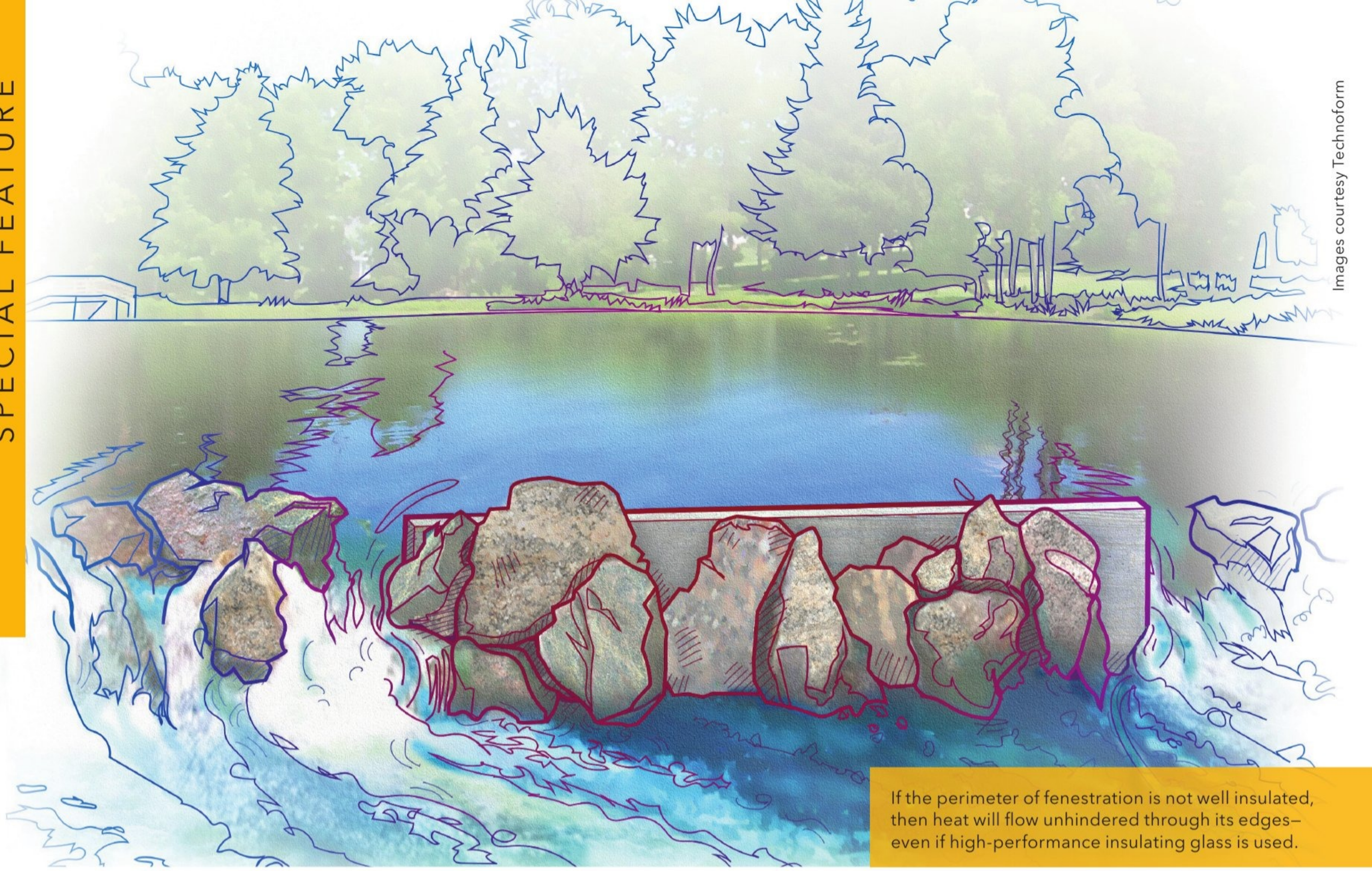


Images courtesy Technoform

If the perimeter of fenestration is not well insulated, then heat will flow unhindered through its edges—even if high-performance insulating glass is used.

The Heat Is On

How to reduce thermal bridging in building facade systems

By Helen Sanders

Thermal bridging describes places on a building's facade system where there is unhindered conduction of heat from the inside to the outside and vice versa. It is the thermal equivalent of an electrical short circuit or of water flowing through holes in a dam. Heat will find the path of least resistance and will flow through the pathways that offer the best conduction path.

The "leakage" of heat can cause serious issues relating to condensation and resultant mold growth, as well as degraded energy performance and thermal discomfort for occupants. Condensation is especially problematic when it occurs in the middle of the wall where mold cannot be seen yet can contribute to poor indoor air quality (IAQ).

With proper planning, design, and construction, high-performance fenestration, opaque cladding, and attachment systems can help mitigate these issues.

Areas of alert

Thermal bridging can occur in many places on a building's facade, including the following:

- At the window frame—if the frame is not thermally broken. To prevent a "thermal short" in the fenestration, it is important to use well thermally broken aluminum extrusions.
- At the edge of glass (EOG)—if highly conductive insulating glass spacers, such as aluminum box, are used in the insulating glass, then these can cause condensation at the EOG.
- At the connection between the perimeter of the fenestration and the adjacent wall—understanding and specifying continuous insulation (ci) from wall to fenestration is important.
- Within spandrel panels—heat flows around the insulation in the spandrel when the position of the insulation is not aligned with the position of the thermal breaks in the metal framing. This allows heat to bypass the insulation via the aluminum frame. Even if the curtain wall is thermally broken, the framing still has less thermal resistance than insulation.
- Between the spandrel areas of curtain wall and the transparent areas—due to the continuous vertical mullions, heat easily conducts to and from the opaque areas. Currently, thermal performance of the curtain wall does not consider this conduction path. Thermal performance of spandrel areas is, therefore, currently overestimated unless 3D thermal modeling is used.
- At the connections of opaque panels to the building structure—typically, continuous metal Z-girts are used to connect high thermally performing opaque panels to the building. This can reduce R-values by more than 50 percent, which is often not considered in building energy modeling. This is a concern when considering window-to-wall ratio, and walls are always considered to have higher insulation performance. Depending on the wall construction and attachment,

it may not be so cut and dried. Thermally broken non-continuous cladding clips are now available to reduce thermal bridging around the perimeter. They can make a big impact on the thermal performance of the opaque elements.

- At floor slab edges/balcony edges—if these edges are not effectively covered and insulated to protect them from the outside environment, there will be a heat conduction path directly from the interior to exterior of the building, leading to condensation and energy performance issues.
- At parapets—where long vertical mullions extend past the roofline, and then both interior and exterior mullion elements are exposed to the exterior environment, heat will be conducted, unhindered, up and down the length of the "interior" mullion from the interior room condition to the exterior condition. This will lead to cold internal surfaces, potential for condensation, and lower energy performance.
- At attachments to the facade—for example, sunshades. Specifying thermally broken attachment mechanisms and requiring thermal simulations to determine the impact on assembly U-factor is important.

Challenges and concerns

The key issues with thermal bridging are the risks related to not addressing the problem:

- Energy performance of the building does not match the target (modeled) performance.
- Condensation risk can be considerable and can cause hidden mold and indoor air quality issues.
- Occupant thermal comfort issues next to the facade.

Thermal bridging is not easily assessed using typical simulation tools. For example, Lawrence Berkeley National Laboratory's THERM computer program does not adequately calculate the thermal bridging within spandrel areas, and between spandrel and transparent areas of the curtain wall. This leads to an overestimation of thermal performance and buildings that do not perform as anticipated.

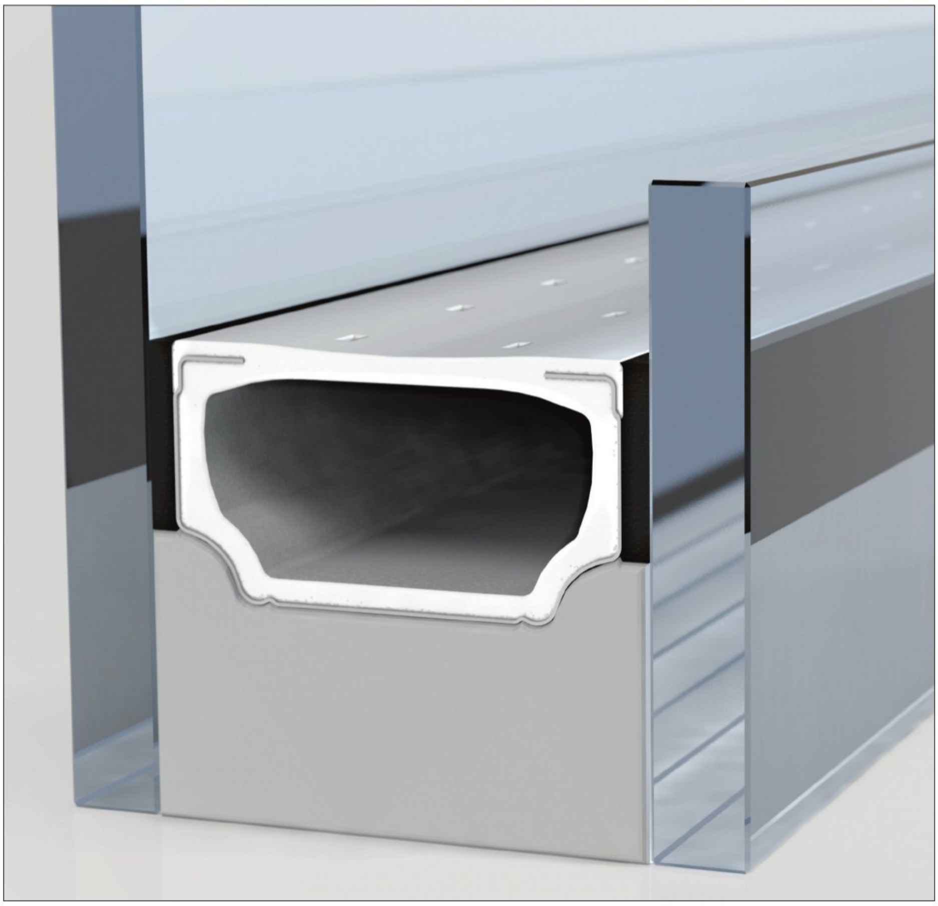
Typically, 3D thermal modeling is needed, which is specialized and expensive. However, a *Building Envelope Thermal Bridging Guide* has been developed by Morrison Hershfield using 3D modeling for many different wall constructions, and can act as a library to help specifiers and contractors understand how to assess performance and choose appropriate wall and spandrel constructions.

University of Central Missouri, Warrensburg, Mo.

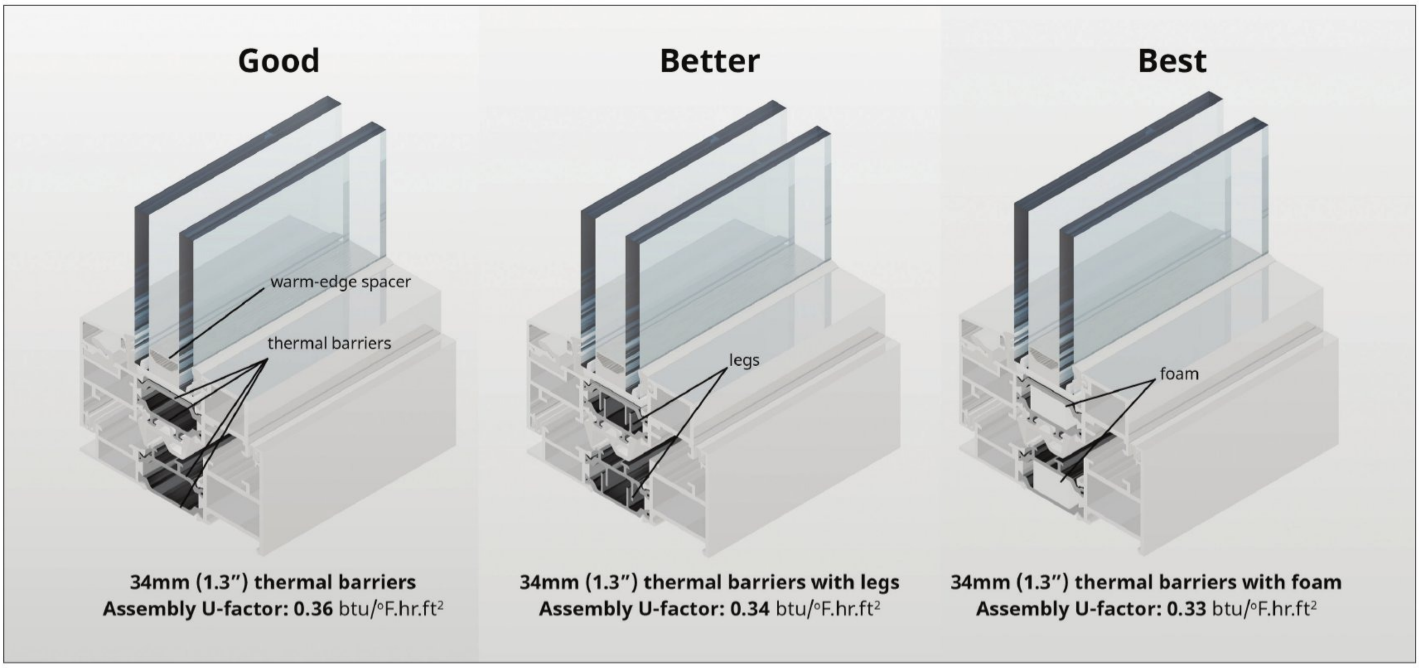
The Student Recreation and Wellness Center's multi-story glazing system minimizes thermal bridging using high-performance, insulating glass with a low-conductivity, warm-edge plastic hybrid stainless steel (PHSS) box spacer.

Designed by Gould Evans, the University of Central Missouri's two-story Student Recreation and Wellness Center includes a fitness area, weight room, basketball courts, indoor track, and a multipurpose area. Its multi-story walls of glass dramatically unite indoor spaces with the natural environment outside. Given the large amount of glass used in this project, and the wide variations in temperature that occur throughout the year in Warrensburg, it was critical to specify the most thermally and structurally efficient window frames and glazing systems available. The solution included incorporating a high-performance insulating glass spacer that delivers outstanding thermal performance, a high degree of structural rigidity, superior gas retention, condensation resistance, and other key performance benefits. The spacer met the stringent criteria for a high-performance spacer by delivering maximum occupant comfort, the highest energy efficiency possible, and major operational cost savings to the center.

Photo by Alistair Tutton Photography Inc./ courtesy Insulite Glass Company and Technoform



A plastic hybrid stainless steel spacer is a standard high-performance, warm-edge spacer in commercial insulating glass. It delivers the high-thermal performance of a non-metal spacer with the benchmark durability of a metal box spacer.



Polyamide thermal barriers are used to reduce thermal conduction and convection across aluminum framing. The wider the barrier, the better the performance.

Focus on fenestration

In aluminum window, curtain wall, storefront, entrance, and other fenestration systems, 85 percent of the thermal bridging occurs at the perimeter. Conduction through the frame and EOG is responsible for 50 percent of the energy flow, convection accounts for 35 percent, and radiation accounts for the remainder. The perimeter is the weakest thermal link in fenestration and is where condensation forms first. The optimum strategy for improving fenestration thermal performance is to improve frame and EOG thermal performance first before focusing on the center of glass (COG).

Improve the framing

Improving the performance of aluminum-framed fenestration typically starts with reducing the conductive heat flow by making a "thermal break" in the continuous metal using a non-metallic material. These non-metal components are called thermal barriers. The wider the separation between the frame's outer and inner surface that the thermal barriers provide, the lower the thermal conduction is in the fenestration system. Specifying a thermal barrier size of at least 25 mm (1 in.) is recommended, as this typically improves the condensation resistance as well as the fenestration U-factor.

Polyamide thermal barriers have a 50-year history of successful use in fenestration, since their introduction in the mid-1970s. Polyamide—commonly known as nylon—is an inert, non-toxic material and safe to use in the fabrication or operation of fenestration systems. To ensure polyamide thermal barriers meet the required structural performance, it is recommended that regular sheer testing is done on extrusion assemblies as a quality assurance measure during manufacturing. Architectural specifications should require compliance with AAMA TIR-A8, *Structural Performance of Composite Thermal Barrier Framing Systems,* published by the Fenestration and Glazing Industry Alliance (FGIA).

For polyamide thermal barriers, widths from 10 mm (0.4 in.) up to 100 mm (4 in.) are possible. Since polyamide can provide the largest separation between framing members, some of the highest performing fenestration systems use this type of thermal barrier.

Once conduction is addressed, strategies to reduce convective heat transfer can be introduced. Strategies such as adding legs or foam to the thermal barriers stop convection currents by breaking up or filling large cavities formed in the extrusions. Additional performance can be gained by reducing the thermal conductivity of the polyamide (low lambda) or adding reflective surfaces to reduce radiative heat flow.

Improve the edge

Historically, highly conductive aluminum box spacers have been used in insulating glass units (IGUs). To reduce thermal conduction across the EOG, aluminum box spacers should be replaced with lower conductivity options generically called "warm-edge" spacers. While stainless steel versions of the standard box spacer are considered warm-edge, those used in commercial applications tend only to deliver a 0.06 W/m^2 K (0.01 BTU/hr•sf F) improvement in window assembly thermal transmittance (U-factor), whereas using lower conductivity warm-edge spacers delivers a 0.11 to 0.17 W/m^2 K (0.02 to 0.03 BTU/hr•sf F) improvement. In structural glazing applications, the benefit can be as much as 0.3 W/m^2 K (0.05 BTU/hr•sf F).

Several lower conductivity warm-edge options are available, including the industry standard plastic hybrid stainless steel (PHSS) box spacer, which delivers the same thermal performance as a non-metal spacer, with the benchmark durability of a metal box spacer. The engineered plastic bridging the top reduces heat flow across the cavity, while the low conductivity, thin stainless steel wrapping the back and sides provides an excellent vapor and gas barrier, plus an effective sealing surface.

Typically, if no spacer is specified, an aluminum box spacer is what is delivered. To prevent this thermal short, specifying a durable, high-performance warm-edge spacer, such as PHSS, is advised.

Once the EOG and frame thermal performance is addressed, improving the

COG performance will have more impact on condensation performance.

Improve the center

The COG performance of a window or other fenestration product is driven by the number, position, and type of low-emissivity (low-e) coatings; the size and number of cavities (double-pane versus triple-pane); and whether inert gas filling is used.

A typical 25-mm (1-in.) dual-pane IGU with a double-silver low-e coating on the inside of the exterior pane (surface #2) and an air-filled 13-mm (0.5-in.) cavity has a COG U-factor of 1.65 W/m ^{2}K (0.29 BTU/hr•sf F). Adding argon typically reduces the COG U-factor to 1.42 W/m^2 K (0.25 BTU/hr•sf F). Changing the double-silver to a triple-silver low-e reduces the COG U-factor further to 1.36 W/m^2 K (0.24 BTU/hr•sf F).

Greater reductions to 1.0 W/m^2 K (0.18 BTU/hr•sf F) can be made by adding a second cavity to create a triple-pane IGU. Triple-pane performance can be enhanced yet further, achieving U-factors as low as 0.74 W/m^2 K (0.13 BTU/hr•sf F) by adding a second low-e coating.

Adding a second low-e coating on the room-side surface of a dual-pane IGU (called a fourth surface low-e) provides an intermediate step in performance before moving to a triple-pane, achieving COG U-factors of 1.14 W/m^2 K (0.20 BTU/hr•sf F). It does, however, lower the temperature of the room-side glass surface, increasing condensation risk.

Scope and sequence

To ensure the installed fenestration and facade systems perform as required, contractors should also be aware of "by others" when it comes to transitions between scopes of work.

The widespread use of the "by others" clause can cause the responsibility for managing the important details of the transitions to be missed. Exactly who has responsibility for tying into the adjacent systems must be specified. If not by the architect, the contractor should ensure it is clear before work is started and that sequencing of work around the transitions is agreed.

In particular, one should ensure sufficient tolerances are provided to make the transition between fenestration and adjacent systems possible and that the contractor sequenced first leaves sufficient length of transition membranes to tie into the second assembly. Contractors should actively collaborate with other subcontractors who have adjacent scopes of work to achieve the best results.

707 Fifth, Calgary, Alta., Canada

Designed by Skidmore, Owings and Merrill (SOM), the 707 Fifth "AAA" office tower in downtown Calgary, Alta., features a distinctive curved glass appearance with high energy-efficiency and a comfortable interior. The building's facade combines convex and concave forms to shape elliptical and undulating elevations. The floor-to-ceiling glass maximizes internal daylighting and comfort, minimizes unwanted solar heat gain and heat loss, and provides panoramic views of the city and the Rocky Mountains.

Despite Calgary's cold climate, the 27-story, 52,400 m^2 (564,000 sf) building met its energy targets, due, in part, to the use of the spacer in the triple-glazed, aluminum-framed curtain wall system. The project earned LEED Gold certification through the Canadian Green Building Council (CaGBC).

Photo by Davide Colonna on Unsplash/courtesy Technoform

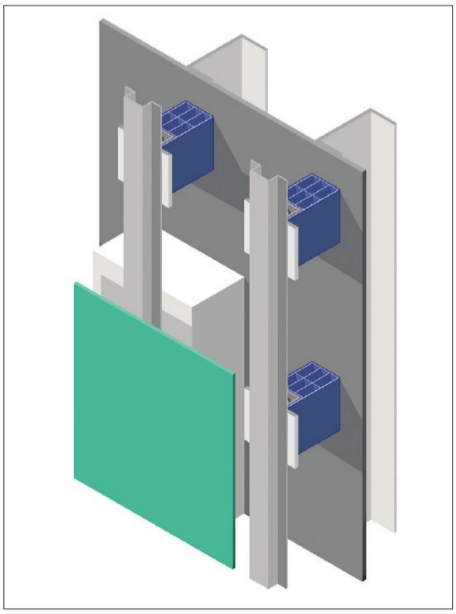
707 Fifth's curved, triple-glazed curtain wall with a warm-edge spacer separating the three panes of glass creates an insulating barrier at the perimeter of the insulating glass units to improve thermal performance.

Photo by Steve LeBlanc/courtesy Technoform

The thermally broken, aluminum-framed facade and floor-to-ceiling high-performance glass of 707 Fifth maximizes internal daylighting and comfort and minimizes unwanted solar heat gain and heat loss.

Responsible contractors understand all the areas where thermal bridging could impact the performance of their scope of work. The thermal performance of the facade is the linchpin of building performance. While it can be traded off with higher efficiency HVAC and lighting systems to achieve the same overall energy performance, this trade-off negatively impacts building resilience and thermal comfort, especially next to the envelope.

To provide the best service to the building team—including the owner and occupants—it is important to understand thermal performance of facade systems inside and out, and to be able to offer practical and aesthetically pleasing solutions.



The use of thermally broken cladding attachments on rainscreen systems significantly reduces thermal bridging at the perimeter of panels compared to regular continuous aluminum Z-girts that can degrade cladding performance by up to 50 percent.

Helen Sanders, *PhD, is a general manager at Technoform North America. She has more than 25 years of experience in glass technology, market development, and manufacturing–especially in functional coatings, insulating glass, and thermal zone technology for fenestration. Sanders has a doctorate in surface science from the University of Cambridge, England. She is an active member of many industry organizations and in codes and standards development. She is the founding president of the Facade Tectonics Institute (FTI) and is the immediate past president. Sanders is a board member of the National Fenestration Rating Council (NFRC) and of the Fenestration and Glazing Industry Alliance (FGIA), co-chair of its Glass Products Council, and of its Innovation and Sustainability Steering Committees. She is also a technical liaison on the Fabricating Committee of the National Glass Association (NGA). She can be reached at* ***helen.sanders@technoform.com.***