GREEN QUALITIES OF SPRAY FOAM INSULATION

By Lisa Jo Rudy

Building insulation is a tool for keeping heat in or out of structures. Insulation makes it possible for buildings to stay warm in winter, cool in summer, and relatively moisture free year-round. Different types of insulation and air barriers have been used over the centuries with varying results.

Today, new materials and technologies make it possible to create and apply extremely effective insulation and air barriers. The result is buildings that can maintain a safe, comfortable temperature while using very little energy for heating or cooling. This translates to greener buildings that create very low “carbon footprints” and meet LEED and other energy efficiency guidelines.

Spray foam is a newer material that combines the benefits of insulation and air barriers. Because of its unique formulation and application, it consistently out-performs older, more traditional forms of insulation. Recycled and environmentally-friendly products are available to make spray foam an exceptionally “green” choice.

LEARNING OBJECTIVES

Upon completion of this course the student will be able to:
1. Discuss the importance of air barriers and insulation for reducing energy consumption and potential health and safety hazards in residential and commercial buildings.
2. Describe open-cell and closed-cell spray foams and explain applications of each.
3. Explain how spray foams work as a green and sustainable form of insulation.
4. Identify uses of spray foam insulation to reduce fuel consumption.
5. Discuss green features of spray foam insulation as opposed to traditional insulation materials and methods.

HOW HEAT MOVES IN BUILDINGS

Heat is a form of energy which causes the molecules in gases or solids to move more rapidly. Heat tends to flow to cooler areas until all areas are at the same temperature. It moves from the warmest to the coolest parts of any structure through three mechanisms: conduction, convection, and radiation.

- Conduction describes the transfer of heat through materials. An example is the heat that is transferred from a stove to a pot, or from a hot liquid to a spoon. Heat and cold
can both be conducted through materials in a building, with the result that warmth is conducted to cooler areas. Some materials are better conductors than others; metal, for example, is a good conductor while wool is a poor conductor.

- Convection is the process by which warmer gas or liquid rises, cools, sinks, heats, and rises again. Convection can be seen in a boiling pot, or felt in a poorly insulated building. During winter, convection is the process that moves warm air from lower floors to the roof. In many cases, warm air then escapes through gaps in the building.
- Radiation is heat that comes from a single source and moves in a straight line. The sun produces radiant heat, as does an electric heater.

Insulation is simply a tool used to manage the flow of heat. In construction, it may be used to keep heat in or out of a building or to maintain a constant temperature. In most cases, its purpose is to slow down the process of convection and conduction, or to reflect radiant heat.

In a building without insulation, heated and cooled air move through the building and are lost to the outside environment. As a result, the heater or air conditioner must work constantly to keep the building at a comfortable temperature. Proper insulation, however, can keep the building at a consistent temperature for long periods of time. This means less energy spent on heating or cooling air—which leads to lower environmental impacts and lower fuel costs.

To maintain comfort, the heat lost in the winter must be replaced by your heating system and the heat gained in the summer must be removed by your cooling system. Properly insulating your home will decrease this heat flow by providing an effective resistance to the flow of heat.

**HOW TRADITIONAL INSULATION WORKS**

The purpose of insulation is to stop the flow of heat from warmer to cooler areas. Natural materials have been used for thousands of years to insulate homes and maintain comfort. Rock and wood can literally stop the flow of air by putting an impermeable barrier in its way. Thick, fibrous material such as wool, horse hair, or thatch can trap heat in gaps between the fibers. While these materials were somewhat effective, they left plenty of room for improvement. With new technologies, more effective materials were developed.

In the 20th and early 21st centuries, foam board and fiberglass became very popular insulation materials. Foam boards physically block the movement of air while also slowing conduction. Spun fiberglass can be stuffed between floors and into gaps in construction, and its many layers of fibers do a good job of trapping warm air.

The job of any insulating material is to stop heat from moving from one location to another. The ability of any individual material to stop this flow is measured by its R-value. A high R-value means that a material is a very effective insulator, while a low R-value means the material is a poor insulator. Paper, for example, has a low R-value while thick fiberglass insulation has a much higher R-value.

The R-value of an insulating material is also based on the degree to which the material is properly installed. An inch of fiberglass material in a five-inch gap will do little to stop the flow of heat. Fiberglass that completely fills a gap will do a far better job of stopping the flow of heat, and thus produces a higher R-value.

**THE LIMITS OF TRADITIONAL INSULATION**

Standard insulation works in very much the same way as a sweater. Like a sweater, it is made up of layers of fibers which trap heat. In the case of clothing, however, heat is generated by the human body rather than by a furnace.

A sweater is perfect for cool autumn days when the sun is shining. Not only is it a thick, barrier between your warm skin and the colder air, but gaps between the fibers do a good job of trapping warm air. But what happens when rain falls or cold winds blow? Because it does not provide an impermeable barrier, the sweater provides only minimal insulation from stormy weather.

A windbreaker is an external covering that helps stop wind and water. Put on a windbreaker over a sweater, and the sweater can do its job better. Together, the windbreaker and sweater provide an ideal climate control system.

The sweater is a good analogy for standard insulation. Insulation is any material used to prevent transmission of heat or cold. Typically, structural insulation is made of fiberglass. In buildings, insulation is used to keep indoor environments separate from outdoor environments. No matter what the weather outside, insulation acts like a sweater—keeping warm air inside and helping to keep cold and heat outside.

When the weather becomes very cold, hot, wet, or windy, however, gaps in fiberglass insulation let in the cold and drafts. That’s when an air barrier becomes important. Traditional air barriers are self-adhered sheets, membranes, films, or board stock that are attached to the outside of structures to stop wind and air leakage from occurring.

**CAUSES OF AIR LEAKAGE**

Air leakage is a result of pressure differences caused by the “stack effect,” wind loading, flues, and ventilation systems. While some air leakage is unavoidable, it can be minimized through the use of high-quality insulation and/or air barriers. Causes of air leakage relate to basic physics, and to the way in which structures are insulated.

**The Stack Effect:** Hot air is lighter than cold air. Because of this, hot air rises to the top floors of a building. Positive pressure inside the building builds toward the roof as more air is forced into the same space. This pressure pushes air out through gaps in the ceiling and upper story windows.
Meanwhile, on the lower floors, air pressure is lower inside the building than outside. Higher pressure outside pulls cold air in through openings in windows, walls, and the building foundation. As the cold air warms, it rises—building pressure toward the ceiling and starting the process all over again.

The stack effect, also called convection, is always in process. It’s an unavoidable reality of physics. But it can be mitigated if buildings are sealed to the degree possible.

OTHER CAUSES OF AIR LEAKAGE:
The stack effect describes one process by which air moves in and out of structures. There are also two other major reasons for air leakage.

Wind loading describes the outcome that occurs when the wind blows most often on one side of the building. As the wind blows, cold air enters through gaps in insulation, building up pressure on the windward side of the building. This leads to negative pressure on the down-wind side of the building. This phenomenon results in wind being pulled through the building—creating drafts and adding to leakage issues.

Flues and ventilation systems are openings in the building structure. They are used to expel air from the building when furnaces and hot water heaters are operating. When air is pushed out, it is replaced by outside air that leaks in through other openings.

Air leakage resulting from wind loading, flues, and ventilation systems is unavoidable. No one can stop the wind from blowing, and flues and ventilation are absolutely essential. But there are methods for minimizing air leakage and the problems associated with it.

PROBLEMS ASSOCIATED WITH AIR LEAKAGE

Why is air leakage such a serious issue?
To go back to the sweater analogy, air leakage is similar to holes in a sweater. Cold air and rain can readily enter through any gaps in a sweater, allowing heat to escape and moisture to increase discomfort.

Air leakage can create a range of problems for home and building owners. It can impact health and safety, durability, occupant comfort, and heat and cooling costs. It can also lead to environmental issues as owners crank up the heat or air conditioning.

In structures, air leakage is a major concern. There are numerous problems associated with air leakage, including:

- Health and Safety Risks
- Durability Issues
- Loss of Occupant Comfort
- Increased Energy Costs

Health and Safety Risks: Air leaks carry moisture—and damage from airborne moisture from air leaks can cause a variety of safety problems. For example:

- When warm moist air leaves a building, and interacts with cold air, icicles form. In some cases, falling icicles can become serious safety hazards.
- When water freezes, it expands. Warm, moist air can freeze on the inside of building facades, pushing bricks or stones out of alignment and causing damage to the façade or masonry cladding. When the frozen water melts and refreezes, it pushes the bricks, stone, or other materials further out of alignment and even more damage is done.
- Warm, moist, dark environments are ideal for mold and mildew. Mold and mildew can cause long-term structural damage to the building. Some kinds of mold can also cause serious health risks, especially to people with allergies or asthma.

Durability Issues: Airborne moisture can negatively impact the durability of a building. When warm, moist air condenses on cold steel, the steel can rust and corrode. In addition, moisture condensing on a roof deck of an attic can lead to mold, mildew, rot, and corrosion.

Occupant Comfort: Air leakage creates cold drafts in winter. It also creates uncomfortable heat and humidity in summer. Even when air is cooled or heated, air leakage can bring in outdoor pollutants such as dust, pollen, and chemicals. These materials are difficult to remove, and can build up over time.

Heating and Cooling Costs: In summer, air leakage means more work for air conditioners as warm, moist air enters through gaps in insulation and air barriers. In winter, heating systems work overtime to warm up cold air. In both cases, costs and energy use are higher than they need to be for the same outcome. In fact, according to the Department of Energy, unwanted air leakage can account for nearly one-third of the heating and cooling energy costs of a typical home. Fortunately, it’s possible to reduce air leakage by as much as 80 percent through the use of air barriers.

WHAT IS SPRAY POLYURETHANE FOAM?
Spray Polyurethane Foam (SPF) is a modern polymer produced as the result of a two-component chemical reaction between a polyalcohol and a polyisocyanate. Polyurethane is an extremely popular material, as it provides huge range of benefits. It is used in a wide range of ordinary products, including:

- Footwear (Shoe Soles/Cushion)
- Sofas
- Mattresses
- Paint
- Bowling balls
- Insulation
- Roller blades wheels
- Golf balls

When it is used as an insulator/air barrier, Spray Polyurethane Foam (SPF) is applied as a liquid. The liquid quickly expands into a foam which surrounds and seals gaps. Over the course of seconds, the foam hardens and becomes an extremely effective insulator and air barrier.

OVERVIEW OF SPRAY POLYURETHANE FOAM INSULATION

Spray Foam Insulation has become the insulation of choice for builders, architects, and homeowners because of the myriad of benefits it provides, all stemming from its ability to provide a seal against air, moisture, and thermal fluctuations, all in one application. Spray foam is applied as a liquid, which allows it to flow into potentially leaky areas such as cracks, gaps, and penetrations. The foam quickly expands, seals, and hardens.

Fiberglass, in batt and blown forms, has traditionally been used in vented attics, walls, and crawlspaces. These traditional insulations act like loose blankets for a home, and much like blankets, only work when air is not moving over, under, or through the blanket. Spray foam
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insulation is a significant improvement over fiberglass options. It expands to fills cracks and corners of attic roofs, walls, and crawlspace joists, sealing conditioned air in and keeping unconditioned air out.

The benefits of this multi-barrier insulation are numerous and include: lower energy bills due to better HVAC performance and smaller size, longer HVAC system life, less dust and air pollutants in the home, equalized room temperatures, cooler and cleaner attics, lower carbon footprint, increased structural strength, added sound abatement, increased value of home, and lower home insurance, all of which lead to happier homeowners.

TYPES OF SPRAY FOAM INSULATION

Open cell spray foam is low density, non-structural, and water vapor permeable. Its expansion rate is about 140 to 1, meaning that the foam, once applied, will expand by 140 percent. Open cell foam chambers are interconnected, so gas (air) can pass through multiple cells. Because it is water vapor permeable, it is used in interiors. Some examples of its use include:

- **Exterior walls**—ocSPF insulation can seal cracks and provide in-house noise reduction.
- **Partition Walls**—ocSPF can provide a sound barrier between rooms to ensure that noise stays in one area a building.
- **Attics**—ocSPF can provide effective insulation in the tradition vented attic or high performing unvented attic.

SPONSOR INFORMATION

SES Foam LLC is a polyurethane systems house headquartered in Houston, Texas. SES specializes in the production of spray applied polyurethane foam insulation for residential, commercial and industrial markets. SES features environmentally friendly insulation products and is committed to the sustainability of the insulation industry. For more information please visit us at www.sesfoam.com.
Closed cell spray foam is applied with gaseous blowing agents. Because of its unique structure and application, it is both rigid and impermeable. As a result, it provides a high R-value insulation while also strengthening building structures.

While it can be used anywhere ocSPF can be used, ccSPF has particular advantages when used on building exteriors and foundations. In fact, it is possible to get insurance discounts for wind uplift mitigation when ccSPF is used on the roof deck. This is possible because ccSPF provides additional structural support, making the roof more resistant to wind uplift. This advantage of ccSPF is particularly significant in areas that are prone to hurricanes or other major wind events.

Savings from insurance costs and lowered energy costs are often enough to mitigate any higher costs that may be associated with closed foam spray, as opposed to traditional insulations.

**SPRAY POLYURETHANE FOAM INSULATION VERSUS TRADITIONAL INSULATION SYSTEMS**

In the earlier example of the sweater and wind breaker, it is clear that both insulation and an air barrier are necessary to maintain constant warmth and to avoid unwanted drafts. The same is true in a structure: to stop air leakage, conduction, and convection, it’s necessary to properly install both high quality insulation and an air barrier. Together, the two parts of the system can maintain a comfortable environment, while also excluding drafts, eliminating convection, lessening conduction, and avoiding unwanted air infiltration/exfiltration.

**Insulation:** Traditional fibrous insulation performs perfectly well when installed in ideal conditions. However, due to real world conditions, seen on all construction sites, it is rarely installed perfectly and therefore does not perform as intended. In fact, according to Oak Ridge National Laboratories, even 2 percent voids in the insulation can result in a drop of 17 percent performance in R-value.

Furthermore, fibrous insulations are usually compressed, fall loose over time, or fail to seal around penetrations or plumbing allowing air to transfer to and from the structure.

**Air Barriers:** Air barriers consist of several parts which, together, make up a system that is air-impermeable. The Air Barrier Association of America explains that simply installing an air impermeable material in a building is not enough to ensure an air barrier. This is the case because “to achieve an airtight building enclosure you need to join the various air barrier materials together using an air barrier accessory.”

The air barrier materials and accessories, together, form an air barrier system:

* The air barrier system is a collection of air barrier assemblies and air barrier components tied together using air barrier accessories to provide a continuous plane of air tightness for the whole building enclosure. The air barrier system determines the air leakage of the whole building. The maximum air leakage of a whole building is typically not greater than 2.0 L/(s•m²) @ a pressure differential of 75 Pa (0.4 cfm/ft² at a pressure differential of 1.57 lb./ft²) (or as required by a code or specification).

**Comparing Traditional and Spray Polyurethane Foam Systems:** Together, fibrous insulation and air barriers can do an adequate job of lowering leakage, heat loss, and moisture. They must, however, be applied as a system: neither is sufficient enough alone to achieve a really energy-efficient solution. In addition, it is often the case that both elements of the system decrease in effectiveness over time. Wind and moisture affect the air barrier’s seal, while insulation flattens and pulls away.

When compared to traditional insulation/air barrier systems, spray foam provides a superior solution. There are several reasons for this:

- Unlike standard systems, spray foam expands in place, forming a continuous, air impermeable barrier, sealing almost every crack, gap and penetration in the components of a building enclosure.
- Spray foam offers high R-value which reduces heat transferred by conduction.
- Spray foam prevents the convective loop (stack effect) from forming.
- Because spray foam functions as both an air barrier and an insulation, it inherently places the insulation in contact with the air barrier (which is often hard to do with fibrous insulations). This avoids problems caused by gaps and avoids the problem of moisture control.
- Spray foam can be sprayed into and onto gaps that would be impossible to insulate with traditional materials. For example, it can be used to seal gaps created when lighting fixtures are installed, or seal small penetrations in hard-to-reach locations.

**SPRAY POLYURETHANE FOAM AND ENERGY STANDARD REQUIREMENTS**

There are many reasons for builders to consider energy standard requirements when choosing insulation/air barrier materials. Of course, there are basic energy requirements set by the US government, and meeting those requirements is non-negotiable. In addition, energy efficient homes and structures are more comfortable, less costly to run, and more likely to meet LEED and other green building standards. For many home and building owners, just knowing they are leaving a smaller carbon footprint is another great benefit.

**Spray Foam Insulation Exceeds Energy Standards.** Spray foam makes it easy to meet and exceed energy standard requirements. According to research studies:

- SPF insulation has been shown to easily meet the air barrier system requirement for building air leakage
- Numerous residential blower door test data show that homes using SPF insulation as an air barrier have 20 to 30 percent of the air leakage measured for similar homes using fibrous insulations

**Spray Foam Increases Energy Efficiency.** SPF also offers another, unique benefit. Because heat rises, many homes experience duct leakage and heat loss in the attic space as heat travels from the HVAC unit. Moving the insulation to the roof deck encapsulates the attic space in the thermal envelope.
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The heat loss and duct leakage are used to semi-condition the attic space, so that instead of overheating, the space is usually within 10 feet of the interior of the home. This approach significantly improves energy efficiency.

But traditional insulation materials cannot be used to achieve this outcome.

Spray foam is the only practical insulation that can be used in this configuration.

A positive change of this magnitude is remarkable for several reasons:

• It increases occupant comfort
• It lowers occupant costs for HVAC
• It easily meets and exceeds government regulations
• It makes it possible to meet LEED and other green guidelines, thus increasing the value of the building to owners and occupants

“GREEN” AND ENVIRONMENTALLY FRIENDLY SPRAY FOAMS

Spray foam insulation can be accurately described as “green by nature” because of its ability to lower fuel use by improving building efficiency. It is, in fact, described as a preferred insulator for LEED-certified construction.

Newer Spray Foams Are Greener: Typically, spray foams are made from new materials and are not renewable. This, along with the fact that spray foams do include petroleum-based chemicals, have worried some “green” contractors and consumers. Increasing interest in “green” spray foams, however, has resulted in the development of new materials available both through general spray foam contractors and “green” contractors. They include:

• Spray foam insulation containing a lower percentage of petroleum-based products
• Spray foam with recyclable content including soy-based materials rather than polyol resin

Spray Foam Meets Green and LEED Building Requirements. The model building codes include air barriers as a requirement—either performance based air leakage measurements for residential and small commercial buildings, and prescriptive requirements for larger commercial buildings. The primary requirement for an air barrier material is a maximum air permeance rating. This rating describes the degree to which air can or cannot permeate a material. In general, spray foams are a better choice for meeting energy standards and requirements than standard air barrier systems.

Most sustainable building programs, such as USGBC LEED, reference ASHRAE 189.1 when it comes to air barriers. Other organizations, such as the Army Corp of Engineers, are requiring air barriers in new construction. There are state-level building requirements linked to require air-barriers in the building enclosure.

EXAMPLES OF SPRAY POLYURETHANE FOAM’S SUPERIORITY FOR INSULATION

There is no doubt that spray foam provides a superior outcome relative to traditional fiberglass—or even to a combination of fiberglass and insulated sheathing. Its superiority may be measured based on its performance in a variety of areas including:

• Vapor Control
• High R-value
• Monolithic nature
• Indoor Air/Sound
• Carbon footprint
• Fuel costs

Case studies can help to illustrate the superiority of SPF as a combination insulator/air barrier; here is one real-world residential example. In 2009, as part of a Build America Project, a TX-based utility and a local builder made three identical homes using different combinations of insulation and air-barrier systems. Blower door data shows the envelope air leakage of a home insulated with SPF is about one-third that of the same home using fiberglass—both homes used the same caulk and seal package.

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New Low-GWP Blowing Agents and Spray Foams Are Making Spray Foam Application Greener: Until relatively recently, blowing agents used to apply spray foam had a high global warming potential (GWP). To address this concern, companies developed new blowing agents which not only lower GWP but also improve the application process.

Properly Installed Spray Foam Is Non-Toxic: It is also important to note that spray foam, when properly applied, is non-toxic once it has hardened and dried. Spray foam chemical elements in their liquid form, however, can be harmful to human health. In order to ensure that spray foam is properly applied, it is important to either receive training or to hire a professional team with training and certification. Improper application of spray foam can result in negative consequences. Training for spray foam application is relatively quick and low-cost, and is easily available.

CONCLUSION
Air leakage is a serious problem in modern construction, because it can lead to problems ranging from mold and mildew to increased utility costs. Traditional systems for mitigating air leakage consist of two elements: insulation (usually fiberglass) and an air barrier (usually a film, wrap, or board cladding). These systems do have a positive impact in that they reduce convection and conduction within structures while also sealing some gaps in construction.

While traditional systems can significantly lessen air leakage, however, a more modern technique called Spray Polyurethane Foam is much more effective. SPF:
- is a polymer made up of two chemicals which are sprayed in liquid form, expand into foam, and harden to create a highly effective seal;
- can be applied as open-cell or closed-cell foam (open cell foam is less expensive and is often used in interiors, while closed cell is rigid, provides structural support, and may be used in interiors or exteriors);
- provides the benefits of both an insulator and an air barrier in a single product;
- flows over uneven surfaces to seal uneven, hard-to-reach, or oddly-shaped gaps;
- has been shown to provide superior protection from leakage, even when compared to high quality air barrier/insulation systems;
- is available in formulations that include renewable, recycled materials and gaseous blowing agents with very low global warming potential.

Because it lowers fuel use, spray foam decreases the carbon footprint of any given structure. This, along with its high R-value and insulating properties, make it a product of choice for meeting energy codes both in standard structures and for green and LEED construction.

SOURCES
1. https://www.airbarrier.org/about/materials_e.php
2. Infante et al. Thermal Insulation, Materials and Systems for Energy Conservation, in the 80s, p341.