

Air Barriers in Building Construction: Understanding Costs, Meeting Performance Standards and Exceeding Codes



The case for closed-cell spray polyurethane foam (ccSPF) insulation air-barrier system in building envelopes.

WHITE PAPER SUMMARY: New requirements in energy codes and expectations for better performance among many building owners underscore the importance of air barriers for commercial-building performance and code compliance. Use of spray polyurethane foam (ccSPF) as a key component in air-barrier assemblies provides good performance characteristics and cost and construction advantages, as shown in this review of industry literature and new research by RSMMeans Business Solutions.

Overview: New Urgency in the Call for Air Barriers

Why air barriers, and why now?

That's a question being asked by many architects, contractors, engineers and building owner-developers, and the answers are varied. For one, the International Energy Conservation Code (IECC) and several state energy codes—Massachusetts, Wisconsin and Michigan, with more expected to follow—now require the use of air barriers. In addition, a growing number of municipal authorities having jurisdiction (AHJs) and green-building trade groups are calling for their use. Some federal agencies and large owner and developer groups also require them.

More important, energy efficiency and occupant comfort—two key ingredients of sustainable design—are driving the use of air barriers across market sectors. With today's high cost of energy and concerns about Indoor Environmental Quality (IEQ), air barriers are one of several construction systems with a critical role to play.

Table of Contents

| | |
|--|---------|
| Overview: | |
| New Urgency in the Call for Air Barriers..... | Page 1 |
| Definition: What Is an Air Barrier? | Page 2 |
| Air Barriers: | |
| A Concise Overview of a Big Topic | Page 2 |
| Air Barriers in Building Construction | Page 3 |
| Glossary: The Taxonomy of Air Barriers | Page 4 |
| Roof Air Barriers: | |
| Resisting Weather and Maintaining Continuity | Page 5 |
| Best-Practice Specifications for Barriers | Page 6 |
| Design Considerations for an Airtight Envelope [sidebar]..... | Page 7 |
| Air Barriers in Building and Energy Codes..... | Page 8 |
| A New ASHRAE Standard | Page 10 |
| Current Air-Barrier Building Technologies..... | Page 10 |
| Characteristics and Advantages of SPF for Air Barriers | Page 12 |
| Testing Air Barriers for Performance (and Compliance) | Page 14 |
| Action Plan: SPF and Air Barriers | Page 14 |
| RSMMeans Cost Data for Air-Barrier Assemblies | Page 15 |
| RSMMeans Cost Data for Spray Polyurethane Foam Insulation Wall & Roof Air-Barrier Assemblies | Page 16 |
| About the Sponsor | Page 18 |

Definition: What Is an Air Barrier?

Air barriers control the unintended movement of air into and out of a building enclosure. *Air-barrier* systems are made up of a number of materials that are assembled to provide a complete barrier to air leakage through the building enclosure. A building enclosure includes all “six sides” of a building—exterior walls, roof and foundation floor—and may also include separations within the structure. An air-barrier system essentially “wraps” the building shell and protects the building from the effects of air leakage. Uncontrolled air leakage can have detrimental effects on how a building functions in terms of occupant comfort, indoor air quality and energy usage, and it reduces the life span of a building.

What an air barrier actually is and does, let alone how one is properly specified, designed and constructed, is not well understood by many professionals. In spite of efforts by sustainability advocates, trade groups and proponents of more energy-efficient buildings, not everyone recognizes their effectiveness and the value of blocking air movement through the building enclosure. However, with today’s all-time high cost of energy, coupled with the green building movement, air-barriersystems performance in the exterior walls, foundation/floors and roof system are getting much more attention in the construction of high performance buildings.

In fact, air-barrier systems in nonresidential buildings are estimated to reduce air leakage by up to 83 percent, save on gas bills by more than 40 percent and cut down on electrical consumption in excess of 25 percent, according to simulations by the National Institute of Standards and Technology (NIST) of typical buildings without air barriers. Although the results of this particular NIST study have not been field tested, the results are compelling. Manufacturers and groups such as the Building Enclosure Council (BEC) have publicly confirmed the importance of air barriers to meeting energy benchmarks and to building performance and sustainability in general. Without an effective, continuous air-barrier system, conditioned air tends to escape through the building envelope, and the heating, ventilation and air-conditioning (HVAC) system has to work harder to keep the indoor environment comfortable. And, as the NIST report demonstrated, harder-working HVAC means higher energy bills.

In fact, the statistics from NIST and other academic and professional research groups have not only caught the attention of certain entities—such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and code officials in Massachusetts, Michigan and Wisconsin—but they have led to new awareness of the fact that air barriers also can increase both the longevity and durability of the building envelope. Considering that walls and roofs account for approximately 25 percent of total building construction costs, according to RSMMeans data, bolstering the building envelope’s quality makes a lot of sense.

In the following pages, we examine the energy and durability considerations of air barriers, as well as the bottom-line issues that drive the selection and specification of building air-barrier products today. In addition, we unveil new information on the relative costs of effective air-barrier assemblies as determined by RSMMeans Business Solutions. We conclude with three constructive recommendations—an “Action Plan”—for consideration by building designers, constructors, developers and owners concerned about sustainability, building costs, energy efficiency and air barriers. First, we present an overview of air barriers, materials and installations costs; an update on current standards; testing for air-barrier compliance; and a discussion of closed-cell spray polyurethane foam (ccSPF)—a highly effective product used to create air barriers.

1. Air Barriers: A Concise Overview of a Big Topic

What exactly are air barriers? These systems are made up of a number of materials that must be assembled to control the undesired movement of air into and out of the building enclosure. Without air barriers, uncontrolled air leakage can negatively affect the operating cost, day-to-day operation and life span of a building. For example, the escape of conditioned air, both in the summer and winter, causes building mechanical systems to work harder to condition occupied spaces. Yet with a proper air-barrier system in place, it may be possible to reduce the mechanical equipment size—a savings which could very well offset the cost of additional enhancements to the building envelope, such as increased effective R-value or the air-barrier

assemblies themselves. Air barriers are often not considered simply because their proper design, performance and energy-saving features are not well understood. However, according to air barrier experts, controlling energy costs requires controlling air leakage into and out of buildings.

In addition, air barriers keep pollutants out of building interiors more effectively than other types of construction approaches, which greatly helps improve the indoor air quality (IAQ). Air barriers also help prevent water vapor—which can condense and turn into liquid water, a key ingredient in corrosion and mold growth—from being transported by the air movement between the exterior and interior of the building envelope. “Air barriers are vital in preventing uncontrolled air migration through the building enclosure,” says George M. Blackburn, III, AIA, CSI, general manager of Construction Consulting International, Carrollton, Texas, and an active BEC member. “Air leakage is a major factor in the amount of energy waste related to heating and cooling the air in buildings, as well as allowing higher volumes of water vapor to enter the building.”

In the same vein, Judd Peterson, AIA, president of the Judd Allen Group, Edina, Minn., explains: “Uncontrolled air flow is the greatest source of moisture and condensation damage in exterior walls, as compared to simple vapor transmission. And uncontrolled moisture is the greatest cause of deterioration of building materials.”

2. Air Barriers in Building Construction

The control of air movement is critical to the control of moisture and the heating and cooling of a building in all climates and is determined by basic physics. The key elements affecting air barriers are wind, stack effects and mechanical pressures.

In addition, a narrow definition of what constitutes an air barrier will help building designers and construction professionals better visualize what goes into its construction and performance. For example, because air-barrier systems consist of specified and tested materials, components and assemblies, each element must be designed, manufactured and carefully installed to work together in order to effectively seal the building envelope. For clarity's sake, the Air Barrier Association of American (ABAA) recommends a single specification area for air barriers in

construction documents and a single reference section for *air-barrier assemblies*. A properly designed and formatted specification for the air-barrier system is critical for the building envelope to achieve maximum performance.

To better understand air barriers as a component of building construction, it's important to first understand the terminology. Key terms such as “air-barrier materials” carry distinct meanings. (See “The Taxonomy of Barriers,” page 4.)

The key benefits of incorporating air barriers in building designs and specifications include creating good Indoor Environmental Quality (IEQ), or a comfortable and healthy indoor environment. Variables such as air temperature, relative humidity, direction of airflow and surrounding surface temperatures all affect indoor comfort. Air convective loops occur when the movement of warm and cold air creates drafts and discomfort while also transporting moisture. Air leakage occurs when either infiltration or exfiltration of indoor (treated) air and outdoor (untreated) air exchange places, bypassing intended barriers built into the building envelope. Air intrusion (also known as venting, “wind-washing” or “breathing”) occurs when the outside climate infiltrates the insulation system and bypasses the insulation barrier substrate, but not the interior walls—the gypsum board, for example—and ceiling substrate. This phenomenon does not count as air leakage, but it still robs R-value from certain insulation systems, especially those that are fibrous or have joints, cracks or gaps, such as board or panel insulations. Moreover, if air is warm and humid, condensation can occur in the wall cavity when the air contacts cooler surfaces, which can lead to mold growth and structural damage.

Air leakage, air convection and air intrusion play a big part in the loads on heating and cooling systems. Air leakage is measured in *air changes per hour* (ACH). Any air entering the building envelope must be heated or cooled and, often, humidified or dehumidified mechanically so that the building interiors regain their designed IEQ “comfort zone.”

Air-barrier systems are designed to address building-performance issues. They can be categorized by various methods, but the most useful categorizations are based on the location, product format and vapor permeance of the air-barrier system components, according to two authorities on the subject, Dr. John Straube, P.Eng., of the University of Waterloo, and Dr. Eric Burnett, DIC, P. Eng. FASCE, of Pennsylvania

Glossary: The Taxonomy of Barriers

For a quick overview of important air-barrier terminology, below is a brief list of key definitions:

Air Barrier – the primary material preventing or reducing the passage of air through the building enclosure system.

Air-Barrier Assembly – a collection of air-barrier materials and air-barrier components installed to provide a continuous barrier to the movement of air through building enclosures.

Air-Barrier Components – transitional element installed to provide a continuous barrier to the movement of air through building enclosures.

According to the Air Barrier Association of America (AABA), “air-barrier components” refers to the material or product used to connect different air-barrier materials or assemblies together to make the air barrier continuous. Examples of air-barrier components include materials used to connect the wall air-barrier assembly to a window or door assembly, a roof assembly or a foundation assembly. Components can also be used to connect two pieces of air-barrier material together to produce an assembly.

Air-Barrier Material – the principal element installed to provide a continuous barrier to the movement of air through building enclosures.

Air-Barrier System – a combination of air-barrier assemblies installed to provide a continuous barrier to the movement of air through building enclosures.

Simply having air-barrier materials in a building does not provide a continuous plane of air tightness. To achieve this, the various air-barrier materials must be joined together with air-barrier components.

Air Permeance – the air permeance of any air-barrier material, including drywall, is 0.02L/(s/m²) at 75Pa. Consequently, any building material—of which there are hundreds—that has an air permeance equal to or less than this value qualifies as an air-barrier material.

Assemblies – A collection of air-barrier materials and components that are assembled together in a specific manner. A wall air-barrier assembly would include the main air-barrier material and then use air-barrier components to join the materials together, for example to connect to a window or door assembly, a roof assembly, a foundation and all penetrations. The overall performance of an air-barrier assembly is of far greater importance than the air permeance of the material.

Building Enclosure System – A system of building components and materials designed and installed to provide a barrier between the interior spaces in the building and the exterior environment. The system is designed and constructed to protect the building’s interior environment from the effects of weather as well as: the intrusion of noise; pollutants; hazardous or deleterious conditions and materials; and unwanted organisms. A building enclosure system also provides structural resistance to both natural and unnatural forces, in addition to adding aesthetic value to the building.

Insulation materials that are not self-sealing and monolithic no matter what the “R” Value of the insulation material will not stop this waste of energy and money.

ccSPF - closed-cell spray polyurethane foams “A” component is a polymeric isocyanate containing reactive isocyanate groups. The “B” component is a combination of polyols, catalytic agents and non-ozone depleting HFC-245fa blowing agent.

State University. The fact that many vapor barriers also retard or eliminate airflow sometimes causes confusion between air-barrier and vapor-barrier systems. Since air barriers are generally designed to stop air movement through a building wall, roof, foundation and the like—collectively, the “building enclosure”—this capacity of the materials or systems must be tested.

To test an air-barrier assembly for air leakage, ASTM E 2357-05 guidelines are used. Results include values describing the *air permeance* of the material—the amount of air that passes through—and the air permeance of the components as well as the air leakage that results from joining all the pieces together. Minimum standards provide the cutoff for performance requirements: The prescribed air leakage of an air barrier component and materials may not exceed 0.02 L/s/m² at 75Pa, which is 0.004 cfm²/ft at 1.57 psf per ASTM E-2178-03.

The issue of installation is also a critical consideration in that a manufacturer must outline in writing the system’s performance characteristics and declare the level of skill of the installer, along with the process and methods required to assemble the various materials to achieve an effective air-barrier system. In fact, most manufacturers require their installers to be trained in their specific installation process and prove that they have the knowledge to install the materials properly through certification programs. Having air-barrier installers who are formally trained and individually certified in air-barrier system application

and technology processes improves the chances of getting an effective, well-designed installation with maximum long-term benefits.

Consider the fact that labeled R-values are rarely achieved in practice because most insulation systems are not air barriers and therefore allow leakage of air into and out of buildings. According to Oak Ridge National Laboratories (ORNL), “Common installations of fiberglass batts result in a 28 percent decrease in labeled R-value”—primarily due to air leakage. A study sponsored by Kansas State University’s Engineering Extension similarly concluded that “small voids in wall cavities or at the end of a batt of 1 to 2 percent of the insulation area can result in a 25 to 40 percent loss of R-value.” These findings highlight the effect of joints, cracks and other small openings in insulation systems that do not incorporate an effective air-barrier system. With an average 8 mph wind, air movement through fibrous insulation can result in a loss of R-value up to 30 percent.

However, there is an air-barrier system that, when installed correctly, provides effective insulation as well. **Closed-cell spray polyurethane foam (ccSPF)** is unique in serving as both as an insulation system and as an air barrier in a single product application. This is primarily due to the fact that ccSPF is a seamless and fully adhered system.

3. Roof Air Barriers: Resisting Weather and Maintaining Continuity

While a roof membrane can be considered an air-barrier material, it is important to note that only fully adhered roof systems operate effectively as part of the entire building envelope air-barrier system. Mechanically fastened and ballasted roof systems cannot be considered effective when looking at the entire building envelope air barriers system. Because such systems can displace and momentarily billow or pump air into and out of the system from other areas where air leakage occurs, such as joints, cracks and other openings in the building’s external envelope, they cannot contain air without displacement. This displacement creates air leakage into and out of the building. Consequently, another air-barrier system must be selected to complement mechanically fastened and

ballasted roofing systems, adding additional material, labor and scheduling costs.

Choices include peel-and-stick membranes or air and vapor barriers on the inboard side of the roof system—depending on interior conditions and climate/weather suitability—or taped gypsum underlayment board beneath the insulation and against the deck; either can be used in a system with adhered underlayers of thermal protection board and insulation. However, those layers must be designed and tested to withstand maximum wind loads without displacement. In addition to the field of the roof needing to perform as an air barrier, all penetrations and roof/wall connections need to be air sealed using air-sealing transition membranes and/or closed-cell spray polyurethane foam which can be dispensed from a spray rig, or single and plural component cans or kits of spray applied foam.

In a technical research white paper on *Energy Performance of SPF Roofs* by Dr. Mark Bomberg, P.E., and Dr. Marcin K. Pazera of Syracuse University (with John Nolan), the authors state that R-value loss at roof-insulation board and panel insulation can de-rate labeled R-values by up to 16 percent to 22 percent. This is due to the effects of joints and gaps between the insulation boards, along with fasteners—typically steel screws and plates—which transfer heating and cooling through conduction and radiant-transfer mechanics. Covering a roof with ccSPF, on the other hand, was shown to have no deleterious effect on stated R-values—while also providing a highly effective, fully adhered air-barrier system.

According to Dr. Joseph Lstiburek, P.E., a principal of Building Science Corporation (BSC), air-barriers are “of critical importance” at connections between the roof and walls, walls and foundation and at all building envelope connections and penetrations: parapets, roof edges, equipment curbs, drains, pipes, windows, doors and the like. The greatest source of air and energy leakage from a building is at these *critical building envelope connections*, which require a critical air seal. In March 2006, BSC assembled and evaluated available information regarding the use of closed-cell spray polyurethane foam (ccSPF). The study focused on building enclosure design, including foundation, wall, cladding and roof construction as well as interior finishes. According to BSC, the unique

characteristics of ccSPF set it apart from all other insulation materials, delivering high R-value per inch, airtightness, low permeability, good material strength and good “liquid water holdout,” or rain control.

Beyond providing an effective thermal, moisture and air barrier, ccSPF can assist in controlling condensation and improving IEQ by reducing air leakage and infiltration due to pressure differential caused by the *stack effect*. According to engineers and construction experts, the stack effect is the primary air-leakage route and occurs as rising warm air creates positive pressure against the top of a building and negative pressure at the bottom. Wind also plays a role by developing airflow around the building, creating pressure differentials that can pull large volumes of air into and out of buildings even if they are well insulated. As the air moves, it transports warm or cool air along with moisture into and out of the building, often to a *condensing surface*. On any condensing surfaces below the dew-point temperature, water will form.

Fan pressures can also create negative pressure on the building envelope, drawing in cool, dry air in the winter and hot, humid air in the summer. Alternatively, positive fan pressures push warm, moist air into the building envelope in the winter, depositing condensation on surfaces within wall and roof enclosures.

Mitigating the stack effect starts by dealing with air leakage from the building envelope. Air-sealing building envelope penetrations, ducts, rim joists and window details assists in providing a tight air barrier and also can eliminate passageways for insects and rodents into the structure.

In order to control the bypassing of air due to stack effects and other forces, continuity of the roof, wall and foundation air-barrier systems is of critical importance. Enclosure experts strongly recommend a pre-construction conference on the air-barrier system involving all the pertinent trades including the wall air-barrier subcontractor, window and door subcontractor, sealant subcontractor and roofing contractor. Together, the group will work out how to best connect the roof air barrier and the wall air barrier, as well as the sequence of making airtight and flexible connections. It is also important for the team to ensure that the materials being joined together are compatible.

One additional caveat: As described in the green-building resource *Whole Building Design Guide*, penetrations into roof systems, such as ducts, vents and roof drains, must be dealt with methodically as well. Suggestions include using ccSPF or another sealant or membrane to airtighten those penetrations at the targeted air-barrier layer. The National Roofing Contractors Association (NRCA) recommends ccSPF to air seal roof edges and penetrations for both new construction and re-roofing. Rene Dupuis of Structural Research Inc. of Middleton, Wis., produced two technical committee reports highlighting the advantages of using spray polyurethane foam in commercial roofs and roof flashings details.

4. Best-Practice Specifications for Barriers

Fortunately, design professionals can avail themselves of useful guidance and tools when it comes to specifying air-barrier systems. In particular, the American Institute of Architects (AIA), and the Air Barrier Association of America (ABAA) offer construction specifications for self-adhering sheet air barriers, fluid-applied membrane air barriers and spray polyurethane foam. Other resources include air-barrier system manufacturers that have three-part CSI formatted guide specifications and prequalified lists of approved or certified contractors and that offer detailed written information about their “Quality Assurance Program.”

In addition, the ABAA has developed a Division 1 Specification delineating the administrative and procedural requirements for designing an airtight building enclosure that successfully controls the infiltration or *exfiltration* of air. Also included is information on: inspection and testing services required to verify compliance; how to coordinate the construction of an airtight building enclosure between subcontractors; and customized fabrication and installation procedures. (See “Design Considerations for an Airtight Envelope,” page 7.)

The rapid growth of air barriers in commercial construction has been driven by early adopter design professionals and states such as Vermont, Pennsylvania, Connecticut, West Virginia, New York, Illinois and Massachusetts, which recognize the value of the advanced technology and design of a quality air-barrier system.

ASHRAE Design Considerations for an Airtight Envelope

In order to successfully design an airtight building envelope—an element that is crucial to proper and efficient HVAC system functioning—the following design tips are offered by the ASHRAE Journal:

- Design the exterior envelope and its components to withstand the combined design wind, stack and fan pressures in an airtight manner.
- Design an air-barrier system into the building envelope that can take this pressure, both positive and negative, without displacement or failure. For areas within a building with significantly varying climates, include an air-barrier system into the separation between the two areas, such as between pools and offices, or humidity-controlled areas and adjacent uncontrolled areas.
- Separate shafts—elevators, stairs, ducts and atria—from the floors they serve by airtight assemblies. Provide vestibules and gasket doors and access panels to control transfer of stack pressure.
- Separate pollutant areas such as photocopy rooms, chemical or cleaning storage areas, toilets and garages with gasket doors, and make the surrounding partitions airtight at the deck and floor.

Adding to that list, Wagdy Anis, AIA, LEED AP, principal of Boston's Shepley Bulfinch Richardson and Abbott, was quoted in the March 2005 issue of the ASHRAE Journal, recommending that the air-barrier system should be:

- Constructed of relatively air-impermeable materials and assemblies, interconnected with flexible joints.
- Continuous throughout the enclosure.
- Structurally supported to withstand positive and negative air pressures (including design wind pressures and gusts, as well as persistent low pressures such as stack effect and fan pressurization) without displacement or failure.
- Durable to last the life of the enclosure if inaccessible, or maintainable if it can be accessed.

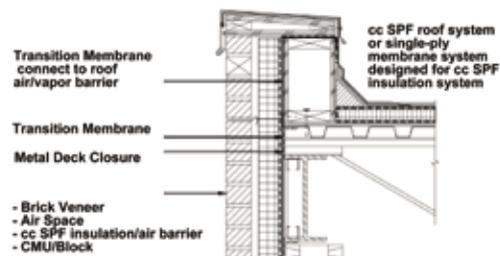
In addition, Anis, who also chairs the Building Enclosure Technology and Environmental Council (BETEC) of the National Institute of Building Sciences (NIBS), points out that the air-barrier system should be clearly identified by the architect in the construction documents on the building-enclosure details, with a strong focus on intersections of different enclosure systems and transitions. "You have to be able to trace through from one identified plane of airtightness in the first assembly through a sealed joint to the plane of airtightness in the adjacent assembly," Anis explains.

In general, it's important to emphasize the fact that the building envelope is part of the mechanical system, even though it is designed by architects (who may not be aware of this) and built by contractors (who may not be particularly focused on airtightness). This being the case, more education, knowledge and informed collaboration about the critical function of the building envelope is crucial to the propagation of these best practices.

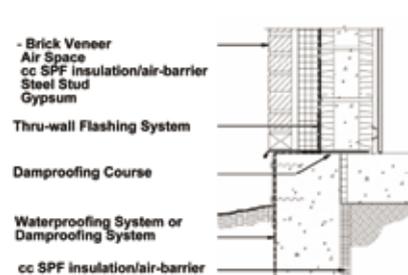
Yet another tool available to designers in Massachusetts, where air barriers are required by code, is free envelope energy-code training, which includes design guidance on air-barrier technology, offered by the state and funded by the U.S. Department of Energy (DOE).

Fortunately for design professionals, responsibility for dealing with compatibility of air-barrier materials, components to join the materials together and the proper handling of penetrations generally falls to any manufacturer who wishes to declare that it provides a total air-barrier assembly solution. Air barriers are complete systems and assemblies, and working with a complete air-barrier system manufacturer cuts down on trial-and-error mixing and matching of materials and components.

Parapet Detail – Wall/Brick Veneer



Foundation Detail – Wall/Brick Veneer



5. Air Barriers in Building and Energy Codes

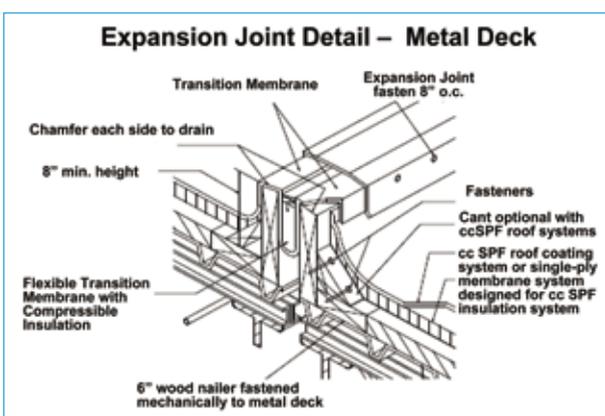
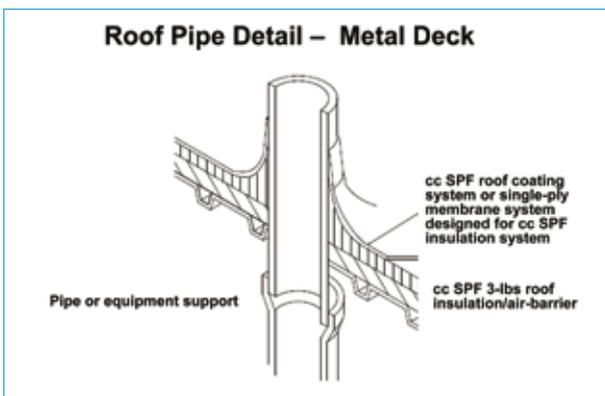
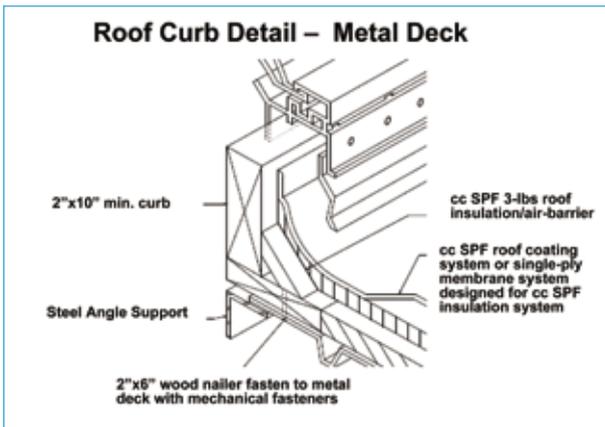
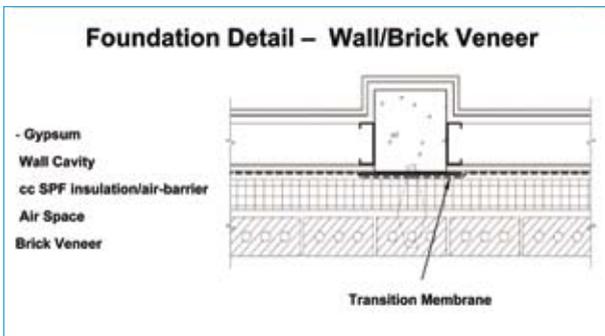
With all of the buzz on air barriers, more and more authorities having jurisdiction (AHJ) are jumping on the Massachusetts bandwagon—actually, they are following the lead of the Canadian Building Code, which has required air barriers since 1990. (Massachusetts came a decade later, in 2001.) Of late, Wisconsin and Michigan changed their building/energy conservation codes to include air barriers, and a number of states, including Louisiana, New Jersey, Ohio and Vermont, have adopted ASHRAE 90.1-2004, which requires that all critical details in buildings be airtight.

As more entities adopt such standards, air-barrier systems and assemblies will become more and more of a critical design component in all buildings.

“The codes and standards play a huge role in the use of air barriers and other construction methods that help buildings operate more efficiently and with greater respect for our health and environment,” says one industry technical expert. “As the use evolves, craftsmen must be trained and field applications must be inspected for compliance to specifications. This generally moves toward installation instructions and training programs from manufacturers and industry trade associations. Now, we start to have nationwide acceptance of the practices and are well on the way to acceptance of the air-barrier systems as being the norm with all construction of commercial buildings.”

Today, the codes and standards affect building design-and-construction teams and are setting the stage for more air-barrier requirements:

- **Canadian Codes spurred action.** In general, most codes have followed the National Building Code of Canada’s generally accepted airtightness requirements of 0.02 L/(s·m²) at 75 Pa pressure (0.004 cfm/ft² at 1.57 psf).
- **ASHRAE’s limited requirements.** Although ASHRAE 90.1-2004, which is based on the International Energy Conservation Code—the basic energy building code for the United States—does include an airtightness requirement, it is somewhat limited. Consequently, the ASHRAE Standard 90.1 Envelope Subcommittee has formed a task group to consider updating the standard to require a continuous air-barrier system. Basically, the current standard offers detailed



State Code Status Table (July 2007)

| | | | |
|-----------|---|-----------|--|
| AK | Residential: 2006 IECC, Effective April 1, 2007 | NV | Clark County, Las Vegas, North Las Vegas, Henderson, Boulder City, Mesquite: Southern Nevada Energy Code based on 2006 IECC, Effective May 1, 2007 |
| CO | 2003 IECC or any successor edition for any jurisdiction that has adopted a building code, Effective July 1, 2007 | NY | Commercial: 2003 IECC; Residential: 2004 IECC with state amendments, Effective August 1, 2007 Tentative date) |
| GA | Amendments to the 2000 IECC, Effective January 1, 2007 | OH | Commercial: IECC 2006/ASHRAE 90.1-2004; Residential: IECC 2006, Effective July 1, 2007 (Until December 31, 2007, buildings may comply with IECC 2003) |
| IA | 2006 IECC, Effective January 1, 2007 (Until March 31, 2007, buildings could comply with previous code) | PA | 2006 IECC, Effective December 31, 2006 |
| ID | 2006 IECC Effective January 1, 2008 | RI | 2006 IECC, Effective August 1, 2007 |
| KY | 2006 IRC, 2006 IBC Effective August 6, 2007 | SC | 2006 IECC, Effective July 1, 2008 |
| LA | Commercial: ASHRAE 90.1-2004 Residential: 2006 IRC with Energy Provisions Signed by governor on June 22, 2007 – effective date to be announced | UT | 2006 IECC, Effective January 1, 2007 |
| MA | Residential: Code for Single- and Two-Family Dwellings; latest (7th) edition based on the 2003 IRC and IBC with state-specific amendments, Effective April 1, 2007 (Until October 1, 2007, buildings could comply with sixth edition) | VT | Commercial: 2005 Vermont Guidelines for Energy Efficient Commercial Construction, based on the 2004 IECC supplement with amendments to reference ASHRAE 90.1-2004, Effective January 1, 2007 |
| MD | 2006 IECC, Effective July 1, 2007 | WA | Washington State Building Code upgraded with 37 energy provisions (More stringent than 2006 IECC), Effective July 1, 2007 United States Army Corp. of Engineers for all military buildings |
| NH | Amendments to the New Hampshire Energy Code that will upgrade energy provisions to 2006 IECC, Effective August 17, 2007 | | |
| NJ | Commercial: ASHRAE 90.1-2004; Residential: 2006 IECC, Effective February 20, 2007 (Until August 20, 2007, buildings could comply with previous code) | | |

Source: Building Codes Assistance Project

quantitative limits for air leakage through fenestration and doors, but only general qualitative guidance for the opaque portion of the building envelope. In other words, sealing, caulking, gasketing or weather-stripping such locations as joints around fenestration and doors, and junctions between floors, walls and roofs is required, but there is no quantitative air-leakage limit specified for the walls, roof and foundation assemblies and other envelope components or the building as a whole.

- **Massachusetts leads the states.** The Massachusetts Commercial Energy Code was the first jurisdiction to mandate air-barrier systems in non-residential construction. Looking at the energy code, one notes that the language conforms to DOE program goals to reduce building energy consumption by 25 percent by the year 2010, and 50 percent by 2020.

The exact language in the Massachusetts energy code, which appears in section 1304.3 *Air Leakage* of 780 CMR, Chapter 13, reads: “1304.3.1 Air Barriers: The building envelope shall be designed and constructed with a continuous air barrier to

control air leakage into, or out of the conditioned space.” The code then stipulates that the air barrier:

- Be continuous, with all joints made airtight.
- Have air permeability of less than 0.004 cfm/ft² under a pressure differential of 0.3 in. water (1.57 psf).
- Be capable of withstanding positive and negative combined design wind, fan and stack pressures on the envelope without damage or displacement.
- Effectively transfer wind load to the structure.
- Be durable and maintainable.
- Be joined in an airtight and flexible manner to the air-barrier material of adjacent systems, allowing for relative movement of systems.
- Have a connection that can be made between: foundations and walls; walls and windows or doors; different wall systems; wall and roof; wall and roof over unconditioned space; walls, floor, and roof across construction, control and expansion joints; and walls, floors and roof to utility, pipe and duct penetrations.

6. A New ASHRAE Standard

Influenced by NIST's findings and by calls for more sustainable types of construction, ASHRAE has been considering new and more restrictive language in ASHRAE 90.1. In fact, the Envelope Subcommittee has called for the inclusion of a continuous air barrier as a requirement in ASHRAE Standard 90.1.

As a proponent of the "air-barrier addenda," Wagdy Anis, AIA, LEED AP, principal of Boston's Shepley Bulfinch Richardson and Abbott was instrumental in focusing attention on better practices and codes. (He also assiduously promoted the improvement of the energy code in Massachusetts.) In "ASHRAE 90.1 Air barrier Addenda EC96-06/07," Anis proposed the addition of language requiring more clarity in the building drawings and documentation, as well as having air-barrier components of each envelope assembly "clearly identified on construction documents and the joints, interconnections and penetrations of the air-barrier components ... detailed." Anis also contended that the term "air barrier" be adequately defined, adding the following text:

The building thermal envelope's opaque assemblies shall include an air barrier that shall control infiltration by: 1. Using materials that have an air permeance not exceeding 0.004 cfm/ft² (1.57psf) (0.02 L/s.m² @ 75 Pa) in accordance with ASTM E 2178-05 or other approved method; or 2. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 (1.57psf) (0.2 L/s.m² @ 75 Pa) in accordance with ASTM E 2357-05 ASTM E 1677-05 or other approved method; or 3. Testing the completed building and demonstrating that the air-leakage rate does not exceed 0.40 cfm/ft² (1.57 psf) (2.0 L/s.m² @ 75 Pa) in accordance with ASTM E 779-03, or other approved method. Openings and penetrations in the building envelope air barrier shall be sealed with caulking materials or closed with gasketing systems compatible with the construction materials and location. Joints and seams shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials spanning joints

between construction materials shall allow for expansion and contraction of construction materials.

The proposed new ASHRAE revision also set forth four key standards to be references in the energy standard. The reason? "Although the current code language addresses air sealing, the end result is uncertain because there are no performance requirements to meet. The additional language ensures better attention will be given to achieving a tight envelope," reads the proposal.

The case for increased performance in codes is strong, as the proposed revision detailed, with DOE and ORNL data to back it up. Moreover, the IECC already recognizes the importance of such a measure to reducing energy waste, costs and carbon production.

7. Current Air-Barrier Building Technologies

According to many experts, practitioners and enclosure specialists, one of the leading materials that meets (and, in most cases, exceeds) these air-barrier code requirements is **closed-cell spray polyurethane foam (ccSPF)**. "I believe there is a consensus among building enclosure experts that ccSPF insulation is one of the most effective methods of installing a continuous, high-performance, simultaneous insulation and air barrier," says Peterson of the Judd Allen Group. "It is really a very multi-faceted, effective solution in creating air barriers."

While many people are familiar with ccSPF being used effectively as an Energy Star®-rated, environmentally friendly system that provides superior thermal insulation and enhanced wind-uplift properties, it's not generally known that ccSPF can be used to insulate and serve as a water, vapor and air barrier in roofs, walls, foundations and floors in commercial buildings. Yet research shows that ccSPF offers good performance in resisting moisture transmission and condensation because of its low vapor permeance and air-sealing capabilities. As a material, ccSPF is a two-component product that is manufactured on the jobsite and spray applied, taking advantage of the molecular behavior of the engineered formulations that optimizes performance for a specific application. Like other

spray polyurethane foams, ccSPF is self-adhering and easily attaches to all types of substrates: masonry, metal, wood, plastic and more.

Once applied, ccSPF is a relatively rigid product that creates an effective air barrier in addition to providing additional structural strength and the highest level of thermal insulation. Manufacturers are typically reporting an R-value of 6.7 per inch at mean temperature of 75 degrees (ASTM C-518-04) and compressive strengths of 40-50 lbs. in 3-lb. (ASTM D1622-05) density roofing foams. In 2-lb. density wall foams, manufacturers report an R-value of about 6.2 per inch at mean temperature of 75 degrees (ASTM C-518-04) and compressive strengths of 20-25 lbs (ASTM D1622-05). This allows ccSPF to serve as a protection against thermal air and moisture vapor, and to qualify as Federal Emergency Management Agency (FEMA) listed products approved for use in flood zones.

Closed-cell spray polyurethane (ccSPF) foam air barriers also offer wind-load resistance, seamless or “monolithic” construction and almost zero air permeability, according to building-science experts. The product conforms to unusual shapes and fills in voids common in building enclosures and is rigid, self-supporting and fully self-adhering. Furthermore, installation is performed in a single operation and does not require large crews, fasteners, gluing or torches, which in many cases will lower labor and insurance costs. Typical closed-

cell spray polyurethane foam (ccSPF) insulation applications include roofs, foundations, framed cavity walls, concrete masonry units (CMU), precast concrete walls, curtain walls and IPS walls. (For information on costs, see page 15.)

In addition to ccSPF, more than 45 different products also meet the minimal properties of a high-performance air barrier. According to the National Institute of Building Sciences (NIBS), when choosing a material or system, basic parameters to consider are:

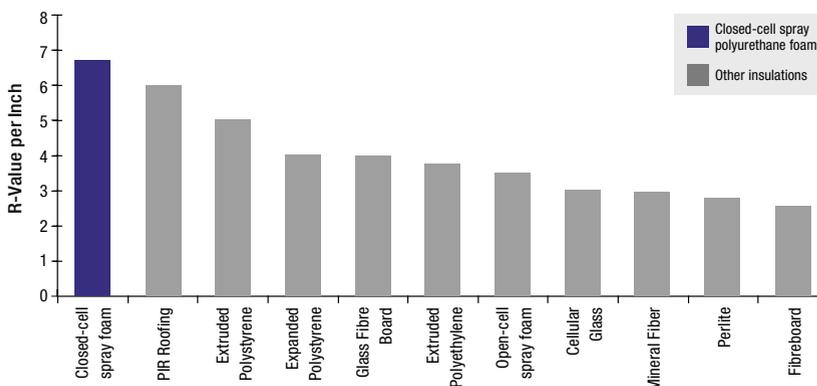
- The product must be able to *bridge at least a ¼-inch gap*. (Not all liquid-applied air-barrier materials meet this requirement.)
- The product should not be a *water-soluble* material after curing.
- The product must have a *relatively short cure time*—less than 24 hours, if possible—to establish membrane integrity and bonding.
- If water-based, the product *should not freeze* if applied during winter weather conditions.
- If the project is being completed in an urban setting or *near another occupied building*, exterior spray-applied products should be avoided or used with caution.
- Any product must be relatively *easy to inspect* after application.

Some specific examples of air-barrier materials and systems for commercial buildings include the following, with notes on their effective use:

- *Polystyrene insulation boards*. These products need to be covered with an additional air-barrier material at all seams and joints to create effective air-barrier systems.
- *Polyethylene films*. While these are excellent as vapor retarders, they are discouraged for use as air-barrier systems alone unless used in elaborate sandwich applications, as the material itself is very thin and nonstructural.

Typical Insulation R-Value per Inch

R-Values of Insulation Materials at 75° F



“Closed-cell Spray Polyurethan Foam” Best Insulator & Air-barrier per Inch

- *Building wrap or pure polyethylene membranes.* One challenge for this type of membrane is how to couple and seal pieces together at seams, with the roof, or into window systems and frames. Attaching these membranes without penetration, while still maintaining air-sealing properties, is challenging.
- *Wood-sheathing products.* In this case, the treatment of the joints needs to be continuous, and because the products absorb moisture over time, they may delaminate.
- *Exterior-grade air-barrier systems.* These include gypsum boards, peel-and-stick products and spray-applied and trowel-applied materials. A few words of caution: Trowel applications work well over masonry block, but they often cannot be used effectively over board or panel materials that contain or create joints and gaps in the substrate. It's also difficult to inspect completely the film thickness of trowel-applied systems. With peel-and-stick products, buildings with slight indoor negative pressures may cause the installed materials to delaminate from the block, and the entire membrane can end up suspended away from the substrate. Experts advise fastening peel-and-stick membranes in place on interior applications when used in negative pressure situations. Exterior applications may be limited due to insufficient support methods.
- *Sheet-steel buildings.* A growing number of building shells have been shown to be relatively airtight, with elements and joints effectively sealed. Note that metal building movement, expansion and contraction can affect the long-term performance of the air-barrier seal.
- *Precast concrete.* Strong and air impermeable—if joints are properly sealed—precast can be an air barrier.
- *Board and batt insulation.* While these products provide R-value, they are not inherent air barriers and must have additional products or technologies added to the wall assemblies to achieve an effective building-envelope air barrier.
- *ccSPF insulation.* Spray-applied insulation can be used as a complete thermal, moisture and air-barrier system solution in addition to its ability to fill in gaps and voids in various types of construction.

According to Straube and Burnett, in many instances several different materials, are joined together as an assembly to provide

an uninterrupted plane of primary airflow control. Regardless of how air control is achieved, the following five criteria must be met by the air-barrier system:

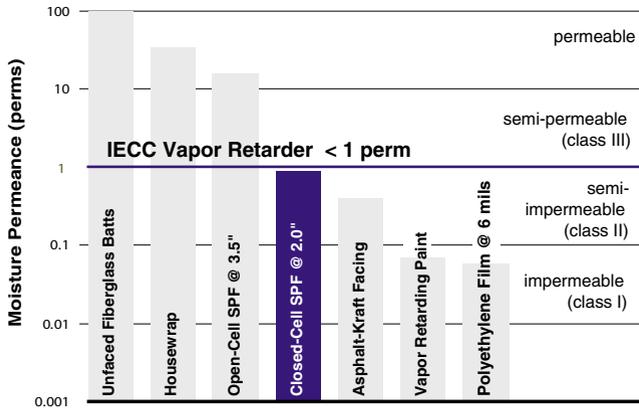
- 1. Continuity.** The air barrier must be continuous and uninterrupted throughout the building envelope and at all penetrations, including at doors, windows and wall joints including at corners and the like.
- 2. Strength.** Because an air-barrier system is much less air permeable than the remainder of the enclosure assembly, it must be designed to transfer the full design wind load—for example, a 30-year gust—to the structural system. Fastenings are often critical, especially for flexible, non-adhered membrane systems.
- 3. Durability.** The air-barrier system must be durable enough to perform as designed for its full service life. Choice of air-barrier system should take repairs and replacement into consideration, as well as the stresses to the barrier plane due to movement, fatigue, temperature and the like.
- 4. Stiffness.** The air barrier must be stiff enough so that deformations do not change the air permeance or distribute loads through unintentional load paths.
- 5. Impermeability.** Naturally, air barriers must be impermeable to air. Although this is an easy property to measure, it is not as important as might be thought. In practice the ability to achieve continuity at joints, cracks and penetrations outweighs the air permeance of the solid materials that make up most of the area of the air-barrier system.

8. Characteristics and Advantages of ccSPF for Air Barriers

Although a number of the products described above can make for effective air-barrier installations, ccSPF, with its unique properties, offers many advantages.

Before describing those benefits, it is important to note that the closed-cell foam (ccSPF), and not open-cell spray polyurethane foam (ocSPF) formulations, is generally preferred for air-barrier applications. Essentially, medium-density foams (1.5 pcf to 3 pcf - 24 kg/m³ to 48 kg/m³) are formulated to have a closed-cell content of greater than 90 percent combined with an effective R-value of about 6.7 per inch at a mean temperature of 75 degrees (ASTM C-518-04). Low-

Integral Vapor Retarder



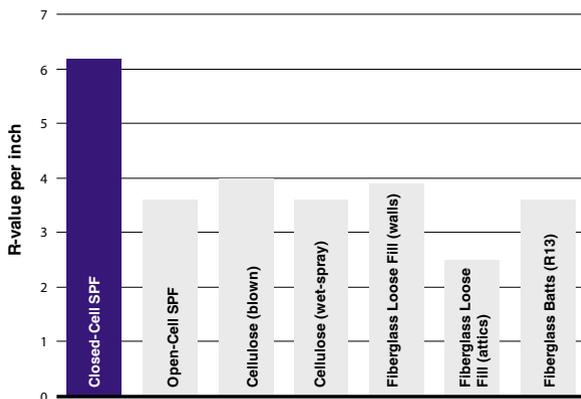
density (0.5 to 0.7 pcf - 8 kg/m³ to 12 kg/m³) open-cell foams have approximately 60 percent open-cell content and offer R-values only between 3.0 and 3.6 per inch at a mean temperature of 75 degrees (ASTM C-518-04). However the open-cell materials are also susceptible to the absorption of both bulk water and moisture vapor. In fact, open-cell foams can absorb in excess of 30 percent water, by volume, which can create an environment for mold and odors.

The closed-cell formulations, on the other hand, can actually improve building durability, structural strength and resistance to water and moisture. Authorities in building enclosures and air barriers note these characteristics in recommending ccSPF as an air barrier for a range of construction types and applications.

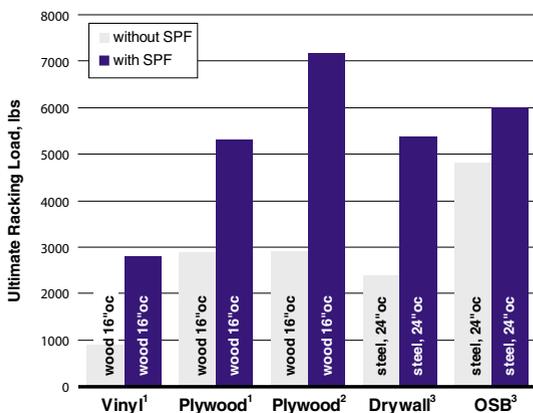
Application of ccSPF is relatively simple. The product is normally installed in the field by processing two liquid compounds through special two-part spray equipment aimed at the target surface or assembly. Foam is formed in a matter of seconds as the liquid hits the target and expands to about 30 times its original volume in a complete reaction of the two compounds. Tests show that the ccSPF material is watertight in 30 seconds, creating a monolithic and seamless mass. The very small cells within the foam are filled with an inert insulating gas, Enovate[®], which is produced by Honeywell. The gas provides long-term insulation at very high aged R-values. Spray foam formulated with Enovate[®] insulating technology produces no harmful ozone-depleting effects and was awarded a 2002 Stratospheric Ozone Protection Award from the U.S. Environmental Protection Agency (EPA). The roof system is also listed by Factory Mutual (FM), Underwriters Laboratory (UL) and EPA's Energy Star program.

Peterson, who has worked extensively with the product, says, "The quality formulations being installed these days have very high thermal performance, display very little if any shrinkage and have the capacity to completely fill voids and unusual cavities that might otherwise be troublesome. The material

Consistently Superior



Increased Safety



is water-resistant and protects against miscellaneous condensation and leakages within the voids. Its rigid final state solidifies the framing, and given certain thicknesses and its resistance to moisture penetration, it helps reinforce the vapor-barrier function.”

9. Testing Air Barriers for Performance (and Compliance)

To ensure that air-barrier materials meet the needs of rigorous, real-world applications, specifiers and building teams can refer to laboratory testing for meeting such standards as ASTM E-2357-05, which tests air-barrier assemblies for air leakage, and ASTM 2178-03, which tests for air leakage of materials. A blower door is typically employed to pressurize a building or specific areas of a building, allowing for the measurement of the leakage of air. Testing is performed on mock-up walls at pressures ranging from 1.6 lb/ft² (75Pa) to 62 lb/ft² (3000Pa). Air leakage is measured and visually checked. The Massachusetts Energy Code currently limits air leakage for air barriers to no more than 0.004 cfm/ft² under a pressure differential of 1.57psf. Some manufacturers, however, test their products to even more rigorous levels to simulate the effects of variable wind loading in real-world circumstances.

It is important to note that air intrusion does not always result in air leakage. This mechanism is also called “wind-wash,” “breathing” or “venting” and illustrates well that the defining line between interior climate and exterior climate in a building is effectively occurring behind the interior wall finish, such as the gypsum board. If the function of a building envelope is to keep outside air out and inside air in, a properly designed and placed air barrier is the best system to perform this function.

Of course, acceptance of a product should never rely solely on air-leakage testing. The physical properties of the materials need to be compatible with assembly and climate—and serve the intended results. “Review other test methods related to the products’ physical properties to determine the durability and long-term performance of the membrane,” says one manufacturer. Just as important as air leakage are such physical properties such as low-temperature flexibility, adhesion, tensile strength and the like.

On the issue of cost-effectiveness, the industry-standard benchmark, as mentioned earlier, is the definitive NIST report, *NISTIR 7238 Investigation of the Impact of Commercial Building*

Envelope Air Tightness on HVAC Energy Use. In brief, this report benchmarks calculated energy costs in several cities and compares the first cost of air barriers.

It’s important to note that one of the air-barrier criteria is the ability to meet a “scalar,” which is a factor of eight that is applied to the energy savings. In other words, the NIST report has determined that the first cost for energy barriers should not exceed eight times the energy savings attributed (defined by NISTIR computer model) to the air barrier. So any payback period, based solely on energy savings, should be eight years or less.

For detailed costing of air barriers, information from RSMMeans follows in Section 11 of this white paper. These comparative assembly costs and “first costs” for the installation of various air-barrier materials employ national average cost estimates based upon the RSMMeans Costworks™ cost database. The unit costs can be adjusted to various locations to define the differential in cost for the suggested air-barrier requirement. Finally, a return on investment can be determined from the calculated energy savings predicted by the NIST computer model. (See “RSMMeans Cost Data for Air-Barrier Assemblies,” page 15.)

10. Action Plan: ccSPF and Air Barriers

In a nutshell, it can be argued that air barriers have become a permanent element of energy conservation in building design and construction and are increasingly being adopted as part of building codes. As Anis states, “Commissioning the air-barrier system is important in the design and construction of buildings that are sustainable, healthful, durable and energy efficient.” For that reason, we recommend the following:

- 1. Reinforce understanding of air barriers as systems, not materials.** As has been pointed out, the use of air barriers must be evaluated as part of the overall building system. Similarly, architects and design professionals must be aware of issues surrounding air barriers, as their design decisions can impact air barriers’ effectiveness, since wind effect, stack effect and HVAC fan pressurization are the three primary causes of air infiltration and exfiltration in a building.
- 2. Increase awareness of ccSPF and other materials for air-barrier applications.** Although there are more than 45 materials that meet minimum criteria for air barriers, ccSPF’s unique chemical composition and adhesion

properties, along with ease of application and air-barrier properties, make it a very strong high-performance choice. Consequently, it is recommended that design professionals familiarize themselves with ccSPF characteristics, and construction professionals and building owners take pains to utilize certified air-barrier contractors who are trained and certified in the application of ccSPF.

3. Promote the use of air barriers to reduce energy waste and enhance sustainability. Whichever material is chosen to seal the building envelope, experts believe that air barriers are an important part of the construction process that will help better control buildings environments. Whether the goal is better occupant experience or reduced carbon footprints, an effective air barrier is just one element on the way to a more sustainable future.

11 RSMMeans Cost Data for Air-Barrier Assemblies

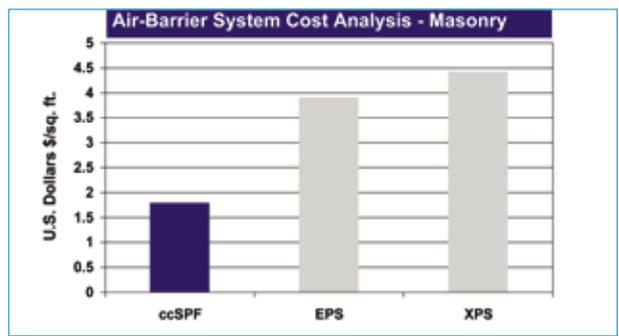
Note: U.S. Dollars

Masonry

| | |
|--|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 8" CMU | \$9.85 |
| Closed-cell spray polyurethane insulation R-15 | \$1.79 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$26.34 |

| | |
|---|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 8" CMU | \$9.85 |
| Polyethylene and rubberized asphalt sheet barrier | \$2.24 |
| Extruded polystyrene insulation R-15 | \$2.19 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$28.98 |

| | |
|---|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 8" CMU | \$9.85 |
| Polyethylene and rubberized asphalt sheet barrier | \$2.24 |
| Expanded polystyrene insulation R-15 | \$1.67 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$28.46 |



Metal Stud

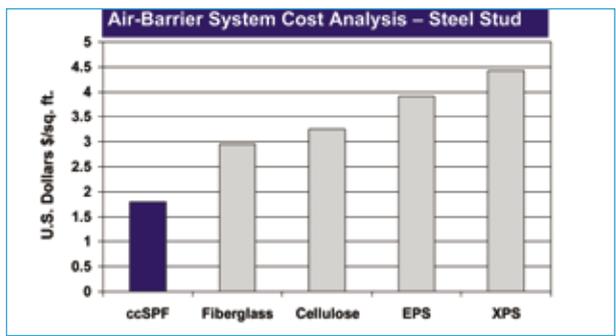
| | |
|--|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 3-5/8" 25 Ga. Metal Stud & track, 16" O.C. | \$1.57 |
| Gypsum sheathing with embedded glass mats | \$1.43 |
| Closed-cell spray polyurethane insulation R-15 | \$1.79 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$19.49 |

| | |
|---|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 3-5/8" 25 Ga. Metal Stud & track, 16" O.C. | \$1.57 |
| Gypsum sheathing with embedded glass mats | \$1.43 |
| Polyethylene and rubberized asphalt sheet barrier | \$2.24 |
| Extruded polystyrene insulation R-15 | \$2.19 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$22.13 |

| | |
|---|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 3-5/8" 25 Ga. Metal Stud & track, 16" O.C. | \$1.57 |
| Gypsum sheathing with embedded glass mats | \$1.43 |
| Polyethylene and rubberized asphalt sheet barrier | \$2.24 |
| Expanded polystyrene insulation R-15 | \$1.67 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$21.61 |

| | |
|---|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 3-5/8" 25 Ga. Metal Stud & track, 16" O.C. | \$1.57 |
| Gypsum sheathing with embedded glass mats | \$1.43 |
| Polyethylene and rubberized asphalt sheet barrier | \$2.24 |
| Fiberglass batt insulation | \$0.71 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$20.65 |

| | |
|---|----------------|
| 1/2" Gypsum wallboard, taped and finished | \$1.30 |
| 3-5/8" 25 Ga. Metal Stud & track, 16" O.C. | \$1.57 |
| Gypsum sheathing with embedded glass mats | \$1.43 |
| Polyethylene and rubberized asphalt sheet barrier | \$2.24 |
| Cellulose insulation | \$1.01 |
| Brick veneer | \$13.40 |
| Total per Square Foot | \$20.95 |



12. RSMMeans Cost Data for Spray Polyurethane Foam Insulation Wall & Roof Air-barrier Assemblies

Note: The following chart refers to new construction. Retro-fit applications may require additional labor, materials, site-preparation, disposal and scheduling cost. Costs shown are in U.S. Dollars.”

| 07 57 Coated Foamed Roofing | | | | | | | | | | |
|--|--|------|--------------|-------------|------|-----------------|-------|-----------|-------|-------------|
| 07 57 13 - Sprayed Polyurethane Foam Roofing | | | | | | | | | | |
| | | | | | | 2008 Bare Costs | | | | Total |
| 0010 | SPRAY POLYURETHANE FOAM ROOFING | Crew | Daily Output | Labor-Hours | Unit | Material | Labor | Equipment | Total | Incl. O & P |
| | Primer for metal substrate, when required | ROFC | 3000 | | S.F. | 0.38 | 0.08 | | 0.46 | 0.56 |
| | Primer for non-metal substrate, when required | ROFC | 3000 | | S.F. | 0.15 | 0.08 | | 0.23 | 0.31 |
| | Closed cell spray polyurethane foam, 3 lbs. per cubic foot density, 1", R6.7 | G-2A | 15000 | 0.002 | S.F. | 0.68 | 0.05 | 0.04 | 0.77 | 0.87 |
| | 2", R13.4 | G-2A | 13125 | 0.002 | S.F. | 1.36 | 0.05 | 0.05 | 1.46 | 1.63 |
| | 3", R20.1 | G-2A | 11485 | 0.002 | S.F. | 2.04 | 0.06 | 0.05 | 2.15 | 2.40 |
| | Spray-on acrylic coating (add an additional \$.20/sq.ft. for silicone coating) | G-2A | 2500 | 0.010 | S.F. | 0.41 | 0.28 | 0.24 | 0.93 | 1.18 |
| | Warranty, 5 - 20 year manufacturers | | | | S.F. | | | | | 0.06 |
| | 20 year, no dollar limit | | | | S.F. | | | | | 0.15 |
| 07 21 Thermal Insulation | | | | | | | | | | |
| 07 21 29.10 - Sprayed Insulation | | | | | | | | | | |
| | | | | | | 2008 Bare Costs | | | | Total |
| 0010 | SPRAYED WALL INSULATION | Crew | Daily Output | Labor-Hours | Unit | Material | Labor | Equipment | Total | Incl. O & P |
| 0030 | Closed cell, spray polyurethane foam, 2 pounds per cubic foot density | | | | | | | | | |
| | 1" thick, R6.2 | G-2A | 6000 | 0.004 | S.F. | 0.43 | 0.12 | 0.10 | 0.65 | 0.78 |
| | 2" thick, R12.4 | G-2A | 3000 | 0.008 | S.F. | 0.86 | 0.23 | 0.20 | 1.30 | 1.55 |
| | 3" thick, R18.6 | G-2A | 2000 | 0.012 | S.F. | 1.29 | 0.35 | 0.30 | 1.94 | 2.33 |
| | 3-1/2" thick, R21.7 | G-2A | 1715 | 0.014 | B.F. | 1.50 | 0.41 | 0.35 | 2.26 | 2.71 |
| | 4" thick, R24.8 | G-2A | 1500 | 0.016 | S.F. | 1.72 | 0.47 | 0.40 | 2.59 | 3.11 |
| | 5" thick, R31 | G-2A | 1200 | 0.020 | S.F. | 2.15 | 0.59 | 0.50 | 3.24 | 3.88 |
| | 5-1/2" thick, R34.1 | G-2A | 1090 | 0.022 | S.F. | 2.36 | 0.64 | 0.55 | 3.56 | 4.27 |
| | 6" thick, R37.2 | G-2A | 1000 | 0.024 | S.F. | 2.58 | 0.70 | 0.60 | 3.89 | 4.66 |

RSMMeans is providing costs based upon the typical assembly information available at present.

Translating these tables into ROI, real savings on energy costs, completes this evaluation of ccSPF and its value as an air barrier.

Providing definition around cost-effectiveness is the definitive NIST report -

NISTIR 7238 "Investigation of the Impact of Commercial Building Envelope Air Tightness on HVAC Energy Use."

This report, echoing a similar study by Oakridge National Labs (ORNL), benchmarks calculated energy costs in

several cities and compares first cost of air barriers. One of the criteria is the ability to meet a "scalar" which is a factor of 8 that is applied to the energy savings. In other words, the NIST report has determined that the first costs for energy barriers should not exceed 8x the energy savings attributed (defined by NISTIR computer model) to the air barrier. Another way to look at this is that the payback period (based solely on energy savings) should be 8 years or less.

Table 1: NIST Summary**Annual Energy Cost Savings for 24,200 ft² Office Building at Target Air Leakage Level**

| City | Gas Savings \$ | Gas Savings % | Electrical Savings \$ | Electrical Savings % | Total Savings |
|-------------|----------------|---------------|-----------------------|----------------------|---------------|
| Bismark | \$1,854 | 42% | \$1,340 | 26% | \$3,195 |
| Minneapolis | \$1,872 | 43% | \$1,811 | 33% | \$3,683 |
| St. Louis | \$1,460 | 57% | \$1,555 | 28% | \$3,016 |
| Phoenix | \$124 | 77% | \$620 | 9% | \$745 |
| Miami | \$0 | 0% | \$769 | 10% | \$769 |

RSMeans has determined “first costs” for the installation of various insulation materials and has localized those costs to the NIST subject cities shown in Table 1 utilizing RSMeans Costworks™ cost database. The next step in the analysis is to calculate material costs for insulation materials used in the office-building simulation and calculate cost of closed-cell spray polyurethane foam (ccSPF) for the same dimensions.

The NIST study looks only at thermal insulation; the study did not consider the additional value of closed-cell spray polyurethane foam as an air barrier in the analysis. Therefore, the purpose of the analysis conducted by RSMeans was to demonstrate cost differentials between an air barrier used solely by itself in today’s office building construction and a typical Means Unifomat II Assembly. The final step in the analysis is to adjust costs to various locations, defining the cost differential for the suggested air barrier requirement. ROI can be estimated from the calculated energy savings predicted by the NIST computer model above.

RSMeans “first cost” analysis calculations indicate that ccSPF is highly cost-effective in northern climates where heating costs predominate. In Bismarck, for example, as shown in the chart above, total energy savings are \$3,195 per year when the target air leakage level is met. The RS Means simulation calculated a material and installation savings of \$2,568 by using ccSPF as insulation in Bismarck. This provides a savings even before heating costs, but these numbers only tell part of the story.

Calculate the savings incurred by using ccSPF in its dual role, as a component in the air barrier assembly and as an insulation material, and the impact becomes even greater. The benefit in the Bismarck building example becomes a \$13,458 savings. In Minneapolis, the material and

installation savings was \$3,683 when ccSPF was used as insulation, again providing a benefit before heating costs. Add the air-barrier advantage and the savings balloons to over \$14,000.

In the St. Louis example, it costs an additional \$8,659 to insulate the building with ccSPF. But again, utilizing ccSPF provides an air barrier in addition to insulation. The value of the air barrier is \$10,890. This, in effect, reverses the additional installation cost, creating savings of \$2,231. In Phoenix and Miami the use of ccSPF as insulation generated an additional cost of about \$7500 for each city. However, in both instances, the savings created when ccSPF was considered as both insulation and air-barrier component outweigh the additional cost to create a \$3400 savings.

In all five cities cited in the example above, using ccSPF as both the insulation and as a component of the air-barrier assembly resulted in substantial construction savings. Furthermore, the annual energy savings achieved by meeting the target air leakage level make ccSPF a very attractive option.

To learn more about ccSPF go to ccSPF.com

Attribution

RCD/RSMMeans analysis conducted by Tim Duggan, Senior Project Director using Means square foot data and Means CCI (Construction Cost Index).

Sources Used for this White Paper

- Air Barrier Association of America
- American Institute of Architects
- American Society of Heating, Refrigeration and Air Conditioning Engineers
- American Society of Testing & Materials
- ASHRAE 90.1-2004
- ASHRAE Journal
- BEC-Minnesota
- Building Codes Assistance Project
- Building Enclosure Council
- Building Science for Building Enclosures - John Straube, Eric Burnett
- Dr. Eric Burnett, DIC, P. Eng. FASCE, Pennsylvania State University
- Construction Consulting International
- Energy Performance of SPF Roofs - Mark Bomberg, Marcin K. Pazera, John Nolan
- International Codes Council
- International Energy Conservation Code
- Judd/Allen Group, Edina, MN – Judd Peterson, AIA, President
- National Institute of Building Sciences
- National Institute of Standards and Technology
- National Institute of Standards and Technology report, "NISTIR 7238 - Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use"
- Oak Ridge National Laboratories
- RSMMeans / Reed Construction Data
- Polyurethane Foam Enterprises LLC
- Shepley Bulfinch Richardson and Abbott
- Spray Polyurethane Foam Alliance
- Spray Polyurethane Foam in External Envelope of Buildings - Mark Bomberg, Joseph W. Lstiburek
- Dr. John Straube, P.Eng., of the University of Waterloo
- U.S. Department of Commerce
- U.S. Department of Energy
- U.S. Environmental Protection Agency
- Walls That Work No Matter What - Neal E. Ganser
- Whole Building Design Guide

Corporate Sponsor

Honeywell International is a \$34 billion diversified technology and manufacturing leader, serving customers worldwide with aerospace products and services; control technologies for buildings, homes and industry; automotive products; turbochargers; and specialty materials. Based in Morris Township, N.J., Honeywell's shares are traded on the New York, London and Chicago Stock Exchanges. It is one of the 30 stocks that make up the Dow Jones Industrial Average and is also a component of the Standard & Poor's 500 Index. Specifically, Honeywell is a recognized leading innovator in advanced insulating technology for foam insulation. Foam insulation formulated with Honeywell Enovate® blowing agent is zero-ozone-depleting and not considered a (VOC) Volatile Organic Compound based on U.S. standards and regulations. Spray Polyurethane Foam insulation formulated with Enovate® provides an effective thermal, moisture and air-barrier solution in one product. Because of the unique physical performance characteristics of polyurethane spray foam insulation systems, buildings are protected from severe weather. This unique technology also serves as a cost-effective and energy-efficient roof, foundation and wall insulation system for commercial buildings. Spray foam with Honeywell's unique insulating technology can be applied over existing roof substrates with minimal business interruption and inconvenience during installation. Honeywell's blowing agent technology has been used for many years to help appliances achieve ENERGY STAR® ratings and hurricane-resistant roofing for commercial buildings such as the Louisiana Superdome, which is protected by an "Unlimited Wind Warranty".

Honeywell