WB14: Fenestration 2
CONSIDERATIONS FOR THE CONDENSATION RESISTANCE OF FENESTRATION ASSEMBLIES

BEST2 2010
Oregon Convention Center – Portland, OR
14 April 2010
Outline of Discussion

- U-factor vs. Condensation Resistance
- Effects of Condensation
- Means to Address/Control
- Design Considerations
- Summary/Conclusions
U-Factor vs. Condensation Resistance

U-Factor (a.k.a. U-Value)

- Thermal Transmittance from air on warm side of fenestration to air on the cold side
- Area-weighted average of the heat flux through all components of the fenestration system
- Averages thermal transmittance effects of Center-of-Glass (COG), Edge-of-Glass (EOG) and Frame areas
U-Factor vs. Condensation Resistance

EOG = 63.5 mm (2-1/2”) perimeter around COG

U-factor is area-weighted average:

\[
U_w = \frac{U_f \cdot A_f + U_{cog} \cdot A_{cog} + U_{eog} \cdot A_{eog}}{A_w}
\]

Legend

- COG: Center-of-Glass
- EOG or E: Edge-of-Glass
- F: Frame
Condensation Resistance

- Ability of a fenestration system to resist the formation of condensation on interior surfaces
- Primarily affected by the thermal conductivity of discrete components
- Highly conductive components can “short circuit” fenestration system performance due to thermal bridging
Condensation Resistance

- Primary factor is localized areas of heat flux vs. area-weighted average for U-Factor
- Can lead to moisture or even frost formation on fenestration systems with otherwise very good U-factors
Rating Systems

U-factor

- American Architectural Manufacturers Assoc (AAMA)
- Uses physical testing of fenestration system and components under AAMA 1503 and ASTM C518
- Physical test data is combined under AAMA 1505 to develop U-Factors for fenestration system glazing configurations
Rating Systems

U-factor

- National Fenestration Rating Council (NFRC)
- Uses computer simulation under NFRC 100 for all fenestration system glazing options
- A representative unit construction is physically tested to validate the matrix of simulated performance data
Rating Systems

As AAMA and NFRC U-factor analyses are performed under the same exposure conditions (exterior = -18°C (0°F), 6 m/s (15 mph) wind; interior = 21°C (70°F), natural convection) and U-factor is a physical attribute of the system, values are interchangeable.

$$U\text{-factor}_{\text{AAMA}} = U\text{-Factor}_{\text{NFRC}}$$
Rating Systems

Condensation Resistance

• AAMA uses physical testing of fenestration system and components under AAMA 1503, 1505 and ASTM C518 to derive the “Condensation Resistance Factor (CRF)”

• CRF is dimensionless rating within range of 30 – 80 with higher number representing greater resistance to condensation
Rating Systems

Condensation Resistance

- NFRC utilizes computer simulation under NFRC 500 to obtain Condensation Resistance rating of fenestration system; no testing.
- Condensation Resistance is dimensionless rating within range of 1 - 100 with higher number representing greater resistance to condensation.
Rating Systems

Condensation Resistance

• AAMA CRF and NFRC Condensation Resistance ratings are relative ratings of systems performance.
• Neither provides a measurement of a physical attribute of the product.
• There is no correlation between AAMA and NFRC condensation resistance rating values.
Comparing U-factor & Condensation Resistance

- U-factor and Condensation Resistance are not related; linearly or otherwise
- Factors that affect an improvement in one may improve the other; may also make the other worse
- Data compiled from NFRC Certified Products Directory (CPD) for two different framing systems
## U-factor vs. Condensation Resistance

<table>
<thead>
<tr>
<th>Product</th>
<th>Glazing Configuration</th>
<th>U-factor (W/m²-K)</th>
<th>Condensation Resistance</th>
<th>CR Variation from Previous</th>
</tr>
</thead>
<tbody>
<tr>
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**U-factor vs. Condensation Resistance: Wood Fixed Window**

Wood Fixed Window: U-factor vs. Condensation Resistance

<table>
<thead>
<tr>
<th>Glazing Configuration</th>
<th>U-factor</th>
<th>Condensation Resistance</th>
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<tbody>
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<td>GLAZING1</td>
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<td>GLAZING7</td>
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U-factor vs. Condensation Resistance: PVC Fixed Window

PVC Fixed Window: U-factor vs. Condensation Resistance

Glazing Configuration

Glazing Configuration

U-factor (W/m²-K)

Condensation Resistance

- U-factor
- Condensation Resistance

PVC Fixed Window: U-factor vs. Condensation Resistance

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Effects of Condensation

- Moisture or ice formation
- Water damage to window or wall surround
- Incurred clean-up
Effects of Condensation

- Mold growth leading to reduced IAQ
- Lower quality perception
- ‘Nasty’ looking
Simple Solution???

Lower Interior Relative Humidity (RH)???

• Tighter building envelopes lead to trapped moisture
• Active air exchange/venting systems may not address problem areas (kitchen, bath, laundry, etc.)
• Reduce interior RH and solve problem…?
• Dry air is not always good air…
Healthy IAQ Has Moderate RH

- Pathogens grow at each end of RH range
- Optimum interior RH range = 30% - 55%

Source: Health Canada
Nice target but…

Indoor Air Temp = 22°C/72°F:

Fenestration Interior Surface Temps for:

30% RH = 4°C/39°F

55% RH = 13°C/56°F

Only 9°C/16°F less than ambient air temp!
Thermally broken AL frame, alubar spacer

U-Factor = 1.772 W/m²-K (0.312)

Condensation Resistance = 40

21°C/70°F interior; -18°C/0°F

Condensation @ any RH%
EOG Effects

Thermally broken AL frame, stainless spacer

U-Factor = 1.737 W/m²-K (0.306)  Condensation Resistance = 41

21°C/70°F interior; -18°C/0°F

Condensation @ any RH%

U-Factors

<table>
<thead>
<tr>
<th>Component</th>
<th>U-factor W/m²-K</th>
<th>delta T °C</th>
<th>Length mm</th>
<th>Rotation</th>
<th>Projected in Glass Plane</th>
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</thead>
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</tbody>
</table>

% Error Energy Norm: 7.15%

Condensation @ any RH%

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**EOG Effects**

Thermally broken AL frame, foam spacer

U-Factor = 1.628 W/m²-K (0.287)  
Condensation Resistance = 46

21°C/70°F interior; -18°C/0°F

Interior RH OK to ≈ 27%
Design for Condensation Resistance

Thermally Broken Framing Systems:

- Aluminum thermal break to conditioned space
- Aluminum cladding to exterior of conditioned space
Design for Condensation Resistance

Reduce Extraneous Air Leakage

- Air leakage through frame joints, around glazing system and/or through gaps in operable units can lead to localized cold spots

- Not a calculational variable as requires physical testing/evaluation of system
Optimize Glazing Dimensions

Minimize Convection Inside IGU:

Bigger not always better!

Optimal glazing gap:
- Air/argon = 13 – 15 mm
- Krypton = 5 – 7 mm

< Optimal increases conduction

> Optimal increases convection
Minimize Conduction thru EOG

Different spacer systems have relative degrees of “WET” (warm-edge tech)
Minimize Conduction Thru EOG

All have similar influence in COG but very different localized effect at IGU edge

Relative Comparison

21°C/70°F interior & 50% RH interior; -18°C/0°F exterior in common test assembly

Full Metal  Less Metal  No Metal
EOG Effects – IG Only

clear/alubar spacer-air/clear

low-e/foam spacer-air/clear
Review/Conclusions

- U-Factor is an area-weighted heat flux measurement
- Condensation resistance is a localized thermal ‘short-circuit’/bridging measurement
- Rating programs for condensation resistance are relative and not interchangeable
Review/Conclusions

- Changes in U-factor and condensation resistance ratings are not related and are sometimes in opposition.
- Poor condensation resistance can result in:
  - Water/ice formation
  - Damage to window/wall surrounds
  - Mold growth
  - Poor IAQ
  - Poor quality perception
Review/Conclusions

- Multiple design factors must be addressed to manage condensation resistance including:
  - Thermally broken/improved framing systems
  - Reduction of extraneous air leakage through joints and/or gaps in operable systems
  - Optimize glazing package with specific focus on spacer/edge seal construction and thermal conductivity
Questions/Comments???
THANK YOU!!!

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