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Contents

WRB-AB Sheathing Streamlines Wall Assembly and Cladding Compatibility

by John Chamberlin

Images courtesy Georgia-Pacific

ABUNDANCE OF CHOICE IS EVIDENT IN TODAY'S LANDSCAPE OF COMMERCIAL CLADDING MATERIALS. RANGING FROM METAL AND BRICK TO STONE, EXTERIOR INSULATION FINISH SYSTEM (EIFS), AND FIBER CEMENT, ARCHITECTS AND BUILDING OWNERS CAN ALIGN THEIR AESTHETIC VISIONS IN SEVERAL WAYS TO CREATE BEAUTIFUL BUILDINGS FINISHED WITH A MIX OF CLADDING TYPES. HOWEVER, PRESERVING THE INTEGRITY OF THOSE MIXED-MEDIA FAÇADES IS LARGELY ABOUT WHAT GOES ON BEHIND THE WALLS. WITH THE VARIETY OF CLADDING MATERIALS AVAILABLE TODAY, AND DESIGNERS' PENCHANTS TO COMBINE STYLES AND TEXTURES, IT IS ESSENTIAL TO SPECIFY BUILDING ENVELOPE CONTROLS THAT ARE COMPATIBLE WITH MULTIPLE CLADDING TYPES.

This balancing act between aesthetic preferences and air and moisture management is where gypsum-integrated water-resistive barrier-air barrier (WRB-AB) sheathings shine.

These integrated materials streamline the entire construction process when different cladding selections are specified. Multi-component wall assemblies with separate WRB and AB layers call for advance work by designers who need to determine proper wall assembly attachments, as well as maintaining a single plane of insulation and weather protection for varying thicknesses of cladding. The separate layers of protection (*i.e.* WRB and AB) turn into additional levels of complexity for design and construction. Opting for an integrated sheathing system offers simplification and continuity of the air-moisture barrier.

Additionally, integrated gypsum offers more consistency in the WRB thickness and reduces field application issues. Designers need only concern themselves with joints and seams, rough openings, and penetration treatments.

Challenges of separate components

In conventional wall assembly design, separate products may be used for sheathing, WRB, and AB. Thermal control elements like continuous insulation (ci) add another layer of material-selection complexity. Exterior sheathing provides the essential support needed to make the barrier layers effective in multi-component cladding systems, and the individual materials must work symbiotically to achieve their overall objectives.[1]

However, assessing an individual material's compatibility for thermal, vapor, air, and water/rain control layers can complicate the design. Gypsum-integrated options resolve the complexity more than non-integrated materials, when looking at the half-a-dozen criteria designers must consider, including weather conditions, fastener requirements, and exposure allowances (Figure 1). Further, an incompatible material can threaten the wall assembly's performance.

Another item to consider is the interface between cladding materials and the WRB. Some claddings, like EIFS, require adhesive and chemical compatibility between their adhesive means of attachment and the WRB. Depending on the configuration, attachment method, and drainage details, the cladding may also influence the location and/or effectiveness of the drainage plane in an exterior wall assembly.

Figure 1

Installation

	Building Wrap/Felt	Fluid-Applied Membrane	Adhered Membrane	Rigid Board Stock	Method A Fiberglass Mat Gypsum Sheathing Coated with WRB Membrane	Method B Fiberglass Mat Gypsum Sheathing with Integrated WRB Core Technology
Wet Weather	✓	✗ Generally no, depends on manufacturer	✗	✓	✓	✓
Cold Weather (Below 40ºF)	✓	✗ Generally no, depends on manufacturer	✗	✓	✓	✓
Special Fasteners NOT Required	✗	✓	✓	✗	✓	✓
Does NOT require sheathing joints and fasteners to be sealed	✗ Does, when used as an air barrier	✗	✓ Does not, but does require gypsum sheathing to be primed	✗ Does for joints	✗	✗
Does NOT require cladding fasteners to be sealed	✓	✓	✓	✓	✓	✓
Long-term exposure allowed before cladding is installed	✗	✗	✗	✗	✓ Up to 12 months	✓ Up to 12 months

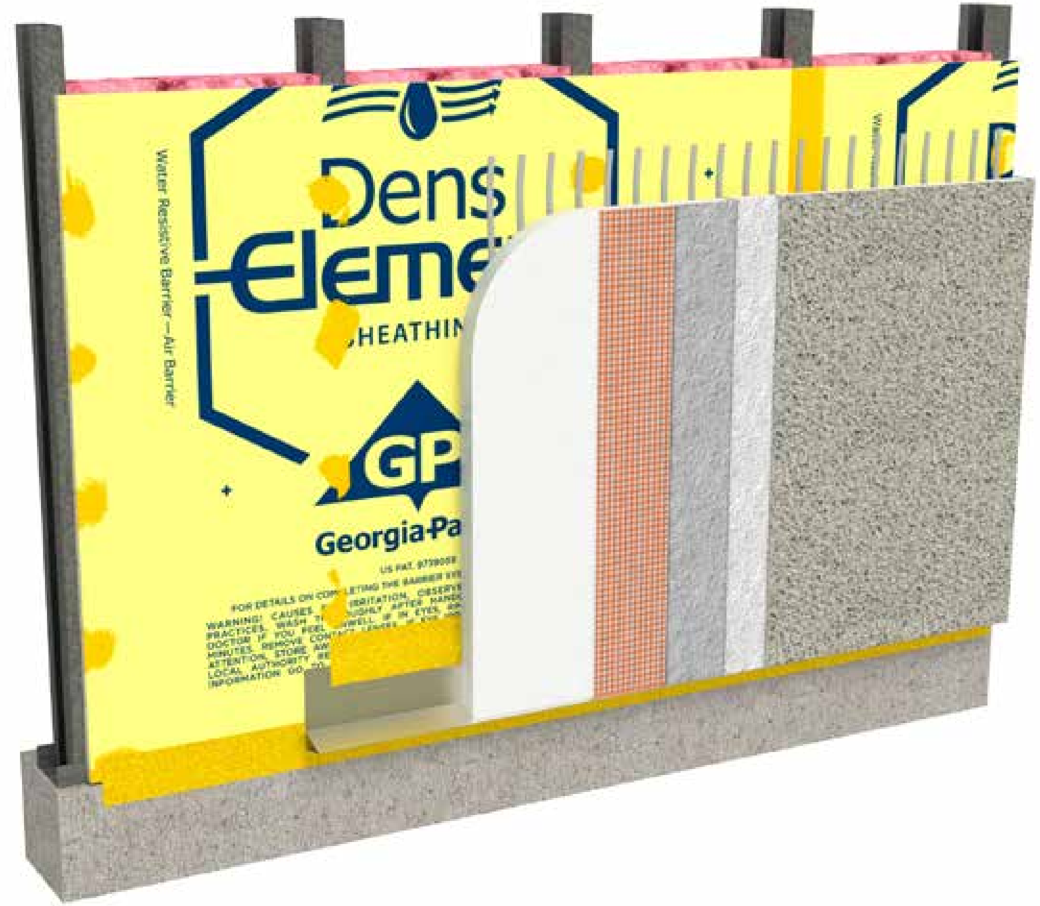
Pros and cons of water-resistive barrier-air barrier (WRB-AB) systems that are available in the market.

As a system, integrated sheathing starts with either wood or gypsum, modified through proprietary manufacturing processes, to produce sheathings that also act as WRBs and air barrier materials. Once the sheathing is installed, a complete and continuous system is created by sealing areas of discontinuity with tape or liquid flashing products. An integral WRB gypsum sheathing can act as a drainage plane without concerns for proper sequencing or shingle-lapping, which come with other technologies. However, the interface between the cladding and the WRB should still be reviewed.

Metal panels
Metal panels have become a popular cladding choice for accent or whole-building applications, but heat can build up behind them. As a result, when using liquid-applied or self-adhered WRBs and ABs in conjunction with metal, wall assembly designers need to have an understanding of the in-service temperature limitations of those barriers, which can be as high as 93 C (200 F), depending on the type of building and the kind, design, and location of the metal panel on the structure. Anecdotally, observations made when cladding choice causes a wall assembly to extend beyond the WRB's temperature limitations indicate delamination, emulsification, or leaching of liquid materials in high-heat situations. Some liquid-applied or self-adhered WRBs and ABs are designed for higher temperatures. However, this sub-category of products underscores the complexity involved in choosing layers for multi-component systems.

Stucco
Stucco and other commercial building finishes may require metal lath fasteners, so selecting the right sheathing is essential. If magnesium oxide (MgO) boards are used, chemical compatibility with fasteners could become an issue. A five-year study out of Denmark, where MgO boards had been widely used, found salts in the magnesium absorbed ambient humidity, causing fastener corrosion and moisture damage to wood-framing materials.[2] While MgO sheathings offer fire-resistance at a lower cost than gypsum, the potential corrosion risk could cause more expensive problems down the roads.

Masonry
Brick and cultured stone are popular options for building façades, but they are also highly absorbent. While building cladding is meant to be the first defense against bulk water intrusion, these material selections all but ensure water will penetrate the cladding. In these situations, designers must be confident their selected sheathing and WRB will drain and dry effectively.



The gypsum-integrated water-resistive barrier-air barrier (WRB-AB) assembly streamlines the entire construction process when different cladding selections are specified.

When building wraps are selected as the WRB of choice, penetrations and perforations in the material become the issue. As building science expert Joseph Lstiburek explains, moisture intrusion through fastener penetrations is fine, as long as the wall can handle (*i.e.* thoroughly dry) the amount of moisture that gets through.[3] If papers tear because of the wind, insufficient folding around punched openings, or other issues, the amount of moisture infiltrating the wrap could overwhelm the sheathing's drying capabilities.

Simplification in a single product

Gypsum-integrated WRB-AB sheathing systems combine water and air control into one system that will work behind almost all types of cladding, provided wall assembly designers have taken effective steps toward good water management. Direct-applied systems would be discouraged without the inclusion of a drainage cavity.

With extensive testing regarding permeability and wind-driven rain, manufacturers have calculated air- and water-barrier qualities that will work successfully with a range of cladding options, thereby eliminating the additional labor and supplies needed to install multiple layers. Third-party testing has been performed to evaluate a variety of performance characteristics of gypsum-integrated WRB-AB materials such as:

- adhesive compatibility, according to ASTM C297, *Standard Test Method for Flatwise Tensile Strength of Sandwich Constructions*;
- drainage capability, per ASTM E2273, *Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies, with adhesively attached claddings such as EIFS;*
- effectiveness of integrated WRB sheathings when penetrated by mechanical means of cladding attachment, including multiple types of rainscreen bracket and clip systems, in wind-drive rain events, according to ASTM E331, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference;* and
- fastener sealability of the WRB, and ability to hold out water under hydrostatic pressure when the barrier is mechanically penetrated, per ASTM D1970, *Standard Specification for Self-adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection.*

In all cases, integrated WRB sheathings have exceeded code requirements for performance.

Depending on the production process of the integrated materials, the protective WRB-AB layers may be incorporated into the gypsum while the slurry is poured, or applied as a coating to the finished gypsum panels. In both circumstances, the resulting single material eliminates the need for architects or engineers to consider the characteristics of multiple materials and their compatibility with the chosen cladding.

As it is with any building material, proper installation is essential for long-term performance. The gypsum-integrated WRB-AB sheathing panels should be butted tight with a 1.6-mm (1/16-in.) gap and screwed to the framing, according to the fastener schedule provided by the manufacturer. Installers will then need to seal the gaps, seams, and fastener locations using liquid-applied flashing, the type and thickness of which would be specified by the sheathing manufacturer. Depending on the situation, a backer rod might be recommended in some instances, but typically, the liquid flashing will suffice.

In terms of code-compliance, the Air Barrier Association of America (ABAA) requires membranes factory-bonded to sheathing to display inherent self- or fastener sealability, as outlined in paragraph 7.9 of ASTM D1970. Integral gypsum WRB-AB sheathing boards meet this requirement on their own, so installers can be confident they will not have issues with excess moisture infiltrating fastener penetrations.

The step of sealing gaps and fasteners in a visible way with liquid-applied flashing also gives the sheathing an added element of quality control upon installation. Crew-members and building inspectors can easily see missed areas, unlike with building wraps where incorrect folds or laps might be difficult to spot, or liquid-applied moisture barriers that demand a specific thickness for proper performance. Ease of installation for integrated sheathing leaves installers and building owners confident that they are not creating new opportunities for air or water intrusion before the cladding even goes on.

Installers will also be pleased to hear gypsum-integrated sheathings are compatible with a wide range of climate and weather conditions. As climate zones impact the wall assembly as a whole, integrated sheathings can be used in any region, provided other wall components allow for it. Product limitations will vary by type and manufacturer, but generally the materials can be installed in any weather condition, and can be typically exposed for up to 12 months.

Case study

A North Carolina off-grid property known as Benoit Farms took advantage of gypsum-integrated WRB-AB sheathing to leverage its performance benefits and cladding compatibility. Atlanta-based architecture firm LG Squared was tasked with creating a building that would have reduced energy use while still managing the unpredictable weather of western North Carolina (Climate Zone 4). Dramatic shifts in moisture levels and temperature swings throughout the year, as well as potential forest fires in nearby mountain areas meant the firm needed a sheathing material that could maximize energy efficiency, provide a continuous WRB-AB layer, and protect the building, its occupants, and the surrounding landscape from fire risk.

The integrated sheathing addressed the majority of these concerns with one product and limited trips around the building to install it. The selected wall assembly incorporated a gypsum-integrated WRB-AB sheathing matched with a liquid flashing approved for damp conditions, which sealed the joints, seams, corners, and penetrations. Altogether, this installation created a hydrophobic, monolithic surface to block bulk water, and an airtight building enclosure to achieve energy-efficiency goals, all while allowing for vapor permeability and effective drying and providing fire resistance, as required by the National Fire Protection Association (NFPA) 285, *Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components.*

With barrier layers fully sealed, the construction team turned its attention to the exterior cladding and aesthetic of the building.

The Benoit Farms project called for a layer of ci to achieve its energy-efficiency goals. On top of that, the project called for 20-gauge corrugated steel cladding on the residential building and one barn, and 14-gauge steel on a second barn. The cladding was attached to 20-gauge hat channels and secured through the ci and into 18-gauge metal framing with long roofing screws. Behind the scenes, the gypsum-integrated sheathing provided the air and water barrier, while serving as a rigid substrate for the insulation, and offering structural integrity in the way of shear strength for the wall assembly.

Architecture firm LG Squared attached integrated gypsum sheathing to the cladding of the Benoit Farms building in North Carolina to provide a continuous WRB-AB layer and protect the building and its occupants from potential fires.

Climate and insulation considerations

Two schools of thought exist around keeping moisture out of buildings, recognizing cladding as the first line of defense. One approach favors wall assemblies—including cladding selection and installation techniques—designed to keep water out altogether. The other method acknowledges water infiltration in some form and quantity is inevitable, and effective moisture management is more important than keeping water out in the first place.

As discussed, many popular cladding options are susceptible to moisture, making the second approach a logical one for commercial builders. So, assuming some water is bound to get behind the cladding, gypsum sheathing is a suitable starting point. All gypsum sheathing is vapor permeable and has the capacity to retain its integrity even as it moves through wetting and drying cycles. In selecting a gypsum-integrated WRB-AB sheathing, designers benefit from this quality, as well as the consistency of a known permeability level that will not be changed by the addition of separate control layers. For example, an integrated sheathing rated at 25 perms will retain that rating on installation because it already accounts for the permeability of the WRB-AB. This is in contrast to a non-integrated sheathing whose permeability changes depending on the control layers applied.

However, the issue is complicated by the widespread use of continuous insulation code requirements on commercial buildings. Depending on the type of insulation and its installation—directly up against the WRB-AB layer, or within the cladding installation framing—the location of the drainage plane and drying capabilities of the wall assembly may change.

For example, in a cold climate, designers may choose an integrated WRB-AB sheathing, followed by mineral wool ci, and an air gap between the insulation and their cladding of choice. This wall assembly should dry well to the outside with the cladding spaced off insulation. However, if a foil-faced polyisocyanurate (ISO) ci is used, it would not dry well to the outside. Pressed up against the WRB-AB layer, the ISO would stop movement of moisture at its surface, and designers have to provide a drainage cavity.

With the thermal control and moisture management requirements of wall assemblies varying by region, designers should remove as many complications as possible from the specification process. Gypsum-integrated WRB-AB sheathings achieve this uniform approach to moisture management, letting designers focus on the remaining building science requirements, regardless of the cladding.

Fire compliance achieved

The benefits of gypsum-integrated WRB-AB sheathing do not just stop at air and moisture protection and cladding compatibility. These materials also help buildings meet fire-safety standards.

WRBs, ABs, and ci are all intended to improve building performance. However, a renewed focus on exterior wall assemblies considers the propagation of fire due to the design and cladding materials. This issue was underscored by the 2017 Grenfell fire in London, United Kingdom. Specifically, authorities are enforcing code requirements of wall assemblies and compliance with NFPA 285 testing.

To meet the *International Building Code* (*IBC*) requirements for wall assembly fire performance, all WRBs must be in compliance with NFPA 285. Unlike systems comprising a primary WRB material and flashing accessories that are sometimes combustible, gypsum-integrated WRB-AB assemblies start with the fire-resistance of gypsum and typically incorporate noncombustible WRB sheathing with liquid flashing accessories.

It is important designers who are creating wall assemblies with wood-based integrated sheathings, or integrated sheathings with a pre-cured liquid membrane on the surface, should recognize these are combustible materials and must find other ways to address fire-resistance requirements.

Some designers may wonder if all combinations of WRB/AB products and sheathing should be tested together to meet NFPA 285. Generally, if the exterior wall assembly includes a combustible component, then a test or engineering judgment is necessary. If all components of the specified assembly are noncombustible, then testing is unnecessary.

As of 2018, *IBC* updated its standard method for evaluating fire propagation characteristics for external wall assemblies. It specifies that NFPA 285 compliance testing criteria no longer considers WRB flashings or accessories to be part of the barrier, as they comprise such a small portion of the assembly. More to the point, this update separates multi-component assemblies into the primary WRB and accessories or flashing products. For example, a termination mastic on a self-adhered membrane system would be consider an accessory, while the membrane itself would be considered the primary WRB. With this in mind, sheathing made from fiberglass mat with a gypsum core—classified as a noncombustible WRB—is exempt from NFPA 285 assembly testing, and *IBC* 1402.5 requirements for combustible WRBs are inapplicable.

With that in mind, using an NFPA 285-approved WRB-AB sheathing simplifies the cladding process by bypassing the need for any additional testing specific to the barrier.

Give the design every advantage

As integrated WRB-AB sheathings increase in popularity, now is the time for architects and designers to give these materials a closer look. Why restrict cladding possibilities based on the parameters of inflexible multi-component barrier layer options? As an industry innovation, integral WRB-AB sheathing systems support cladding versatility and maintain fire and water-resistance compliance while simplifying wall assembly design and supporting efficient construction.

Broadening a world of design possibilities without the complication of individual component synergy eliminates the hassle of accounting for the differences across a variety of cladding and sheathing combinations. With gypsum-integrated WRB-AB sheathing, designers can accent the north-facing side of a building with brick, while styling the south in EIFS. **CS**

Notes

[1] Consult "Considerations in the Design of Cladding Systems with Continuous Exterior Insulation" by Mar J. Klos.

[2] Details at www.sciencedirect.com/science/article/pii/S1876610217349378.

[3] Visit www.buildingscience.com/documents/insights/bsi-067-stuck-on-you.

ADDITIONAL **INFORMATION**

Authors

John Chamberlin is a senior product manager at Georgia-Pacific. He is responsible for the DensElement Barrier System and the DensDefy line of products. Chamberlin has worked in the building materials industry for his entire career, focusing on new product development for disruptive technologies in the building envelope space. Chamberlin is on the board of the Air Barrier Association of America (ABAA). He graduated from the University of Tennessee with a bachelor's degree in marketing and later received his MBA from Emory University. He can be reached at john.chamberlin@gapac.com.

Key Takeaways

With the variety of cladding materials available today, and designers' penchants to combine styles and textures, it is essential to specify building envelope controls that are compatible with multiple cladding types. This balancing act between aesthetic preferences and air and moisture management is where gypsum-integrated water-resistive barrier-air barrier (WRB-AB) sheathings shine.

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Key Words
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Air barrier
Cladding
Gypsum sheathing
Water-resistive barrier

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See how the DensElement Barrier System performed in the field.
Read on to learn how a building team up against a tight deadline gained strength and efficiency on their school-expansion project with the DensElement Barrier System.

The Right Supplies: Sheathing a School in British Columbia Interior

Kamloops, British Columbia, Canada

A School Set in the Canadian Desert

When you think about the Canadian landscape, a desert may not immediately come to mind. But the British Columbia Interior is an area known for its desert-like climate. The weather conditions include high winds and while rainfall is typically low, it has been slowly increasing over the years. Valleyview Secondary School is located in this region in the city of Kamloops. And when the school required a new structure to house critical areas of study including tech labs, home economic workshops, AV rooms and more, a 68,000-square-foot addition needed to be built onto the existing 75,000-square-foot facility. Beyond offering additional space, it was imperative that the new structure could hold strong against punishing winds and potentially invasive moisture.

A Lesson in Choosing the Right Materials

The building team needed to find the right materials that would not only withstand windy conditions and increasing rain, but also boost efficiency on the jobsite, since they had to finish before the new school year. That's why they chose Georgia-Pacific's DensElement® Barrier System and its DensDefy™ Products. These products offered the team the most innovative water-resistive barrier and air barrier (WRB/AB), along with the benefit of a quick and easy installation.

DensElement Barrier System streamlines installation of the building envelope with an integrated gypsum sheathing that also acts as a water-resistive barrier and air barrier. DensDefy Products protect against air leakage and water intrusion by preventing bulk water and air leakage at the seams, fasteners and rough openings, and distinct transitions to other surfaces.

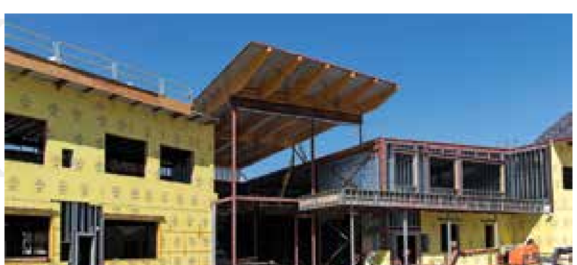
The Valleyview Secondary School addition was the largest project to date in British Columbia featuring Georgia-Pacific's DensElement Barrier System. Station One Architects, who specialize in the education segment, recommended this system specifically due to its stellar reputation. Their feeling was echoed by the project's envelope consultant, Paul Surgeson at CSA Building Sciences Western Ltd., who vetted and approved the barrier system. He was impressed by the data sheets, the specifications and the materials' ability to resist moisture and wind. So, he pushed the products forward with confidence as a method to speed up construction. Dawson Wallace Construction Ltd., the general contracting firm on the job, also praised the products for making the building watertight more quickly, saving time on installation without incurring additional costs.

"You should have a look at this product, it's going to save a lot of time."

– Paul Surgeson, CSA Building Sciences Western Ltd. (Envelope Consultant)

"This product puts all the warranty requirements and envelope in the hands of a single trade. It's easier to ensure the quality of the install."

– Andrew Van Beilen, Dawson Wallace Construction Ltd. (General Contractor)



Type of Building:
Education

Location:
Kamloops, British Columbia, Canada

Component Quantities:
30 MSF of DensElement Barrier System

Key Companies:

Architect:
Station One Architects

Consultant:
CSA Building Sciences Western Ltd.

General Contractor:
Dawson Wallace Construction Ltd.

Georgia-Pacific Gets a Glowing Report Card

The school's structure consists of more walls than windows, making DensElement® Barrier System and DensDefy™ Products perfect for the job. Working in segments, the installation process was more efficient than putting on mechanically fastened or self-adhered membranes.

DensElement Barrier System and DensDefy Products were so simple to handle, the project's drywall contractor, Steve Caron at LAPC Drywall Ltd., was able to install the integrated sheathing himself. Specifically, DensDefy® Liquid Flashing went on smoothly, even in the rain, curing quickly despite the moisture. All this helped to simplify and build a better building envelope in a fraction of the time.

The building team agreed that the value, cost and time-saving aspects of the products, along with Georgia-Pacific's reputation in the industry, made it an easy choice. In particular, the project's general contractors at Dawson Wallace Construction Ltd., Andrew Van Beilen and Bob Beaulieu, experienced firsthand how Georgia-Pacific always puts their customers first. The Georgia-Pacific team took them through DensElement Barrier System step by step, so they had more comfort and familiarity before officially committing to the materials.

"Georgia-Pacific is a big company and for them to have their tests and validations and say that 'this is our product and we [provide the entire warranty for] it'—you know that goes a long way."

– Bob Beaulieu,
Dawson Wallace Construction Ltd.
(General Contractor)

With so much innovation continually improving the materials they use, building industry professionals remain students of their craft. The Valleyview Secondary School project taught this team that finding the right products for the job is easy when you stay focused on efficiency, value and brand reputation.

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Role of Air Barriers

Mitigating disease transmission

by Sarah K. Flock, CDT, AIA, and Andrew Dunlap, AIA, CDT, LEED AP, NCARB

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THE COVID-19 PANDEMIC HAS REINTRODUCED THE IMPORTANCE OF INFECTION CONTROL IN THE BUILT ENVIRONMENT. COVID-19 IS A NOVEL INFECTIOUS DISEASE AND IS UNDERSTOOD TO BE CAUSED BY SEVERE ACUTE RESPIRATORY SYNDROME CORONAVIRUS 2 (SARS-COV-2), WHICH ONGOING RESEARCH SUGGESTS IS TRANSMITTED PRIMARILY THROUGH AEROSOLS. WHILE PAST PANDEMICS LED TO DESIGN ADVANCEMENTS IN CITY PLANNING AND URBAN IMPROVEMENTS, INFECTIOUS DISEASES TRANSMITTED THROUGH AEROSOLS CAN ALSO BE IMPACTED BY APPROPRIATELY DESIGNED AND INSTALLED MECHANICAL AND ENCLOSURE SYSTEMS. THEREFORE, WHILE CURING AND COMBATTING COVID-19 IN PATIENTS REMAINS UNDER DEVELOPMENT IN THE MEDICAL FIELD, MANY DESIGN-, AND CONSTRUCTION-RELATED INDUSTRY GROUPS HAVE BEEN WORKING HARD TO UNDERSTAND OTHER WAYS TO PREVENT THE SPREAD IN ENCLOSED SPACES.

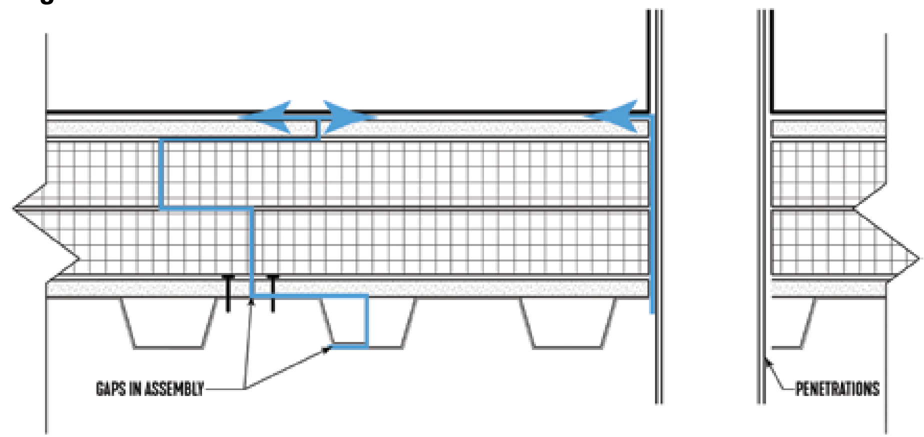
On April 14, 2020, the American Society of Heating, Refrigerating and Air-conditioning Engineers Position Document (ASHRAE PD) was released to offer guidance to mitigate disease transmission and as a reference for building readiness for post-pandemic return to operation. While the ASHRAE PD advises increased ventilation is not capable of addressing all aspects of infection control, changes to building operations, including the mechanical systems, can reduce airborne exposures. Though the ASHRAE PD does not make a definitive recommendation on indoor temperature and humidity set points for the purpose of controlling infectious aerosol transmission, it does offer immunobiologists correlated mid-range humidity levels with improved immunity against respiratory infections and unfavorable survival rates for microorganisms when the relative humidity (RH) is between 40 and 60 percent. Further, the research associated with the ASHRAE PD have shown a correlating increase in infections when the interior environmental conditions fall below the 40 percent RH.

Based on this, practitioners are left to evaluate if RH levels between 40 and 60 percent are viable and/or advisable for their existing building design or operation. Other factors can also come into play prior to adoption and implementation, such as building use and pressurization, general climatic conditions, the amount of time occupants are indoors, and limitations of the existing building mechanical system. An imperative consideration is also the impact on the building enclosure should interior climatic setbacks be elevated to levels recommended by current research for both new and existing buildings. This article explores the performance of existing building enclosures in climate zones with colder wintertime temperatures in response to interior environmental setpoint changes, as well as the increased importance for air barrier systems.

Enclosure design and performance

If altering the operating conditions in an existing building is being considered, the enclosure design and construction, such as the walls, roof, fenestration, and below-grade assemblies, must be understood as well as their respective air, thermal, and vapor control strategies. Air, thermal, and vapor control fundamentals have congruences and differentiations but can work together to prevent dewpoint conditions, the temperature at which humidity in the air will begin to condense.

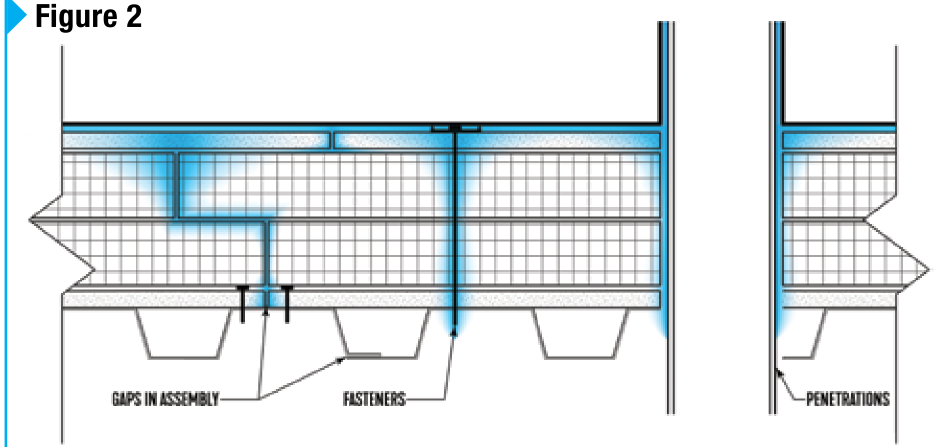
Figure 1



Potential air paths through roof assembly.

Images © Ryan Asava, AIA, NCARB

Figure 2



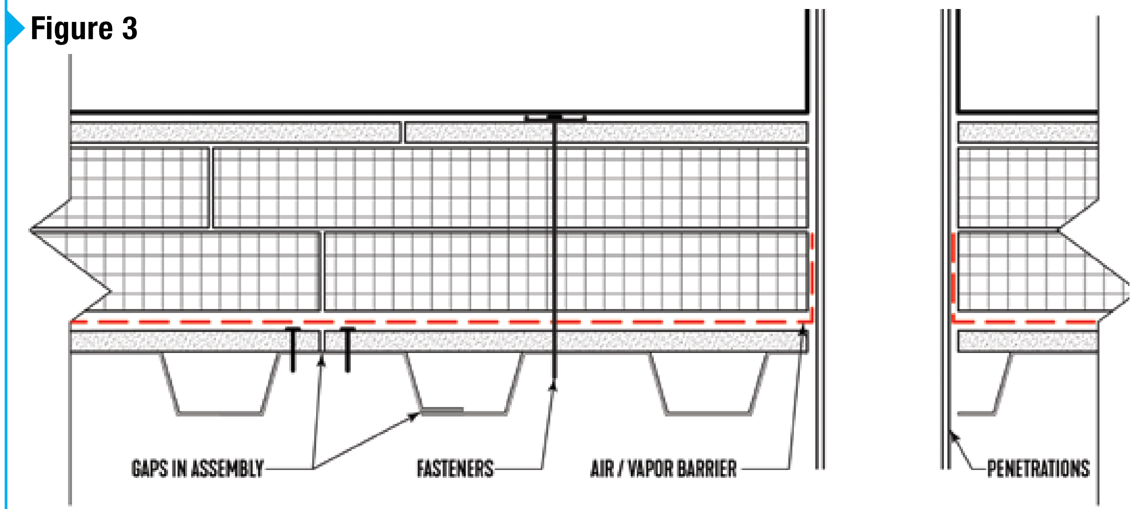
Potential condensation within roof assembly due to air intrusion.

Should humidified air encounter a surface below dewpoint, condensation can result, with an increased potential for premature deterioration of building components, corrosion, or mold formation. Buildings in colder climates are particularly susceptible to these concerns.

Heat can transfer in various ways, such as conduction, convection, or radiation; and it moves from areas of high to low temperatures independent of orientation. Conduction is the flow of heat through solid materials, such as window frames or metal studs, whereas convection is the transfer of heat through a gas or liquid, such as air, and occur naturally. Natural convection in buildings is the result of differing air densities, while forced convection can be generated by mechanical systems of variations in exterior and interior pressures. Radiation is the transfer of heat due to emission of electromagnetic waves. Thermal transfer is typically controlled by incorporating insulating components, limiting thermal bridges, as well as regulating solar radiation. The use of an air barrier system can also impact the thermal efficiency of an enclosure by limiting heat transfer through air movement.

Code requirements for air barrier systems are a comparatively recent addition unlike provisions related to thermal or vapor control. An air barrier system, as defined by the Air Barrier Association of America (ABAA), is considered to be a "combination of air barrier assemblies and air barrier components, connected by air barrier accessories that are designed to provide a continuous barrier to the movement of air through an environmental separator." It is important to understand air permeance is the transfer through the material, whereas air leakage is movement through deficiencies in the material, assembly, or system. Air transfer also occurs from areas of high to low pressure, which can be created by wind, stack effect, and fan pressure in HVAC systems. Air movement is typically considered to move significantly larger volumes of water vapor through or within the enclosure than vapor diffusion and is a concern from an infection control perspective, enclosure performance parameter, and operating costs associated with maintaining the elevated humidity. This highlights the importance of an air barrier system in building enclosure design and construction.

Figure 3



Mechanically attached roofing assembly.

Figure 4

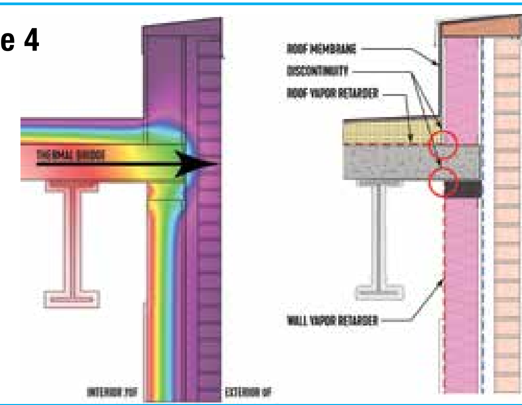
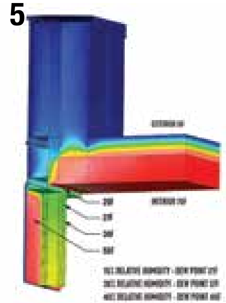


Illustration of difficult transitions and thermal bridging at roof to wall interface.

Figure 5



Three-dimensional thermal model of curtain wall at a parapet illustrating reduced condensation resistance.

Figure 6

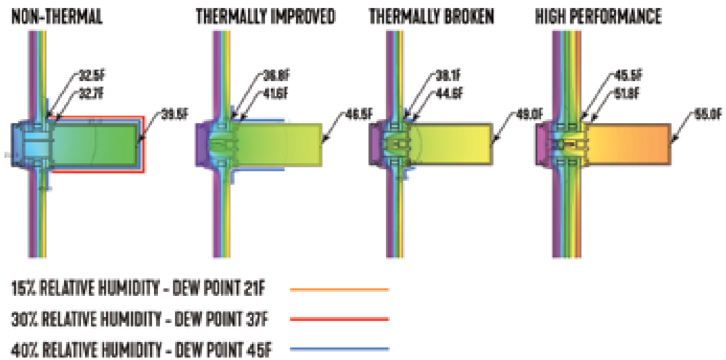


Illustration identifying locations of potential condensation on various curtain wall types at -18 C (0 F) at the exterior and 21 C (70 F) at the interior.

Vapor diffusion and air transport tend to function independently of one another, as vapor diffusion can occur without air movement. Water vapor diffusion is also driven by variations in vapor pressure and moves vapor from areas of high pressure (warm and humid) to low pressure (cold and dry) to reach equilibrium. Vapor control in building enclosures is achieved using a vapor retarder (vapor impermeable materials that are installed and integrated to limit vapor migration). Vapor retarders are currently used primarily in cold climates and in spaces with higher indoor RH. However, if the vapor retarder is not airtight, large volumes of moisture can be transported through air movement.

Interior operating conditions

Typically, indoor building environments operate according to use and type. While some building types, such as healthcare, laboratories, and museums may have been specifically designed to

Figure 7

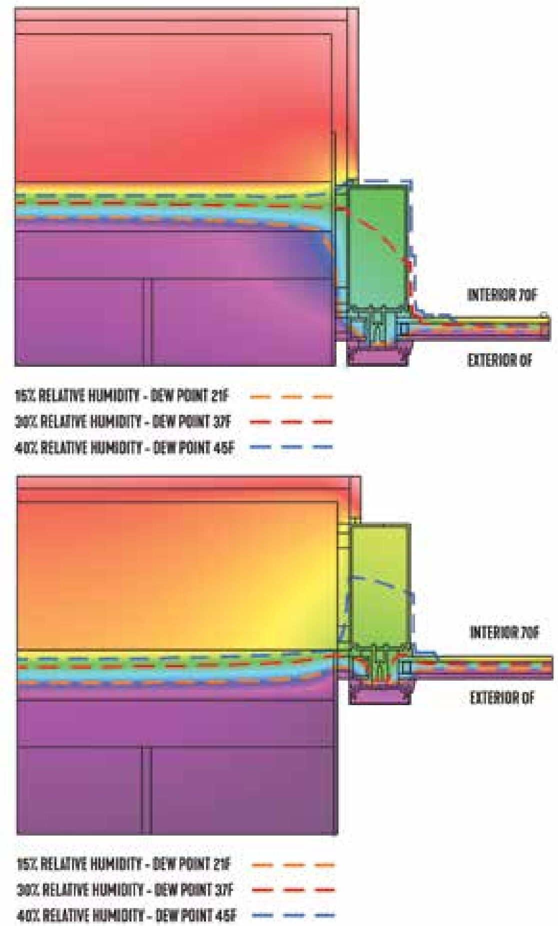


Illustration of location of potential condensation based on window placement.

Figure 8

Air exfiltration contributing to ice formation on the exterior.

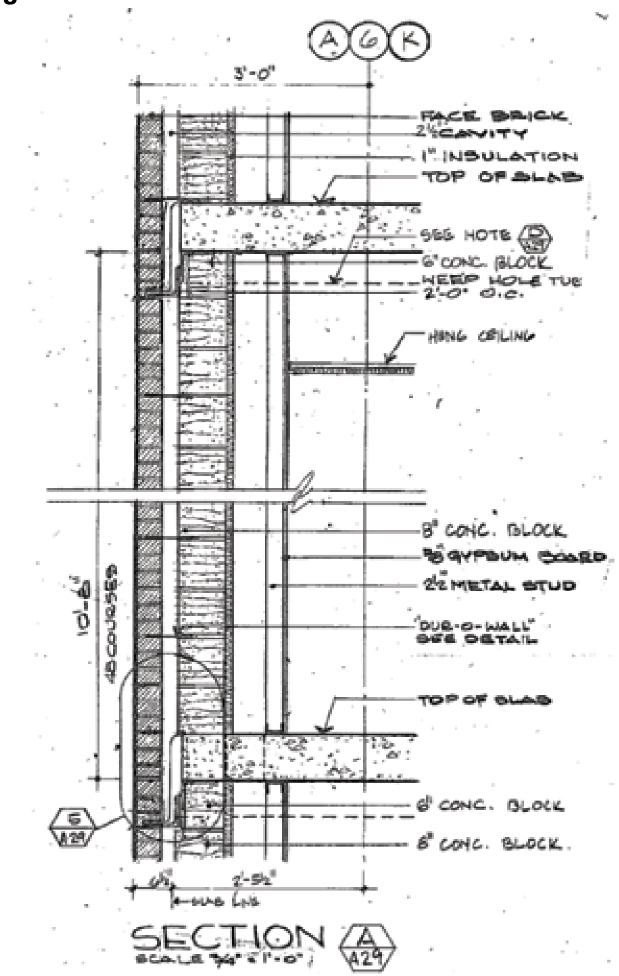
accommodate a certain amount of active interior humidification, many existing buildings were not designed with that intent or ability.

Healthcare facilities have prescribed interior climatic conditions to maintain occupant health and safety. While local health departments may offer specific requirements, this writing will reference guidance related to RH, temperature, and ventilation conditions offered by Facilities Guidelines Institute (FGI) as the basis for discussion. Forty-two states have adopted some edition of FGI, and three states allow its use as an alternate path. FGI also incorporates the American National Standards Institute (ANSI)/ASHRAE/American Society for Healthcare Engineering (ASHE) 170, *Ventilation of Health Care Facilities*, which includes Table 7.1, "Design Parameters – Hospital Spaces." The parameters for many of the spaces listed in the table are designed and operated for temperature ranges between 21 and 24 C (70 and 75 F) with an RH between 20 and 60 percent. Air changes per hour (ACH), which is a measure of air volume added to or removed from a space divided by the volume of space, as well as pressure relationships, can also vary greatly according to the function of the space.

It is also important to note the higher end of the RH range often occurs during summer months based on seasonal exterior climate changes. In fact, facilities in climate zones with colder wintertime temperatures are often operated with seasonal setbacks that lower the interior RH during the coldest times of a year. Many of the spaces listed in Figure 1 (page 16) include a lower RH that would fall below the recent guidelines that are outlined in the ASHRAE PD.

Specialized building types, such as laboratories, museums, natatoriums, may more closely align with healthcare facilities due to their likelihood to operate at comparatively higher interior RH than offices or commercial spaces. Other building types, including offices, residential, commercial, schools, etc., reference different standards, such as ASHRAE 62.1-2019, *Ventilation for Acceptable Indoor Air Quality*, which now expresses humidity control as dewpoint and not an RH. However, in prior editions, the lower

Figure 9



Section of an existing wall assembly.

boundary of the recommended RH range was set at 25 percent (ASHRAE 62-2001), which at 20 C (69 F), can equate to a dewpoint of 32 degrees.

It is also important to note the reference standards discussed above outline design parameters but may not represent what the actual wintertime RH is during operation. Further, the enclosures for many of these types of buildings were not designed with the intent to have active interior, humidification provided during colder, winter months, and it is the authors' experiences that many existing buildings operate below 20 percent RH for periods of time during heating months.

Many existing buildings are also fully or partially naturally ventilated. This may be accomplished via operable windows or intended/unintended openings in the building enclosure. In these instances, airflow may be variable or unpredictable, which creates difficulty for maintaining a stable environment via a mechanical strategy. This also highlights the need for air control between the interior and exterior, as well as among interior areas that may operate differently.

Given the issues previously indicated, an evaluation is recommended to gain an understanding of capabilities and limitations of the existing building enclosure prior to modification. To illustrate these issues, the authors will review some common details associated with existing building enclosure, their limitations related to condensation resistance and air infiltration/exfiltration/intrusion, and some techniques that can be utilized to evaluate anticipated performance.

Roofs

Two basic types of roofs are used in existing buildings—steep slope and low slope. Both have challenges specific to their type, but there are also common items that could lead to issues with adding elevated interior RH. Many materials that have been used in roofs can limit air and vapor permeance, such as craft paper, some sheet goods, or even metal roof decking. However, some of these same materials have limitations regarding effectiveness to be installed in an airtight manner. If they are not airtight, they can allow humidified air to intrude into the roofing

Figure 10

Existing wall air paths.

Figure 11

Gypsum wallboard partially removed.

Figure 12

Unsealed insulation.

system and reach surfaces below the dewpoint. It is also important to determine whether a vapor retarder was intended to function as a part of an air barrier system, thereby precluding air movement through control layers.

Penetrations, such as pipes, drains, mechanical equipment curbs, screen wall posts, and access hatches are common locations for breeches at control layers. While these penetrations may prevent exterior rainwater penetration, they also need to be verified for limiting air, thermal, and vapor transfer before considering increasing interior RH. Figures 1 and 2 (page 16) illustrate potential air paths through a low-slope roof system and the potential condensation that could result under specific operating condition.

Another consideration when evaluating the roofing assembly is whether the system was mechanically attached or adhered. Mechanically attached roofs include fasteners extending from the exterior down through the roofing assembly into the interior (Figure 3, page 17). While this type of system may perform in a low RH building, the fasteners can

Figure 13

Backside of exterior veneer masonry.

potentially add more paths for air migration by penetrating the air/vapor barrier membrane above the roof deck.

The roof-to-wall interface can also be an area for concern, and extra care should be considered should the RH be increased. For example, the material properties of the roofing membrane and the water-resistive barrier at the wall may be able to function as a part of an air barrier system, but if they are not connected in an airtight manner, moisture-laden air can exfiltrate, leading to potential condensation within the parapet.

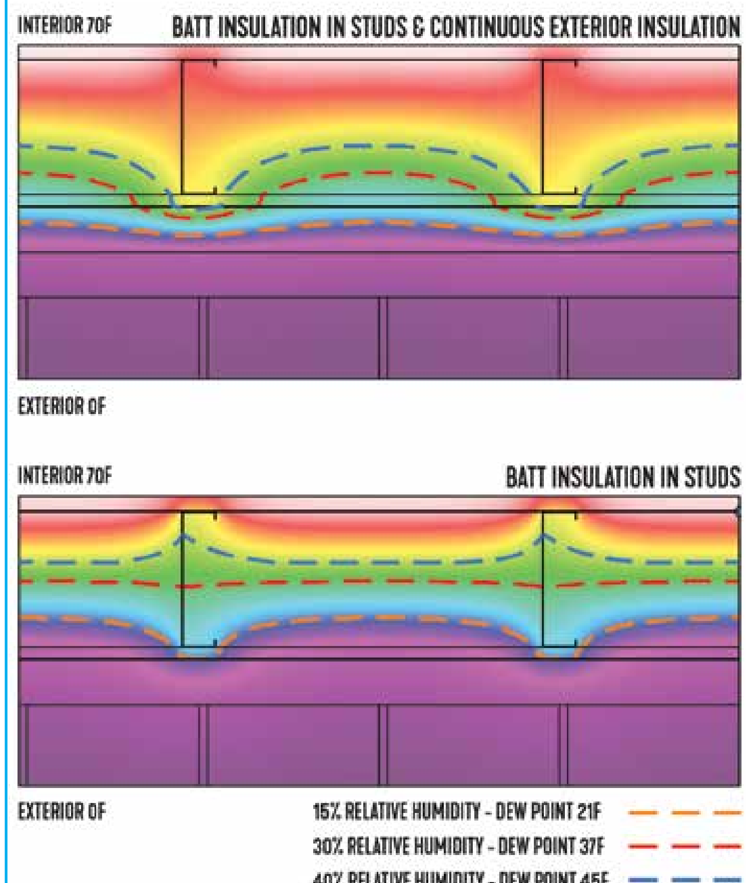
At another common roof-to-wall condition, an interior vapor retarder was included but was not designed or installed as a part of the air barrier system. It is also not uncommon to have the perimeter structural beams very close to the exterior wall, limiting the ability to access the underside of the roof deck for termination of the vapor retarder or transition to the roof deck. The roof slab can also act as a thermal bridge, as demonstrated in Figure 4 (page 17), representing a potential area for condensation under elevated RH.

Similarly, some roof parapets include curtain wall systems as part of the assembly. Vertical mullions within this assembly extend into the cold parapet area and can act as vertical thermal bridges. These thermal bridges may contribute to the surfaces of the curtain exposed to the interior to drop below the dewpoint temperature (Figure 5, page 17).

Fenestration

Like roofs and walls, numerous types of fenestration systems currently in service on existing buildings vary widely in their ability to resist condensation. These systems can range from historic, single-pane glass in non-thermally broken frames to contemporary systems. Contemporary glazing may be coated or non-coated glass, in a double- or triple-pane configurations, and they can utilize more efficient airspace gases such as argon. Modern systems may include thermally improved aluminum frames or may be more highly efficient with robust thermal breaks. Figure 6 (page 18) illustrates the thermal behavior of three slightly different curtain wall systems. All three utilize the same double-pane

Figure 14



Thermal modeling of wall assemblies.

insulated glass unit (IGU), but are modeled in three different framing systems—a non-thermal frame, a thermally improved frame, and a thermally broken frame. A high-performance curtain wall system with enhanced thermal breaks and triple-pane IGU was also modeled for comparison. Based on the estimated surface temperatures, these systems can accommodate RH levels of approximately 24, 28, 31, and 40 percent respectively, and with the exception of the high-performance option, all are below the recent guidelines outlined in the ASHRAE PD. Further, in the authors' experiences, single-pane glass can accommodate an interior RH of 15 percent or less.

Another issue with fenestration systems is their transition to adjacent wall assemblies and placement within. Figure 7 (page 18) illustrates the difference in condensation resistance performance when comparing two different window placements. The left image shows a thermal model with the window placed outward, which creates a misalignment of the thermal control layers, as shown with the dashed blue line. The right image aligns the thermal components of the window with the adjacent wall showing greater accommodation for higher interior RH.

Additionally, air control both within the fenestration product and at the transition between fenestration products and adjacent wall assemblies, can impact enclosure performance. Fenestration products often rely on gaskets and sealants for their air- and water-tight capabilities. These types of materials degrade over time and can create paths for air infiltration, which can cool the interior surfaces of the fenestration below dewpoint temperatures. Similarly, if air control is not achieved at the window-to-wall connection, an increase in interior RH can create conditions evidenced in Figure 8 (page 18).

Exterior walls

Like roofs and fenestration, varying wall types are utilized in existing buildings. The vapor retarder, air barrier systems, and insulation, as well as the methodology and placement within the wall assembly of such components can differ greatly. Some wall types do not include any of those components, such as mass masonry walls, and can have numerous

Figure 15

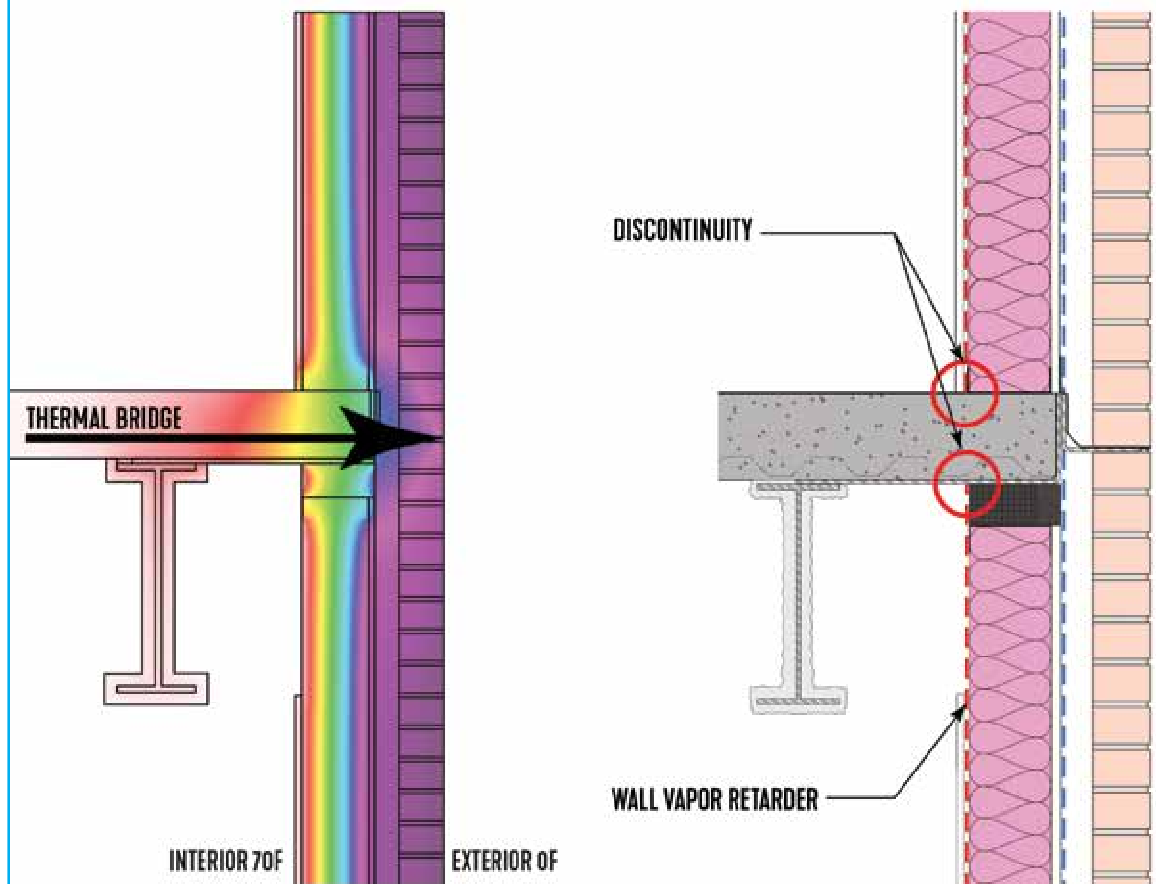


Illustration of difficult transitions and thermal bridging at floor slab.

air paths through the wall. Increased interior RH can allow these paths to transport moisture-laden air into the wall assembly, potentially leading to condensation and/or deterioration of the wall.

The assembly depicted in Figure 9 (page 19) is an example of another wall type, which includes insulation on the backside of the concrete block backup wall. The insulation was extruded polystyrene (XPS), which has the material properties to limit vapor and air permeance through the insulation. However, in this case, the insulation was spot adhered in place, the board joints were not sealed, and it was not sealed to adjacent enclosure components in an airtight manner. As demonstrated in Figures 10 (page 20) through 13 (page 21), air transfer was possible from the interior to the exterior, creating the potential for condensation.

Another common wall assembly used in existing buildings incorporates cold-formed metal framing for the structural backup wall. Some of these walls can include insulation within the stud cavity, others in the exterior air cavity, and some in both. The location of intended vapor and/or air control can impact the assembly's condensation resistance.

The upper image in Figure 14 (page 22) illustrates a thermal model of a wall assembly that includes batt insulation in the stud cavity. The lower image includes both batt insulation in the stud cavity and exterior insulation in the air cavity. This is sometimes referred to as a split insulation method. The dashed lines represent the temperature within the wall at various corresponding dewpoint temperatures. If this wall assembly does not include effective air and vapor control at the interior, condensation could potentially form on surfaces within the stud cavity at elevated interior RH levels.

Like the roofing system, if the design includes an interior vapor retarder, it should be determined as to whether this component is also meant to provide air control. When utilizing interior vapor retarders that are also intended to provide air control, challenges can occur when detailing at penetrations and transitions to adjacent exterior enclosure assemblies, as demonstrated in Figure 15 (page 23)

Figure 16

Unsealed beam penetration at exterior wall.

and Figure 16 (page 24). This configuration also creates a thermal bridge at the floor line that can be a potential source of condensation when exposed to elevated levels of interior humidity.

Conclusion

In conclusion, the recently updated ASHRAE PD guidelines indicate the benefit of increasing the interior RH to a minimum of 40 percent to assist with infection control by reducing aerosol transmission. However, existing building performance can vary greatly when it comes to air leakage, thermal efficiency, and condensation resistance, and may not be able to accommodate this level of humidity in certain seasons. The enclosure performance can also be impacted by the type of building pressurization, both positive and negative. Evaluating and assessing the existing enclosure's performance and condition is an important first step to avoid potential issues with increasing the RH.

Several forensic techniques can be employed to evaluate the existing construction in advance of altering the interior RH, including the removal of select materials (Figures 10 to 13), thermal modeling, diagnostic moisture testing, as well as infrared thermography. As highlighted above, verifying the presence and/or integrity of an air barrier system is also a priority. The forensic results can then be used to determine when, if, and for how long RH can be increased while limiting the risk for condensation. **CS**

Note

[1] The authors would like to credit Ryan Asava, AIA, NCARB, for the figures and the thermal modeling/analysis that informed the development of the figures. Asava is an associate at SmithGroup and a member of its Building Technology Studio. His primary focus is in the analysis of new and existing building enclosures. His project responsibilities include product research, energy code analysis, thermal calculations, and hygrothermal analysis. He can be contacted at ryan.asava@smithgroup.com.

ADDITIONAL **INFORMATION**

Authors

Sarah K. Flock, CDT, AIA, is an associate principal at Raths, Raths, and Johnson (RRJ). She has more than 18 years of architectural experience in water/moisture intrusion investigations, repair design, and field testing of distressed structures, nonperforming buildings, and material systems. Specializing in building enclosure assessment, Flock has performed hygrothermal modeling to analyze a wide range of projects involving various types of building materials and systems. Her experience has involved peer review of building enclosures and assemblies to ensure the designs meet codes and standards for energy efficiency and environmental performance. Flock is the co-chair of the research committee, co-vice chair of the executive committee, and on the board of directors for the Air Barrier Association of America (ABAA). She can be contacted at skflock@rrj.com.

Andrew Dunlap, AIA, CDT, LEED AP, NCARB, is leader of the building technology studio at SmithGroup. His primary work experience is in the analysis and development of exterior building enclosures including roofing, skylights, windows, curtain walls, rainscreen/cavity walls, and waterproofing. Dunlap regularly participates in reviewing and validating existing and new building enclosures for airtightness, thermal performance, energy efficiency, and condensation resistance. Dunlap is the co-chair of the Air Barrier Association of America (ABAA) research committee, co-vice chair of the executive committee, and is a member of the board. He can be reached via e-mail at andrew.dunlap@smithgroup.com.

Key Takeaways

The importance of infection control and the impact of operating conditions on the built environment have taken renewed focus in the wake of the COVID-19 pandemic. As a part of the ongoing response, industry organizations, such as the American Society of Heating and Refrigerating and Air-conditioning Engineers (ASHRAE), have released updated considerations for design and construction professionals, including airflow strategies and temperature and humidity controls, as well as ventilation and pressurization. Such conditions have a direct impact on the building enclosure and the building enclosure of existing buildings should be evaluated prior to implementing an increased relative humidity (RH) during colder months of the year.

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ASHRAE
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Relative humidity
Ventilation

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The State of Energy Efficiency

The *International Energy Conservation Code* (*IECC*) and the building enclosure

by Craig A. Hargrove, AIA, LEED AP

All images courtesy Hoffmann Architects

ON 24 FEBRUARY, 2017, THE NEW YORK TIMES RAN AN ARTICLE REGARDING THE EVENTUAL DE-COMMISSIONING OF THE INDIAN POINT NUCLEAR POWER PLANT JUST NORTH OF NEW YORK CITY. ACCORDING TO THE ARTICLE, THE GOVERNOR INTENDS TO CLOSE THE PLANT BY 2021. THIS RAISES THE QUESTION: HOW DOES NEW YORK STATE INTEND TO REPLACE THE ENERGY THE PLANT CREATED SO THEY CAN STILL MEET POWER DEMANDS?

As it turns out, they do not; not entirely. The article goes on to cite a report that determined New York's best option is not finding alternative sources of power, but to follow states like Massachusetts and Rhode Island in enacting programs to reduce energy use.

New York is not alone in applying this calculus to energy policy, and the cumulative effect such decisions have on the built environment is significant. In 2010, the required insulative value for a new, low-sloped roof on a commercial building in climate zone 4 (the region that includes New York City) was R-20. Today, the 2018 *International Energy Conservation Code* (*IECC*) requires that same roof to have a value of R-30—a 50 percent increase. For windows, the change has been even more dramatic. In 2010, new fixed windows needed an R-1.82; today it is R-2.63—a 45 percent increase. Further, while similar values for exterior walls have remained largely the same, the method of assessing performance has changed greatly.

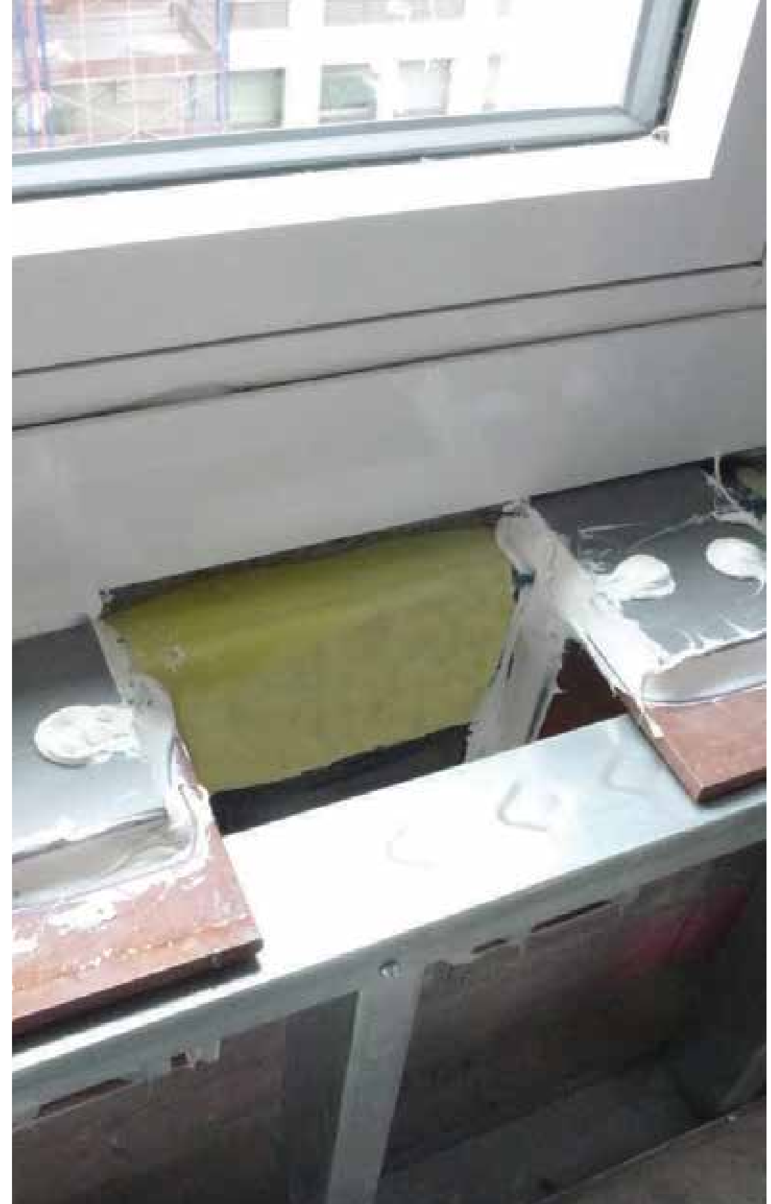
The 2018 *IECC* is the latest in a line of increasingly stringent regulatory requirements. While it is not necessarily a response to, these regulations certainly support a shift in policy being adopted by states like New York that seek to meet energy needs in part by reducing usage.

Today, the path to energy code compliance can be nuanced and complicated, requiring knowledge not just of standards and materials, but a basic understanding of scientific concepts like the laws of thermo- and fluid-dynamics. Stricter requirements now bring designers into potential conflict with competing codes on issues like combustibility and structural stability. It is, of course, unlikely this trend will ever reverse itself. Instead, the requirements for energy performance will simply continue to become more stringent and paths to compliance will be more complicated. With all of this in mind, an overview of the 2018 *IECC* and the science behind it might be helpful. To simplify things, the discussion in this article will be limited to commercial buildings.

Since its introduction in 2000, some version of *IECC* has been adopted in 48 states, the District of Columbia, and the U.S. Virgin Islands.[1] The code incorporates the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, by reference. While *IECC* incorporates approximately 87 outside publications by reference, these two standards (*IECC* and ASHRAE 90-1-2016) create the essential framework for establishing and demonstrating compliance with the mandated energy performance requirements of the building enclosure. During this discussion, unless otherwise stated, 'code' refers to the combined requirements of *IECC* and ASHRAE 90.1.

Climate

To understand the code, it is important to grasp that a path to compliance is entirely dictated by geography. Different locations require different strategies to achieve energy efficiency, and the first question to ask is: Is the project in a 'heating' or 'cooling' climate? The terms mean exactly what they might seem—in a heating climate there are more annual 'heating degree days' than 'cooling degree days,' and vice versa. While the code has specific definitions for these conditions, simply stated, a heating climate is



An example of high-efficiency detailing, where a thermal break is provided at point transmittances, such as metal-to-metal connections.

one in which more days are spent heating the building than cooling it. For example, Boston is in a heating climate, while Miami is in a cooling zone.

ASHRAE 90.1 further divides the continental United States into seven climate zones that can broadly be defined as varying degrees of the following conditions:

- moist heating climate;
- dry heating climate;
- moist cooling climate; and
- dry cooling climate.

So, in general, the code establishes requirements in a region based on two criteria: temperature and moisture. The control of these two conditions is essential for thermal comfort and energy efficiency.

Understanding thermal efficiency

Every material used in construction can resist the transfer of energy—this is its R-value. The reciprocal of a material's R-value is its U-factor, or its tendency to transfer energy. R-values of many common building materials can be found in ASHRAE 90.1 in, for instance, Table A9.4.3-1, "R-values for Building Materials." Manufacturers are also good sources for R-values of specific products. However, it is always advisable to verify such claims by a review of test data supporting the published values.

The prescriptive requirements of the code for, say, opaque wall assemblies can be met in one of two ways. The first is the "R-value method," where an exterior wall is deemed in conformance if insulation of a certain R-value is provided as indicated in *IECC*, Table C402.1.3, "Opaque Thermal Envelope Insulation Component, Minimum Requirements, R-Value Method." This is the most straightforward path to compliance, but is not always possible or the most practical.

A second path to compliance is the "whole assembly U-factor" method. In this case, the thermal efficiency of the entire wall assembly is calculated to determine the overall U-factor, and that amount is, in turn, compared to the maximum values in *IECC*, Table C402.1.4, "Opaque Thermal Envelope Assembly, Maximum Requirements, U-Factor Method."

This is a more complicated path to compliance, as the thermal values used for the various wall components are strictly dictated by Normative Appendix A, "Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations," of ASHRAE 90.1. However, this method often offers an advantage to designers when placement of the amount of insulation dictated by the prescriptive requirements of the code proves impractical.

Eventually, high-efficiency detailing that cuts energy use will likely be mandated by code.

The path to compliance

As discussed, the code provides prescriptive values for the building enclosure, minimum requirements components like roofs, walls, and fenestration must meet. Whether or not one can avail of those values depends on the amount of glass on the building. Section C402.4.1, "Fenestration (Prescriptive), Maximum area," of *IECC* states (with some exceptions):

The vertical fenestration area (not including opaque doors and opaque spandrel panels) shall not be greater than 30 percent of the gross above grade wall area.

With the use of prescriptive values being the easiest path to code compliance, why would the International Code Council (ICC) restrict its use based on the amount of glass on a building façade?

As it turns out, most of the inefficiency that is experienced at the building enclosure is through the fenestration. The second law of thermodynamics states that energy flows from hot to cold, so, in the summer, windows, being the most thermally inefficient portion of the enclosure, will warm the cool, conditioned air of the interior, requiring more energy to achieve thermal comfort. This happens in two essential ways: through conduction and convection (the transfer of energy through and across the assembly), and via solar radiation. Glazed assemblies are made more energy efficient by reducing the amount of energy it can transfer by decreasing its overall U-factor and solar heat gain coefficient (SHGC). These performance improvements are achieved in a variety of ways, including thermal separations at metal frames, internal frame components such as warm spacers, glass coatings, and inert gases such as argon and krypton between the panes of insulating glazing units (IGUs).

Yet, fenestration is still a weak point in the quest for thermal efficiency and code compliance. There is documentation supporting the notion that limits to the amount of exterior glass in a room does not necessarily reduce the user's well-being. The U.S. Green

Opaque walls and fenestration must form a uniform air barrier providing the requisite protection from leakage, even across joints and transitions.

Building Council (USGBC), for instance, has stated, "window areas below 0.6 m (2.6 ft)" do not contribute to daylighting of interior spaces and [should] be excluded."[2]

The code recognizes that glazed assemblies are inefficient when compared to the opaque portions of the building enclosure, and more glazing is often unnecessary to achieve a desired indoor environment. As a result, both *IECC* and ASHRAE 90.1 attempt to encourage the reduction of glazing by restricting the use of prescriptive values and requirements within the code. While this requirement is not new, large glass towers have not exactly disappeared from the landscape. So how do these buildings establish a path to compliance when they have more than the required percentage of vertical fenestration?

In such cases, compliance lies in the ability to 'model' the building to show it performs as efficiently as a building with the requisite percentage of glass (the 'budget building'). This can be accomplished in several ways, but most often means following the requirements of Normative Appendix C, "Methodology for Building Envelope Trade-Off Option," as further defined by Section 5.6, "Building Envelope Trade-Off Option," of ASHRAE 90.1. This option enables designers to make up for inefficiencies in certain elements of the building enclosure (in this case, a preponderance of glass) by trading off with systems performing in excess of the code requirements, such as opaque wall assemblies, roofing, or lighting. Depending on the amount of vertical fenestration, such trade-offs could tax the abilities of these other systems to compensate in ways that fit the design requirements and do not become cost prohibitive.

The ramifications of having too much glass, and then having to employ alternative paths to code compliance such as the "Building Envelope Trade-Off Option," do not end there. Starting in 2013, ASHRAE 90.1 included the following statement in Normative Appendix C:

C1.2.6 For Uninsulated Assemblies. All uninsulated assemblies (*e.g.*, projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages, roof parapet) shall be separately modeled.

High percentages of glass require compensatory efficiencies in other systems.

Less than 30 words, and yet, it has significant implications in how the façade of a building is assessed for thermal performance. Under the prescriptive requirements, an opaque wall assembly's ability to resist thermal transfer (its R-value or U-factor) has traditionally been established by an analysis of its 'clear wall value.' In other words, by assessing "a portion of the wall containing only insulation and a minimum of necessary framing materials at a clear section with no windows, corner columns, architectural details, or interfaces with roofs, foundations, or other walls."[3] The result is an optimal assembly presenting the best possible performance of that wall for energy.

However, this is not reality. What an analysis of this portion of the wall fails to consider are the host of conditions in a façade that can lead to thermal transfer: the linear and point transmittances. Examples include:

- parapets;
- uninsulated slab edges;
- window heads, sills, and jambs; and
- façade cladding anchors.

When these transmittances are accounted for, the actual insulative value of a wall can be reduced by as much as 60 to 70 percent.[4]

By including C1.2.6 in Normative Appendix C, ASHRAE's message is clear: reduce the amount of glass on buildings or switch to high-efficiency detailing to address all thermal inefficiencies on the building enclosure.

It should be noted the use of high-efficiency detailing to eliminate thermal transfer at façade transmittances can represent a net cost savings to owners. By establishing a more efficient building enclosure during design, the size of mechanical systems and subsequent utility costs could be significantly reduced.

Air and vapor migration

This article has discussed how the key to thermal efficiency is the control of temperature and moisture. Up until now the focus of this has been on temperature, but clearly that is only part of the equation.

Because heat, air, and moisture transfer are coupled and closely interact with each other, they should not be treated separately. In fact, improving a building envelope's energy performance may cause moisture related problems. Evaporation of water and removal of water by other means are processes that may require energy. Only a sophisticated moisture control strategy can ensure hygienic conditions and adequate durability for modern, energy-efficient building assemblies. Effective moisture control design must deal

Every material used in construction can resist the transfer of energy.

with all hygrothermal loads (heat and humidity) acting on the building envelope.
ASHRAE Handbook – Fundamentals (2013)

While limiting the infiltration of liquid water is essential for the health and sustainability of a building, any discussion about the control of moisture in regard to energy efficiency is really about the control of air and water vapor.

The design and installation of appropriate and comprehensive air barriers are mandated by Section C402.5, "Air leakage–thermal envelope (Mandatory)," of *IECC* and must be continuous "throughout the building thermal envelope." As the name suggests, an air barrier system's primary purpose is to reduce the flow of air between the interior and exterior. However, it may also serve a secondary purpose of restricting the flow of water vapor.

Providing a comprehensive and contiguous air barrier "throughout the building thermal envelope" is a complex undertaking, and particular care should be taken in its design. Large-format details showing the continuity of the air barrier across changes in the thermal envelope should be developed, including at the field of the opaque wall assembly and its interface with:

- transitions in materials and assemblies;
- changes in plane;
- fenestration; and
- roofs.

The barrier must be designed and installed to resist forces that may deteriorate the assembly, particularly at seams and transitions. Additionally, entrances may require vestibules depending on their size, use, and climate zone location.

Standards for air barrier performance are very rigorous, and installed barrier systems, which include fenestration, must undergo testing to see they do not admit more air leakage than is permissible. Materials used in the opaque wall assembly must comply with ASTM 2178, *Standard Test Method for Air Permeance of Building Materials*, and "shall be deemed to comply…provided joints are sealed and materials are installed as air barriers in accordance with the manufacturer's instructions." Doors, windows, and skylights must conform to ASTM E283, *Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen.* Together, opaque walls and fenestration must form a uniform air barrier providing the requisite protection from leakage, even across joints and transitions.

While the requirements for the control of air through the building enclosure are stringently mandated, the requirements for vapor control are less so. This may seem counterintuitive, but there is a compelling reason. Energy efficiency and vapor control strategies are ineffective without a comprehensive air barrier system to restrict

Energy efficiency and vapor control strategies are ineffective without a comprehensive air barrier system to restrict airflow.

airflow. However, the extent to which a vapor control strategy is needed and how it should be designed and installed depends on several variables, including climate, building use and construction, and the potential and the extent to which moisture sources other than interior water vapor exist. ASHRAE 160, *Criteria for Moisture Control Design Analysis in Buildings*, is a recognized standard for evaluating the need for and placement of vapor retarders.

Additionally, consideration should be given not just to vapor control, but to the need of the building enclosure to effectively dry after it gets wet. This may require a 'semipermeable' vapor retarder, while in other cases, systems with a very low permeance may be appropriate. Care should be taken during design to avoid the potential to trap moisture through the inadvertent use of multiple vapor retarding layers in an assembly.

When vapor retarders are required, their placement relative to the insulation layer of the wall assembly is extremely important.

The retarder should be at or near the surface exposed to higher water vapor pressure and higher temperature. In heating climates, this is usually the winter-warm side.
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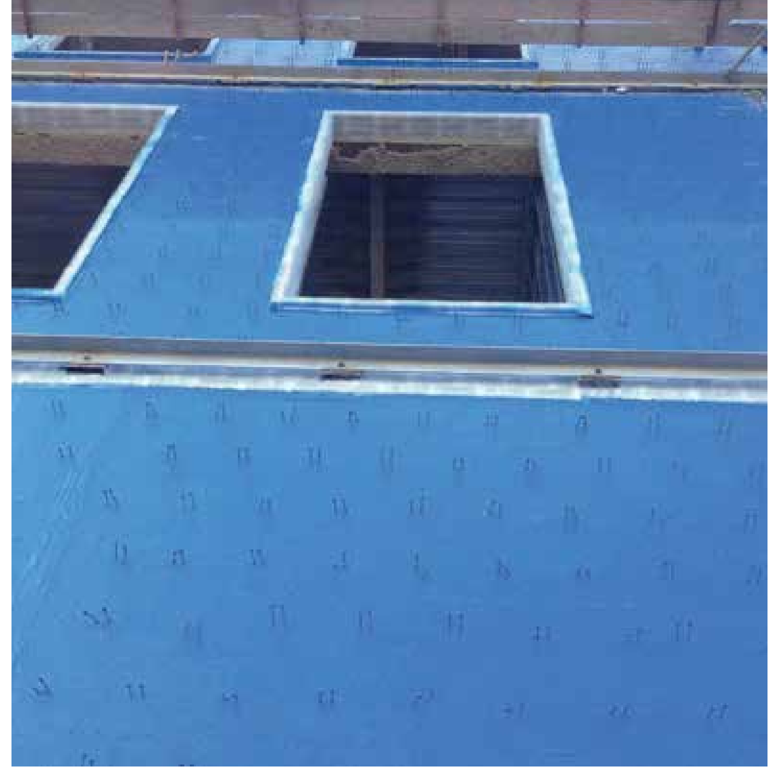
In other words, the vapor retarder is often installed on the 'warm side' of the insulation.

As always, proper installation is as important as proper design. In the case of vapor retarders, a significant increase in permeance can occur as a result of very small holes in the material.

Condensation

Surface condensation occurs when water vapor contacts a non-porous surface that has a temperature lower than the dew-point of the surrounding air. Insulation should therefore be thick enough to ensure that the surface temperature on the warm side of an insulated assembly always exceeds the dew-point temperature there. However, even without reaching the dew-point, relative humidity at the surface may become so high that, given time, mold growth appears."
ASHRAE Handbook – Fundamentals (2013)



Addressing thermal flow at linear transmittances, such as the relieving angle shown, is now being required under certain conditions by code.

An unfortunate byproduct of the strides toward thermally efficient buildings is the increased propensity for condensation in buildings through the effective separation of interior and exterior environments. Limited interstitial condensation can often be tolerated under the right conditions and provided there is ample opportunity for the assembly to dry out. However, chronic condensation can be detrimental to things like the health of the building and indoor environmental air quality.

Analysis of moisture migration within a system is extremely complicated and requires an understanding of numerous variables within that system. However, a simplified analysis is often used to make certain broad-based assumptions regarding the potential for condensation to occur. If such an analysis is of a 'steady-state' system, results are achieved by reducing the number of variables and, by extension, the model's resemblance to actual conditions. The results are limited, and extreme care should be used when deriving conclusions from them. Simplified condensation analysis in a steady-state environment, while instructive, does not provide a comprehensive picture of the effects of hygrothermal flow across an assembly. One problem is that it neglects to account for the effects of vapor pressure, which can create conditions conducive to mold, material failure, and displacement of assemblies.

The road to net-zero

In 2017, residential and commercial buildings accounted for 39 percent of the nation's energy consumption.[5] Changes in climate and government policy, diminishing resources, and an aging infrastructure all underscore the need to create a built-environment that meets a high standard for energy efficiency. Clearly, *IECC* continues to evolve with this goal in mind.

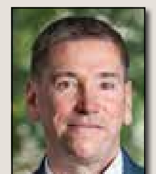
Out of necessity, this process is a protracted one, with the mandates of code being balanced against their potential impact on the economy, the limitations of available technologies, and other practicalities. However, net-zero buildings—structures whose net energy use is zero—exist, and while they are currently few, the number grows each year.[6] While incremental changes to the code are prudent, the cumulative result over the coming decades could be quite remarkable. **CS**

Notes

[1] Visit www.iccsafe.org/wp-content/uploads/Code_Adoption_Maps.pdf.
[2] Get more information from the U.S. Green Building Council's New Construction and Major Renovation Reference Guide (Version 2.2, Second edition, September 2006).
[3] Consult Building Science Corporation at www.buildingscience.com/glossary/clear-wall-r-value.
[4] For more information, read British Columbia Hydro's Thermal Envelope Bridging Guide, Version 1.1, 2016.
[5] Access details at www.eia.gov/tools/faqs/faq.php?id=86&t=1.
[6] For more information, visit www.wbdg.org/resources/net-zero-energy-buildings.

ADDITIONAL INFORMATION

Author



Craig A. Hargrove, AIA, LEED AP, is senior vice-president and director, architecture, with Hoffmann Architects, an architecture and engineering firm that specializes in the rehabilitation of building enclosures. Manager of the firm's busy Manhattan office, he oversees demanding high-performance building envelope projects, leading project teams in developing design details that meet weather integrity, energy efficiency, and aesthetic goals with cost-effective solutions. He may be reached at c.hargrove@hoffarch.com.

Key Takeaways

As federal, state, and local governments continue to look for ways to reduce energy consumption in their jurisdictions, the requirements for the construction of energy-efficient buildings becomes increasingly stringent. Often this means more efficient lighting, heating, and cooling systems. However, no building system has the potential to affect energy use as much as the building enclosure. This article provided an overview of the 2018 *International Energy Conservation Code* (*IECC*) and explained how the current code will impact building design and construction.

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