Spray Polyurethane Foam: Benefits for Passive Houses

ACC Center for the Polyurethanes Industry

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The Center for the Polyurethanes Industry[1] and the Spray Foam Coalition,[2] which are part of the American Chemistry Council (ACC), represent U.S. producers or distributors of chemicals and equipment used to make polyurethane or manufacturers of polyurethane products. Passive House Institute US (PHIUS) has provided ACC an opportunity to publish a document in the PHIUS newsletter alongside a document by the PHIUS Technical Committee on spray polyurethane foam (SPF). We appreciate the opportunity extended to us to discuss and to clarify some reasons why SPF can be an excellent choice for Passive Houses.

As those involved with PHIUS know, as much as 40% of a building's energy is lost due to air infiltration. SPF offers a solution: it performs as both insulation and an air sealant, or air barrier, closing those gaps and cracks that let air escape. SPF combines two key attributes vital for passive houses in one product. As SPF has been utilized more in recent years due to the value that builders, specifiers and consumers see in its unique insulating and air sealing properties, there has also been a corresponding increase inaccurate information about SPF and its component materials. We are not attempting to address every aspect of SPF in this document, but we highlight specific issues, many raised in the PHIUS document within the newsletter this month. More information about spray foam can be found on www.spraypolyurethane.org and www.whysprayfoam.org. We encourage you to review those websites for any questions you have about SPF now or in the future.

TYPES OF SPF AND THEIR APPLICATIONS

Spray polyurethane foam is an insulation and roofing material that is formulated on the jobsite by the combination of Methylene Diphenyl Diisocyanate (MDI) or “A-side” with an equal amount of a polyol blend or “B-side. While the formulation of the A-side is essentially constant, the proprietary formulations of the B-side, which includes polyols, blowing agents, flame retardants, catalysts and surfactants, varies depending on the desired properties of the foam.

There are three basic classifications for SPF used in the U.S. construction industry for insulation and roofing systems. These classifications are based on material density and cell structure. A summary of key physical properties of these foams is provided in Table 1.

The first classification is open-cell or low-density SPF. This material has a core or nominal density of 0.4 to 0.7 pounds per cubic foot (pcf), and often this type of foam is referred to as “half-pound” or “water-blown” foam. These foams are formed using a reactive blowing agent, which is typically water. Water reacts with the A-side MDI to create CO_2 gas that expands the curing liquid into a cellular foam material.

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[1] The Center for the Polyurethanes Industry (CPI) of the American Chemistry Council serves as the voice of the polyurethanes industry in North America, promoting its sustainable development and coordinating with polyurethane trade associations across the globe. CPI members are companies that produce and sell the raw materials and additives that are used to make polyurethane products, equipment used in the manufacture of polyurethanes, and companies engaged in end-use applications and the manufacture of polyurethane products.

[2] The Spray Foam Coalition (SFC) champions the use of spray polyurethane foam in U.S. building and construction applications and promotes its economic, environmental and societal benefits while supporting the safe manufacture, transport, and application of spray polyurethane foam. SFC consists of manufacturers of spray polyurethane foam systems as well as suppliers of raw materials and machinery used to apply the foam.

Since this material has an open cell structure, the cells are filled with air, so that the thermal performance (R-value per inch thickness or thermal resistivity) is equivalent to fibrous insulations such as fiberglass, cellulose and stone wool – in the range of R3.6 to R4.0 per inch. Like these fibrous products, open-cell SPF is permeable to moisture, and may need an additional vapor retarder in cold-climate building applications. Unlike fibrous insulations, open-cell SPF is far less air permeable, and can also serve as an air barrier material at certain thicknesses.

The second SPF class is closed-cell or medium-density SPF. This class of foam has a core or nominal density between 1.7 and 2.3 pcf, and is often called "two-pound" foam. This material has a cell structure where 90% or more of the cells are closed. When fluorocarbon (physical) blowing agents are used, the fluorocarbon liquid in the B-side converts to a gas from the heat of the reaction to expand the cells. Like a double-pane insulated window, this low thermal conductivity fluorocarbon gas is retained in the closed cells, yielding a thermal resistivity between R5.8 to R6.8 per inch, which can be nearly twice that of an open-cell foam or fibrous insulation. Medium density SPF is resistant to water absorption and effectively impermeable to moisture and air. In addition, medium density foams have measureable stiffness and strength and can provide a moderate increase in the structural performance of certain building assemblies.

The third class of SPF is roofing foam. Like medium density foams, these materials have a closed cell structure using the same captive fluorocarbon blowing agents as a medium density SPF. The major difference between roofing SPF and medium density SPF is the foam density. Roof foams have densities typically ranging from 2.5 up to 4.0 pcf, and are often called "three pound" SPF. This increased density provides a higher compressive strength needed to support foot traffic when installed on top of surfaces of a low slope roof.

The three classes of SPF described above are applied by professionally-trained contractors to large areas of the building envelope using a two component, high-pressure delivery systems. For insulation of smaller areas, two-component low-pressure, self-contained kits may be used by trained professional applicators. In addition, there are also single-component systems delivered in small aerosol cans where the A and B sides are pre-mixed. These one-component polyurethane sealant foams are used for air sealing. In recent years, foam formulations that have densities, closed-cell content and thermal performance that fall in between the three traditional foam classifications described above have been developed. Since these foams are still being introduced, this paper will be limited to the three traditional SPF classes described above.

Table 1: Summary of SPF properties

	Sealant	Low-Density or ocSPF	Medium-Density or ccSPF	Roof SPF
Density (pcf)	0.6 – 1.8	0.4 – 0.7	1.7 -2.3	2.5 – 4.0
Thermal Resistivity (R/in)	not reported	3.6 - 4.5	5.8 - 6.8	5.8 - 6.8
Air Impermeable Material	*	✓ (>4-6")	✓ (>1")	✓ (>1")
Integral Air Barrier System		✓	✓	✓
Class II Vapor Retarder			✓ (>2")	✓ (>2")
Water Resistant			✓	✓
Cavity Insulation		✓	✓	
Continuous Insulation		✓	✓	✓
Low-Slope Roofing				✓
Structural Improvement			✓	✓

SPF INGREDIENTS

Two-component SPF is manufactured on-site by trained, professional applicators. It is created by mixing two components in a 1:1 volumetric ratio (the A-side isocyanate and the B-side polyols).

The A-side of SPF is made from a blend of MDI (Methylene Diphenyl Diisocyanate). Typical A-side blends consist of monomeric and polymeric forms of MDI.

The B-side directly controls the type of foam that is created, impacting the physical and mechanical properties of the foam. In the U.S., companies called Systems Houses develop and manufacture the B-side. While each formulator typically offers a number of different B-side formulations for different applications, these exact proprietary formulations are not published for competitive reasons.

SPF B-side formulations for SPF use five basic chemical classes: polyols, blowing agents, catalysts, flame retardants and surfactants. For high pressure two-component foams, the blowing agents are included in the B-side. For low-pressure foams, the blowing agent is mixed into the A-side. Table 2 shows examples of the typical compounds and the percentages used in the B-side of high-pressure SPF.

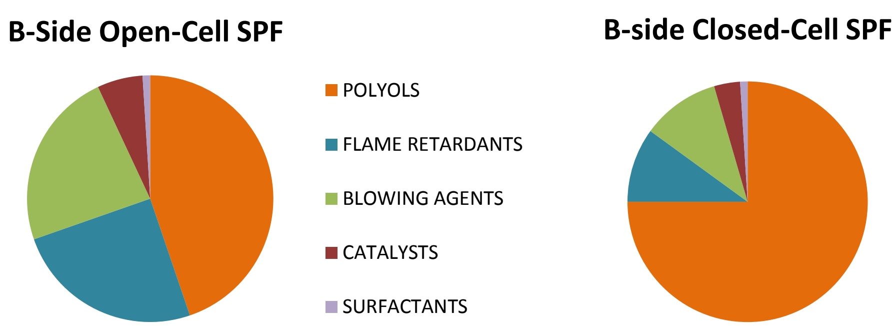


Table 2: Options for Typical B-Side Components

CHEMICAL CLASS	Open-Cell SPF 0.5 pcf insulation	Closed-Cell SPF 2.0 pcf insulation	Roofing SPF 3.0 pcf roofing
POLYOLS			
Polyester	-	45%	35%
Compatibilizer	10%	-	-
Polyether	35%	30%	45%
BLOWING AGENTS			
Reactive (water)	24%	2%	2%
Physical (fluorocarbon)	-	9%	7%
FLAME RETARDANTS			
TCPP	25%	4%	8%
Brominated/TCPP	-	6%	-
CATALYSTS			
Amine	6%	3.0%	2%
Metal	-	<1%	<1%
SURFACTANTS			
Silicone	<1%	<1%	<1%

Polyols constitute a significant portion of the B-side formulation. Generally, a blend of polyester or polyether polyols is used; these are petroleum based. Some SPF products use an alternative source of polyols from natural sources such as soybeans, castor or rapeseed oils (not shown in the table above). Current technology limits the use of natural oil polyols to about 1/3 of the total polyols as excessive use of natural oil polyols can affect the dimensional stability of SPF.

When polyols are combined with MDI, a solid polyurethane material is the resulting product. In order to create a cellular structure to the foam, a blowing or expanding agent is required. SPF uses two types of blowing agents: reactive and physical. Water is the reactive blowing agent used to make all open-cell SPF, and a small percentage of closed-cell foams. Water reacts with MDI to create CO_2 gas that expands the foam. Physical blowing agents used in SPF are fluorocarbon gases. These are present in liquid form in the B-side. The exothermic reaction with the A-side converts this liquid into a gas to expand the foam. The low thermal conductivity fluorocarbon gas is contained inside the closed-cell structure to provide increased thermal resistance.

The creation of SPF involves two major competing processes: the curing of the MDI-polyol into polyurethane and the development of the cell structure by the blowing agent. These competing processes are moderated by the use of catalysts to control the speed of the curing reaction. Catalysts directly influence the rise time of the foam, and ultimately whether or not the foam will be open or closed cell. SPF typically uses amine-based catalysts, although some formulations may use metal-based catalysts as well.

Polyurethane foams, like all plastic foams and many other organic materials, are combustible. To meet the rigorous demands of SPF applications, flame retardants are used. These chemicals are stable and generally have long life characteristics needed to retain performance in insulating foams.

POTENTIAL EXPOSURE RISKS AND ENVIRONMENTAL IMPACTS

As with all building materials, SPF should be used with care. While many plastic building products are manufactured using the same or similar chemicals, SPF has the unique attribute of being installed and manufactured at the building site. The potential health effects that could result from SPF exposure are contained in the product MSDS, which describe how a worker or bystander could potentially be exposed to SPF chemicals by breathing chemical mists or vapors or through skin or eye contact. A few key points are presented here. Extensive information on health and safety considerations for SPF is available at www.spraypolyurethane.org and www.polyurethane.org.

A-Side: MDI

Overexposure to MDI can cause skin, eye, nose, throat, and lung irritation. Overexposure can also lead to skin or to respiratory sensitization in some individuals. To prevent these adverse health effects, the Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit (PEL) for 4,4'-MDI of 0.2 milligrams per cubic meter (mg/m^3) as a ceiling concentration. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a threshold limit value (TLV) 8-hour time-weighted average (TWA) exposure limit of 0.051 mg/m^3.

Airborne MDI levels in the breathing zone of the SPF applicator during installation commonly result in levels above the occupational exposure limits previously referenced. To prevent exposure to MDI, SPF applicators use personal protective equipment (PPE) such as gloves, coveralls, and respirators (see www.spraypolyurethane.org for information about PPE). In addition, many SPF contractors use engineering controls (e.g., forced air such as exhaust fans or blowers) during interior SPF installation work to help reduce the airborne concentrations of SPF chemicals in the work area.

Soon after SPF application work is completed, airborne MDI concentrations can rapidly decrease according to an air monitoring study conducted by Lesage, et.al.[1] In this study, five residential structures during and following SPF application indicated that airborne MDI could not be detected in air samples collected 1-hour following the end of SPF installation. Furthermore, surface wipe samples collected from newly-installed SPF surfaces indicated that unreacted isocyanates were not detected 15 minutes following the end of SPF installation.

Other studies (Roberge, et.al IRRST[2] and Karlovich, Bayer[3]) also indicated that within two hours following the end of spraying, airborne MDI levels are not detectable. The IRRST study indicated that within two hours following the end of spraying, airborne MDI levels were at extremely low levels, below the EPA MDI Reference Concentration (RfC) of 0.6 micrograms per cubic meter (ug/m^3).

B-Side

In the B-side, there may be ingredients that present potential human health risks, when humans are overexposed to them.[4] High concentrations are generally present when the raw chemicals are manufactured or blended by the formulators. These upstream chemical operations usually take place under controlled and regulated manufacturing conditions, with personnel following proper safety precautions as required by OSHA.

Polyols

The major component of the B-side is polyols. Polyols are oil-like liquids that are used in many different products, including personal care products like shampoo, skin creams and baby oil.

Fluorocarbon Blowing Agents

For the past five decades, closed-cell SPF has used fluorocarbon compounds. In the United States, the first SPF blowing agents were CFC-11, followed by HCFC-141b and then HFC-245fa. These different blowing agent have evolved over the past three decades in order to eliminate the ozone depletion potential (ODP) of certain fluorocarbon gases. Today's third-generation blowing agent for high-pressure closed-cell SPF, HFC-245fa, used since 2003 and mandated by EPA, has zero ozone depletion potential, but does have a global warming potential (GWP) of 1020 CO_2 equivalents. In the coming years, fourth generation, hydro-fluoro-olefin (HFO) based blowing agents with zero ODP and GWP from 6-15 CO_2 equivalents are anticipated. The table below summarizes the evolution of blowing agents for high-pressure, closed-cell SPF.

Table 3: Blowing Agents

Years	Generation	SPF Blowing Agent	ODP	GWP
1960s -1993	1	CFC-11	1.0	4750
1993 - 2003	2	HCFC-141b	0.12	760
2003 - pres	3	HFC-245fa	0	1020
2013?	4	HFO	0	6 - 15

Aside from the published ODP and GWP environmental impacts, development of fluorine-based blowing agents include several years of extensive bio-assay testing to measure human toxicity, and carcinogenic, mutagenic and reproductive (CMR) effects, prior to commercialization as required by the EPA. This testing has shown no measurable impacts.

Flame Retardants

Flame retardants are incorporated in SPF as a part of the B component to prevent fires from starting and/or to dramatically slow the burning process. To meet the rigorous demands of SPF applications, phosphorus and halogen based flame retardants are used. Typically the flame retardants used include Tris (1-chloro-2-propyl) phosphate (TCPP) combined with a reactive brominated compound which bonds into the polymer or a polymeric brominated flame retardants. These chemicals are stable and offer long life characteristics needed to retain performance in insulating foams. These and other flame retardants enable SPF and other insulations to meet the National Fire Protection Agency (NFPA) and building code requirements. Some flame retardants have gone through the full European Union risk assessment as well.

Catalysts

Most catalysts used in SPF are amine based. Overexposure to airborne concentrations of amine catalysts may result in irritation to the respiratory system, skin, and eyes.[5] Under certain installation conditions, there may be unreacted amine catalysts that can be emitted from SPF. These catalysts can create a distinct odor that can be noticed by some people. It is often described as a fishy or urine like odor. While these odors present a nuisance to some, ventilation of the workspace for a few days after application usually solves the problem. Covering the foam with thermal or ignition barriers may also reduce these odors. Levels above the threshold to cause halo-vision are typically found during and immediately after spraying and a combination of work zone ventilation and proper PPE protect workers from these chemicals.

Surfactants

Silicone-based surfactants are used in very small quantities to control the formation and shape of the cells during curing.

Installed Foam

When the A- and B-side components are combined, numerous chemical reactions take place simultaneously. Most notably, the MDI and polyols combine to make polyurethane. Reactive blowing agents (water) react with MDI to create CO_2 gas to expand the cells. In addition to these primary reactions, the flame retardants, catalysts and surfactants undergo side reactions during the process. Many of the known potential chemical hazards from these raw materials change when they undergo chemical transformations during processing.

It is often stated that SPF emits volatile organic compounds or VOCs. Several SPF products have undergone standardized VOC testing in both the US (GreenGuard[6] and CA 01350[7] standards) and in Canada (ULC S774[8]). These tests show that the SPF tested meets all of the VOC limits in these standards and thus SPF is not considered to be source of standard VOCs in these tests.

As stated earlier in this paper, airborne levels of MDI may be above the occupational exposure limit during SPF application, but drop off rapidly both with distance and time. In fact, researchers have shown that for interior SPF application work, within two hours following the end of spraying, airborne MDI levels were not detectable.[9]

At present, an ASTM workgroup with participants from EPA, NIOSH, OSHA, emission laboratories and the chemical industry are working to develop a new emissions test protocol to measure SPF-specific emissions from MDI, blowing agents, and catalysts.

Disposal and Recycling

SPF has been determined safe for disposal in landfills as it does not meet the criteria of a hazardous waste according to the Resource Conservation and Recovery Act. Although landfilling of foam plastics appears to be the most common disposal method today, some SPF materials are shredded and used as filler materials. SPF can be incinerated and used as a fuel. Chemical processing to degrade polyurethane foam into usable chemicals is being done on a limited basis, particularly in Europe.[10] When incinerated, the GWP of the retained fluorocarbon blowing agents is eliminated by combustion. A study was conducted to consider sequestration of fluorocarbon blowing agents in foam plastics, but it was determined that the environmental impact of transportation of the materials to a central processing location would far outweigh the impacts of the released blowing agents.[11]

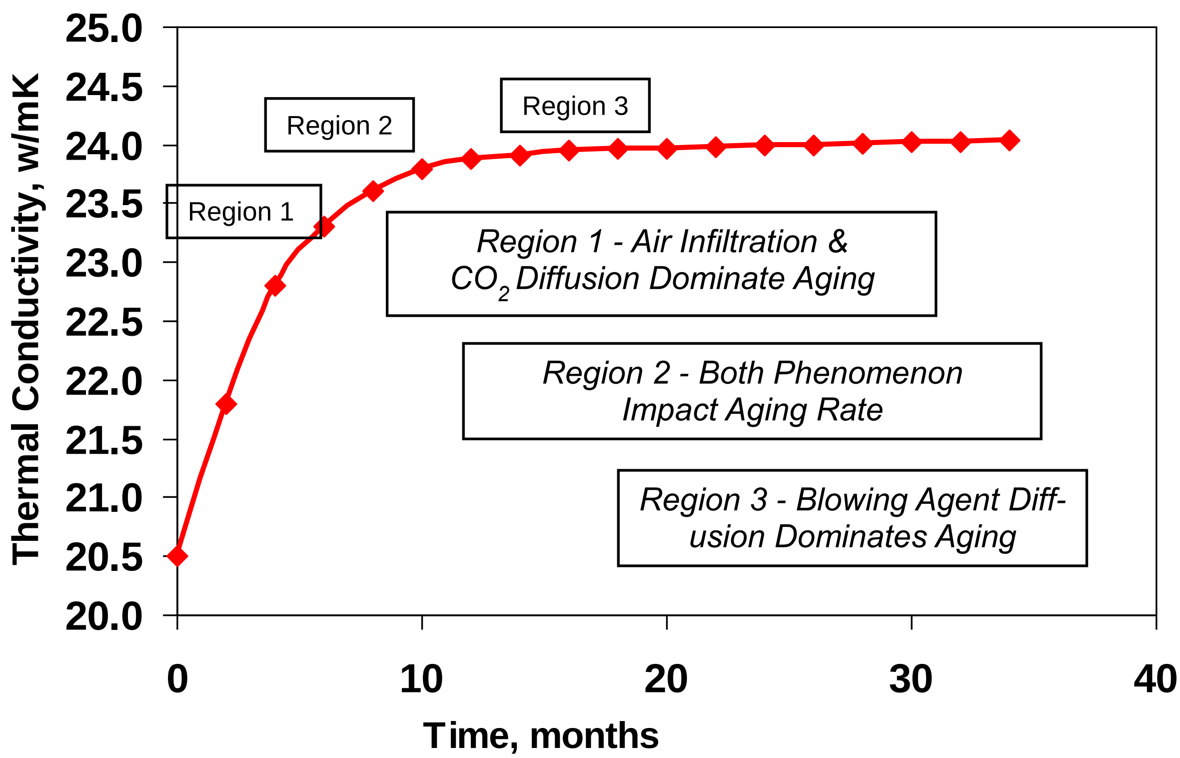
THERMAL PERFORMANCE

As mentioned previously, open-cell SPF provides thermal resistance by creating still air pockets in the open-cell foam structure. Conversely, closed-cell SPF provides improved thermal resistance from low thermal conductivity blowing agents retained in the closed-cell structure. It is known that these captive blowing agents can, over time, diffuse from the cells near the free surfaces of the foam, resulting in a slightly lower R-value than measured immediately after installation. To address this under the Federal Trade Commission (FTC) Insulation Rules (16 CFR 460)[12], all foam plastic insulations are aged prior to measuring and reporting R-value. For several decades, the practice for closed-cell SPF is to age the sprayed foam for 180 days under room temperature conditions before measuring the reported R-value. More recently, accelerated aging processes (90 days at 140ºF) have been shown to provide the same result.[13] After aging, all SPF products are tested in a guarded hot plate apparatus using the procedures outlined in ASTM C518.[14]

Traditionally, aging and thermal testing of SPF has been performed on 1" thick specimens, as this is a common thickness for SPF roofing installations. As SPF is also used as interior insulation, most manufacturers also test closed-cell foams at 3-4" thicknesses. This testing requirement, including the use of a third-party, accredited laboratory for conditioning and thermal testing, is described in International Code Council Evaluation Services (ICC-ES) Acceptance Criteria for Spray Foam Plastics (AC-377).[15] Any SPF product that has an ICC-ES Evaluation Services Report has undergone thermal testing by a third party laboratory.

Diffusion of blowing agents may occur near the free surfaces of the foam and may be slightly lower the thermal performance of closed-cell SPF. After the initial diffusion of the blowing agent which measurably lowers thermal performance, the blowing agent remaining in the core of the material is released much more slowly. Over several millennia, the captive blowing agent in the core may be completely released, but it is not likely to occur over the 60-100 year service life of the building. Below are the results of a study showing the thermal conductivity or k-value (inverse of the thermal resistivity, R/inch) of a closed-cell SPF material.[16] After a few months, the thermal conductivity reaches a stable value, which continues to increase very slightly over time.

Table 4: Thermal conductivity (inverse of R/inch) of a closed-cell SPF material



Based on this and similar studies, the SPF industry believes that 180-day room temperature aging prior to R-value testing per ASTM C518 provides a suitable estimate of the long-term thermal performance of closed-cell SPF.

Loss of initial R-value from blowing agent diffusion is controlled by several factors. For SPF, there are surface skins, pass lines and substrates that can provide barriers that slow blowing agent diffusion. These features are often dependent on specific installation. There are conditioning protocols for foam plastic insulation that involve thin-slicing of the material and subsequent thermal measurement of these slices (ASTM C1303[17] and CANULC S770[18]). While these methods have been shown to work well with some foam plastic insulations, there are concerns that these conditioning techniques will invasively damage the closed-cell structure of SPF, and may not include the real-world affects provided from substrates, skins and pass lines in mitigating the diffusion of blowing agents. Research is underway to determine if the thin-slice test methods are appropriate for closed-cell SPF.

MOISTURE CONTROL

In colder climates, moisture permeable insulations like fiberglass, cellulose and open-cell SPF require additional vapor retarders (films or paints) applied to the interior surface to avoid unwanted condensation. Closed-cell SPF, at a thickness of about 1.5 inches, provides an inherent moisture permeance of 1 perm, meeting Class II vapor retarder requirements per the model building codes.[19] Closed-cell foam is also water resistant and meets current FEMA standards for flood-resistant materials,[20] which can make it an excellent choice for insulating areas at or below grade in most buildings.

Air sealing of walls can be achieved using a small thickness of closed-cell SPF. Thus, closed-cell SPF is frequently used in tandem with fibrous insulations to create a hybrid insulation system that is known as "flash and batt." For high-pressure closed-cell foam, it can be applied at a thickness of 1-3 inches in the wall cavity against the exterior sheathing, and the remainder of the cavity is filled with fibrous insulation to achieve the desired R-value. In this application, an interior vapor retarder is usually unnecessary if the closed-cell foam is installed to an appropriate thickness. The appropriate thickness of foam, determined by hygrothermal (WUFI[21]) modeling, can provide between 25 and 65% of the total cavity R-value, depending on climate zone. Moderate climates (IECC Zone 4) require about 25%, while colder climates (IECC Zone 6-7 require about 65%. These insulation percentages are included in Table 601.3 of the 2009 IRC.[22]

AIR SEALING

The Air Barrier Association of America (ABAA) provides an excellent definition for air barrier materials, assemblies and systems on their website.[23] It states that open-cell SPF is air impermeable at a thickness between 3.5 and 5.5 inches, per ASTM E2178 or E283. Closed-cell SPF is air impermeable at a thickness of 1.5 inches using these tests. At these installed thicknesses, both product classes qualify it as an air-barrier material per ABAA, and an air impermeable material per the model building codes. These qualities of spray foam are important to make large energy efficiency gains and demonstrate one of the key benefits that spray foam brings to a passive home.

When SPF is applied in a wall assembly, it can expand to fill most cracks and gaps. Test data from an ABAA study[24] shows that spray foamed wood-frame wall assemblies have air leakage far below the maximum assembly leakage limits per ABAA.[25]

When SPF is used as a component of an air barrier system, other air sealing details may be required. For example, wood-framed walls often use double-studs (crips and jack studs) around fenestration. SPF cannot seal these sources of air leakage, and caulking may be recommended.

As for whole building air leakage, there are a number of studies that demonstrate air sealing performance of SPF insulation. A study conducted by NAHB[26] shows that open-cell homes have reduced air leakage rates. A 2009 study was conducted on three identical homes built in San Antonio, TX.[27] The control home conventionally insulated with blown fiberglass on the attic floor and fiberglass batts in the walls had measured air-leakage of 5.84 ACH_{50}. The same home with fiberglass insulated walls and open cell SPF used to create an unvented attic had a measured air leakage of 3.64 ACH_{50}. A third identical home using SPF insulation throughout the entire envelope had a leakage rate of 1.95 ACH_{50}. All homes had identical house wrap and a caulk and seal package. The study showed a three-fold decrease in air leakage between fiberglass and SPF insulated homes. A HERS evaluation of a SPF insulated home, with a caulk and seal package, foam around all doors and windows with taped window flashing achieved an air leakage rate of 0.41 $ACH_{50.}$[28]

SPF plays a significant role in minimizing air leakage. Air leakage not only improves energy efficiency, but also reduces uncontrolled moisture movement through the building envelope, which can result in condensation and mold, mildew, rot and corrosion, reducing the service life of the building. Minimizing air leakage from SPF use can improve indoor air quality and occupant comfort by controlling the entry of pollen, outdoor pollutants and pests into the building.

STRUCTURAL BENEFITS OF SPF

The structural improvements provided by closed-cell SPF are well documented. Several studies measuring the racking performance of frame walls per ASTM E72 show that 1 to 2 inches of closed-cell foam can provide nearly the same racking strength of a frame wall using plywood sheathing.[29],[30],[31] In

2008, a study[32] showed that wind uplift resistance of wood roof decks increased more than three times by using 3 inches of closed-cell SPF between rafters under a typical plywood roof deck. Not only does closed-cell SPF provide significant structural benefits as described above, its inherent water resistance can provide a secondary water barrier – which is important when the primary roof system (shingles and underlayment) are removed in a hurricane.

SPF AND SUSTAINABLE BUILDINGS

At present there are many opinions for selecting sustainable building materials for both residential and commercial construction. Several of these programs suggest certain minimums on recycled content or renewable resources used to make and install the product. These restrictions are considered single attribute measures. While they represent ways to minimize a particular environmental impact, they can mistakenly overlook the entire set of impacts of a product throughout its complete life. For example, the environmental impacts of collecting and processing certain recycled materials can be greater than the environmental impact of landfilling of a material.

To properly address the environmental impacts of a product, an ISO-compliant[33] life-cycle assessment (LCA) is an important tool. Generally, LCAs include the entire product life cycle, from cradle to end-of-life. These include processes needed to mine, extract and process raw materials, manufacture them into finished products, as well as the impacts of using and disposing or recycling the products. LCAs typically measure standard environmental impacts such as primary energy demand, and potentials for global warming, acidification, eutrophication, ozone depletion, and smog creation for a functional unit of the product throughout its entire life. LCAs can incorporate all of the single-attribute measures, without favoring one over another.

The Spray Polyurethane Foam Alliance (SPFA) commissioned an LCA project in November 2010, and the results will be published in mid-2012. The results include all impacts from raw materials, manufacturing, transportation and disposal offset by the environmental impacts avoided by the energy saved over the life of a typical building. The final report of this study will be of interest to passive house practioners.

In terms of super-insulated buildings, there is a well-known diminishing return on increasing R-value. As we consider designs of super-insulated buildings, LCA approach should be considered, not a single-attribute measure of the product. For example, many super-insulated buildings require thick walls that can exceed 2-3 feet in thickness to achieve R60 walls. This requires use of more framing materials with associated negative environmental impacts. In addition thick walls combined with small windows reduce natural daylighting in these buildings – perhaps requiring the use of supplementary lighting during daylight hours. This lighting can have a negative impact, which may or may not be offset by the incremental heat savings moving from an R30 to an R60 wall. These types of interactions must be considered for sustainable building design, and a life cycle assessment provides a transparent means to do so.

CONCLUSIONS

SPF has many benefits for passive houses and can increase energy efficiency. While SPF is a unique product since it is manufactured onsite, it can be handled and applied safely by a trained professional applicator. SPF can provide benefits beyond those of conventional fibrous insulation materials. Both open and closed-cell SPF are air barrier materials and provide a significant contribution to reduced air leakage in buildings. Closed-cell foam also provides an inherent vapor retarder meeting Class II vapor retarder requirements of the model building codes and provides structural reinforcement.

SPF has unique attributes that make it ideal for use in passive homes and builders, architects and homeowners should learn more about the product before making a decision on its positive or negative attributes prior to utilizing the product. A key to a successful experience with SPF in a passive house, or on any building, is hiring a trained and experienced professional contractor, who knows and understands the proper way to install SPF and follows the manufacturer's guidelines.

Significantly more information about SPF can be found on www.spraypolyurethane.org and www.whysprayfoam.org. We encourage you to review those websites for any questions you have about SPF now or in the future.

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[1] Lesage, J., J. Stanley, W.J. Karoly, and F.W. Lichtenberg. 2007. "Airborne Methylene Diphenyl Diisocyanate (MDI) Concentrations Associated with the Application of Polyurethane Spray Foam in Residential Construction", J. Occup. Environ. Hyg. 4:145–155.

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[3] Karlovich, B. 2009. "Air Monitoring Investigation: SPF Installation in Residential Dwellings", Bayer Material Science, Unpublished report.

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[6] GreenGuard Environmental Institute certification programs www.greenguard.org.

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