SwisspacerV.
The thermal properties of this section are given for information only. They are not part in the calculation of the window U-value.

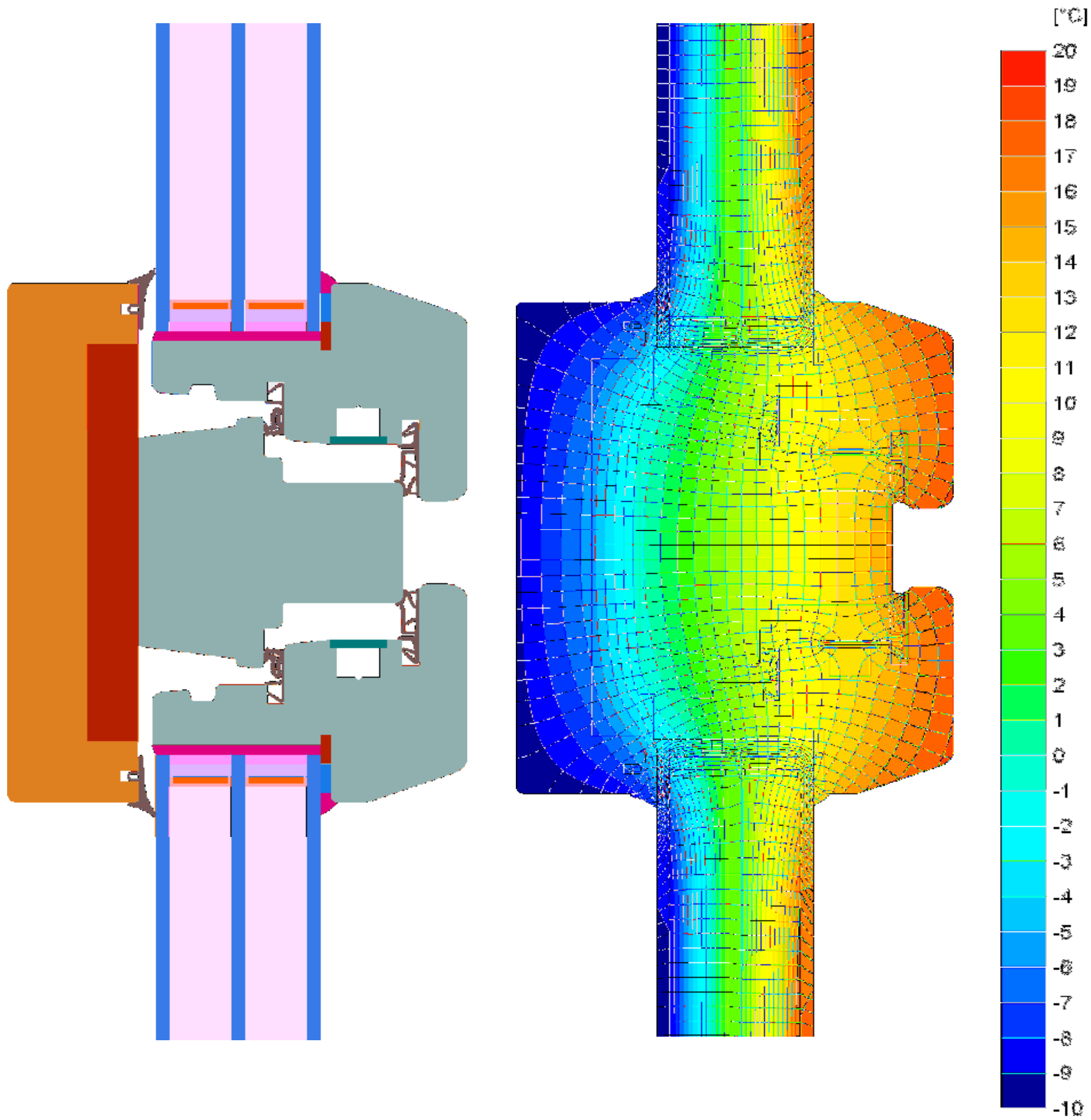


Figure 2: Section of the mullion of the window system with respective isothermal and heat flux graphic.

6. Window U-values for different window sizes

The U-value U_W of an uninstalled window of any size can be determined using the following equation:

$$U_W = \frac{A_g \cdot U_g + A_f \cdot U_f + l_g \cdot \Psi_g}{A_g + A_f}$$

where:	A_g	Glazing area [m²]	U_g	Average glazing U-value [W/(m²K]
	A_f	Frame area [m²]	U_f	Average frame U-value [W/(m²K]
	l_g	Length of edge bond [m]	Ψ_g	Av. th. bridge of edge bond [W/(mK)]

7. Installation

Besides the heat transfer through window frames and glazing, the connection of the frame to a suitable Passive House wall construction is of considerable importance for the whole system (the U-value of the wall must be less than 0.15 $W/(m^2K)$). Therefore, three typical installation situations (the specific arrangement of which were given by the manufacturer) were tested for their suitability.

The results are shown in table 5 and 6. For the calculation models and the respective isothermal graphics, see the following pages.

The U-value of an installed window of any size can be determined using the following equation:

$$U_{W,installed} = \frac{A_W \cdot U_W + l_{instal.} \cdot \Psi_{instal.}}{A_W}$$

where:	A_W	Window area [m^2]	U_W	Window-U-value [$W/(m^2K)$]
	$l_{instal.}$	Length of installation [m]	$\Psi_{instal.}$	Av. th. installation bridge [W/(mK)]

7.1 Exterieur Wall with Insulation and Finnishing-System (EIFS)

The following figure shows the installation of the Progression 'side/top' and 'bottom' in a Exterieur Wall with Insulation and Finnishing-System (EIFS).

The respective isothermal figures are shown on the right. The heat flows perpendicular to the isotherms in colour, as indicated by the black lines. The heat flow rate between the lines is 0.1 W/m.
In order to better represent the details, only relevant sections of the calculation model are shown.

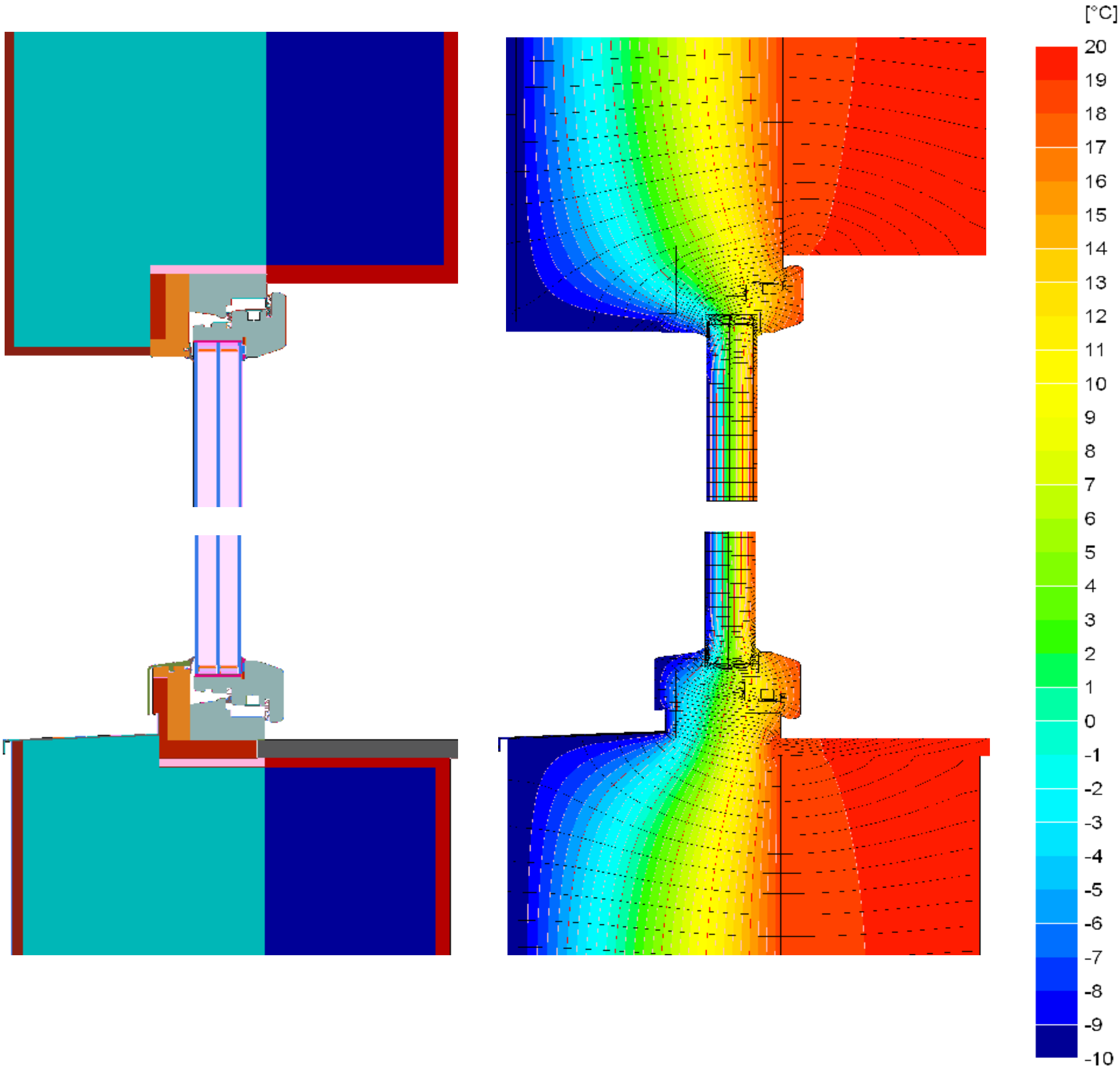


Figure 3: Installation 'bottom' und 'side/top' in a Exterieur Wall with Insulation and Finnishing-System (EIFS) with respective isothermal graphic

	U wall [W/(m²K)]	$\Psi_{instal., bottom}$ [W/(mK)]	$\Psi_{instal., s./top}$ [W/(mK)]	$U_{W,installed}$ [W/(m²K)]
Progression	0,133	0,010	-0,005	0,79

7.2 Timber construction wall

The following figure shows the installation of the Progression 'top/side' und 'bottom' in a Timber construction wall.

The respective isothermal figures are shown on the right. The heat flows perpendicular to the isotherms in colour, as indicated by the black lines. The heat flow rate between the lines ist 0.1 W/m.

In order to better represent the details, only relevant sections of the calculation model are shown.

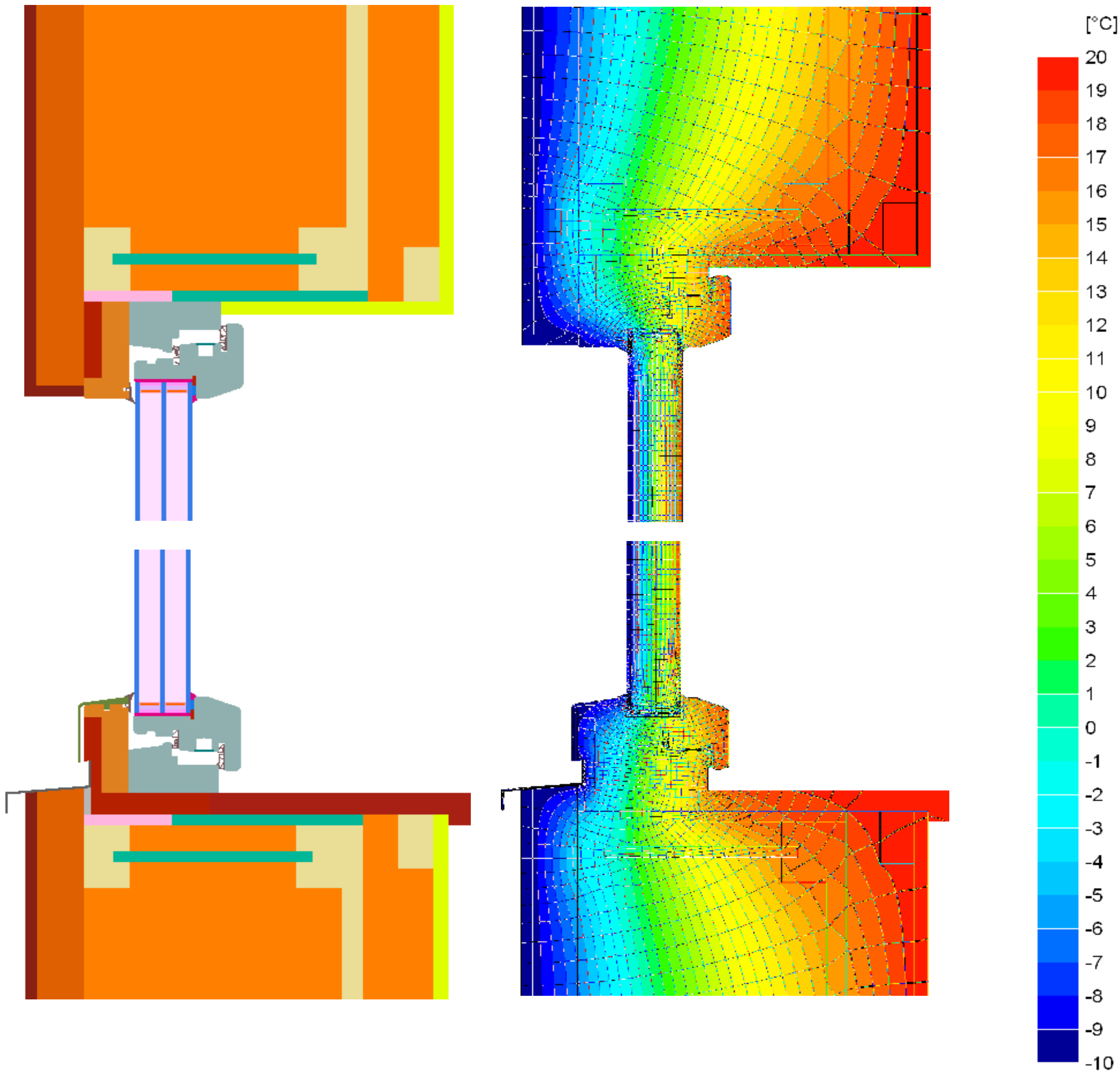


Figure 4: Installation 'bottom' und 'side/top' in a Timber construction wall with respective isothermal graphic

	U wall [W/(m²K)]	$\Psi_{instal., bottom}$ [W/(mK)]	$\Psi_{instal., s./top}$ [W/(mK)]	$U_{W,installed}$ [W/(m²K)]
Progression	0,131	0,020	0,014	0,84

7.3 Ventilated facing

The following figure shows the installation of the Progression 'side/top' and 'bottom' in a Ventilated facing.

The respective isothermal figures are shown on the right. The heat flows perpendicular to the isotherms in colour, as indicated by the black lines. The heat flow rate between the lines ist 0.1 W/m.

In order to better represent the details, only relevant sections of the calculation model are shown.

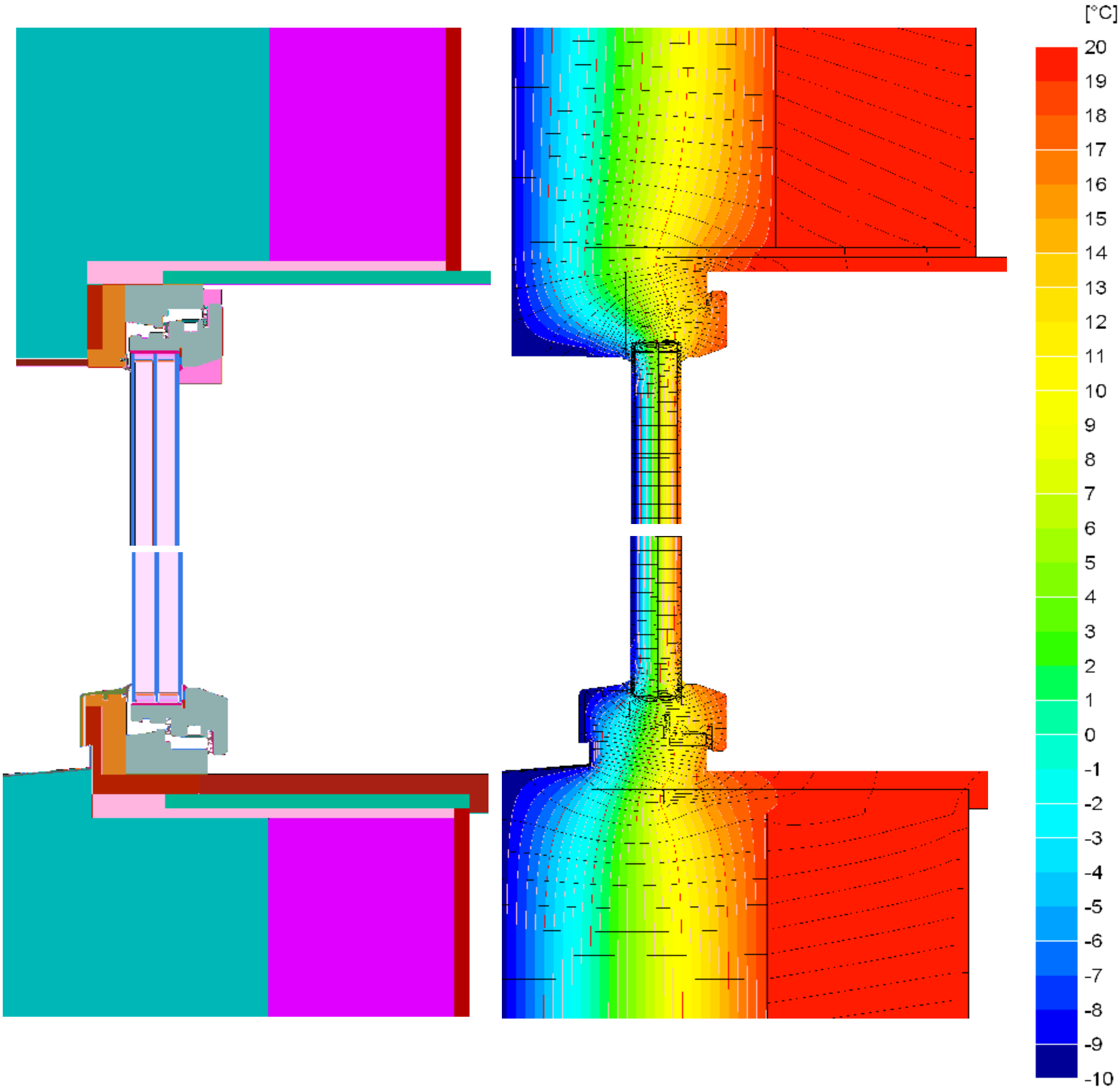


Figure 5: Installation 'bottom' and 'side/top' in a Ventilated facing with respective isothermal graphic

	U wall [W/(m²K)]	$\Psi_{instal.,\ bottom}$ [W/(mK)]	$\Psi_{instal.,\ s./top}$ [W/(mK)]	$U_{W,installed}$ [W/(m²K)]
Progression	0,133	0,008	0,000	0,80

8. Final evaluation

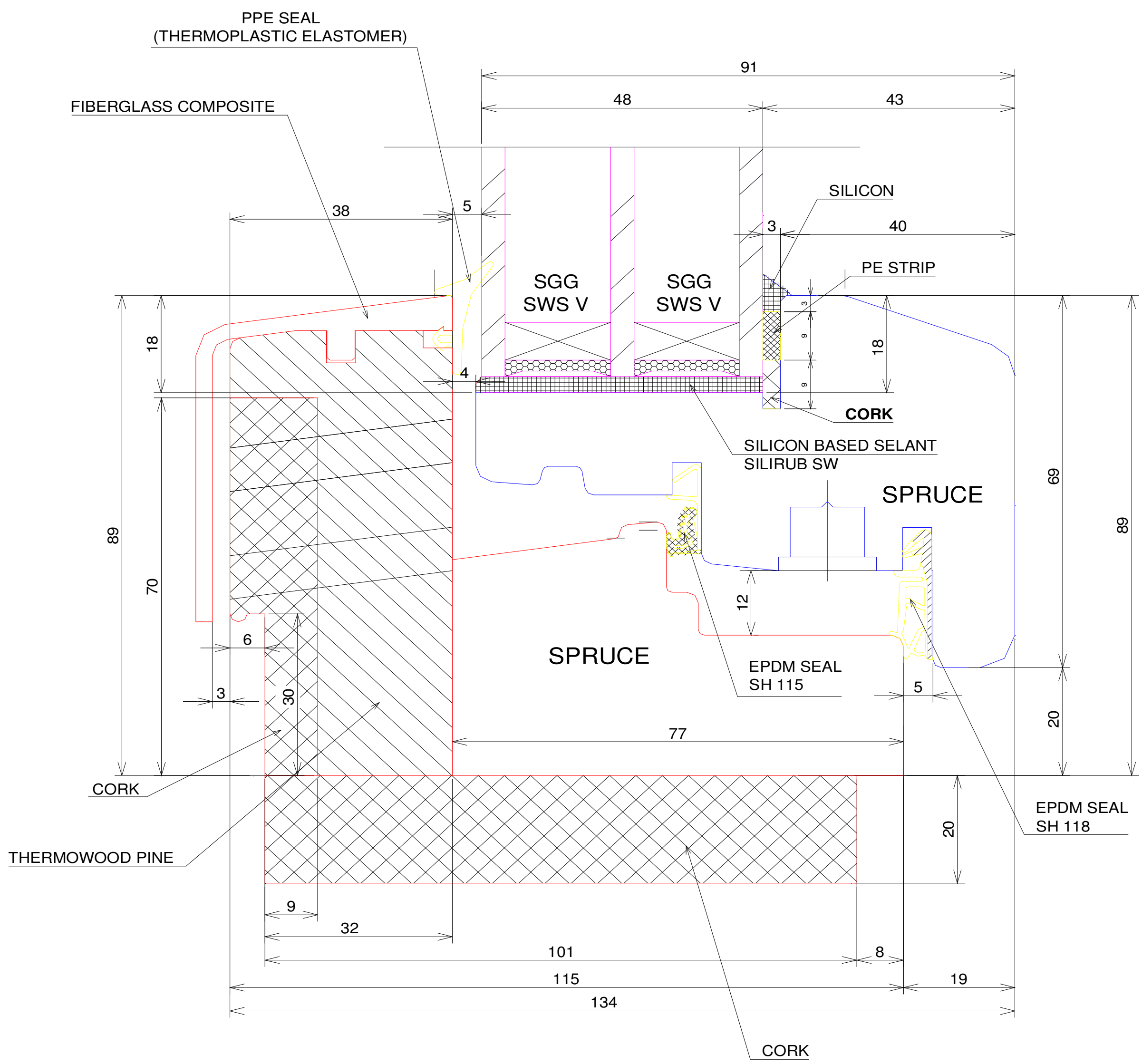
The present PROGRESSION of the SLAVONA, s.r.o. company is a successfull and effective construction of a Passive House suitable component in therms of the tested parameters.
Due to the use of the spacer SwisspacerV the criteria are reached.

The results of the heat flow calculations, which are documented in this report, prove that the values required for U_W and $U_{W,installed}$ are met.

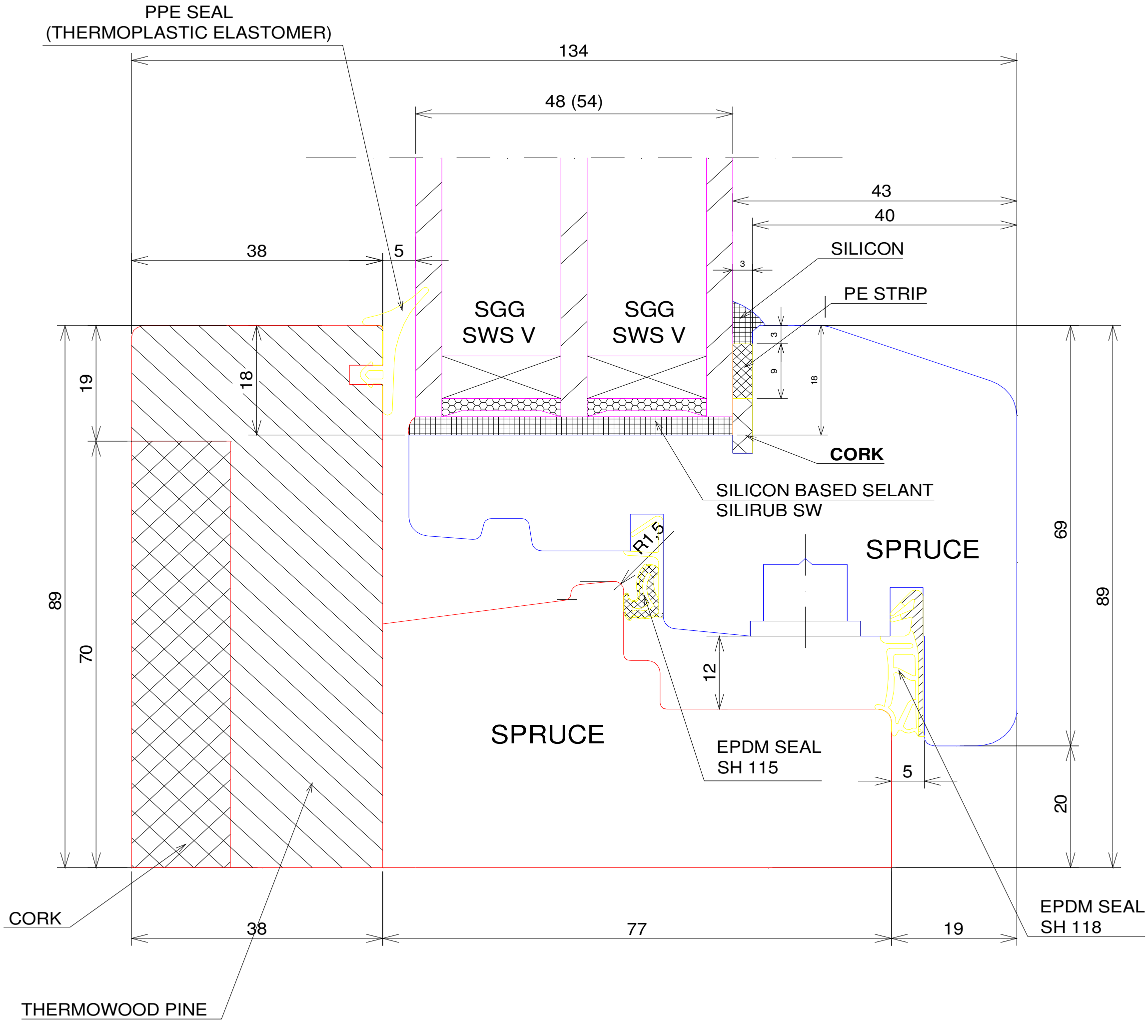
During the construction care should be taken that the windows are installed as stated in the report, otherwise the thermal bridge heat loss coefficient for the installation may be considerably worse.

9. Appendix: Construction drawings

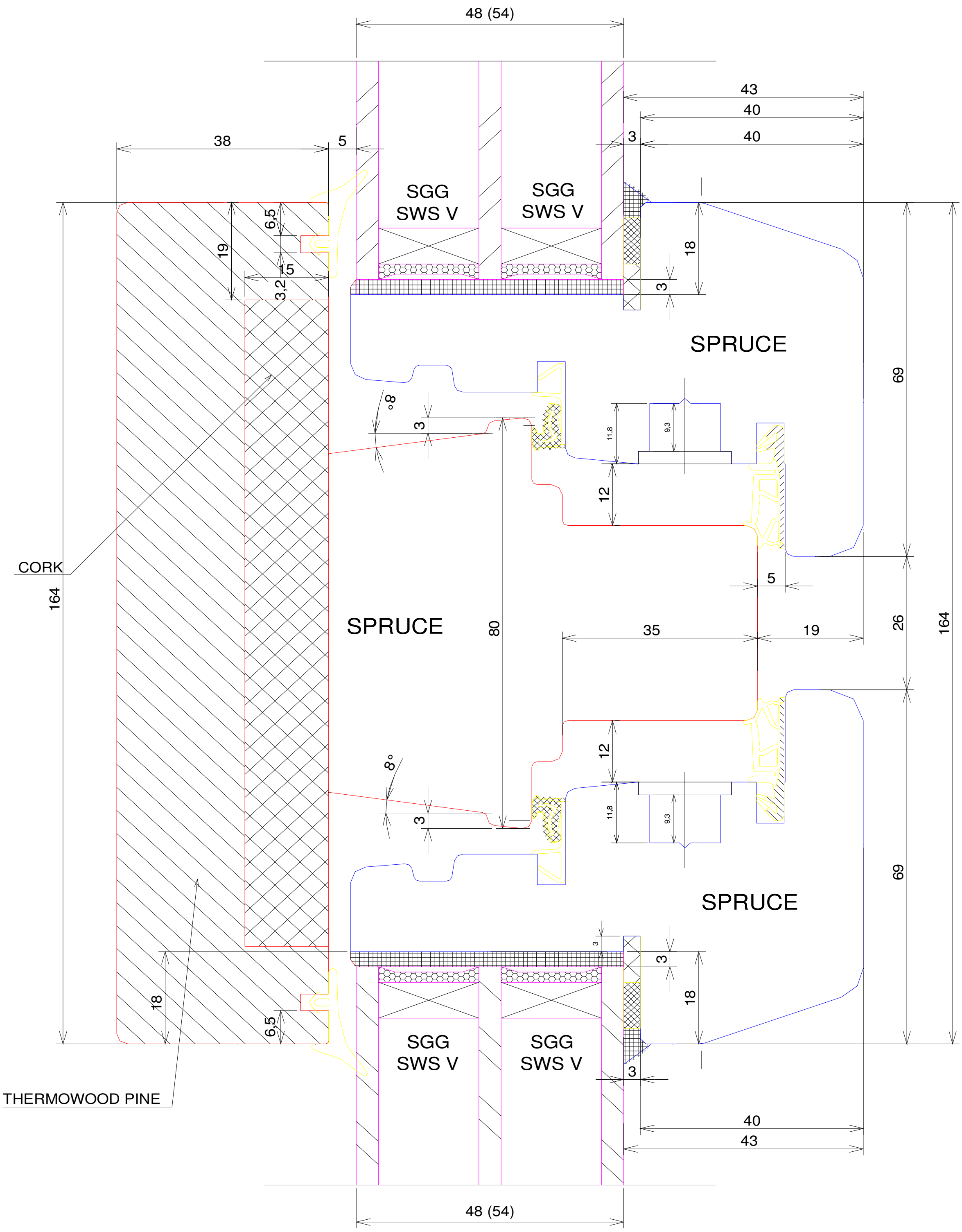
Progression: Frame sections 'bottom' (not to scale)



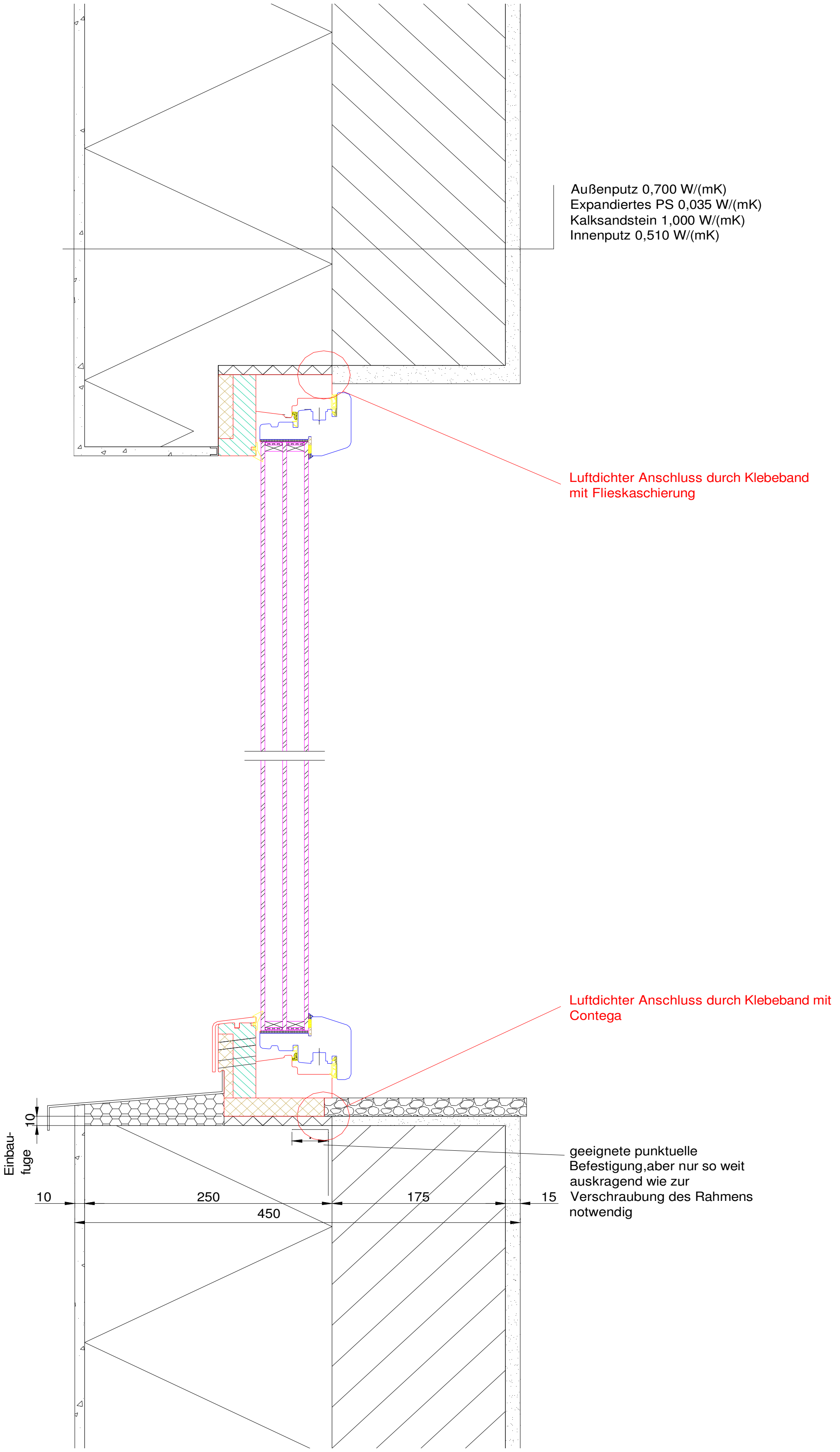
Progression: Frame sections 'side/top' (not to scale)



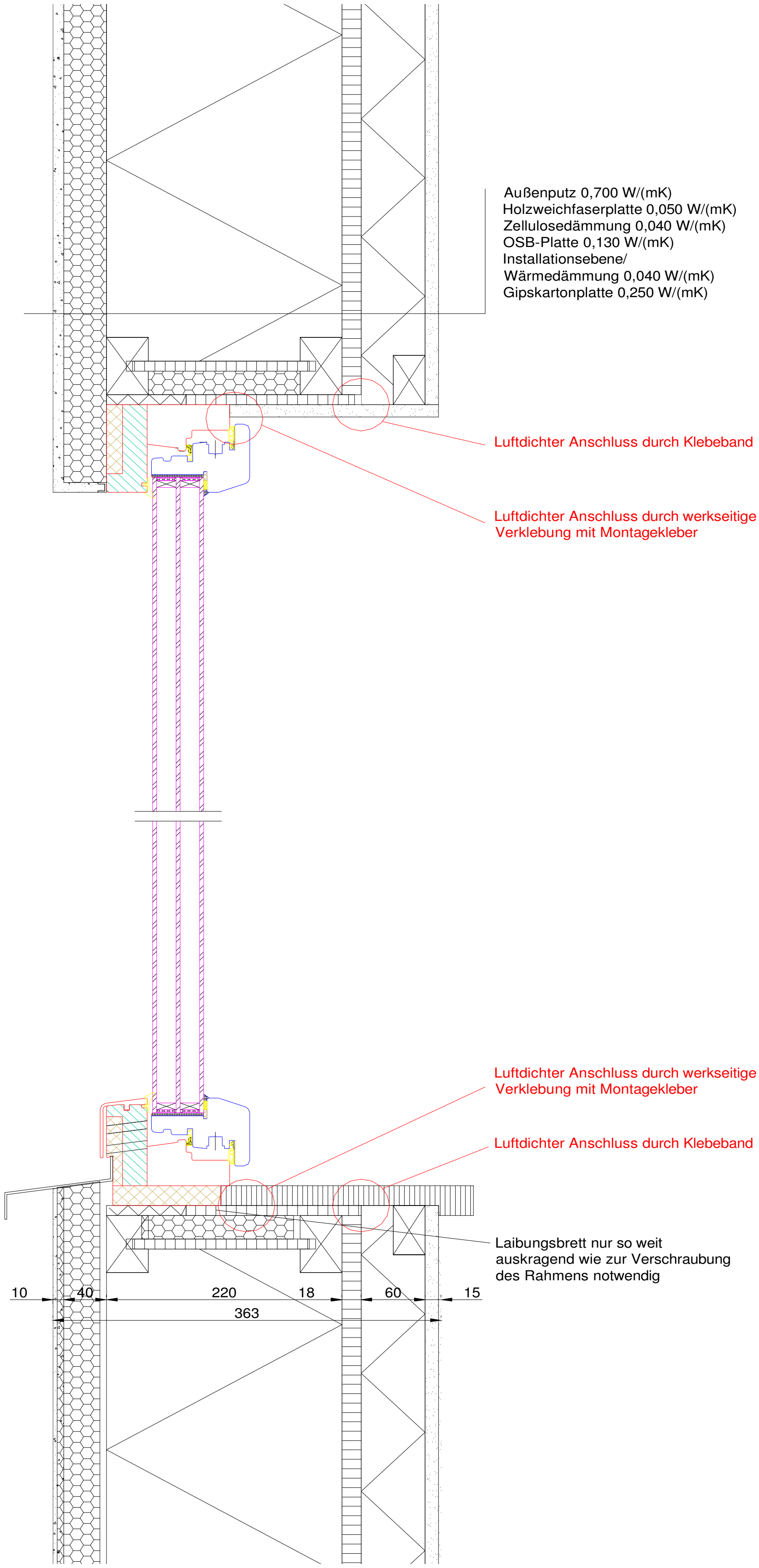
Progression: Frame section mullion (not to scale)



Progression: Installation in a Exterieur Wall with Insulation and Finnishing-System (EIFS) (not to scale)



Progression: Installation in a Timber construction wall (not to scale)



Progression: Installation in a ventilated facing (not to scale)