



## ASSIGNING DISTANCES AND CONVECTIVE HEAT TRANSFER COEFFICIENTS for $U_{fr}$ and $U_{eg}$ CALCULATIONS ACCORDING TO NFRC-100

### Introduction

[case1.bsc](#), [case2.bsc](#), [case3.bsc](#)

This document clarifies how frame sections are set up for calculation of the equivalent U-values according to NFRC-100. NFRC-100 specifies the following equations from ISO 15099 for deriving the equivalent U-values for 1) the frame and 2) the edge of glazing.

$$U_{fr} = \frac{\phi_{fr}}{l_f \cdot (T_i - T_e)} \quad (1)$$

$$U_{eg} = \frac{\phi_{eg}}{l_{eg} \cdot (T_i - T_e)} \quad (2)$$

in which  $l_f$  is the projected length of frame area and  $l_{eg}$  is the length of the edge of glass area and is equal to 63.5 mm. These lengths are measured on the internal side. The quantities  $\Phi_{fr}$  and  $\Phi_{eg}$  are the heat flows through the frame area and the edge-glass area respectively, including the effect of glass and spacer.

NFRC-100 defines the concept 'sightline' as the line formed by the outermost opaque member (such as a frame, sash, spacer, divider, or shading system), whether located on the interior, exterior, or within the glazing system cavity, in a plane perpendicular to the surface.

When assigning the distances  $l_f$  and  $l_{eg}$  and heat flow rates ( $\Phi_{fr}$  and  $\Phi_{eg}$ ), the concept of a 'sightline' plays a crucial role.

In the context of U-value calculations, it is important to note different types of boundary conditions applied to the frame area and the glass areas. For both, NFRC 100 specifies view-factor-based infrared radiation on the interior surface (BC\_SKY). However, the convective surface heat transfer coefficients differ. For the frame area, NFRC 100 prescribes a fixed convective coefficient based on the frame type (see table below (or Table 4.2 in NFRC 100)). In contrast, for the glass area, a temperature-difference-dependent convective coefficient must be used, as specified in ISO 15099.

| Boundary Condition Radiation model                  |     | Convective Film Coefficient<br>(Tilt = 90°) [W/m²K] |
|-----------------------------------------------------|-----|-----------------------------------------------------|
| NFRC 100-2010 Exterior                              | *   | 26.00                                               |
| Interior Aluminum Frame (convection only)           | **  | 3.29                                                |
| Interior Thermally Broken Frame (convection only)   | **  | 3.00                                                |
| Interior Thermally Improved Frame (convection only) | **  | 3.12                                                |
| Interior Wood/Vinyl Frame (convection only)         | **  | 2.44                                                |
| Interior Glazing System boundary condition          | *** | hc=f(ΔT)                                            |

\* Blackbody (type = BC\_SIMPL, standard = ISO 15099)

\*\* Automatic Enclosure model (type = BC\_SKY, standard = NIHIL)

\*\*\* Automatic Enclosure model (type = BC\_SKY, standard = ISO 15099)

In summary there are 3 important aspects to consider in the calculation of  $U_{fr}$  and  $U_{eg}$  in BISCO, for which the first two depend on the position of the 'sightline':

- Length of frame  $l_{fr}$  and length of edge of glass zone  $l_{eg}$ , defined in BISCO with 'distances'.
- Heat flow through frame  $\Phi_{fr}$  and through edge of glass zone  $\Phi_{eg}$  defined via boundary conditions colours.
- Different convective surface coefficients at frame and glass defined via boundary condition colours (not necessarily the same as in the previous point).

This document explains the settings in BISCO for the three possible situations where the sightline can be located:

- Sightline at interface opaque-transparent (case 1)
- Spacer bar outside frame (case 2)
- Frame with protruding part (case 3)

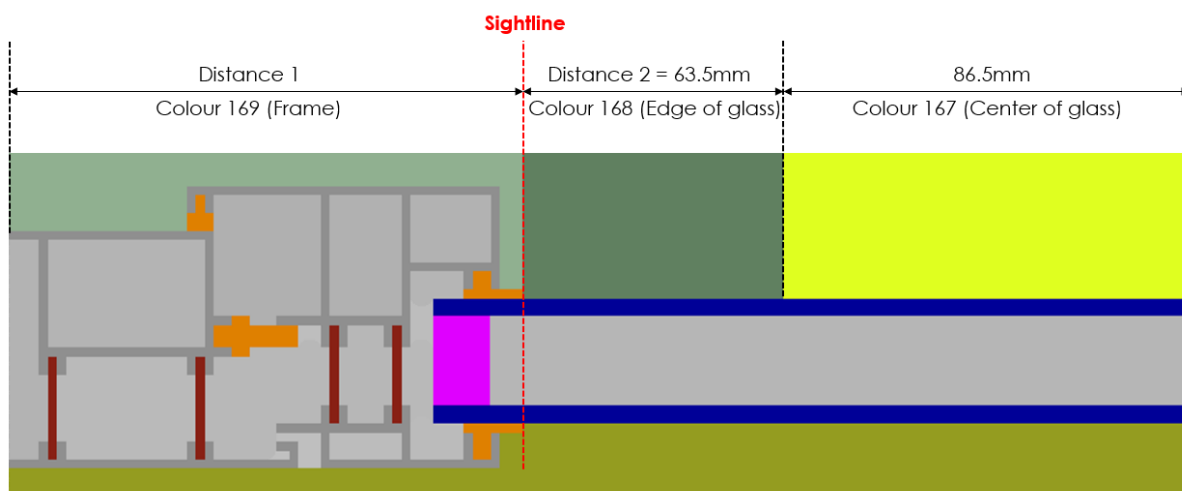
## 1. Case 1: Sightline at interface opaque-transparent

[case1.bsc](#)

In the configuration below, the most right opaque element in the assembly is EPDM. According to the definition of NFRC-100, the sightline will be on the interface between EPDM and glass. Hence all elements on the lefthand side of this sightline should be considered a part of the frame. The edge of glass zone is located on the right side and ends 63.5 mm from the sightline.

This configuration is most straightforward and does not require any manual adjustment of the boundary condition colours or distances by the user when the automatic preparation procedure in BISCO (*Bitmap → NFRC 100/500 Preparation...*).

The bitmap below illustrates this situation with an example.



In the calculation of  $U_{fr}$  and  $U_{eg}$  (see equation (1) and (2) above)  $l_{fr}$  = Distance 1 and  $l_{eg}$  = Distance 2. Also, it can be seen from the bitmap that each distance only has one boundary condition colour where  $\Phi_{fr}$  is the heat flow coming into the frame (colour 169) and  $\Phi_{eg}$  is the heat flow coming into the edge of glazing (colour 168).

Initially, the distances must be assigned through the **Distances window**,

| No. | Mode   | Dir. | Extent | State  | Length [pix.] | Length [m] | X1   | Y1 | X2   | Y2 | U [W/m²K] | Enforced U [W/m²K] |
|-----|--------|------|--------|--------|---------------|------------|------|----|------|----|-----------|--------------------|
| 1   | LOCKED | X    | MAX    | NORMAL | 1151          | 0.1151     | 0    | 0  | 1150 | 0  |           |                    |
| 2   | LOCKED | X    | MAX    | NORMAL | 635           | 0.0635     | 1150 | 0  | 1784 | 0  |           |                    |
| 3   | LOCKED | X    | MAX    | NORMAL | 865           | 0.0865     | 1785 | 32 | 2649 | 32 |           |                    |

Once assigned, to set up the output of  $U_{fr}$ ,  $U_{eg}$  and  $U_{cg}$ , *Edit* → *Derived Thermal Properties...*

☒ Equivalent thermal transmittance (U) - based on incoming heat flow from boundary condition

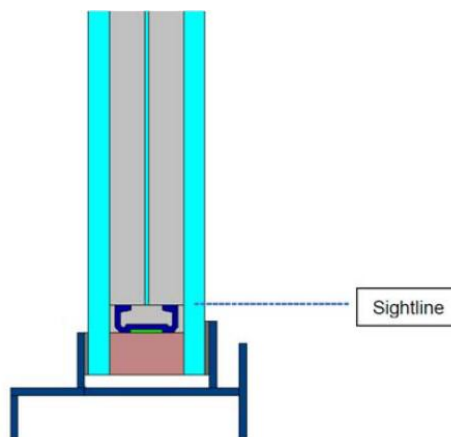
| Element 1                                                                       | Element 2                                                                                   | Element 3                                                                                   |
|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Subscript: <input type="text" value="fr"/>                                      | <input checked="" type="checkbox"/> Element 2<br>Subscript: <input type="text" value="eg"/> | <input checked="" type="checkbox"/> Element 3<br>Subscript: <input type="text" value="cg"/> |
| Width along distance no.: <input type="text" value="1"/>                        | Width along distance no.: <input type="text" value="2"/>                                    | Width along distance no.: <input type="text" value="3"/>                                    |
| <input type="checkbox"/> Add width distance no.: <input type="text" value="2"/> | <input type="checkbox"/> Add width distance no.: <input type="text" value="3"/>             | <input type="checkbox"/> Add width distance no.: <input type="text" value="3"/>             |
| Heat flow BC colour no.: <input type="text" value="169"/>                       | Heat flow BC colour no.: <input type="text" value="168"/>                                   | Heat flow BC colour no.: <input type="text" value="167"/>                                   |
| <input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/>    | <input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/>                | <input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/>                |

OK Cancel

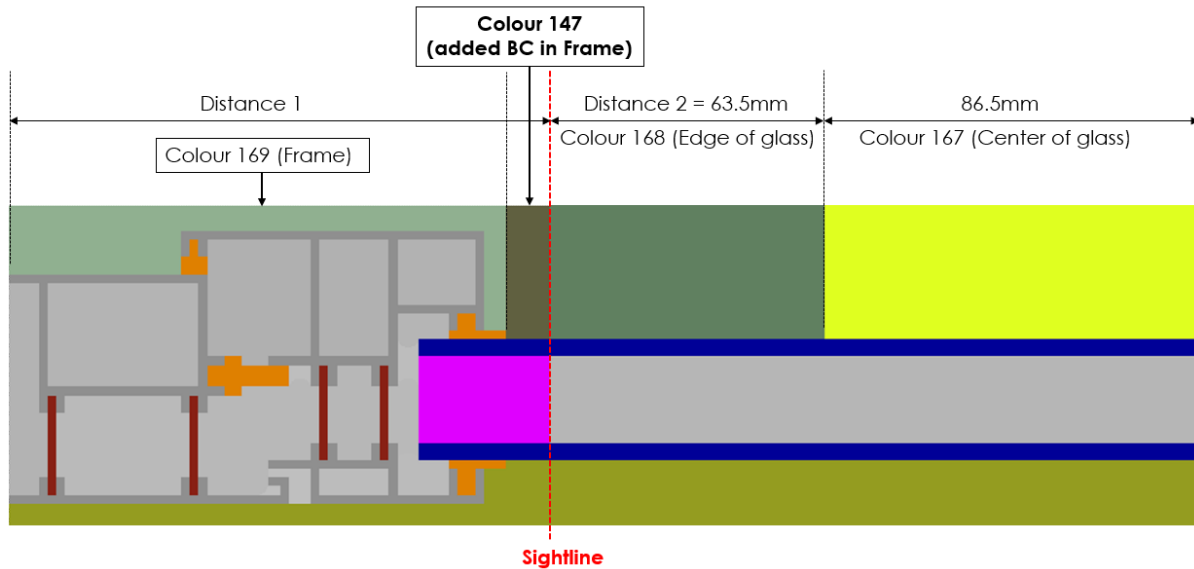
## 2. Case 2 : Spacer bar outside frame

[case2.bsc](#)

When the glazing spacer bar is the outermost opaque material, the sightline is created at its interface with the glass. The figure below - taken from the NFRC simulation manual – illustrates the position of the sightline. Consequently, the area below the sightline has both glass and frame surfaces, for which different convective surface coefficients hold. However, the heat flow below the sightline is accounted to the frame.



This is illustrated below using the same example, but with the spacer bar now extending beyond the EPDM. In this case, it is necessary to manually assign an additional boundary condition colour (in this example, colour 147) to the interior glazed area between the sightline and the frame. This additional colour allows to assign a different convective surface coefficient to the glazed surface in the frame zone (on lefthand side of the sightline).



Now in the calculation of the  $U_f$  (see equation (1) above),  $\Phi_{fr}$  corresponds to the sum of the heat flow leaving boundary condition colours 169 and 147.

In addition, distances must be defined in the **Distances window**. Since Distance 1 involves two boundary condition colours, it must be assigned manually.

| No. | Mode   | Dir. | Extent | State  | Length [pix.] | Length [m] | X1   | Y1 | X2   | Y2 | U [W/m²K] | Enforced U [W/m²K] |
|-----|--------|------|--------|--------|---------------|------------|------|----|------|----|-----------|--------------------|
| 1   | LOCKED | X    | FREE   | NORMAL | 1253          | 0.1253     | 0    | 0  | 1252 | 0  |           |                    |
| 2   | LOCKED | X    | MAX    | NORMAL | 635           | 0.0635     | 1253 | 0  | 1887 | 0  |           |                    |
| 3   | LOCKED | X    | MAX    | NORMAL | 762           | 0.0762     | 1888 | 32 | 2649 | 32 |           |                    |

Once assigned, to set up the output of  $U_{fr}$ ,  $U_{eg}$  and  $U_{cg}$ , *Edit* → *Derived Thermal Properties...*

☒ Equivalent thermal transmittance (U) - based on incoming heat flow from boundary condition

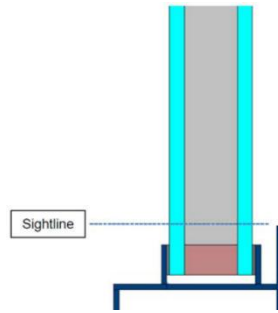
| Element 1                                                                               | Element 2                                                                       | Element 3                                                                       |
|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Subscript: <input type="text" value="fr"/>                                              | Subscript: <input type="text" value="eg"/>                                      | Subscript: <input type="text" value="cg"/>                                      |
| Width along distance no.: <input type="text" value="1"/>                                | Width along distance no.: <input type="text" value="2"/>                        | Width along distance no.: <input type="text" value="3"/>                        |
| <input type="checkbox"/> Add width distance no.: <input type="text" value="2"/>         | <input type="checkbox"/> Add width distance no.: <input type="text" value="2"/> | <input type="checkbox"/> Add width distance no.: <input type="text" value="3"/> |
| Heat flow BC colour no.: <input type="text" value="169"/>                               | Heat flow BC colour no.: <input type="text" value="168"/>                       | Heat flow BC colour no.: <input type="text" value="167"/>                       |
| <input checked="" type="checkbox"/> Add BC colour no.: <input type="text" value="147"/> | <input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/>    | <input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/>    |

OK Cancel

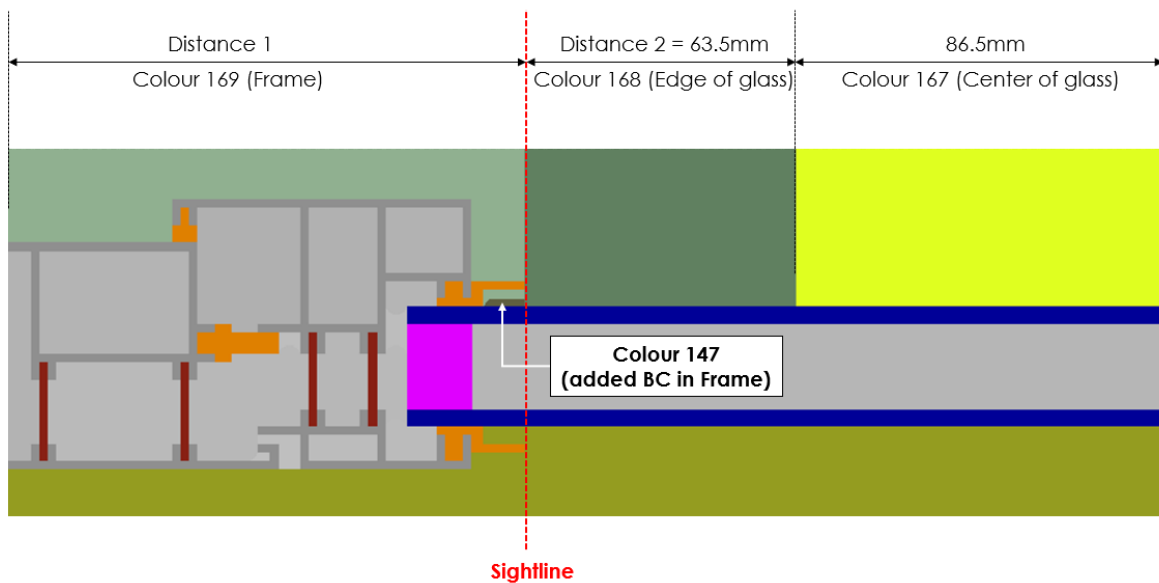
### 3. Case 3: Frame with protruding part

[case3.bsc](#)

Again the sightline is positioned at the highest opaque part, being the protruding part of the frame. The figure below – taken from the NFRC simulation manual - illustrates that below the sightline the boundary conditions touches both glass and frame material. This results in the same situation as described in the previous paragraph, where the heat flow corresponding to the frame consists of two boundary condition colours.



Using the same example, but now including a protruding part of EPDM, the figure below illustrates the manual assignment of an additional boundary condition colour (in this case, colour 147).



Again, in the calculation of the  $U_f$  (see equation (1) above),  $\Phi_{fr}$  corresponds to the sum of the heat flow leaving boundary condition colours 169 and 147.

| Distances |        |      |        |        |               |            |      |    |      |    |           |                    |  |
|-----------|--------|------|--------|--------|---------------|------------|------|----|------|----|-----------|--------------------|--|
| No.       | Mode   | Dir. | Extent | State  | Length [pix.] | Length [m] | X1   | Y1 | X2   | Y2 | U [W/m²K] | Enforced U [W/m²K] |  |
| 1         | LOCKED | X    | MAX    | NORMAL | 1227          | 0.1227     | 0    | 0  | 1226 | 0  |           |                    |  |
| 2         | LOCKED | X    | MAX    | NORMAL | 635           | 0.0635     | 1226 | 0  | 1860 | 0  |           |                    |  |
| 3         | LOCKED | X    | MAX    | NORMAL | 789           | 0.0789     | 1861 | 6  | 2649 | 6  |           |                    |  |

Once assigned, to set up the output of  $U_{fr}$ ,  $U_{eg}$  and  $U_{cg}$ , *Edit* → *Derived Thermal Properties...*

☒ Equivalent thermal transmittance (U) - based on incoming heat flow from boundary condition

|                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Element 1</b><br>Subscript: <input type="text" value="fr"/><br>Width along distance no.: <input type="text" value="1"/><br><input type="checkbox"/> Add width distance no.: <input type="text" value="2"/><br>Heat flow BC colour no.: <input type="text" value="169"/><br><input checked="" type="checkbox"/> Add BC colour no.: <input type="text" value="147"/> | <b>Element 2</b><br>Subscript: <input type="text" value="eg"/><br>Width along distance no.: <input type="text" value="2"/><br><input type="checkbox"/> Add width distance no.: <input type="text" value="2"/><br>Heat flow BC colour no.: <input type="text" value="168"/><br><input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/> | <b>Element 3</b><br>Subscript: <input type="text" value="cg"/><br>Width along distance no.: <input type="text" value="3"/><br><input type="checkbox"/> Add width distance no.: <input type="text" value="3"/><br>Heat flow BC colour no.: <input type="text" value="167"/><br><input type="checkbox"/> Add BC colour no.: <input type="text" value="182"/> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|