VALIDATION OF THE PROGRAM BISCO ACCORDING TO NFRC-100 AND ISO 15099: COMPARISON BETWEEN BISCO AND THERM

1. Introduction and normative background

This report presents a comparison between simulation results from **BISCO** and **THERM** for window frame calculations based on NFRC-100 and ISO 15099 standards. In total six window frames and three curtain wall/ spandrel panels are used in the analysis. The comparison includes both the U_{fr} and U_{eg}. The simulations in this document are executed using **BISCO version 13.0.07** and **THERM version 7.8.80.**

The reference documents for this validation are ISO 15099 and NFRC-100. ISO 15099 outlines methodologies for calculating thermal transmittance of windows and doors by numerical simulation. In some aspects ISO 15099 is open, presenting multiple modelling options. NFRC-100 is the American standard based ISO 15099 for calculating the thermal transmittance of fenestration products. NFRC-100 complements ISO 15099 by providing consistent modelling choices.

In the first part of this document we strictly follow in **BISCO** the modeling rules set by NFRC-100 which are also implemented in **THERM**. Herein, the interior convective surface coefficient on the entire glass surface is fixed to the value calculated at the center of glass. In the discussion section we also explore the impact of using a different convective surface coefficient in the edge of glass zone which is physically more correct, but deviates from the NFRC guidelines.

2. Examples

Six window frames and three curtain wall/spandrel panels are used in the comparison. The frames comprise reference cases from EN ISO 10077-2 (Annex I/H) and tutorial examples from the THERM Knowledge Base.

The nine simulation examples represent typical jamb sections.
The window frame set includes two wooden profiles, three thermally broken aluminium frames, and one PVC window. In the first five cases, the spacer has been simplified to a single equivalent material. In the final example, the detailed geometry of the spacer is included in the model.

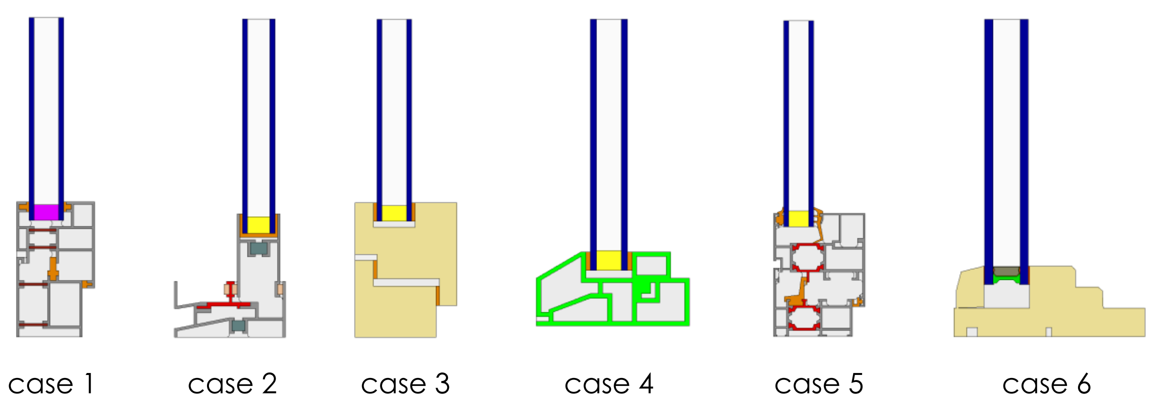


Figure 1. Window frames modelled

The second set includes a curtain wall and two types of spandrel panels.

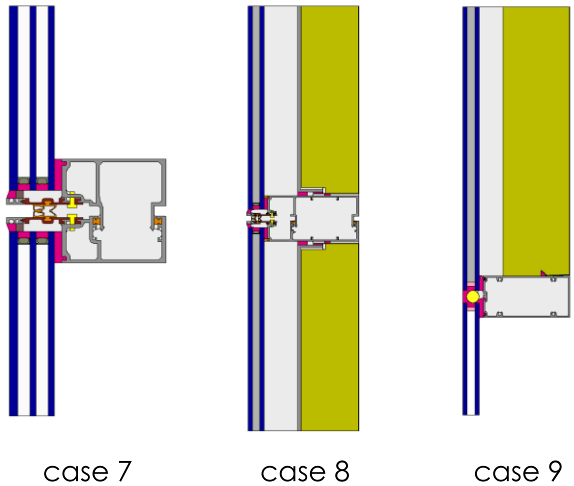
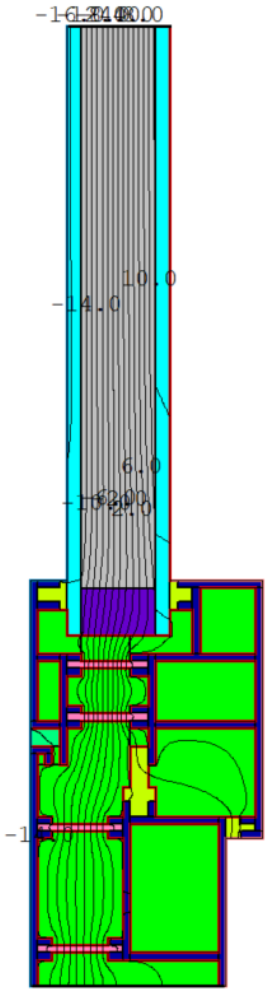


Figure 2. Curtain wall/ Spandrel panels

3. Results

3.1. Example 1

THERM

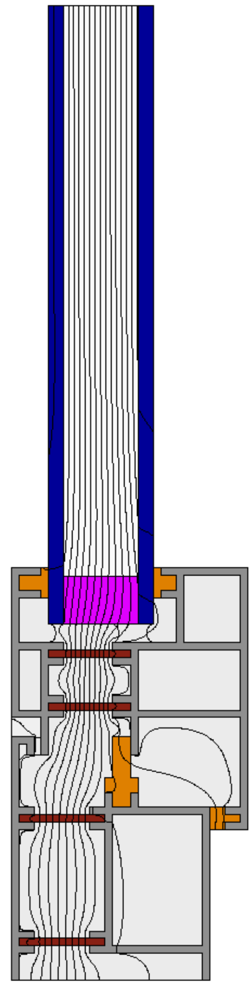


U_{fr} = 3.36 W/(m².K)

U_{eg} = 1.55 W/(m².K)

1-Jamb.THM

BISCO



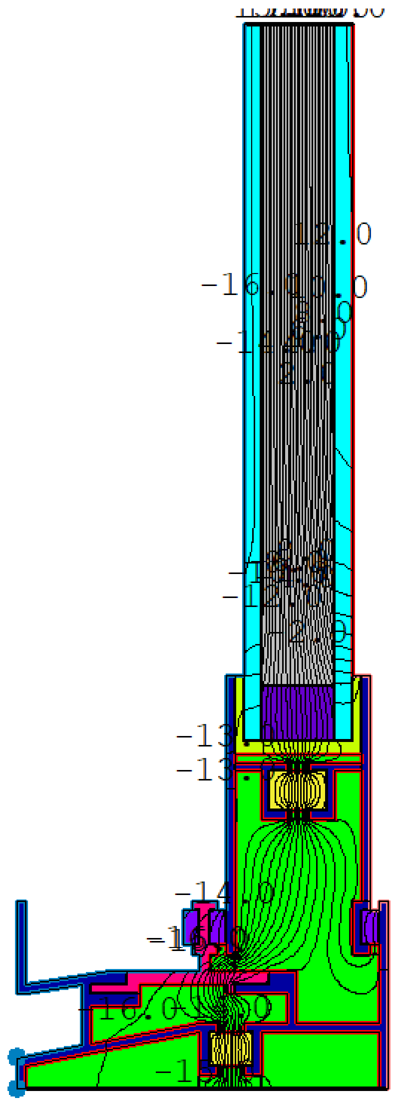
U_{fr} = 3.37 W/(m².K)

U_{eg} = 1.56 W/(m².K)

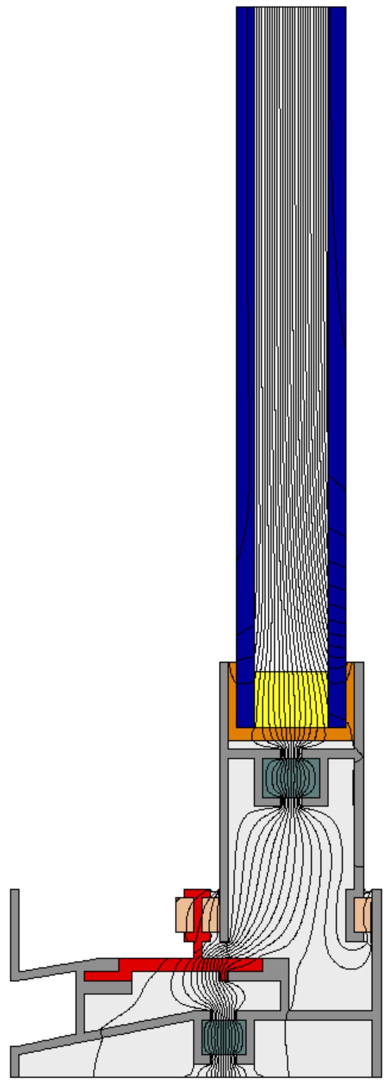
1-NFRC.bsc

3.2. Example 2

THERM



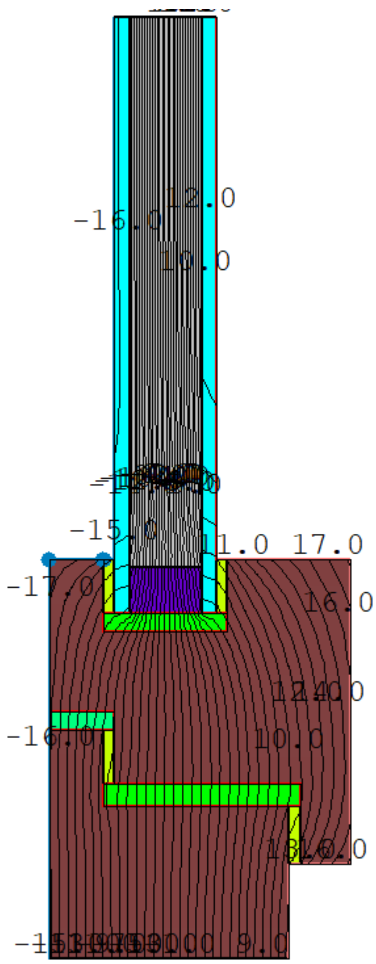
BISCO



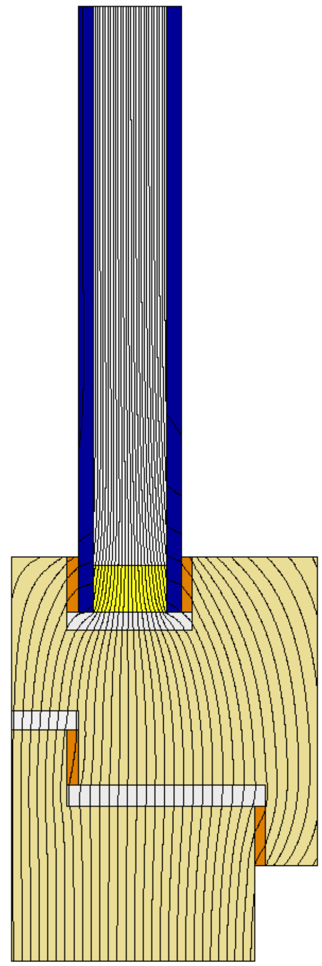
THERM	BISCO
U_{fr} = 4.34 W/(m².K)	U_{fr} = 4.35 W/(m².K)
U_{eg} = 1.90 W/(m².K)	U_{eg} = 1.93 W/(m².K)
2-Jamb.THM	2-NFRC.bsc

3.3. Example 3

THERM



BISCO



U_{fr} = 1.44 W/(m².K)

U_{eg} = 1.58 W/(m².K)

3-Jamb.THM

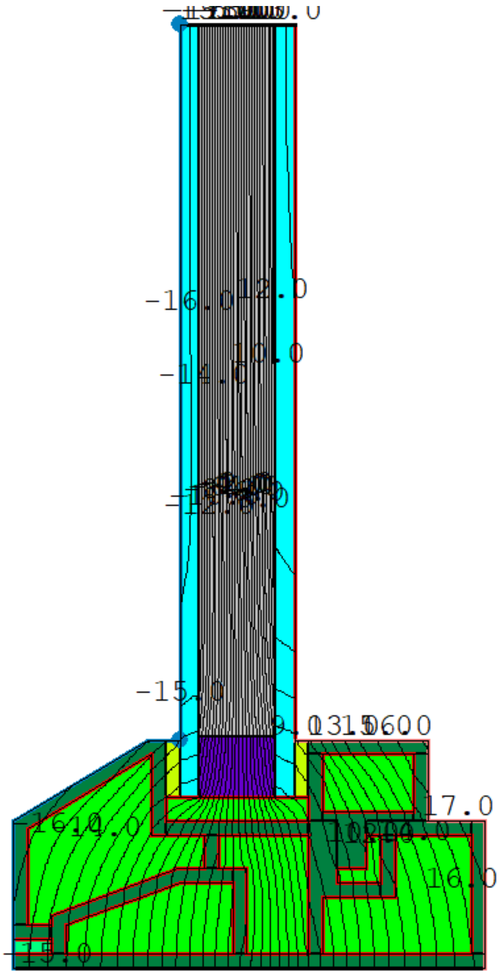
U_{fr} = 1.43 W/(m².K)

U_{eg} = 1.58 W/(m².K)

3-NFRC.bsc

3.4. Example 4

THERM

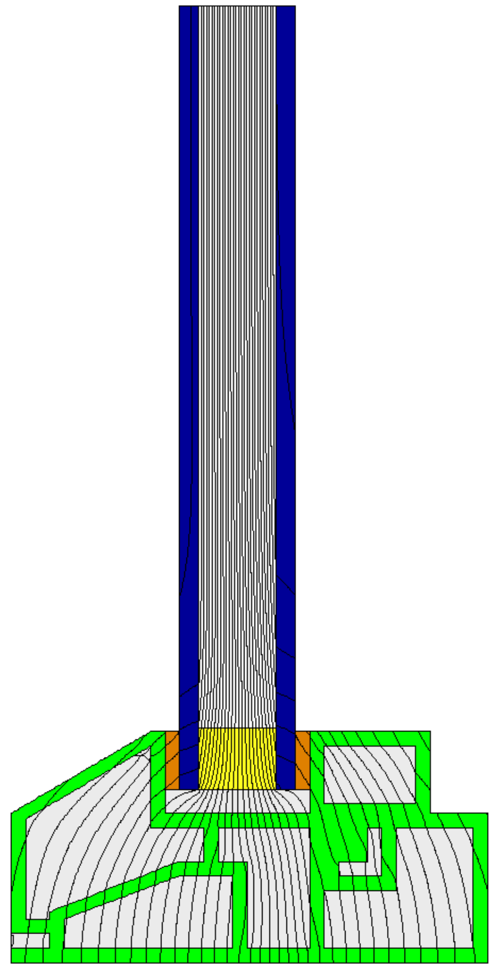


U_{fr} = 1.42 W/(m².K)

U_{eg} = 1.56 W/(m².K)

4-Jamb.THM

BISCO



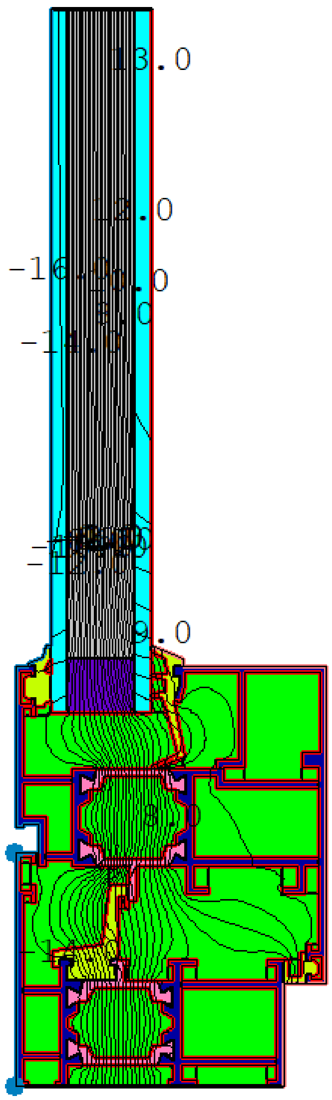
U_{fr} = 1.42 W/(m².K)

U_{eg} = 1.56 W/(m².K)

4-NFRC.bsc

3.5. Example 5

THERM

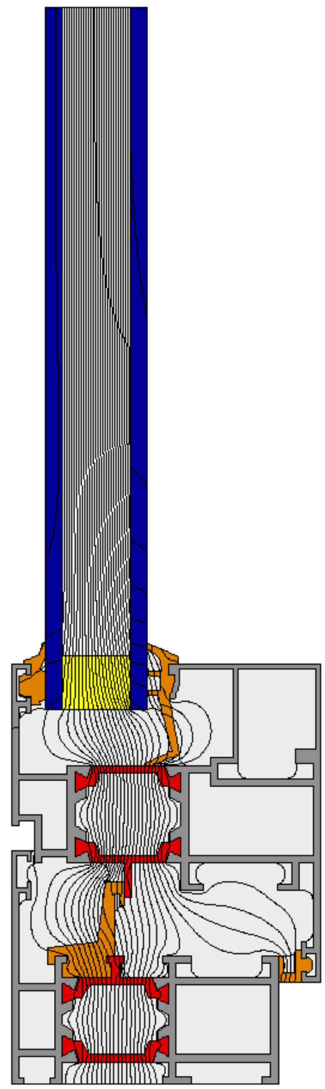


U_{fr} = 3.28 W/(m².K)

U_{eg} = 1.56 W/(m².K)

5-Jamb.THM

BISCO



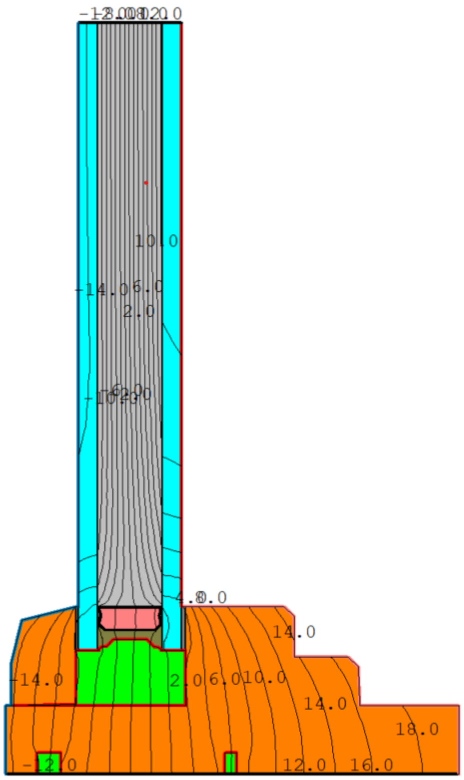
U_{fr} = 3.26 W/(m².K)

U_{eg} = 1.56 W/(m².K)

5-NFRC.bsc

3.6. Example 6

THERM

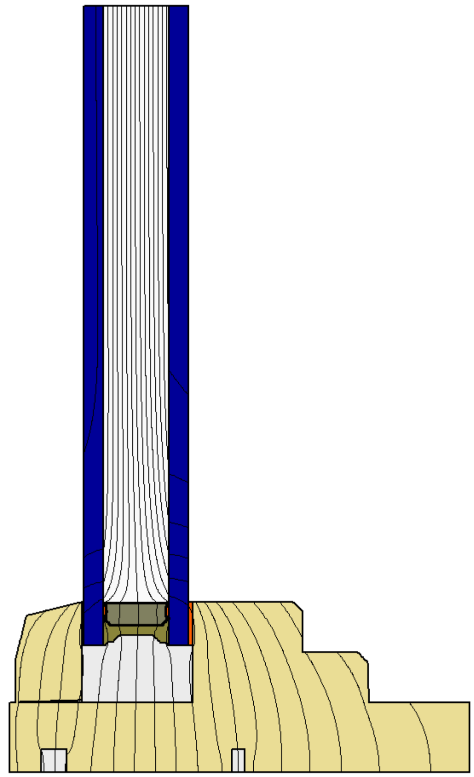


U_{fr} = 1.95 W/(m².K)

U_{eg} = 1.96 W/(m².K)

6-Jamb.thm

BISCO



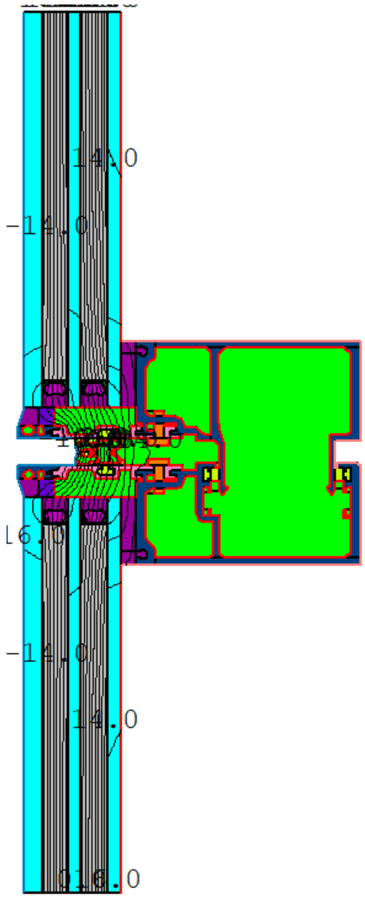
U_{fr} = 1.94 W/(m².K)

U_{eg} = 1.97 W/(m².K)

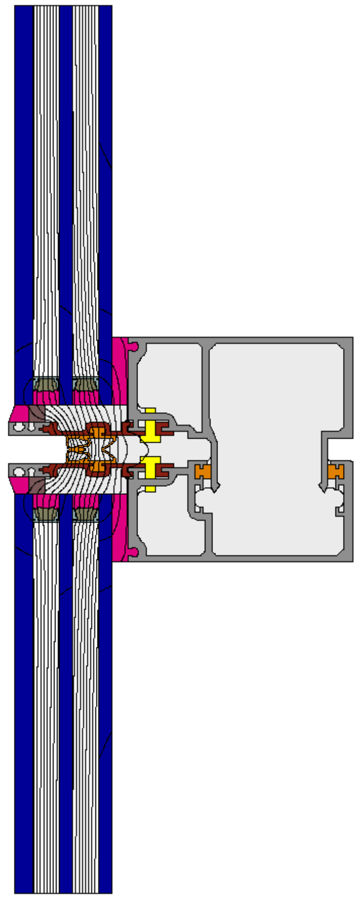
6-NFRC.bsc

3.7. Example 7

THERM



BISCO



U_{fr} = 3.51 W/(m².K)

U_{eg} = 0.79 W/(m².K)

EX7_Jamb.THM

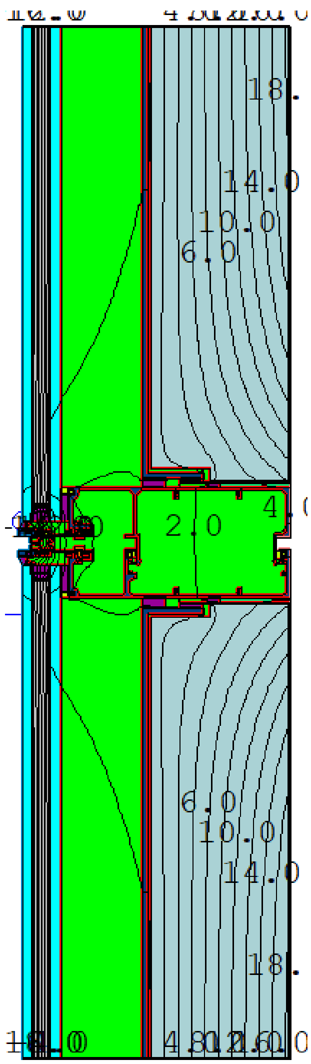
U_{fr} = 3.46 W/(m².K)

U_{eg} = 0.82 W/(m².K)

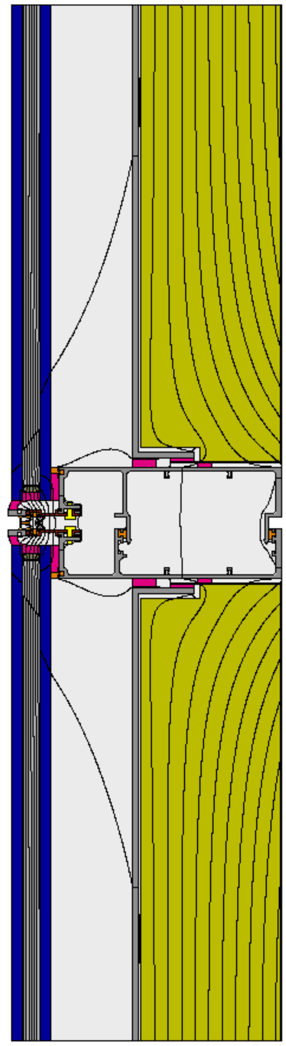
EX7_NFRC_Jamb.bsc

3.8. Example 8

THERM



BISCO



U_{fr} = 3.12 W/(m².K)

U_{eg} = 0.70 W/(m².K)

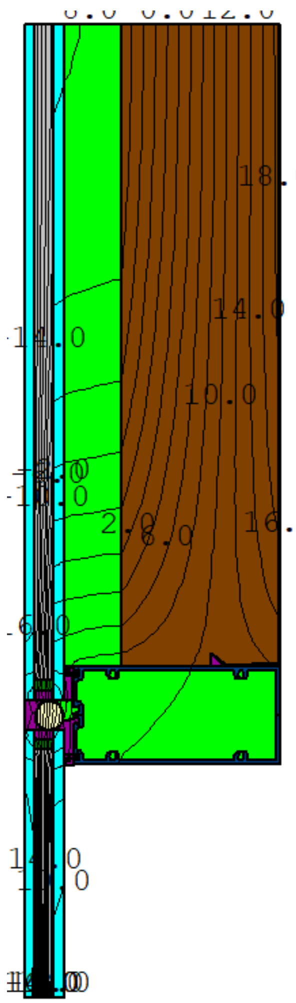
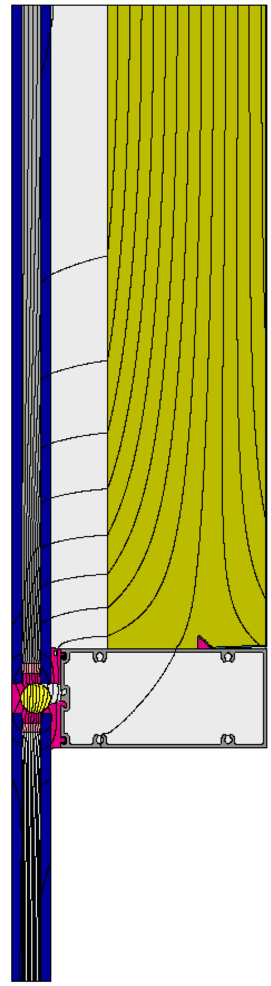
EX8_Jamb.THM

U_{fr} = 3.210 W/(m².K)

U_{eg} = 0.69 W/(m².K)

EX8_NFRC_Jamb.bsc

3.9. Example 9

THERM	BISCO
	
U_{fr} = 5.04 W/(m^2.K)	U_{fr} = 5.00 W/(m^2.K)
$U_{eg\text{-}top}$ = 0.46 W/(m^2.K)	$U_{eg\text{-}top}$ = 0.46 W/(m^2.K)
$U_{eg\text{-}bot}$ = 1.47 W/(m^2.K)	$U_{eg\text{-}bot}$ = 1.46 W/(m^2.K)
EX9_Jamb.THM	EX9_NFRC_Jamb.bsc

4. Discussion

4.1. NFRC-100 approach: center of glass convective surface coefficient on entire glass surface

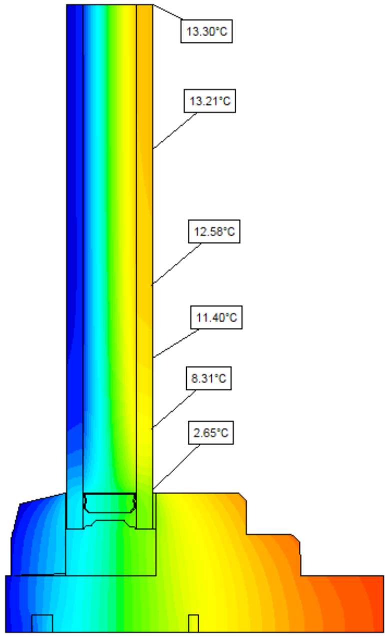
The results show that the reported U_{fr}-values and U_{eg}-values in **THERM** and **BISCO** are in very good agreement, with differences of less than 1.5% for window frames and 3% for curtain wall/ spandrel panels. To be fully in line with NFRC-100 (and THERM) it is important to force BISCO using the calculated convective surface coefficient at centre of glass in the edge of glass zone.

BISCO vs. THERM								
		FRAME – U_{fr} (W/m²K)			EDGE – U_{eg} (W/m²K)		
		BISCO	THERM	Diff.	BISCO	THERM	Diff.
WINDOW FRAME	case 1	3.37	3.36	0.33 %	1.56	1.55	0.54 %
	case 2	4.35	4.34	0.26 %	1.93	1.90	1.44 %
	case 3	1.43	1.44	-0.43 %	1.58	1.58	0.10 %
	case 4	1.42	1.42	-0.27 %	1.56	1.56	-0.09 %
	case 5	3.26	3.28	-0.70 %	1.56	1.56	-0.19 %
	case 6	1.94	1.95	-0.42 %	1.97	1.96	0.57 %
CURTAIN WALL	case 7	3.46	3.51	-1.46 %	0.82	0.79	3.05 %
	case 8	3.21	3.12	2.85 %	0.69	0.70	-1.13 %
	case 9	5.00	5.04	-0.70 %	0.46	0.46	0.37 %

Table 1 - BISCO vs. THERM (NFRC-100 approach) – Jamb section

4.2. Impact of using a different convective surface coefficient in the edge of glass zone

BISCO also allows to use a different convective surface coefficient in the edge of glass zone. In this zone, the presence of the frame and spacer leads to a lower interior surface temperature on the glass (see example for case 6 below), and thus a higher convective surface coefficient (see Annex A).



Convective surface coefficient for vertical inclination (ISO 15099):

$$h_{cv,int} = Nu \, . \left(\frac{\lambda}{H}\right)$$

$$Ra_H = \frac{\rho^2 . H^3 . g . C_p . (T_{b,n} - T_{int})}{T_{m,f} . \mu . \lambda}$$

$$Nu = 0.56(Ra_H)^{1/4}$$

Figure 3. Temperature profile and illustration of surface temperatures for case 6.

The simulations are repeated with updating the convection surface coefficient in the edge of glass zone based on the local temperatures. The results are summarized in Table 2 below. The impact on the U_{fr} is limited and the difference with THERM remains below 1.5% for window frames, 3.5% for spandrel panels. The U_{eg}-value is now slightly higher, with differences up to 6% for the all examples.

BISCO vs. THERM

		FRAME – U_{fr} (W/m²K)			EDGE – U_{eg} (W/m²K)		
		BISCO	**THERM**	**Diff.**	**BISCO**	**THERM**	**Diff.**
WINDOW FRAME	case 1	3.38	3.36	0.69 %	1.59	1.55	2.86 %
	case 2	4.34	4.34	0.03 %	2.01	1.90	5.64 %
	case 3	1.43	1.44	-0.63 %	1.61	1.58	1.87 %
	case 4	1.41	1.42	-0.77 %	1.59	1.56	1.90 %
	case 5	3.25	3.28	-0.85 %	1.60	1.56	2.31 %
	case 6	1.92	1.95	-1.34 %	2.07	1.96	5.26 %
CURTAIN WALL	case 7	3.44	3.51	-2.01 %	1.59	1.56	5.95 %
	case 8	3.23	3.12	3.42 %	1.60	1.56	-0.70 %
	case 9	5.05	5.04	0.21 %	2.07	1.96	-3.57 %

Table 2 - BISCO vs. THERM (with BISCO applying different convective heat transfer coefficient in edge of glass and centre of glass zone)

We can assume that this approach – with a different local convective surface coefficient in the edge glass zone – is physically more accurate.

4.3. Sill section

When applying the sill section following the NFRC-100 approach, the agreement between THERM and BISCO remains equally strong with differences of less than 1.5% for window frames, and 3% for curtain wall/ spandrel panels.

		BISCO vs. THERM					
		FRAME – U_{fr} (W/m²K)			EDGE – U_{eg} (W/m²K)		
		BISCO	**THERM**	**Diff.**	**BISCO**	**THERM**	**Diff.**
WINDOW FRAME	case 1	3.39	3.37	0.69 %	1.56	1.55	0.48 %
	case 2	4.32	4.30	0.40 %	1.93	1.90	1.41 %
	case 3	1.39	1.40	-0.30 %	1.56	1.57	-0.64 %
	case 4	1.40	1.40	-0.25 %	1.54	1.54	-0.02 %
	case 5	3.34	3.35	-0.24 %	1.57	1.57	-0.33 %
	case 6	1.94	1.96	-0.72 %	1.97	1.96	0.25 %
CURTAIN WALL	case 7	3.37	3.42	-1.43 %	0.81	0.79	2.90 %
	case 8	3.16	3.07	2.95 %	0.67	0.68	-1.11 %
	case 9	4.65	4.67	-0.52 %	0.44	0.44	0.50 %

Table 3 - BISCO vs. THERM (NFRC-100 approach) - Sill section

5. Conclusion

This document compares the results of the software tools **BISCO version 13.0.07** and **THERM version 7.8.80** for the thermal analysis of nine examples.

The results illustrate that - for calculation according to NFRC-100 – it is important to fix in **BISCO** the convective surface coefficient in the edge zone equal to its value at the centre of glass. When this option is selected, the **BISCO** project is fully in line with NFRC-100 and the differences between **BISCO** and **THERM** are below **1.5%** for window frames and **3%** for curtain wall/ spandrel panels

BISCO also allows updating the convective surface coefficient at the edge of the glass zone based on the local surface temperature. This approach better reflects physical reality, but it no longer aligns with the NFRC-100 standard. Simulation results for the current six examples show that this can increase the U_{eg}-value by up to 6%.

Annex A

Automatic calculation of h_c for BC_SKY CONVEC ISO15099:

$$h_c = Nu\frac{\lambda_{air}}{H}$$

With:

Nu dependent on the tilt angle γ (see below)

$$Ra_H = \frac{\rho_{air}^2 H^3 g c_{p,air}(T_s - \theta_a)}{\mu_{air}\lambda_{air}(T_{m,f} + 273.16)}$$

$T_s = \frac{T_{s,max}+T_{s,min}}{2}$ = average external surface temperature [°C]

$T_{m,f} = \theta_a + \frac{1}{4}(T_s - \theta_a)$ = mean film temperature [°C]

θ_a = user defined environment air temperature [°C]

$\lambda_{air} = 2.873 \cdot 10^{-3} + 7.760 \cdot 10^{-5} \cdot (T_{m,f} + 273.16)$ [W/(mK)]

$\rho_{air} = \frac{101300 \cdot 28.97}{8314.5 \cdot (T_{m,f}+273.16)}$ [kg/m³]

$c_{p,air} = 1002.737 + 1.2324 \cdot 10^{-2} \cdot (T_{m,f} + 273.16)$ [J/(kg·K)]

$\mu_{air} = 3.723 \cdot 10^{-6} + 4.94 \cdot 10^{-8} \cdot (T_{m,f} + 273.16)$ [Pa·s]

- Window inclined at $0° \leq \gamma < 15°$

  $Nu = 0.13 Ra_H^{\frac{1}{3}}$
- Window inclined at $15° \leq \gamma \leq 90°$

  $Nu = 0.56(Ra_H \sin\gamma)^{\frac{1}{4}}$ if $Ra_H \leq Ra_{cv}$

  $Nu = 0.13\left(Ra_H^{\frac{1}{3}} - Ra_{cv}^{\frac{1}{3}}\right) + 0.56(Ra_{cv}\sin\gamma)^{\frac{1}{4}}$ if $Ra_H > Ra_{cv}$

  With $Ra_{cv} = 2.5 \cdot 10^5 \left(\frac{e^{0.72\gamma}}{\sin\gamma}\right)^{\frac{1}{5}}$
- Window inclined at $90° < \gamma \leq 179°$

  $Nu = 0.56(Ra_H \sin\gamma)^{\frac{1}{4}}$
- Window inclined at $179° < \gamma \leq 180°$

  $Nu = 0.58 Ra_H^{\frac{1}{5}}$

Figure 4. Automatic calculation of h_c for BC_SKY ISO15099