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Open vs. closed cell foam:
Know your options, make the right decision.

By John Bartlo, President of Energsmart Foam Insulation

The spray foam industry has matured quite a bit since 2004 since we started installing here at Energsmart. The number one question from consumers continues to be: "is open cell better or closed cell?" As much as the Internet makes our lives easier, it unfortunately provides a forum for anyone to give their opinion and often leads to a lot of confusion amongst consumers. The insulation market is no different. One of the goals of this paper is to explain why such information is out there and to present a clear and unbiased view of both open and closed cell foams. Energsmart installs both foams and we make similar margins on each.

For starters, let's discuss why there is so much information floating around about closed cell foam. Open cell and closed cell foams each have a component called a blowing agent, which forms the cells and fills them with gas. All open cell foams use water as a blowing agent, which, when blended with isocyanate, produces carbon dioxide as the insulating gas within each cell. Water is so inexpensive that it should be considered free to manufacturers for purposes of this discussion. On the other hand, every major closed cell foam on the market uses Enovate (also known as 245fa) or Solstice as their blowing agents. These products are exclusively developed and produced by Honeywell, a Fortune 100 company with annual sales approaching $40 Billion. These blowing agents are very lucrative for Honeywell and they promote them every chance they get, which is relatively easy given their vast corporate resources. They also have little to no competition. The result is a massive propagation of "positive press" for closed cell foams. These products are fantastic, which is why they are used extensively, but sometimes the benefits of open cell foam get lost in the discussion. In summary, water is free and therefore no one has the incentive to push the product on the market, while Enovate and Solstice, the closed cell blowing agents, are the patented products of a very large Fortune 100 company that wants to market it as much as possible to get a good return on their investment. This paper attempts to explain the benefits and drawbacks of each type of foam in an attempt to arm consumers with the information they need to make the correct insulation choice for their project.

What Does Open Cell and Closed Cell Mean?

When foam is installed in a home or other structure a cellular plastic is being made on site. For simplicity, think of it as bubbles in a bubble bath. The insulation cures very quickly and of course is dry once cured, unlike the bubbles in a bubble bath.

In open cell foam, a majority of the millions of bubbles share walls with one another, thus making it soft and airy. It's a little harder than angel food cake. Only a few percent of the finished product is plastic and the rest is mostly carbon dioxide trapped within the structure. These

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foams typically are light and only weight .4-.6 pounds per cubic foot. The general definition in the industry for open cell foam is that greater than 50% of the cells are open.

Closed cell foam forms in a similar manner, but a majority of the cells in closed cell foam are independent from the other cells in that they have their own cell structure and do not share any of their structure with other cells. The resulting foam has a much higher plastic content and less air/gas content. The foam is strong and rigid and typically weighs in the 1.7-2.0 pound per cubic foot range. It's just a little softer than wood. The general definition in the industry for closed cell foam is that greater than 90% of the cells are closed. These are typical densities for residential insulation. For exterior commercial roofs we use 2.5-3.0 lb closed cell foam. Spray foam is actually made in excess of 10 lbs per cubic foot, but not for residential use.

What's are the major differences between open cell and closed cell?

There are three major differences between these two products, insulating value per inch of thickness, cost, and moisture permeability.

Insulating Value.

Open cell foam is typically R-3.5-R-4.0 per inch as opposed to R-6.0-R-7.0 (aged) for closed cell foam. Open cell foam lends itself to applications where space is not limited, like in an attic or crawl space. On the other hand, closed cell foam is a great option for getting very high R-values in shallow spaces (i.e. a 2x4 wall). The "R-value" of both of these products is a high quality stable R-value that will not materially fluctuate with wind speed, moisture, or temperature. Fibrous insulators like cellulose and fiberglass are constantly changed by these factors. It's important to note that open cell foam is an air barrier. Many people take its name - "Open Cell" - to mean that the cells are wide open for air to freely move through the foam. This is not true. Typical air permeance for open cell foam is around .005 L/S/M2 (liters per second per square meter) under 75 Pa pressure at a depth of 3.5". Closed cell is less than half of that at the same R-value. Both of these rates are incredibly small and undetectable by humans without the use of measuring devices.

Cost.

Closed cell foam is always more expensive per "R". So, you could expect an R-13 of closed cell to be more expensive than R-13 of open cell. This is simply due to the fact that plastic costs more than air. There is much more plastic in closed cell than in open cell. It takes three times the amount of chemicals to make a board foot of closed cell foam as it does to make open cell foam. The chemical blowing agents in closed cell foam are also much more expensive than the water used as the blowing agent in open cell foam. Expect to pay an installer 30%-40% more for closed cell foam.

Moisture Permeability

Moisture permeability is the most controversial characteristic of these two insulators and is the focus of this paper. Moisture permeability is measured in perms and represents how much

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moisture can move through a given material. A perm is defined as a grain of water per hour per square foot per inch of atmospheric pressure. For purposes of this discussion, let's just say that a perm is the amount of water on a small pinhead. The higher a perm rating, the greater the amount of moisture that can pass through the material. Open cell foam typically has a perm rating of around 15 for a 2" depth. Closed cell foam typically has a perm rating less than 1 perm for 2" of depth. For comparison purposes, unfaced fiberglass has a perm rating over 100 for an R-13 batt.

Moisture has been a concern in homes since the dawn of time. Fred Flintstone probably had cracks in his stone ceiling that let water into his living room. In the 21st century building science has advanced far beyond caves and involves hundreds of building materials. For purposes of this discussion, let's just discuss the gas and liquid forms of water.

Any polyurethane foam will hold up well to liquid water relative to other building materials. They are plastics and inevitably they will get wet at some point during the life of a building. Closed cell foam has stellar performance in these situations. In most cases, no significant amount of water will even enter the cell structure of the foam. Once the conditions that cause the water problem are removed, assuming the foam isn't under water for months on end, the foam will simply dry out and return to action no worse for wear. On the other hand, the structure of open cell foam is not nearly as strong and it will take on water if a leak is bad enough. In the case of a roof leak or wind driven rain, open cell will simply dry out and return to normal once the leak is stopped. However, in the case of a flood that lasts for days on end whereby the foam is submerged, the pressure and weight against the foam will likely damage its cell structure beyond repair. However, it does not wick water. What does all of this tell you about foam and liquid water? Both open cell and closed cell foam will hold up better than fiberglass and cellulose insulation. Closed cell will hold up best, but neither foam is designed to be constantly exposed to liquid water. These aren't waterproofing solutions.

Now to the fun part – water vapor and moisture permeance. This is an area of great debate and misunderstanding in the insulation market and construction world as a whole. Most building in-

Insulation moisture permeability varies significantly. Here are the most popular in our region:

Fiberglass	• Vapor Permeable • Much Greater Than 20 perms
Cellulose	• Vapor Permeable • Much Greater Than 20 perms
Open Cell Foam	• Vapor Semi-Permeable • 10 perms at 5" depth
Closed Cell Foam	• Vapor Semi-Impermeable • Less than 1 perm at 2"

spectors and other industry "specialists" have very limited knowledge of it. As discussed earlier, closed cell foam has a low vapor perm rating (<1 for 2") and Open cell foam has a higher rating of around 10 (for 5"). Using generally accepted terms in the industry, closed cell foam is referred to as a "vapor semi-impermeable" and open cell foam is referred to as "vapor semi-permeable". A few points should be made prior to this discussion. First, moisture will move from areas of high pressure to areas of low pressure, which usually means it moves from warm to cold. Second, warm air can hold more moisture than cold air. Finally, this country has many different climates, so if you hear an expert from Texas tell you the "correct" way to insulate your home, you may want to consult a local expert. A good insulation solution in Minneapolis isn't necessarily good for Miami and a good solution for Buffalo may not be good for Seattle. The people you consult for building and insulation advice should have a thorough understanding of the local climate and building science. Unfortunately, most people in the industry don't have this expertise. This is another example of why you should be very careful about drawing conclusions from something you see on the Internet. Every opinion you see on the Internet likely has an opposing opinion somewhere else on the Internet. Gather as much info as you can and hire experienced installers.

Every material used in building has a vapor permeance rating. Let's discuss walls. In this region (western New York) we typically see a wood framed wall cavity filled with insulation. It has painted drywall on one side and plywood or oriented strand board (OSB) sheathing on the other. On the outside of the sheathing we typically see a Tyvek type house wrap. Outside of that we see either brick, vinyl, or stucco. Without discussing insulation yet, every one of these building materials (as installed on your home or building) is vapor semi-permeable or permeable meaning that moisture can flow or diffuse through them with relative ease. To add another dimension, most of these materials have the capacity to hold various amounts of moisture, sometimes referred to as hygric capacity. For example, the wood used to build an average home is capable of holding 50 gallons of water without causing a moisture problem. Vinyl siding and Tyvek have no storage capacity. Drywall has a little storage capacity. Brick and block have tons of storage capacity – like ten times the amount of wood! Steel studs have no storage capacity.

Fiberglass and Cellulose are often installed with polyethylene (plastic) or Kraft facing. Polyethylene will effectively make the fiberglass or cellulose semi-impermeable, and Kraft facing will make fiberglass semi permeable.

New York State Climate

The climate of New York state is typically considered cold (not as extreme as sub-arctic or arctic). The US Department of Energy has seven climate zones. The major cities in upstate NY, like Buffalo, Rochester, Syracuse, and Albany, are all in zone 5. Interior and northern portions of the state are considered zone 6 (colder). We have both a heating season and a cooling season with the heating season being longer than the cooling season. Buffalo, for example, has 6,840 heating degree days on average, and 570 cooling degree days. A degree day is when the average

temperature for a day is above or below 65 degrees. If the average temperature for today was 60 degrees it would result in 5 heating degree days. If the average turned out to be 70 degrees there would be 5 cooling degree days. In recorded history, annual heating degree days have never exceeded 7,400 in Buffalo, and cooling degree days have never exceeded 1,000.

Acceptable Building Design

Building in WNY consists of literally thousands of combinations of building materials to construct wall and roof assemblies. Each material has a vapor permeance and the assembly as a whole should be taken into account when determining if it is acceptable from a moisture control standpoint, along with the expected interior and exterior weather conditions. This is exactly why the generalizations of the Building Code or an inexperienced building envelope professional can be detrimental to your structure. This paper will focus on a typical wood framed dwelling with drywall and latex paint on the inside. Metal skinned buildings or buildings with a high vapor drive like pools and coolers need special attention and are not discussed in depth here.

Water vapor can travel through convection and diffusion. With respect to polyurethane foams, convection is a non-issue since they are, for all intents and purposes, air barriers. Diffusion on the other hand is where moisture permeance comes into play in foam. The general rule of thumb with moisture is to keep it out of building assemblies, but when it gets in make sure it has a way out. It's important to note here that most building codes require a vapor barrier to be present on the winter warm side in wall and roof assemblies. We and most other building science experts feel that typical buildings in mixed climates like ours don't need a vapor barrier at all. This is also known as a flow through design that allows moisture to move toward the exterior in winter and the interior in summer. It sounds radical to many, but it makes sense. In the winter, moisture will tend to drive from inside to outside. A flow through design using open cell foam will allow the moisture to move through or be stored in the structure itself (note that this is not a bad thing unless the moisture content exceeds the hygric capacity of the materials used). In the summer the hot humid air will drive moisture into the house in the opposite direction. It's basically one big moisture swap game whereby the moisture content of the building builds during winter and then dries out during summer. This is what happens just about everywhere in NY and why open cell works well in this climate. If the climate was colder, then moisture would build to damaging levels in the materials of the home during winter. Open cell can still be used, but usually in conjunction with good mechanical ventilation or a spray on vapor barrier.

Closed cell foam in a wall cavity works just as well so long as it is applied to a depth whereby its warm side surface temperature is kept above the dew point (usually 1.5"-2"). In the winter the exterior sheathing will not be at risk for saturation because cold air doesn't hold much moisture. On the interior, the moisture will not condense on the foam and the minimal amount of moisture produced in the home will be stored within the wood studs and drywall. In the summer any moisture driven toward the home will be absorbed and stored by the sheathing and

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will dry in the fall and winter. Any moisture stored in the drywall and studs on the interior of the home will dry to the inside in the summer. Keep in mind that although there are ten times as many heating degree days in our region than cooling degree days, the vapor drive in the summer is much higher because warm summer outdoor air can hold much more moisture than conditioned indoor air. Open cell foam works well so long as the installed depth is 3.5", at which point it meets the technical definition of an air barrier. This is a flow through design where moisture will flow in the direction it wants to go or store and release at various times during the year. The depths mentioned in this paragraph are minimums to prevent moisture damage. More insulation would be desired for efficiency reasons.

Insulating of attics with foam can be done in two different ways in our region. The attic can be sprayed directly to the underside of the roofline with no ventilation, or the floor of the attic can be sprayed in a so-called cold roof system. Using the attic floor method, the use of either foam will adequately control moisture as long as the depth of the foam (R-13 or higher) prevents condensation on its surface and attic ventilation through soffit and ridge vents is adequate.

Insulation directly to the underside of the roof deck works perfectly with closed cell foam although it is relatively expensive. Some moisture will accumulate in the wood rafters during the winter, but it will be driven out during the summer.

There exists some disagreement within the building science community about the use of open cell foam directly to roof decks in our climate. The concern lies in its moisture permeance and the fact that it isn't really possible to build a flow through system in a roof. In other words, the moisture from the home in the winter is driven through the foam and collects within the roof deck because it can't get past the (mostly) impermeable roof paper and shingles. Some feel that a vapor retardant paint should be used in our region over the surface of the foam so moisture can't get to the roof deck. Our opinion on the roofline application of open cell foam in our climate is that vapor retardant paint is not necessary unless the home is expected to have unusual amounts of moisture present (i.e. many inhabitants, bathroom fans not used, excessive indoor temps). In the winter, the materials in the home will either absorb this moisture or let it pass through. The moisture content of the wood will never reach damaging levels (25%-30%). In the summer the roofline will dry to the inside due to very hot roof temperatures. The 2012 International Residential Code confirmed our position as open cell foam is allowed to be sprayed to a roofline in Zone 5 (Buffalo) with no vapor barrier.

Our opinion is also based on logic. Open cell foam has been installed in this manner in upstate New York for decades now. Energsmart has installed thousands! We are unaware of any roof failures resulting from this application method in the region. Additionally, we are only aware of a few failures in the entire country and those were all in extremely cold winter climate areas where heating degree days surpass 8,000. The applicator in those cases either put an insufficient amount of insulation in the roofline or they failed to use a vapor barrier (which must be used with open cell in climates that are that cold). This anecdotal evidence and the Code acceptance should put this issue to rest, but if you're concerned, open cell foam sprayed directly

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to a roofline can be coated with a vapor retardant paint for $0.10-$0.15 per SF, which will effectively give it the moisture permeability properties closer to closed cell foam.

Side Note – Roof Shingles

As a side note, the lack of ventilation to the roof deck has been studied extensively. The consensus opinion is that the lack of ventilation will degrade roof life only a few percent. The color and quality of the shingles are much larger factors. For example, a black shingle will have a 30% shorter lifespan than a gray shingle even though they are made of the exact same material. This was presented nicely in an Oct 2002 ASHRAE journal article by William Rose and Anton Ten-Wolde. Spending additional money to ventilate a roof deck (baffles, soffits, vents) in an effort to prolong the lifespan of your shingles by a few percent is not a good investment in our opinion.

Conclusion

In summary, both open and closed cell foam are phenomenal products that outperform all of their competing insulation materials by far. You can use either product with confidence, but remember that every structure is different and special attention must be given to the moisture and air permeability properties of your ENTIRE wall and roof assemblies to ensure that they can accept and release moisture to avoid degradation of the structure and other associated problems.

In general, try to make use of open cell foam since it is a less expensive product that has the identical efficiency and comfort as closed cell (assuming same R-value). On the other hand, closed cell foam is stronger, stands up to moisture better, and can reach high R-values in a small amount of space. It can be confusing, but you can always count on the experienced professionals at Energsmart to help you sort through your options in a low pressure manner.

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