Retrofitting with High-Performance, Aluminum-Framed Window Systems

By Jean J. Wu

In the world where two-year-old children can operate a tablet computer with ease, almost every aspect of our lives has been affected, and improved, with advances in technology. Just as older employees may reminisce about their company acquiring its first copy machine or word processor while younger staff members listen in amusement, building technology has come a long way. The variety of high-performance fenestration (i.e., window, storefront and curtain wall) systems and insulation materials on the market have increased with time. Yet, they can be confusing to navigate. This article will address some of the changes in aluminum-framed fenestration systems. For the purposes here, fenestration systems are collectively referred to as "windows."

Current Energy Conservation Code Requirements

In the *International Energy Conservation Code* (IECC), which has become the standard energy conservation code for most U.S. states and local municipalities, thermal-performance requirements have steadily increased with each edition. For example, using ANSI/ASHRAE/IES 90.1-2013, *Energy Standard for Buildings Except Low-Rise Residential Buildings*,[1] the insulation requirement for mass walls for a commercial building in Climate Zone 5 increased from R-7.6 continuous insulation to R-11.4 continuous insulation between past and current editions. Similarly, the insulation requirement for metal-framed walls increased from R-13 + R-3.8 continuous insulation to R-13 + R-7.5 continuous insulation. At the same time, more-efficient mechanical systems increased the demand to upgrade existing facilities. These typically are done through upgrades to the exterior envelope systems, especially in the wall insulation and window systems.

Window Systems: Old vs. New

Windows provide the essential element of natural light through otherwise opaque walls, but they have very minimal insulation value. According to Lawrence Berkeley National Laboratory (LBNL), "Energy lost through residential and commercial windows costs U.S. consumers about $40 billion a year."[2] The two major components of a window system are the glass and the frame, both of which contribute to energy loss.

Glass

Glass technology has come a long way since the 1950s, when insulating glass units were introduced. (Prior to the 1950s, single-pane glass units usually were the only choice available.)

Typical thermal problems with existing window and wall systems include condensation and mold growth on interior finishes (left), as well as ice buildup on window frames and glass (right).

Today's architects can specify a broad spectrum of products, in terms of aesthetics and energy performance. Among these innovations are low-emissivity (low-E) coatings, argon-gas fills and triple-glazed units.

Frames

Over the same period, designers and engineers also have improved the thermal performance of window frames. Previously, window frames consisted of painted steel shapes or aluminum extrusions that held a single pane of glass and were exposed on both a building's exterior and interior without a thermal break, resulting in condensation during cold exterior temperatures. Today, aluminum-framed systems include double-urethane thermal breaks, polyester-reinforced nylon or polyamide structural thermal strips that are strategically located to thermally separate the exterior portion of a window frame from its interior counterpart.

Existing Wall Systems

Depending on the age of an existing building, a wall system may or may not contain wall insulation. Similarly, if wall insulation exists, it likely does not meet the insulation requirements in the current IECC. The most common wall system in 15-year-or-older buildings has wall insulation on the interior side of the exterior sheathing (within stud framing) or masonry backup walls. Many building professionals have begun retrofitting existing wall systems with closed-cell spray foam insulation—a popular choice because spray foam insulation has a relatively high R-value per inch thickness (compared to fiber glass or mineral wool insulation). With sufficient thickness, the insulation itself can form a continuous air barrier and vapor retarder at the interior surface of the wall. For older multi-wythe masonry walls, the framing for the interior finishes should be held back from the interior surface of the masonry to allow for continuous insulation and air-barrier continuity.

Poor Integration of Windows

Most of the common thermal problems in existing windows range from air leakage and condensation to occupancy comfort and mold development. Correcting condensation problems can be costly in terms of monetary value and occupancy disruption, which is why proper window perimeter detailing is extremely important.

Building professionals also should recognize that window manufacturers do not develop their window systems based on numerous wall system designs. Therefore, the design team (i.e., architect, delegated designer, exterior enclosure consultants, etc.) must provide an integrated design for window systems to optimize thermal performance.

Identifying Thermal Bridges

A thermal bridge occurs when the interior portion of a window frame is in contact or otherwise affected by the exterior temperature. This contact results in the frame cooling during cold exterior temperatures in one of three ways: direct contact, air movement or radiant heat (or cold) transfer.

In addition, condensation occurs on any surface whose temperature falls below the dew point temperature, which is a function of ambient-air temperature and relative humidity. Any of these three paths can reduce the surface temperature of the interior portion of a window system to below the dew point temperature of the interior space and result in condensation.

Direct Contact

Thermal bridges due to direct contact occur when the interior portion of a window system is in direct contact with the exterior portion of the system or with a building element that is in direct contact with the exterior temperature. One example is a non-thermally broken sill pan flashing installed below a window system. Another example would be anchors that extend through the interior portion of a frame and penetrate directly into an exterior cladding element (e.g., brick, metal panel, etc.).

Air Movement

A thermal bridge caused by air movement usually occurs when a cavity or air seal around a window's perimeter is absent—this often happens when windows are installed within a drainage wall or rain screen wall system. Typically, a cavity seal located at the full perimeter of a window's rough opening

Continued on page 12

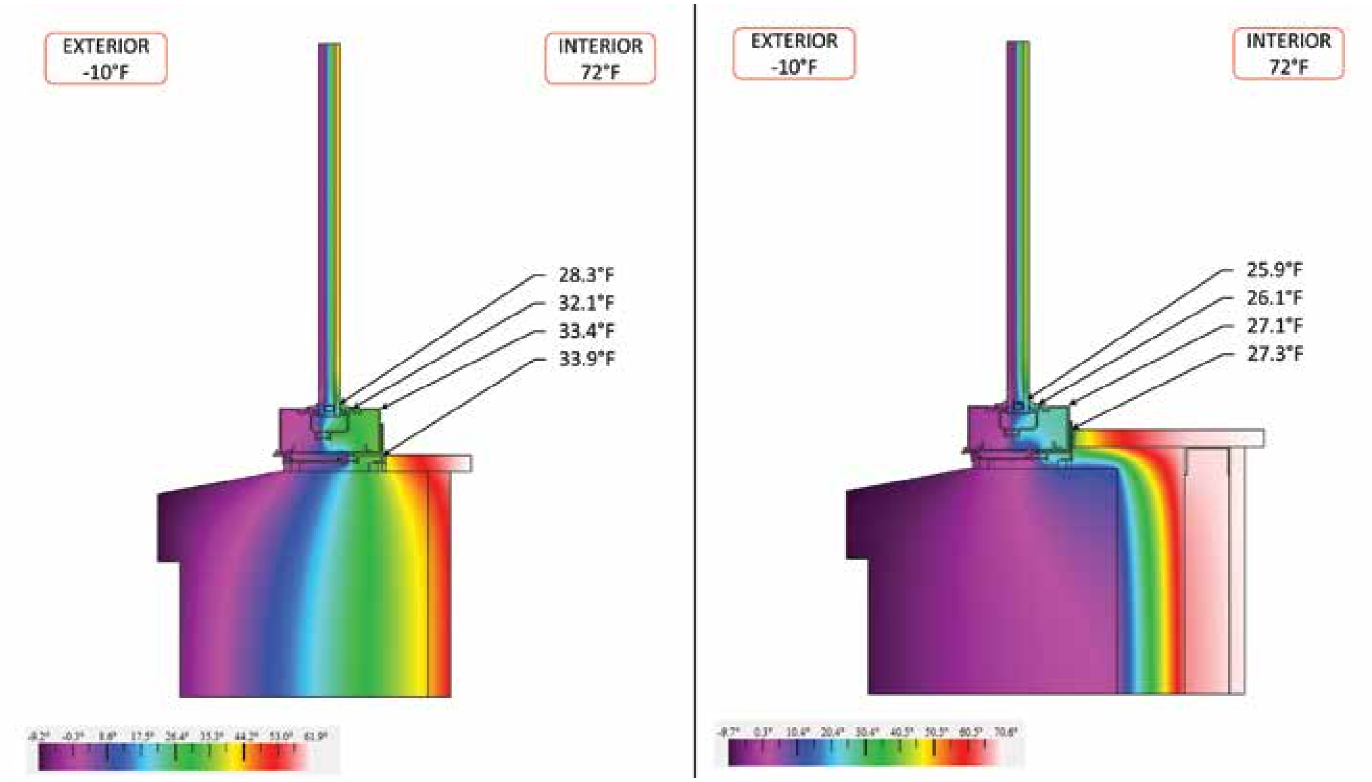

Figure 1: These illustrations offer a side-by-side thermal analysis comparison of storefront surface temperatures before (left) and after (right) insulation is installed at the interior side of a mass masonry wall.

is recommended to prevent the air within the wall drainage cavity (cold in the winter, hot and humid in the summer) from coming in contact with the interior portion of the window frame. This includes closing off the drainage cavity of the adjacent cladding system with sealant, membranes or closure angles at the full perimeter of the window system. Window systems also can leak air, particularly at movable sash joints. In addition, excessive air infiltration can result in condensation and reduced occupant comfort. Designers should select a window system by carefully considering the location of the gaskets and their position relative to the thermal break.

Radiant Heat Transfer

Thermal bridges from radiant heat transfer are, perhaps, the most overlooked factor with mass walls (masonry or precast concrete walls), where insulation is installed at the interior of the wall panels. It is common for the window system to be placed directly on top of the mass walls. However, the insulation at the interior side of the walls keeps the walls cold in the winter and cools the interior portion of the window system.

Upgrading Wall Insulation

Unfortunately, upgrading the thermal performance of an existing mass wall system may inadvertently reduce the performance of existing window systems by lowering the temperature of the masonry adjacent to the windows. In order to satisfy the R-11.4 continuous-insulation requirement outlined in the 2015 IECC, a 2- to 3-inch-thick layer of closed-cell spray foam insulation, rigid insulation board or mineral wool insulation usually is necessary at the interior side of the walls. This keeps the exterior portion of the wall close to the exterior temperature. The interior portion of an existing window system

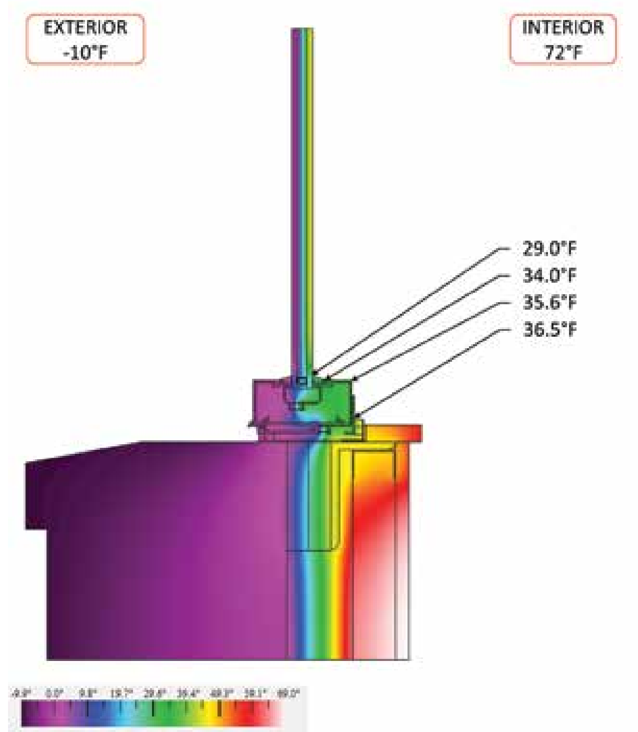

Figure 2: This thermal analysis shows the effect of shifting a storefront toward a building interior to align the thermal break with wall insulation.

can be "cooled" by the cold thermal mass now located directly below (radiant thermal bridge), which effectively reduces the interior frame and glass surface temperature. Sealant, membrane flashing and fluid-applied waterproofing will create an interior air seal at the window-to-wall joint, which may help lessen this issue. However, to thermally separate the cold mass

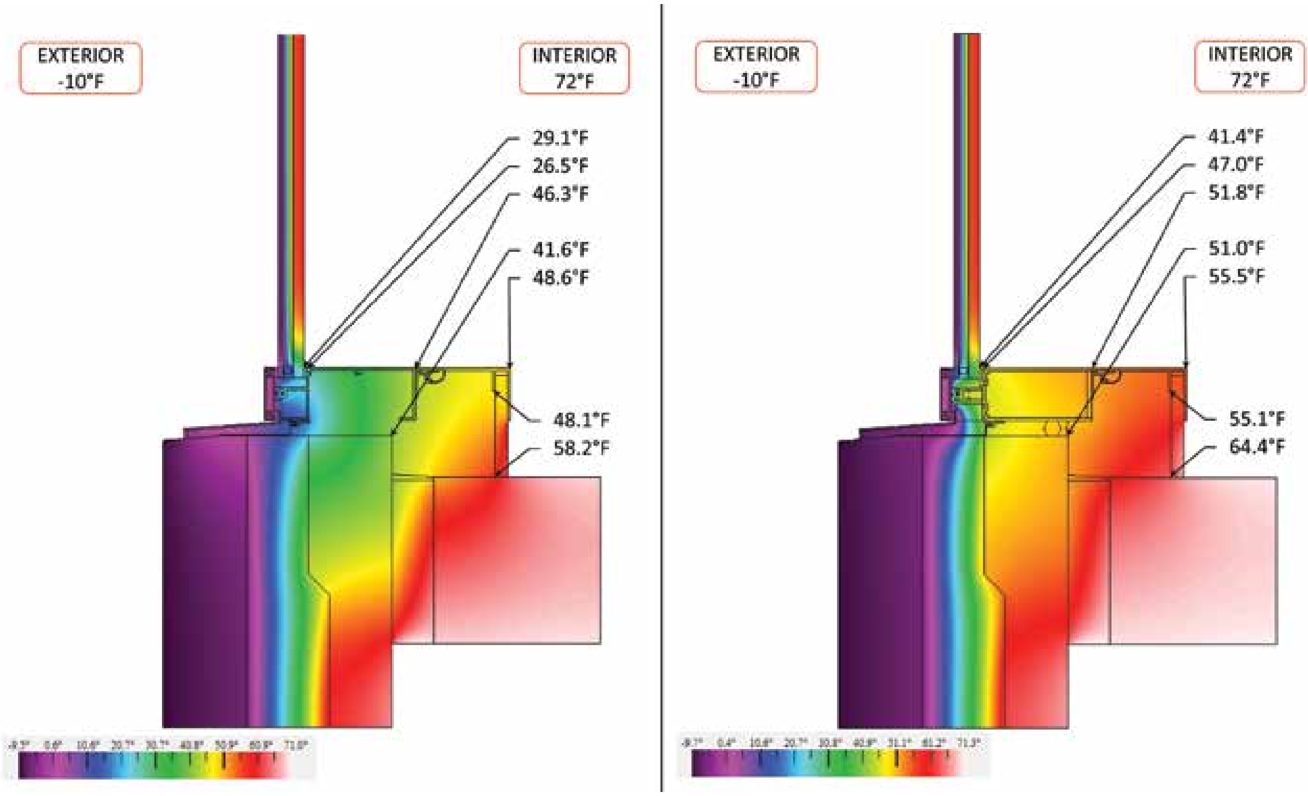

Figure 3: Different frame extrusions of the same curtain wall system are illustrated with side-by-side thermal analysis comparisons.

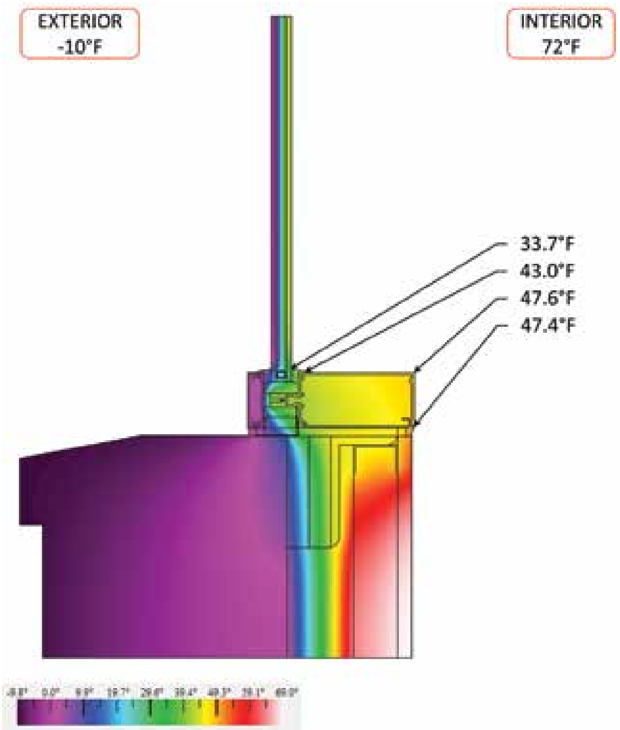

Figure 4: This thermal analysis provides the results of replacing the storefront in "Figure 2" with a curtain wall system.

from the windows, designers and contractors should consider insulating the gap between the wall and the frame.

Thermal Modeling

Computerized thermal modeling is a popular and useful tool to predict the potential for thermal-performance issues in exterior walls. Many programs already exist—and more are in development—that can assist when designing wall systems. For perimeter detailing around window systems, a 2-dimensional (2D) thermal modeling program (such as THERM[3] developed at LBNL) can be useful in predicting surface temperatures at various points in wall and window systems—and is especially helpful with humidified buildings, such as hospitals and museums, in cold climates.

The before-and-after thermal modeling images in *"Figure 1" (see opposite page, top)* illustrate the cooling effect of adding insulation to the interior of an existing mass wall system. Yet, when the window location is shifted to align with the new wall insulation, surface temperatures increase by more than six degrees at some locations *(see "Figure 2," opposite page)*. Aligning the thermal break within a window system with the plane of the wall insulation allows for the optimal thermal performance of both the window and the wall systems. This is why, when adding insulation to a wall system, it often is practical to remove and relocate/replace the window system (with revised detailing).

Designers assume a high-performance curtain wall system will perform well thermally. Sometimes, however, they overlook the fact that the curtain wall extrusion types may adversely affect the performance of the system. As shown in "Figure 3" *(see above)*, two different extrusions of the same curtain wall system located at an insulated precast concrete wall panel can translate to a 20-degree difference in surface temperature at the interior. Even though the thermal break of the frame on the left side of the image is aligned with the insulation in the wall panel, a portion of the curtain wall frame extends towards the exterior and, combined with the sill cover, brings the cold to the interior portion of the frame. This could not have been detected without thermal modeling.

Continued on page 14

Suggested Construction Detailing Concepts

When detailing the window perimeter condition, aligning the thermal break of the window system with the wall insulation helps eliminate potential thermal bridges. The thermal break in a window or storefront system often is located near the center of the system, while the thermal break for an exterior glazed curtain wall system usually is located at the front of the system. The location of the curtain wall thermal break allows the majority of the curtain wall frame to be "warmed" by the interior conditioned air. This is why these curtain wall systems typically perform better thermally when compared to windows and storefronts, as shown in "Figure 4" *(see page 13)*. "Figure 4" illustrates the surface temperature difference when the storefront system from the previous example is replaced with a curtain wall system. Locating diffusers for the building mechanical system under windows also can improve performance by directing the interior air onto the system to warm and dry them.

Improper perimeter detailing at windows not only affects the intended performance of the wall system, it creates unwanted health issues, such as the development of mold. With a better understanding of building enclosure technologies, as well as the science that affects the performance of a designed system, the thermal performance of these systems can be maximized and condensation problems can be prevented. JNIBS

ABOUT THE AUTHOR: Jean J. Wu*, senior associate in the Northbrook, Illinois, office of Wiss, Janney, Elstner Associates, Inc. (***www.wje.com***), has been involved in numerous mid-rise and high-rise building façade investigation projects, including brick masonry walls, EIFS, reinforced concrete structures, terra cotta building façades, windows, curtain walls and high-rise thin stone cladding veneer construction. She also consults on exterior envelope design for various new construction projects, focusing on interface detailing, water penetration, air infiltration and condensation, as well as develops and performs practical test programs related to façade mock-ups and quality control during construction.*

References:

[1]American National Standards Institute (ANSI); ASHRAE; Illuminating Engineering Society (IES). ANSI/ASHRAE/IES 90.1-2013, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, **www.ashrae.org/resources--publications/bookstore/standard-90-1**.

[2]Lawrence Berkeley National Laboratory, Energy Technologies Area. *From the Lab to the Marketplace: See Windows Through*, May 4, 2016, **http://eetd.lbl.gov/l2m2/windows.html**.

[3]THERM is a heat flow analysis program used to assist in estimating surface temperatures and the potential for condensation in each condition modeled. Because THERM is 2-dimensional, effects of airflow in a system, corner geometrics, anchorage and internal heat sources near an enclosure system cannot be included in the analysis. Conduction of heat at connections, radiation from radiant floor heating systems and other heat sources and natural and mechanical convection airflow will alter actual surface temperatures. This only can be modeled using a more sophisticated thermal analysis software (e.g., 3-dimensional analysis). More information is available at **https://windows.lbl.gov/software/therm/therm.html**.

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