Evaluation Method

EM8 [version 1, May 2021]

Window installation – an evaluation method for thermal assessment of the window to wall junction

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Preface

This evaluation method (EM8) assesses the thermal performance of windows installed into housing using a standardised method for the window sill. It can be used to set targets and benchmark one installation system compared to another and aims to realise the better thermal characteristics of higher thermally performing window frames. The scope is currently focussed on the installation of thermally broken aluminium-framed external windows with compact frame platforms (not bifolds, sliders and so on) in low-rise and mid-rise residential buildings. Only the sills are assessed since they must deal with water drainage in different ways than the head and jambs. The same method can be used for assessing the thermal performance of heads and jambs. However, the thermal target should be increased.

An associated evaluation method (EM9), which tests the management of failure water in the window-frame junction at the sill, should be read in conjunction with this document. The two documents were produced to provide more certainty around two critical aspects of higher-performing windows.

Acknowledgements

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BRANZ Evaluation Method EM8 (version 1)

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Reference

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Abstract

This document provides a practical method for thermally assessing a window installation construction detail in a typical New Zealand housing situation. It targets the sill of thermally broken aluminium-framed windows with the aim to achieve better overall thermal performance compared to current New Zealand Building Code details. The scope is limited to windows with compact frame platforms (not bifolds, sliders and so on) in low-rise residential buildings. It is designed primarily to encourage improvement rather than to compare different installation methods between different suppliers. The driver for this project stemmed from various actors recognising that the thermal performance of almost all higher-performance windows was not being achieved in practice currently in New Zealand. The catch is that weathertightness cannot be compromised in any way (when compared to E2/AS1 solutions) nor can practical in situ buildability. Providing a robust weathertight installation solution for thermally broken window framing will supplant the many ad hoc, unproven and risky solutions that are marketed as being of higher thermal performance, which do not acknowledge weathertightness.

Keywords

Thermal performance, window installation, EM8, double glazing, test method, evaluation method.

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Note: This evaluation method shows models of actual window sections that were available in the New Zealand market as of 2018. Different sill sections from different manufacturers have been chosen randomly. BRANZ has sought permission to use the extrusions but does not take any position regarding their performance, nor does BRANZ recommend their use over any other system that may be available.

1. Background

In terms of thermal performance, it is recognised internationally that the window system (the combination of the window glazing, window frame and the building structure) is a weak link in the building thermal envelope. Typically, a window system in New Zealand has about 1/10th the thermal resistance of walls (a window R-value of 0.26 m²K/W compared to a wall R-value of 2.0 m²K/W) and accounts for between 35% and 50% of the heat loss of a house newly built to Code in New Zealand.

The New Zealand Building Code (NZBC) thermal insulation requirements (clause H1 *Energy efficiency*) do not currently reference the thermal characteristics or performance of the window-wall installation junction. The only window installation detail currently shown in the NZBC is in E2/AS1, which provides a weathertightness solution appropriate for several window frame materials but has less than ideal thermal properties. This is due to the ability for external air to access internal surfaces of the window framing and, particularly in thermally broken aluminium window systems, to access both the indoor and outdoor sides of the thermal break. This effectively bypasses the thermal break, which means that the thermal benefit of thermally broken window frames is not being fully realised when the E2/AS1 solution is used.

BRANZ undertook a programme of thermal modelling of typical New Zealand window installations covering the practical range of potential installations. The thermal performance changes due to the location of a window in relation to a typical timber framed wall are shown in Figure 1.[1]

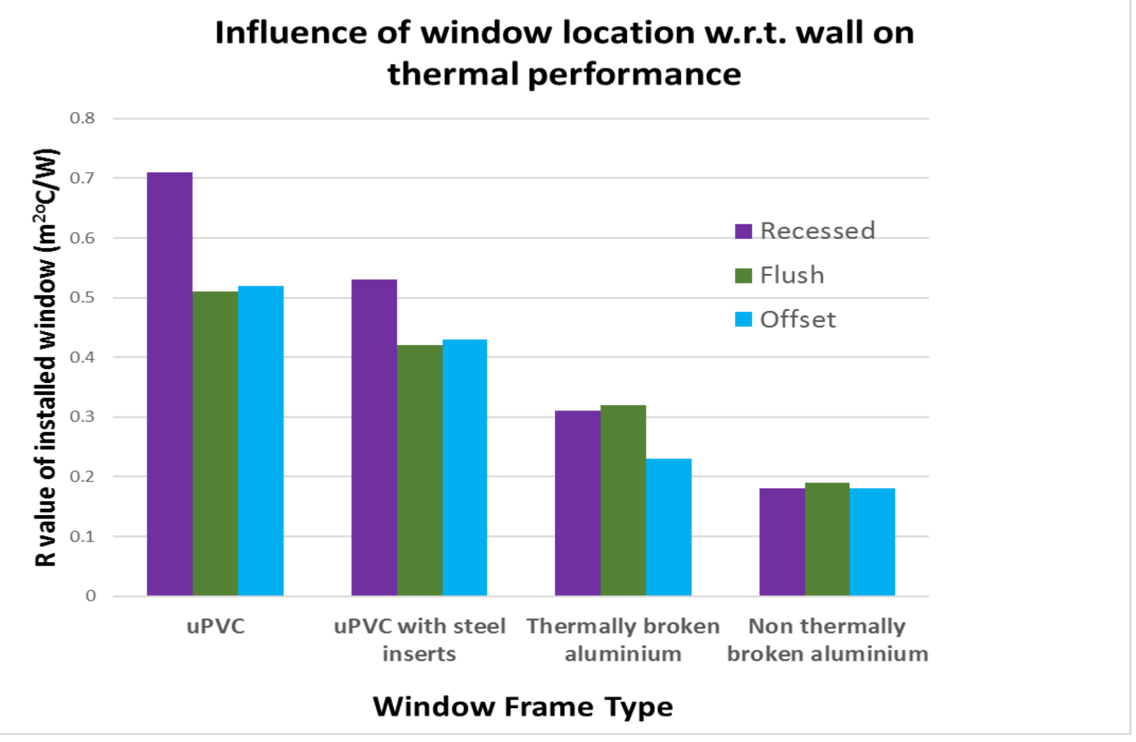

Figure 1. Thermal performance of a variety of windows located differently in a wall.

[1] Note: This graph has been produced solely to compare the thermal influence of the location of window systems within a wall using New Zealand construction methods and window systems available as of January 2018.

In Figure 1, the R-value of the glazing, frame and a portion of the installation has been included so that the R-value of the complete system can be calculated.

The terms 'offset', 'flush' and 'recessed' are used here to mean the following:

- **Offset:** The window frame is moved horizontally (offset) towards the exterior of the wall so that the outside edge of the frame is outside the cladding. This is excellent for weathertightness (provided an adequate head flashing is used) and is the approach taken in E2/AS1.
- **Flush:** The outside edge of the window frame is flush with the outside of the structure (which can also be the cladding in the case of some masonry or solid walling systems). This can pose issues for drainage of water from the window system, since it is expected that any water from around the window installation or failure water from within the window system will be drained to outside the structure.
- **Recessed:** The window frame is installed within the depth of the wall so that the outside edge of the window frame is inside the line of the structure and the line of the cladding. Although this is encouraged in Europe, this has significant issues for drainage of water, both from around the window installation and from failure water within the window system.

As can be seen in Figure 1, there is approximately 30% improvement in thermal resistance for the thermally broken frame window when moving it from the offset position (typical New Zealand practice) to the flush position where it is in line with the wall's thermal envelope. The E2/AS1 solution (offset approach) for the sill of thermally broken aluminium windows has an R-value (for the window installation) of 0.23 m^2W/K. This can easily be improved by about 30% to 0.30 m^2K/W. Moving a thermally broken frame further back into the structure (recessed) does not improve the R-value of the window and in fact could make it slightly worse. For standard aluminium-framed double glazing, the installation location has no significant effect on the thermal performance of the window. However, for uPVC-framed window systems, the location of the window within the wall does impact on the thermal performance of the window. Similarly, it can be seen that the location of a double-glazed window with a non-thermally broken aluminium frame (a typical aluminium window) within the depth of a typical New Zealand wall system has no significant impact on its thermal performance.

Given that there is an increasing interest in higher-performance windows (including those with thermally broken aluminium framing) in New Zealand dwellings, the thermal performance of the window installation needs addressing. It is suspected that a large portion of the building industry is unaware that installation impacts the thermal performance of windows and it is a concern for all, but particularly for:

- window fabricators/builders/window installers who aren't always achieving best thermal practice.
- those involved in building compliance and verification who have to deal with many ad hoc window-wall solutions presented that differ from E2/AS1 and may be difficult to properly assess using desktop methods
- the new home dweller whose indoor comfort benefits aren't always being realised and will be locked into paying higher space conditioning (heating and cooling) costs for the building's lifetime
- energy modellers who desire to more accurately model key building elements in their simulations to provide input into assessment methods.

The thermal performance of thermally broken windows has been able to be tested and modelled for decades. This has led to significant performance improvements in these products. However, there has been a lack of good installation solutions that account for the complex (and often competing) thermal and other performance needs when windows are installed in situ.

This evaluation method aims to address the need to leverage the improving thermal potential of thermally broken aluminium windows by providing a robust thermal simulation methodology to assess their installation. With its proper application, a significant amount of the thermally broken window's performance can be recaptured. It is recognised that windows have a variety of performance characteristics to meet, and energy efficiency is just one of these. While striving for good performance in energy efficiency, the ability for the system to achieve good weathertightness (NZBC clause E2 *External moisture*) must not be compromised. As such, this evaluation method (aligned to NZBC clause H1) has been designed so it can be used in parallel with EM9, which addresses weathertightness issues of the installed window. It is expected that window manufacturers who are intent on maximising the performance qualities of their windows will provide solutions that comply with both EM9 and this document.

It should be noted that the installation of windows in New Zealand is significantly different from overseas practice due to our differing wall construction material selection, window design and building practice. In New Zealand, it is expected that any water in the joint between the window and the structure will be drained outside of the structure. Likewise, any failure water from within the window itself is expected to be drained outside of the structure. Thus, there was not an option to simply accept overseas examples for use in New Zealand without completely changing the construction of exterior walls. It is recognised that there may be costs involved for carrying out this evaluation method, which is not ideal. However, we believe that the gains in terms of improved thermal performance of window to wall junctions outweigh any potential cost penalties. The head and jambs are not included in this method since it is assumed that they can be sealed in a way that allows both water drainage and improved thermal performance, which is not always possible at the sill.

It also must be noted that a thermally broken aluminium frame could be located directly on top of an aluminium flashing or a steel sill trimmer that bypasses the thermal break of the window and denigrates the thermal performance of the complete window system. This installation thermal performance assessment method does not address this difficulty, since it assumes an adiabatic line between the top of the sill trimmer and the bottom of the installation materials. So while this method addresses the thermal performance of a window installation, it does not address any thermal difficulty in the connection to the wall system below. Whole-wall thermal modelling is needed to address this issue.

It is anticipated that this evaluation method can be used by anyone proficient in the thermal modelling program flixo or through use of THERM, or BRANZ can be commissioned to undertake the work.

2. Thermal performance assessment

2.1 Options

There are two competing approaches to defining and calculating the thermal impact of installing windows in a wall. One method assumes the junction between the wall and window is a thermal break between the two insulation values of the wall and the window, and the other approaches the window installation as a third material. There are definite benefits to each approach. Using the thermal break approach attributes a psi (ψ) value to the junction, which can easily be calculated with thermal modelling software such as flixo. The junction is treated as a short one-dimensional interruption to the predefined thermal performance of a window and wall based on area. It is not easily measured in a heat flow experiment but is mathematically elegant.

The 'third material' approach attributes an R-value to the installation, assuming that the installation area can be clearly defined and treated as another area with a specific R-value. This avoids confusion between the ψ value used for the spacer in an IGU and modelling methods that calculate an average ψ value for constructions including more than one thermal break.

In this work, we have chosen the second approach since it is simpler and focuses on the performance of the window installation without needing to define the R-values of the wall or the window. This does not prevent users from continuing to use the ψ value approach (which is well documented in flixo tutorials) but provides a simpler approach to achieve the same ends.

2.2 Aim

The aim of this evaluation method is to meet the thermal target value for installation of a thermally broken aluminium fixed window sill into structural framing of ≤ 0.33 W/m²K or the equivalent R-value of ≥ 3 m²K/W. This is based on using EN ISO 10077-2:2017 *Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames* with the New Zealand-specific variations noted in the following section. It is only applicable to the sill. While the same method can be used for the sill, head or jamb of a window system constructed with any frame size and material, in any structural material, the target R-values will not necessarily be the same. This is because using window framing with significantly different platform widths and heights, different thermal break ratios (and constructions for the head and jambs) may alter the basic thermal performance of the system. This method has only been tested with a small number of system variations at the sill and may not accurately allow the comparison of widely different window or door systems.

The wider aim of this document is to:

- increase the installation of energy-efficient windows in the New Zealand housing and small building stock
- provide more certainty for the building and related industries on window installation performance and benchmarking
- contribute to local and central government objectives on the mitigation of climate change and the focus on warmer, drier and healthier homes
- allow the direct comparison of window installation practices for the purposes of window installation method development.

2.3 Method

2.3.1 Computer model set-up

Thermal modelling of the window installation is undertaken for the horizontal heat flow perpendicular to a vertical line up from the top of the building structure at the sill (usually sill trimmer) to the underside of the window system. This specifically is the horizontal underside of the lowest horizontal section (of more than 5 mm length) of the window system, which typically will be the underside of the reveal/liner. All the materials used for structural support, water drainage and airflow management under the window sill are included, unless they are non-continuous.

Modelling with flixo (version 8.1)[2] is required and is the only method this evaluation method has been designed for. flixo is a robust thermal analysis program that has been validated to EN ISO 10211:2017 *Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations* and EN ISO 10077-2:2017 in accordance with a component assessment method. Other simulation methods or packages (such as Window 7.7.07) could be applied in future once comparative checks and verification have been carried out and may be considered in a future update.

The following steps provide the calculation methodology for determining the thermal performance of window framing installation systems in New Zealand to allow comparisons on standard basis. It extends the WEERS[3] method. If standard comparisons between systems are not required, the method can be modified. Figure 2 shows the window-wall junction detail that should be referred to when reading this evaluation method.

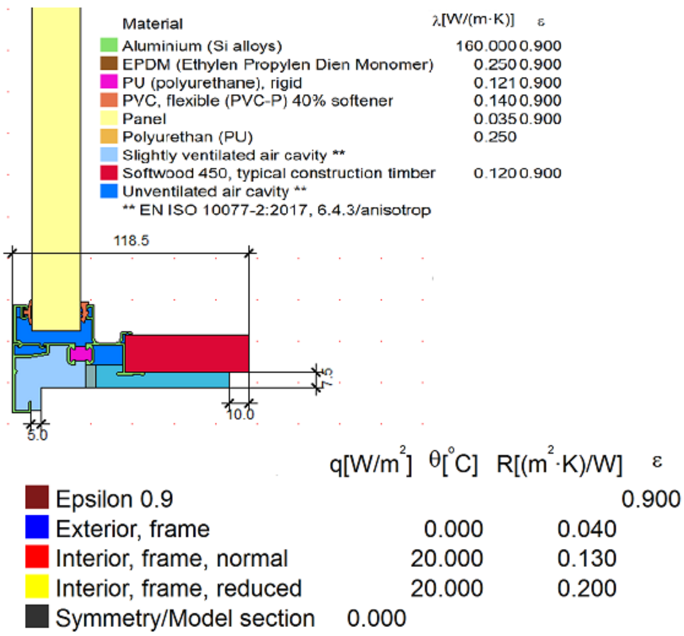

Figure 2. flixo set-up for window-wall system.

[2] https://www.flixo.com/products/flixo-pro/

[3] The Window Energy Efficiency Rating System (WEERS) provides a robust method to determine and rate the thermal performance of window systems. It was developed by BRANZ for a consortium of interested parties in 2000 and adopted by several major New Zealand window manufacturers. It formed the base of the ENERGY STAR rating for windows in New Zealand before the Energy Efficiency and Conservation Authority exited ENERGY STAR®.

2.3.2 Standard modelling method

1. Model the window sill section with a horizontal timber reveal with the internal surface and timber liner/reveal on the right-hand side, with any associated hardware, seals and equipment necessary to provide weathertightness. The underside of the reveal provides the top surface for the model. (This is a departure from EN 10077-2:2017. In this method, reveals are retained in the thermal modelling.)
2. As in EN ISO 10077-1:2017 *Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: General*, insert a 250 mm high panel in place of the IGU of 24 mm width with thermal conductivity (λ) of 0.035 W/mK. (If using triple glazing, the width and thermal conductivity can be different, but the default is double glazing.)
3. Ensure the thickness of the air cavity between the bottom of the panel and top of the sill frame platform is at least 6 mm to meet requirements in NZS 4223.3:2016 *Glazing in buildings – Part 3: Human impact safety requirements*.
4. The thickness of the timber reveal shall be 19 mm, of softwood with density of 450 kg/m³ and conductivity of 0.12 W/mK.
5. Alter the length of the timber reveal to provide an overall length of the adiabatic line (width of the window system) between 115 and 120 mm as shown in Figure 3.

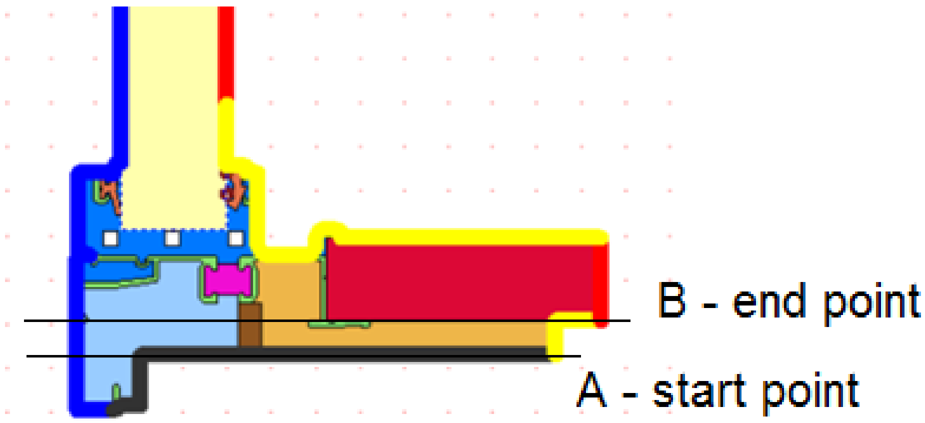

Figure 3. Boundary conditions highlighted as per Figure 2.

6. Use the materials from the "EN ISO 10077-2: Frame" directory in flixo.
7. Retain the exterior weathering fin/flange typical in current aluminium windows. (This is a departure from EN 10077-2:2017, relevant to New Zealand only.)
8. Model the character of the air under the sill as "slightly ventilated" air unless the opening to outside air is actually closed or open only through intermittent drainage slots/holes/passages. (This is a departure from EN 10077-2:2017, relevant to New Zealand only.)
9. Extend the horizontal size of the "slightly ventilated" air on the inside of the outer sill flange to provide a 5 mm horizontal offset of the frame from the sill trimmer.
10. Ensure the vertical height of the "slightly ventilated" air under the sill frame is modelled with a trim cavity of 7.5 mm. (This dimension is recommended for comparison purposes and should be used as the default dimension. However, if your system must have a different dimension, then that value should be used.)
11. Retain a value of 0.9 for the emissivity of all the surfaces within the system. (This value is recommended for comparison purposes and should be used as the default dimension. However, if your system must have a different emissivity, that value should be used.)

12. Retain the boundary conditions from EN ISO 10077-2:2017 of 0.04 m²K/W for the outside surfaces and 0.13 m²K/W for inside surfaces using the "Interior Frame" surface tag (see also Figure 3).
13. Locate the lower adiabatic boundary (Symmetry/Model section) on the top of the sill trimmer (which need not be modelled) at point A as in Figure 3.
14. Do not include the interior wall lining in the model. However, retain a gap of 10 mm wide by 7.5 mm high at the inside of the timber liner where this lining would be located at point A as in Figure 3. (This guidance is recommended for comparison purposes. However, if your system integrates with the lining, include it in the model.)
15. As in EN ISO 10077-1:2017, ensure that the internal and external air temperatures of 0°C and 20°C are used.
16. Ensure that flixo modifies the internal surface coefficient (usually to 0.2 m²K/W) for any significant horizontal surfaces where air may 'pool'. (Note the red and yellow colouring of these lines in Figure 3.)
17. Calculate the U_f (equivalent U)-value of the section at the interior from the top of the sill trimmer (not from the bottom of the flange) to the bottom of the timber reveal liner (not to the glazing sightline) from point A to point B as in Figure 3. In version 8.1 of flixo pro, this can be difficult to achieve, since flixo is expecting a horizontal adiabatic line at the bottom of the window and typically in New Zealand we have a flange that drops below the horizontal bottom of the sill reveal/liner. This sometimes results in flixo calculating the thermal performance using sloped lines (see Figure 4), but other versions of flixo may have different approaches.

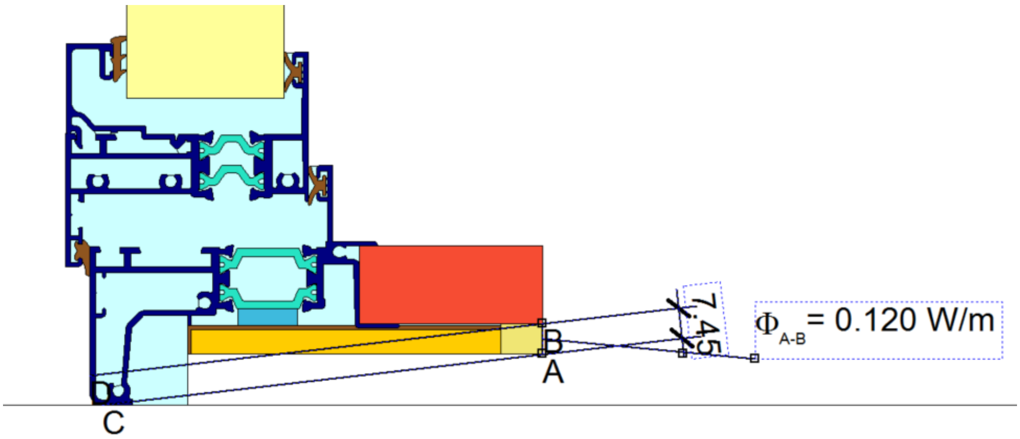

Figure 4. flixo automatically sets calculation nodes incorrectly with normal anti-clockwise point selection.

There are several ways to achieve the right setting, including the following for reverse selection:

a. Select and delete the phi (Φ) calculation and sloped lines. After choosing "Equivalent U value", click on the bottom corner of the sill reveal/liner first, then below it to the top of the sill trimmer (clicking clockwise, instead of the normal counter-clockwise direction). This provides parallel lines but defaults to an incorrect dimension (in this case 20 mm) to the bottom of the flange, as in Figure 5.

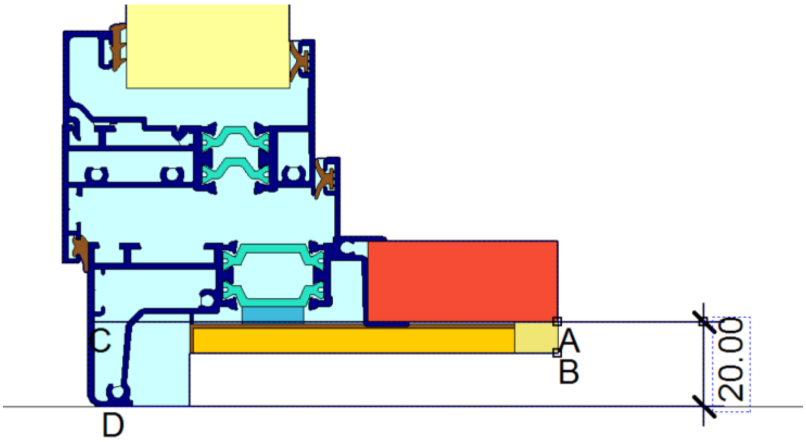

Figure 5. Correct location for the equivalent U-value calculation of the window installation but incorrect distance 'b'.

b. To correct the 20 mm dimension for the divisor 'b' (from A to B), click on the "Automatic" entry in the Calculation option of the "Properties" box, as in Figure 6.

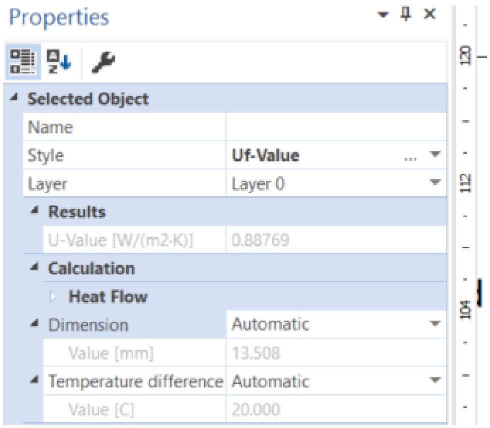

Figure 6. Selection of the "Automatic" dimension for heat flow.

c. Select the other option of "Custom" from the drop-down arrow menu and enter the dimension of the installation gap, which we typically choose to be 7.5 mm, as in Figure 7.

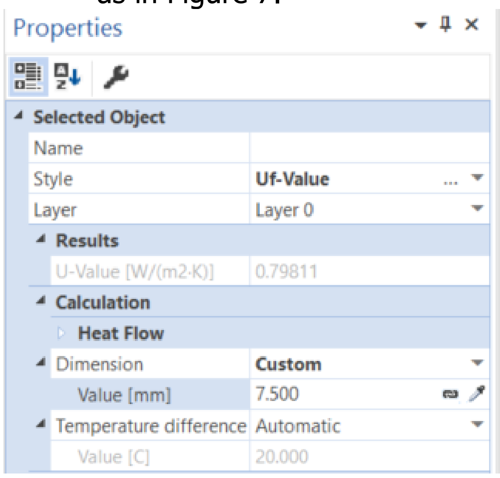

Figure 7. Selection of the "Custom" dimension for heat flow.

d. Note that, in Figure 8, flixo rounds this value to 0.008 m but correctly calculates the equivalent U-value between points A and B. In this case, it is 0.798, which converts to an R-value (1/U) of 1.25 as in Figure 8. (Note that this is not compliant with the target of < 0.33 W/m²K.)

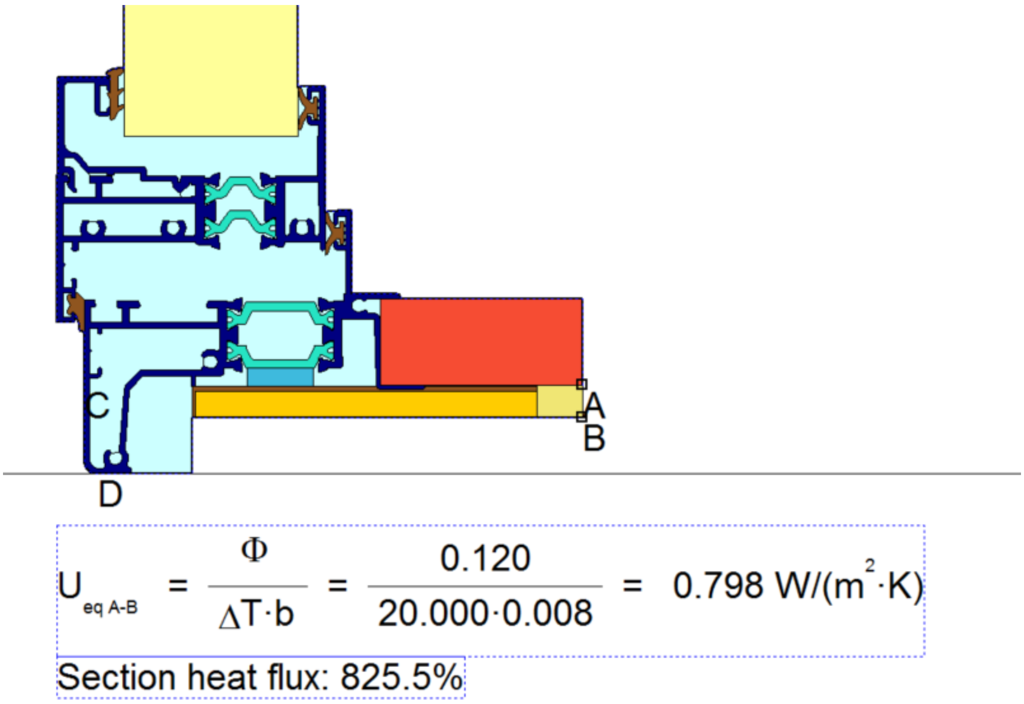

Figure 8. Correct location and distance for U/R-value calculations for a window installation.

It should be noted that, due to the need to use an adiabatic line below the modelled elements, no heat flow is modelled through the sill trimmer so the correct distribution of heat flow is not achieved. While this allows accurate comparison of sections, their interaction can only be assessed with a model combining all the elements. This is of particular concern when elements that have high thermal conductivity (such as metals) are located at the edges of the thermal models and poses challenges for adequately modelling the performance of steel-framed structures.

2.3.3 Pass/fail criteria

The window installation method is compliant with the test requirements providing the target thermal transmittance value for installation of a thermally broken aluminium fixed window into timber framing (U) is < 0.33 W/m²K (i.e. an R-value greater than 3 m²K/W).

2.3.4 Notes to the modelling method

1. To determine the target U-value or R-value, thermal modelling was undertaken on four different representative thermally broken aluminium window sill sections. It was assumed that, in the worst case, the following may occur:

    - Water may leak through the connection between the thermal break and the aluminium frame portions.
    - The installation may allow the thermal break to be bridged by more-conductive materials, hence bypassing the thermal break.

These concerns have the following implications:

- No water-absorbent materials should be used in the sill trim cavity towards the outside of the thermal break.
- The sill trim cavity cannot be sealed at the outer face since it must allow water to drain from any potential leaks under the thermal break and from corner mitre joints in the sill section or from fixings penetrating the sill for mullions or other window hardware as well as water draining down from the jambs or head.
- The sill trim cavity between the underside of the reveal and the top of the sill trimmer can only be sealed along a line below the innermost extent of the glazing platform.

Examination of Figure 2 (and Figure 3) shows that these concerns have been implemented where a 5 mm wide bead of flexible sealant is installed around the complete circumference of the window between the interior-side of the thermally broken frame and the support timbers. The cavity outside of this bead remains open and contains "partially ventilated air" as per EN ISO 10077. The trim cavity inside of this bead is filled with a polyurethane foam where no failure water is expected.

2. It is expected that the proprietary system supplier (i.e. window suppliers/designers) will develop their own installation details that will achieve the dual goals of:

   - passing the water ingress test (EM9)
   - achieving a U-value ≤ 0.33 W/m²K (R-value > 3.0 m²K/W) according to this method.

3. Only the sill is being thermally modelled, not the jamb or head, since the sill poses particular difficulties due to requiring both water drainage and thermal performance. The industry already has techniques where the head and jambs can be constructed to allow both drainage and good thermal performance.

4. To complete this evaluation method, it is suggested that detailed installation instructions should accompany the window systems. This provides an easy way for educating installers and ensures the necessary process is being followed consistently. Where the in situ installation is not being carried out by the window manufacturing company, a clear and comprehensive set of instructions should be provided to the installer to follow.