Cold-Weather Performance of Polyisocyanurate

Researchers are beginning to understand the causes of the problem, but solutions remain elusive

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It's R-6 per inch during the summer, but only R-4.5 per inch on a cold day in winter. The insulating performance of polyisocyanurate insulation is significantly degraded at cold temperatures.

The ability of insulation products to resist the flow of heat changes with temperature. Most insulation products — including fiberglass batts, extruded polystyrene (XPS), and expanded polystyrene (EPS) — perform better at low temperatures than high temperatures. At lower temperatures, there is less conduction, less convection, and less radiation — so insulation materials usually work better than they do at warmer temperatures.

However, one type of rigid foam, polyisocyanurate, doesn’t follow this pattern. At temperatures below 50°F, polyiso performs worse than it does at a mean temperature of 75°F.

Although many building scientists have known about this phenomenon for years, published data from recent testing by Chris Schumacher and John Straube — two researchers at Building Science Laboratories in Waterloo, Ontario — have sparked new questions about the performance of polyiso at cold temperatures. (See links to previous GBA reports on the topic in the “Related Articles” sidebar, below.)

There are two ways that polyiso can disappoint

Some people confuse the problem of polyiso's poor cold-weather performance with a different problem — that of “thermal drift.” The phrase “thermal drift” refers to the gradual dissipation of gaseous blowing agents which are replaced by air as they exit the foam. This process takes several years.

Gaseous blowing agents are chosen for their thermal properties, so the escape of these gases causes the R-value of polyiso to decline. Polyiso manufacturers have faced decades of criticism from those who assert that thermal drift makes the R-value labels on polyiso unrealistic. Responding to these critics, polyiso manufacturers agreed in 2002 to adopt a new method of R-value testing, the “long-term thermal resistance” (LTTR) method. This testing method strives to come up with a more realistic R-value for polyiso — one that takes thermal drift into account.

Freon is a big fat molecule

In hopes of finding out more about polyiso performance at cold temperatures, I recently telephoned John Straube. In addition to being a principal at Building Science Laboratories — the lab responsible for recent cold-temperature tests of polyiso — Straube is a professor of building envelope science at the University of Waterloo. Below is a transcript of our conversation.

Q. Manufacturers of polyiso have used several blowing agents over the years. Does the problem of cold-weather performance degradation happen with all different blowing agents?

Straube: In 2000 or thereabouts, polyiso manufacturers switched away from HCFC 141B, a blowing agent that causes ozone layer damage, to a combination of CO2 and pentane. After that change, people began noticing that the R-value at cold temperatures became a problem. Older samples of polyiso perform just fine at cold temperatures — we know this because of modern tests on old foam.

There are two things that can change the R-value of polyiso. The first issue is that over time, the blowing agent is gradually replaced by by nitrogen and other atmospheric gases. The reason the blowing agents give you a better R-value [than air] is that they have lower thermal conductivity. As the blowing agent is replaced with atmosphere, the R-value of the insulation goes down.

We’ve known about that for a long time, ever since we first switched away from Freon, also known as CFC-11 [in 1993]. The industry transitioned away from Freon to reduce the problem of ozone depletion. That raised a new worry — the gradual reduction in R-value. Freon is a larger molecule [than the newer blowing agents] so it has a lot of nice benefits. For one thing, it leaked out at a much slower rate than smaller molecules.

The discussion about the gradual reduction in R-value was a kind of pissing contest for a decade, until the industry came up with LTTR, which is a way of trying to predict the long term R-value of polyiso.

At the time [when the LTTR debate was raging] Honeywell was trying to convince people to switch to their chemical [Enovate 3000], a blowing agent with a low potential for ozone depletion. But manufacturers switched instead to pentane and CO2. The Honeywell blowing agent maintains a good R-value at low temperatures. By using pentane and CO2, polyiso manufacturers ended up with R-value problems at low temperatures. These people seem to have been caught off guard. But researchers like Mary Bogdan at Honeywell knew about these problems back in 2003.

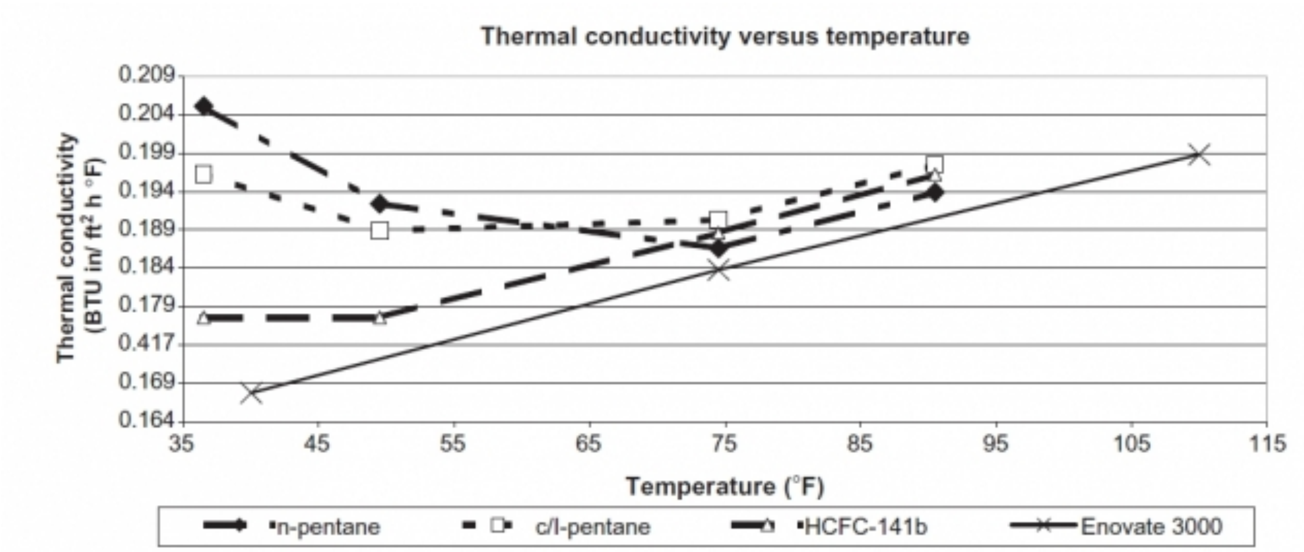


Figure 6. Thermal conductivity vs temperature at 100 days – 1.5 in. core samples.

Below 50°F, the thermal conductivity of polyiso blown with pentane (shown in the upper two lines on the graph) goes up — which is another way of saying that the insulating performance of the products goes down. On the other hand, the thermal conductivity of polyiso blown with Enovate 3000 (a rarely used Honeywell blowing agent) goes down when temperatures drop below 50°F (a shown in the lowest line in this graph) — which is another way of saying that its insulating performance improves. [Image credit: Mary Bogdan, Honeywell]

Straube: Manufacturers could have used the Honeywell blowing agent. But since then the industry has moved on. Now we have to a new push for blowing agents with a low global warming potential [GWP]. The latest solution from Honeywell is the company's new low-GWP product called HFO 1234yf. This is the gas used in some brands of closed-cell spray polyurethane foam. The same blowing agent can also be used to make polyiso, but it costs more money.

In Europe, there are impending regulations to switch to blowing agents that are low-GWP, while in North America, it is just a market-driven thing. Manufacturers are kind of getting it, because they believe that the market is headed there.

The blowing agent condenses

Q. So why is the performance of polyiso worse at cold temperatures?

Straube: We don't have evidence as to why this is happening, but we have ideas as to why this is happening. The leading contender is that we have condensation of the blowing agent within the pores of the insulation. Chris Schumacher dug into testing at a finer level of detail, hoping to could find out when the condensation occurs.

Some samples of polyiso insulation, when tested, do significantly better than others. But we can't presume that they are all blown with pentane. The manufacturers don't tell you whether they are pentane-blown.

Differences from factory to factory

Q. You've been hinting that there are other chemicals — chemicals other than pentane and CO_2 — in the blowing agents used by some manufacturers. Is the difference in performance you're talking about — differences you see when you compare samples from one factory with samples from another factory — due to contaminants in the blowing agent or chemicals deliberately added to the blowing agent by the manufacturer?

Straube: I'm not sure. Both of those are possible. So maybe the manufacturers are jiving us. Maybe they are not telling us the truth. But in apparently honest conversations with several polyiso manufacturers, they've told me that they do not fully understand why this is happening.

PIMA [the Polyisocyanurate Insulation Manufacturers Association] doesn't even believe the phenomenon is real. Some of their members don't believe it is real. They say, 'I am not 100% sure it is a real effect.' Well, it is real.

Obfuscation from PIMA

Q. I didn't find the recent PIMA press release on the topic to be convincing. It was all about averages — trying to convince builders to look at average temperatures instead of cold temperatures.

Straube: I agree. I think this is all obfuscation. They are trying to buy themselves time. You know, no one is willing to put their name on that PIMA report. Who is the person who wrote it? Why aren't they willing to put their name on that report? That report is bullsh*t. It is all talking about averages.

That's proprietary information

Straube: Here's the thing about polyiso manufacturers: They do not share their proprietary formulations. Manufacturer A may not know what is in Manufacturer B's foam. So now, when we discuss cold weather performance, they are kind of going, 'I'm really surprised.' But it's possible that they are jiving me.

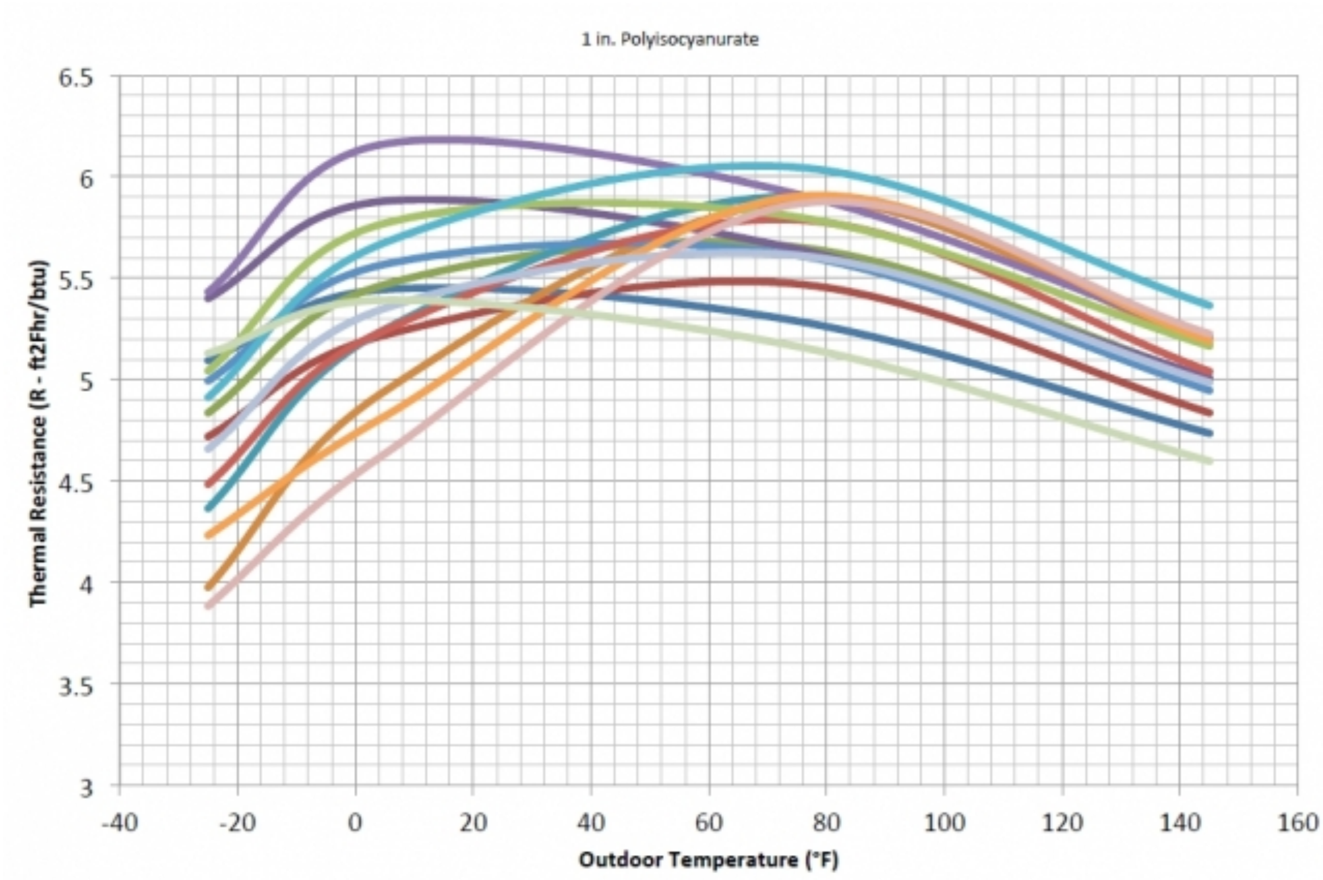
A polyiso manufacturer has two plants. One plant produces polyiso that performs better at cold temperature than the polyiso from the other plant. One hypothesis was that the two plants used different gas mixes for the blowing agent. So we said, 'Guys, will you let us understand your process better?'

Many manufacturers are in the business of manufacturing and not in the business of developing products or looking at marketing their products. I don't know of any polyiso manufacturer who has a certain idea of what is going on or who has a clear path to a solution. They could go to a new blowing agent, but that approach is expensive. They will probably try to use small tweaks to their existing systems and to see if that gets them the performance they need.

We're talking about this as if it were foam and a gas, but it is really a recipe. There are other ingredients in the recipe — fire retardants, for example. What that means is that there may be other chemical interactions that could be part of the explanation.

Polyiso R-values are all over the map

Straube: The National Roofing Contractors Association tested a lot of polyiso samples. If you look at the R-value chart, you realize that there isn't a good one and a bad one. There is a range.



[Editor's note: For a thorough explanation of this graph, see Chris Schumacher's comment (Comment #13) below.]

The idea of calling polyiso a single product is a joke. From the data we have in front of us, that idea will never work. Even at room temperature, there is a significant variation in performance from one manufacturer to another.

You’d have to be naïve to think that all brands of polyiso perform at around R-6 per inch. With variations like the ones we see in this chart, the message is: don’t stress out over the decimal points.

Why doesn't one manufacturer try to make a better product?

Straube: A market leader [among polyiso manufacturers] might say, ‘I’m going to produce the best stuff and show data proving I make the best stuff.’ But that hasn’t happened.

You know, installers of closed-cell spray foam sometimes brag, ‘We’re spraying foam at R-7 an inch.’ Maybe it’s R-7 instantly, right after you spray it, but after just a little bit of aging, you won’t getting anything near that. We’ve never seen any foam that achieves R-7. You may be spraying it, but it doesn’t make it to my lab. Lots of people make claims but no one is checking. Who is the consumer watchdog?

How much do these differences in R-value really matter?

Q. Maybe these variations from manufacturer to manufacturer aren't that important, because of all of other ways that variations can occur. After all, with many types of insulation, installation errors probably account for more variations than manufacturing differences.

Straube: It matters. The reason it matters is twofold. First, we are asking for higher R-values than we used to. The second reason is that we are getting more sophisticated. People are trying to take into account thermal bridging. A large percentage of people in the industry care about these issues, so now this becomes important. Thermal bridging through wood framing might amount to 25% of your wall, but the variation in performance from one brand of polyiso to another could be on the same order.

That is why this topic has some resonance. An increasing number of people care. And no one is checking on behalf of the consumer.

The polyiso industry deserves some credit for changing their marketing claims to say it that polyiso is R-5.7 per inch. Everyone seems to agree now that you should use R-5.7 per inch. So let's give them credit for that. That is close to the honest truth if you are talking about polyiso at room temperature. If you are selling to residential customers, that's how you are supposed to report it. But how does it perform when it is cold? What about that? There is no legal requirement [in the Federal R-Value Rule] to report that performance.

The polyiso people have done the right thing from a legal perspective. They seem to be moving their marketing claims to be legally compliant.

Any advice for builders?

Q. What should builders do: switch to EPS? Use a sandwich of two types of foam, with polyiso toward the interior and EPS on the exterior? Or just use thicker polyiso?

Straube: One option is to stick with polyiso and just make it thicker. If we do that, let's call polyiso R-5 per inch. I would stick with polyiso rather than a sandwich with polyiso plus EPS on the exterior. The problem with advising people to use 2 inches of polyiso covered with 2 inches of EPS is that now I have to have two types of material on the job site. That's a pain to do on a small residential job. Maybe you can do that if it is a big school — for a big job, it isn't so difficult. Also, it's very painful to try to install a torch-down roofing membrane over EPS, because the EPS melts. Solvents can also melt EPS. Asphalt can melt EPS.

So normally, I would advise builders to just up the thickness of the polyiso.

I'm hopeful that the polyiso people will be able to make tweaks to make it better. They don't want to have to tweak too much in their factories, though. We may see a manufacturer finally get it, finally understand that they need to do better. They may finally get their chemists to work.

Some of the polyiso manufacturers are aware of it. Some of them will try to address the issue. We are past the denial stage and moving to the grief stage.

Read more: http://www.greenbuildingadvisor.com/articles/dept/musings/cold-weather-performance-polyisocyanurate#ixzz41CjGxXhR