INTRODUCTION TO
Polyiso Foam Insulation

By John Clinton

Polyiso foam insulation is the most widely used insulation product for roofs in both new construction and in the reroofing market. As such, polyiso foam performs a variety of roles in a modern roofing system. It is the thermal insulation, minimizing heat loss and heat gain of the building and reducing operating costs; it supports the waterproofing membrane, providing a stable surface, often tapered to promote drainage; it is expected to be a structural element to withstand the common wind loads on a building when the roof membrane is attached to the upper facer; and it is fire resistant, often protecting membrane materials from the heat in tests simulating internal fires. Some functions are unpredictable, such as in cases where it becomes the working surface for all the different trades.

This built-up roof at the Charles Schultz Info Center of Sonoma State University, Sonoma, CA, utilized E'NRG'Y2 flat and tapered polyiso insulation by Johns Manville.

What is Polyiso Foam Insulation?

Polyiso foam insulation is actually a mix of polyisocyanurate and polyurethane polymers that form a closed-cell structure. Polyurethanes are produced after a chemical reaction between polyol and polymeric isocyanate, while polyisocyanurate can be produced with no polyol. The isocyanate reacts with itself to form a highly cross-linked, thermosetting polymer. For commercial polyiso foam, the polyurethane is modified with some polyisocyanurate, creating superior fire resistance and maintaining toughness. The "index" of polyiso foam roof insulation products today is 250-300. That means the amount of isocyanate is 250 to 300% of that needed to react with any polyol used. Any isocyanurate over that required to react with the polyol is used to make polyisocyanurate other polymers.

There are many different formulations to produce polyiso foam insulation. A manufacturer may select formulations based on available raw materials and the insulation product properties required by the intended use.

Polyiso Facers

The facing material most commonly used for polyiso roof insulation today is a fiberglass-reinforced cellulosic felt. While the color of the facing material may be dark gray or black, the facer does not contain asphalt. One main reason is that the polyiso foam products sold today are practically universal in compatibility with the variety of waterproofing membranes installed over them. The presence of asphalt may harm certain types of membranes installed in contact with the facer, and for this reason, polyiso foam facers do not contain asphalt. The foam-forming chemicals used to produce polyiso foam are remarkable adhesives, which is why no additional adhesive material is necessary to attach the facings to the foam core.

The Manufacturing Process

The liquid, foam-forming mix (created in isolated and temperature-controlled mix tanks), is deposited on a continuously moving lower facing, where it expands. Then the upper facing is brought into contact with the rising foam. This combination moves continuously into a heated conveyor press where the expansion of the foam and the attachment of the facers are completed.

This dynamic molding process requires some movement of the foam-forming ingredients relative to the facing materials which usually results in layers of higher-than-average density immediately adjacent to the facing. The flow of the expanding foam (which increases in viscosity until it finally sets) creates structure or "cell orientation" in the final foam. This cell orientation has an impact on some physical properties. For example, compressive strength will be different if measured in the rise direction, machine direction, or cross machine direction of the board.

Polyiso Blowing Agents

The United States is a signatory to the Montreal Protocol that limits the production and use of ozone-depleting substances. Consequently, in 1994, the polyiso industry reformulated using a new blowing agent, HCFC 141b. This compound has only about 10% of the ozone-depleting potential of CFC-11, which had been used as a blowing agent since the introduction of polyiso back in the 1970s. This transition was very complex and required new formulations and in some cases, modification or development of other new raw materials specifically designed to be used with the new blowing agent(s).

The industry is once again investigating new blowing agents, and two producers have announced the availability of polyiso foams manufactured with zero ozone-depletion blowing agents, far in advance of the HCFC 141b production phase-out date of 2003.

All the polyiso producers meet the requirements of the Clean Air Act Amendments of 1990, the U.S. legislation that implemented the Montreal Protocol and that is enforced by the USEPA. The first transition resulted in a greater understanding of many of the product properties and development of new tests to predict field performance. Details about options for blowing agents are provided later in this article.

ASTM C-1289 Product Standard

The tables in the standard show the *minimum* physical properties that a board must have if the manufacturer claims to meet the standard. All the members of the Polyisocyanurate Insulation Manufacturers Association (PIMA) manufacture roof insulation products to meet ASTM C-1289. Below is a table that shows several of the minimum properties for a 2-inch (50.8 mm), Type II insulation board (from the current C-1289 edition) with a listing of the test standard used to measure the specific property.

In the case of determining thermal resistance, several different methods may be used. Consultants should refer to the actual standard for a complete list of minimum properties and conditioning requirements.

Property	Value	Test Method
Compressive Strength (psi)	16	D-1621
Dimensional Stability (% linear change after 7 d.) -40 F, ambient humidity 158 F, 97 % RH 200 F, ambient humidity	2 4 4	D-2126
Tensile Strength (psf)	500	C-209
Water Absorption (% by vol., 2 hr. immersion, max.)	1.5	C-209
Water Vapor Transmission (perm, max.)	1.0	E-96
Thermal Resistance @ 75 F mean temperature, after conditioning	11.2	C-177, C-236, C-518, C-976, C-1114

The properties shown in the table are those that are usually called out in specifications or that may be of direct interest to the contractor in terms of handling and use of the insulation board on the job site. An important fact overlooked in use of the values shown is that they are determined on laboratory-sized samples, usually necessary due to physical limitations of measuring devices. In some cases, it may not be correct to extrapolate the values determined on small samples to the full-size board in the field. Many of the test standards contain language to clarify the purpose of the test standard, making it clear to the user.

Changes to ASTM C-1289 have been proposed and balloted using the ASTM process. Several significant changes were accepted at the April 2001 C16 Committee meeting in Phoenix and will appear in a new 2001 edition of the C-1289 product standard. They include:

- Class II roofing products have been separated into two classes, depending on the facer type, fibrous felt/glass fiber mat membrane, or polymer-bonded glass fiber mat.
- Each class contains three grades, depending on minimum compressive strength—16 psi, 20 psi, or 25 psi.
- Dimensional stability limits for length and width have been reduced to 2%.
- A note referencing ASTM C-1303 test method for long term R-value estimates will be inserted.

The current dimensional stability limits for polyiso products, as determined by ASTM D-2126, are up to 4% linear change, depending on the environmental condition to which they are subjected. This is often thought to apply to full-sized boards as installed, but in fact is limited to the 12" x 12" samples described in the product standard.

A 4% change in a board with the length dimension of 96" would allow a dimensional change of up to +/- 3.84 inches! This is hardly a practical limit and is not the intended result of the standard. The reasoning is best expressed by Section 4.3 of D-2126:

> "Dimensional changes measured by this test method can be used to compare the performance of material in a particular environment, to assess the relative stability of two or more cellular plastics, or to specify an acceptance criteria for a particular material. *The results of this test method are not suitable for predicting end-use product performance* [italics added by author] or characteristics, nor are they adequate for engineering or design calculations."

What the results mean must be considered in the context of the production industry and the use of the product. Rigid polyurethane foams have been used for over thirty years as roofing insulation and rigid polyiso boards for about twenty years in the same application. Producers and users have learned (and applied in consensus development of the standard at ASTM meetings) which laboratory test conditions and results must be met in order to establish good performance in the field; the values shown in the standard are the benchmark for the small samples tested in the laboratory. In fact, the values in the field must be superior for the product to function properly. Simply, one meets the standard with small samples to help ensure good field performance.

Similarly, the significance of compressive strength tests is often misunderstood. A common procedure employed in the event of a question about product quality is to remove a sample of the suspect product from a completed roof assembly and then subject it to a series of tests to demonstrate conformance with either contractual requirements or values advertised by the manufacturer. Of course, most people want to keep destructive sampling to a minimum so the number of samples is usually limited and hopefully not damaged to the point where test results may be suspect.

The standard test method for compressive strength, D-1621, requires that five specimens be tested. In practice, this normally means a full board width strip is cut into six or 12 pieces, conditioned, tested, and the result of the tests is quoted as an average of all the results. Since it is an average, some values may be higher and some lower, but as long as the average value is higher than the required value, the product is deemed to meet the specification. Frequently, a single, low result may be considered to disqualify a product, but that is not the intent of the standard, which recognizes normal manufacturing variability.

On the Horizon

Looking to the future, the polyiso industry again faces the challenge requiring a change in the blowing agent used to expand the foam and to continue to provide superior thermal resistance in the finished product. Beginning in 1992, the polyiso manufacturers converted from CFC blowing agents to HCFC blowing agents, a step required by the Clean Air Act Amendments of 1990, to be completed by January 1994. This change reduced the ozone depletion potential of the product by over 90% but was only a stage in the process mandated by the federal regulation to completely eliminate ozone-depleting substances in the polyiso board. The producers intend to eliminate the HCFC blowing agents by the end of 2002 due to a planned production ban of HCFC 141b.

There are two options considered or in use by the polyiso producers. Rigid polyurethane foam manufacturers in Europe have used hydrocarbon blowing agents for several years. The hydrocarbon of choice today is pentane in various isomeric forms—normal pentane, isopentane, or cyclopentane. While they have the same chemical make-up, the isomers have different molecular structure that results in different physical properties such as boiling point and solubility in the other raw materials. In the U.S., most research work has been done using pentane blowing agents, and two manufacturers are producing polyiso board today using hydrocarbon blowing agent.

Hydrofluorocarbons, or HFCs, are also being considered for use by the industry. However, there is no current commercially-available product, although one producer has announced intentions to build a commercial-scale plant for HFC 245fa to be on-line before the phase-out date for HCFC 141b blowing agent.

What can users expect from the next generation of polyiso products? During the previous conversion, the producers learned a great deal about how properties of the product are impacted by the fundamental change in blowing agent. They developed new tools to help predict and improve the performance of the finished product. It may appear simple to remove one inert blowing agent liquid and substitute another, but many aspects of the change must be considered. Is the blowing agent safe to use for production workers and users of the finished product? How must the production line be changed to handle a new material? Will the finished product deliver the same performance as before?

Because of their chemical formula, somewhat less of the hydrocarbon blowing agent will be necessary to replace the HCFCs. The result most likely will be equal or superior physical properties, such as compressive strength, dimensional stability, and facer adhesion. The current producers of polyiso foam using hydrocarbon blowing agents have claimed the same R value as for their products made using HCFCs. Because of the length of time necessary for research and conditioning, all producers have not yet published values for their products.

Final Comments

Roofing system and component manufacturers conduct extensive test programs to ensure the performance of completed roof assemblies. The simple introduction of a coverboard into a system may void Factory Mutual Research (FMR) and/or Underwriters Laboratories (UL) approvals and/or warranty of the selected system or may require additional testing to confirm performance or ensure continued approval.

The roofing system supplier may require the use of coverboards in some applications but not in others based on the type of insulation, the type of membrane selected, and the application method employed. This requirement is confirmed by the necessary research and testing to verify the performance of the system.

Before adding a coverboard or any additional material to a roof assembly, a roof consultant should contact the roof system manufacturer, specifier, and/or designer to ensure that the approvals, system performance, warranties, building codes, insurance ratings, and all other requirements comply with the specifications.

A hallmark of current polyiso products is their versatility and compatibility with many roofing systems while still meeting all the necessary code requirements, including the important fire and wind uplift ratings at FMR and UL. There is no indication that the next generation of polyiso products will be any less versatile. ■

About the Author

John Clinton is vice president of Intech Consulting Inc. Prior to Intech, he held a variety of senior management positions in research, production, and marketing at ICI Polyurethane, NRG Barriers, and Johns Manville. Intech provides consulting services on building code and related issues to manufacturers of building products and trade associations involved in the construction industry.

JOHN CLINTON