Insulation Boards for the 21st Century

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Polyiso insulation, polyisocyanurate, blowing agent, hydrocarbon, pentane, IsoGard® Foam Technology, dimensional stability, full boards, rolling load emulator (RLE), long term thermal resistivity (LTTR).

Abstract

Most polyisocyanurate (polyiso) board manufacturers will be producing boards expanded with blowing agents that do not contribute to the depletion of the stratospheric ozone layer by January 2003. In fact, production of such boards has been ongoing at a few plants in North America for more than a year. The need to eliminate the use of HCFC-141b is consistent with the Montreal Protocol of 1987 on chemicals that effect the ozone layer, as well as by mandates set forth by the Environmental Protection Agency (EPA) to meet the requirements of Title VI of the Clean Air Act (section 602).

Polyiso boards manufactured with a variety of pentanes have been evaluated using a systems approach to determine whether a change in blowing agent has an effect on the roof system and, thereby, on our customers, roofing contractors. All evaluations have been done using full-scale, commercial boards produced at the authors' plants in Jacksonville, Fla., and Salt Lake City. Advanced test methods that accurately mimic short- and long-term field performances more accurately have been employed.

Huntsman Polyurethanes, a major supplier to the insulation board industry, assisted in many of the evaluations and system/process optimizations. These drew upon the company's expertise from the transition to HCFC-141b from CFC-11 in Europe and North America and the transition to pentanes from HCFC-141b in Europe. Long-term R-Value, dimensional stability including full board evaluation from exposure in a walk-in freezer, resistance to facer delamination, and fire performance were among the many tests performed. It was seen that with changes to the formulation, including addition of flame retardant(s) and an increase in the isocyanate index, and a modification to the manufacturing process, pentane expanded boards perform equal to or better than the corresponding HCFC-141b boards.

Firestone has developed and has been manufacturing polyiso insulation boards that maintain all the long established benefits of these products while using a blowing agent that does not deplete the ozone layer. These insulation products also help mitigate

global warming concerns. Such attributes make the pentane expanded polyiso boards truly the insulation board of choice for the 21st century.

Author Biographies

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John B. Letts is the technical director of insulations in the technology department at Firestone Building Products Co. Before joining Firestone he was employed at Union Carbide, primarily in urethane technology. He received his doctorate degree in chemistry from Ohio State University in 1982. He has 17 years of experience in urethane technology, from research and development to technical service to plant support. His primary experience is in polyisocyanurate insulation board and its performance in roof systems, with extensive uretahne knowledge and experience in spray, pour in place, packaging, flexible foam, elastomers and adhesives. Dr. Letts' research has focused on the chemistry, processing and application of polyisocyanurate insulation boards in roofing applications. He was the past chairman of the technical committee at PIMA (Polyisocyanurate Manufacturers Association).

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Wayne E. Laughlin is the Division Process Engineer for foam insulations in the manufacturing department of Firestone Building Products Co. (FSBP). Prior to joining the FSBP team in 1999, he was employed in polyisocyanurate rigid foam research and development by the former Celotex Corporation. He has 24 years of experience in PUR/PIR foam technology with a broad range of expertise including formulating, process and product development, product testing, process control, technical field service and manufacturing support. He received a B.S. degree in Chemistry/Biology from the University of Central Florida in 1977.

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Sachchida joined Huntsman Polyurethanes in 1987 after receiving his doctoral degree in Materials Science and Engineering from MIT. Having worked in various applications areas, he is currently a PU application Development Associate in the Construction group of Huntsman Polyurethanes Rigid Foam Regional Development Center in West Deptford, NJ.

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Monica Ntiru is a Senior Technical Specialist at Huntsman Polyurethanes. Since joining Huntsman in 1997, she has provided technical service and development for the door and water heater industry, and is currently providing technical service to the boardstock industry. She has a Master's degree in Chemical Engineering from Howard University, and a Bachelors degree in Chemical Engineering from Texas A & M University.

Introduction

Background

It is widely accepted that energy-related issues will play increasingly larger roles in the 21st century. Sources and management of energy have become global and national priorities. Buildings use more than one-third of the energy consumed in the United States, and the heating and cooling of these building costs hundreds of billions of dollars each year. Wide use of insulation in buildings is an effective method to reduce energy consumption without sacrificing comfort. Insulation I, in fact, in a nation's national interest because conserving energy makes us less dependent on oil imports.

Polyiso was developed during the late 1970s in response to a need for a better insulation product. Polyiso boards have high R-value per inch, meaning a higher insulating value can be achieved with polyiso than the same thickness of any other insulation material. It is the only plastic insulation to pass both the UL 1256 (Fire Test of Roof Deck Constructions) and FM 4450 (Class 1 Insulated Steel Deck Roofs) fire tests without a thermal barrier. Its unique chemistry makes it dimensionally stable throughout a large temperature range [-100 °F (-73° C) to +250° F (121° C)]. Polyiso boards meet the requirements of all model building codes, including CABO (Council of American Building Officials), BOCA (Building Officials & Code Administrators International), ICBO (International Conference of Building Officials), SBCCI (Southern Building Code Congress International), IBC (International Building Code) and IRC (International Residential Code). These coupled with cost-effective installation make polyiso the insulation of choice for most roof assemblies. According to NRCA's 2000-2001 Annual Market Survey, polyiso insulation accounted for 54.8 percent of all low-slope roof systems and 44.2 percent of the steep-slope roof systems during 2000.

Insulation and the Environment

Although insulation products are inherently better for the environment from an energy consumption point of view, their use of stratospheric ozone-depleting blowing agents has, until recently, limited their total environmental benefit. Use of nonozone-depleting blowing agents to make insulation products enhances the environmental attractiveness of such products. Concerns about stratospheric ozone led to a global agreement to phase out ozone-depleting chemicals. This agreement is referred to as the Montreal Protocol and has now been signed by more than 180 nations. As a founding signatory to this agreement, the U.S. government mandated implementation of this protocol in Title VI of the Clean Air Act and made the EPA responsible for the program [1]. The switch from CFC-11 to HCFC-141b in 1993 was the first step taken by the polyiso manufacturers towards reducing the ozone-depletion effect of their product. The work outlined in this paper represents the final phase of the challenge to eliminate ozone-depleting blowing agents.

Besides ozone-depletion, another environmental issue confronting us today is global warming. Once again, as outlined below, authors' company has selected a blowing agent that contributes minimally to the global warming directly and yields R-values that enhance the effectiveness of such products to mitigate global warming. It is anticipated that other manufacturers of polyiso boards will follow the same strategy and such closed-cell boards will be the only highly insulating, environmentally friendly, cost-effective plastic foam boards available in North America.

Blowing Agent Selection

The purpose of a blowing agent in polyiso insulation foam is two-fold. It expands the polymer matrix to the requisite density and provides for increased energy efficiency through its intrinsically low thermal conductivity and its ability to remain in the cell for a long time. Earlier publications have discussed the various available blowing agent options and the large number of factors that must be considered while making a final selection [2-4]. After a deliberate and thorough analysis of all available data, the authors' company has chosen pentane as the blowing agent to replace HCFC-141b. Pentanes offer the best environmental properties as evidenced by zero ozone-depletion potential, extremely low global warming potential (GWP) and low atmospheric lifetime in Table 1. Clearly, the physical and flammability characteristics of pentanes are different from that of HCFC-141b and this required, as elaborated below, significant reformulation and capital investment. At the same time, the fact that pentanes have been in use to make polyurethane foam insulation boards in western Europe since 1992, gave confidence that pentane could be used safely and cost-effectively to produce polyiso boards meeting North American market requirements [5].

The transition from HCFC-141b to pentanes involves changes in processing and formulation. Table 1 outlines the physical properties of HCFC-141b relative to the three pentane isomers. The first property to note is the molecular weight of the blowing agents. The higher the molecular weight, the more blowing agent required to expand the foam to equivalent density. Hence, on a weight basis, it takes approximately 40 percent less pentane to expand foam to the same density as HCFC-141b.

Table 1: Physical and environmental properties of hydrocarbons available as blowing agents.

	HCFC-141b	Pentane		
		Cyclo-	n-	Iso-
Molecular Weight	117	70	72	72
Normal Boiling Point, F (C)	90 (32)	121 (49)	97 (36)	82 (28)
Gas Conductivity at 77 F (25 C), Btu-in/hr-ft^2-^{o}F (mW/mK)	0.072 (10.4)	0.083 (12)	0.104 (15)	0.099 (14.3)
Vapor Pressure, psia (kPa) @ 86 F (30 C) @ 68 F (20 C)	 13.6 (94) 10.0 (69)	 7.7 (53) 4.9 (34)	 11.9 (82) 8.3 (57)	 16.0 (110) 11.3 (78)
Flammable Limit in Air (vol. %)	7.6 – 17.7	1.4 – 8.0	1.3 – 8.0	1.4 – 7.8
ODP (with CFC-11 = 1)	0.11	0	0	0
GWP (with CO_2 = 1)	700	11	11	11
Atmospheric Lifetime, years	9.2	Few days	Few days	Few days

The physical properties of foam can be affected by the amount of blowing agent remaining in the polymer network. Excessive amounts of blowing agent can plasticize the polymer network and weaken cell walls, which can lead to lower board strength and poor cold-age dimensional stability. During the transition from CFC-11, it was recognized that HCFC-141b could plasticize the foam because of its higher solubility and higher usage level [6]. HCFC-141b expanded boards performed well after the formulation and processing were modified relative to a standard CFC-11 expanded board. The lower overall usage and lower solubility of pentanes, as compared with HCFC-141b, make the cell walls stronger and less susceptible to cold-age dimensional stability changes [7]. Only cylcopentane has any appreciable solubility in the polymer network.

Depending on the amount and types of pentane used, the pressure in cells can be greater, less or equal to that with HCFC-141b. The greater the cell pressure, especially at lower temperatures, the less susceptible the cell and foam are to shrinkage.

Isopentane and n-pentane have limited solubility in the precursors to foam manufacture. The precursors are the B-Side, which typically includes all the components except the isocyanate and the A-Side, which is the isocyanate. As a result, they have limited solubility in the final product. Although too much solubility is not desirable, too little is not good either because it can lead to poor cell structure. The way the chemicals are mixed together, sometimes with emulsifiers, can minimize or eliminate this concern.

Although it is true pentanes are flammable, changes in the formulation make the final product equivalent to HCFC-141b foam in terms of standard fire performance tests [4, 8]. Three changes to the formulation were incorporated to mitigate the flammability of the pentanes. First, flame retardants were added to minimize the buildup of flames caused primarily by the presence of halogens, such as chlorine. Second, typically these flame retardants contain phosphorus, as well as a halogen, which produces char that protects the underlying fresh foam from further damage. Other types of flame retardants can be used that augment the use of these standard flame retardants. And third, the higher index of the foam also serves to promote more char formation.

Gas thermal conductivities roughly correlate to the R-Value of the board. Although the gas thermal conductivities of the pentanes are slightly higher than HCFC-141b, the smaller cell size generally found with pentane expanded boards along with their lower rates of diffusion offset this disadvantage. This topic will be discussed in more detail later in the paper.

Board Manufacturing Formulation Considerations

A typical pentane formulation contains most, if not all, of the following components:

Polyester polyol
Flame retardant(s)
Trimerization catalyst(s)
Amine catalyst(s)
Surfactant
Small amounts of added water
Pentane(s)
Polymeric isocyanate

Plant Modifications

The conversion to pentane technology requires a significant capital investment. To ensure the maximum in product performance and safety, and minimize environmental impact, approximately 1$ million was expended to convert each plant. This investment involved special ventilation equipment to control any pentane vapors during the manufacturing processes, unique technology (IsoGard® Foam Technology) to blend all the components effectively and a regenerative thermal oxidizer (RTO) to burn any significant pentane vapors that are exhausted during the manufacturing process.

Conversion Status

In North America, the conversion process is further along in Canada relative to the United States due to local issues. In the United States, two companies have started producing boards expanded with pentanes at least in some of their plants, and other conversions are imminent as of this writing. All U. S. polyiso board manufacturers are expected to switch to alternative blowing agents by the EPA mandated Jan. 1, 2003 deadline; however, it is possible to stockpile and use HCFC-141b for a short period of time after this date. Hydrocarbons, such as pentane, are also expected to be the blowing agent of choice; however, blends of pentane with HFC-245fa, HCFC-22, or other EPA compliant blowing agents are possible. In Europe, insulation board manufacturers have successfully been using pentanes to expand the foam for almost a decade.

It is expected that this conversion and subsequent optimization will follow the HCFC-141b optimization process where small incremental changes are made over the course of several years. For example, initially all board manufacturers switched from CFC-11 to HCFC-141b around Jan. 1, 1994. Then, a couple of years later, most companies added small amounts of HCFC-22 for increased foam efficiency and better dimensional stability. In this most recent conversion, there are more options available to board manufacturers, including cyclopentane, isopentane, n-pentane and HFC-245fa and possibly others. Hence, fine-tuning in the years ahead is anticipated.

It is with this knowledge and expectation that the authors' company decided to convert Jacksonville relatively early and considerably before the Jan. 1, 2003, deadline. The time spent in Jacksonville has allowed the company to convert other plants relatively easily and with a lot of confidence that the product will perform. A systematic approach has been used to evaluate the new pentane-expanded board and reflected in the conversion schedule. Results from the authors' plant in Jacksonville and recent results from the Salt Lake City plant follow.

Board Performance

During the development and optimization process, primarily in the Jacksonville plant, the technical expertise and assistance of Huntsman Polyurethanes was utilized. This company was earlier involved in the transition to HCFC-141b from CFC-11 in Europe and North America and the transition to pentanes from HCFC-141b in Europe. During these transitions, it developed tools to better evaluate the long-term performances of urethane boards, especially in terms of dimensional stability and R-Value [4, 6, 7].

Pentane board performance in a variety of 2-inch (25 mm) thick boards is outlined in Table 2 relative to boards made with HCFC-141b. Using the same basic formulation in Table 2, the full range of product thickness is delineated in Table 3. Table 4 shows dimensional stability performance in full boards made with IsoGard® Foam Technology relative to two established small-scale tests. These boards were all manufactured with a proprietary pentane blend.

Appearance

These pentane blown polyisocyanurate boards are identical in appearance to HCFC-141b blown boards. The rectangular or tapered boards are produced in the standard dimensions of 4 feet by 8 feet (1.2 m by 2.4 m) or 4 feet by 4 feet (1.2 m by 1.2 m) and in a range of thickness from one inch (25 mm) to four inches (102 mm).

The cores of the boards are composed of a rigid, off-white colored, essentially uniform micro-cellular foam structure sandwiched between two black fibrous felt facers.

Compressive strength

Compressive strength is reflective of overall strength of a board. In roofing, good compressive strength is required so a board can withstand normal installation traffic.

Type II, Class I polyisocyanurate (ASTM C 1289-01) is classified into three grades of compressive strength measured in the thickness direction of a board. Grades I, II and III have minimum compressive strengths of 16 (110), 20 (138) and 25 (172) psi (kPa), respectively. Tables 2 and 3 clearly show that a range of compressive strengths [from 18.3 psi (126 kPa) to approximately 30 psi (206 kPa)] can be produced depending on formulation, thickness and processing conditions.

Dimensional Stability – standard tests, extreme tests, and full board evaluations

Polyisocyanurate boards are tested for dimensional stability according to the guidelines specified in the ASTM C 1289-01 product standard. ASTM C 1289-01 refers to ASTM D 2126 for dimensional stability testing and lists the conditions to be used. In the humid-aging condition, a 12-inch by 12-inch (305 mm by 305 mm) test specimen is exposed at 158° F (70° C) and 97% relative humidity for seven days. The changes in length, width and thickness are measured. The maximum allowable change in length or width is 2 percent.

As shown in Table 2, humid-aged dimensional stability results were acceptable and below 2 percent linear change for the pentane boards. The same was true for the HCFC-141b board, except for one case where it was slightly high in the length direction.

The standard cold-age dimensional stability results in Table 3 for pentane expanded boards, as well as for HCFC-141b boards, were well below 1 percent linear change.

A more demanding but time consuming test for dimensional stability is the Dimvac test developed by Huntsman Polyurethanes during the 1990s [6]. Referred here as the extreme dimensional stability test, a vacuum is pulled on a 4- by 4- by 1-inch (102- by 102- by 25 mm) core foam to evacuate from the foam cells fast diffusing gases, such as carbon dioxide, thereby creating conditions for the most severe shrinkage. A small amount of carbon dioxide is typically generated in foam production. Under the right set of conditions, it diffuses out of the cells quickly and leaves a greater partial vacuum, which makes the foam more susceptible to unexpected dimensional stability problems.

The sample is then exposed to a –13° F (–25° C) environment for seven days and the maximum linear change is measured. As shown in Tables 2 and 3, the pentane boards showed less than 1 percent linear change whereas the HCFC-141b boards showed less than 2 percent linear change, and neither showed any visible distortion. Such observations under this extreme dimensional stability test are indicative of good long-term dimensional performance [6].

Several 4- by 8-foot (1.2- by 2.4-m) laminate boards, manufactured specifically to give various levels of dimensional performance, are currently being aged in a walk-in freezer nominally maintained between –20° to –5°F (-29° to –20°C) at the Huntsman Polyurethanes West Deptford, N.J., facility. The dimensional stability as determined by ASTM D 2126-00 and by the extreme test described is also being measured. Results will be reported during the presentation.

Table 2: Physical properties for 2" board expanded with a Proprietary Pentane Blends or with HCFC 141b.

	Proprietary Pentane Blends				HCFC-141b	
	#1	#2	#3	#4	#1	#2
Compressive Strength, psi (kPa)						
Thickness direction	22.9 (158)	18.4 (127)	18.3 (126)	24 (165)	22.3 (154)	24.1 (165)
Grade	2	1	1	2	2	2
Cold Aging Dim. Stability						
7 days @ -40°F, Amb. RH						
% change in length	0.1	-0.1	-0.7	-0.2	-0.1	-0.1
% change in width	0.0	-0.2	0.4	0.1	0.0	-0.2
Ultimate Dimensional Stability Test						
(Dim Vac)						
% change in length	-0.7	-0.7	-0.6	0	-0.5	-1.3
% change in width	-0.2	-0.2	-0.3	0.1	-0.4	-0.6
Humid Aging Dimensional Stability						
7 days @ 158°F , 98% RH						
% change in length	0.2	1.1	1.2	0.5	0.8	2.4
% change in width	0.1	1.2	0.8	0.3	0.3	1.3
Closed cell content, %	92	90	91	92	90	88
Long Term Thermal Resistance						
Hr.ft^{2}F/Btu in (mK/W)						
3"	18.6 (129)	18.9 (131)	18.6 (129)	18.6 (129)	18.9 (131)	18.8 (130)
2"	12.0 (83.6)	12.2 (85.0)	12.0 (83.6)	12.2 (85.0)	12.2 (85.0)	12.0 (83.6)
1"	5.9	6.0	NA	NA	NA	NA
Rolling Load Emulator						
(RLE) @ 20 psi						
(No of Passes / % Delamination)						
Top	100 / 0	100 / 0	100 / 0	100 / 0	100 / 5	100 / 0
Bottom	100 / 0	100 / 0	100 / 0	100 / 0	100 / 0	100 / 0

Table 3: Proprietary Pentane Blends - Physical properties for boards of various thickness

Board Thickness	1"	1.5"	2"	2.7"	4"
Compressive Strength, psi (kPa)					
Thickness direction	26.8 (185)	23.4 (161)	26.1 (180)	30.8 (212)	24.0 (165)
Grade	3	2	3	3	2
Extreme Dimensional Stability Test					
7 days vacuum, 7 days @ - 13°F / Amb. RH					
% change in length	-0.1	-0.1	0	0.1	-0.1
% change in width	-0.1	0.1	0.1	0.2	0.1
Closed cell content, %	91	91.1	92	91	90
Long Term Thermal Resistance, Hr.ft^{2}F/Btu in (mK/W)	5.9* (41.0)	9.0* (62.5)	12.1 (84.0)	16.7 (116.0)	25.2 (175)
* Estimates based on data to date					
Rolling Load Emulator (RLE) @ 20 psi (No of Passes / % Delamination)					
Top	100 / 0	100 / 0	100 / 0	100 / 0	100 / 0
Bottom	100 / 0	100 / 0	100 / 0	100 / 0	100 / 0

Resistance to Facer Delamination

The RLE (rolling load emulator) has been a valuable tool in reducing facer delamination problems in the field [2, 9]. Figure 1 is a photocopy of the testing equipment that mimics a rolling load on a roof. Prior to installing this equipment in all of our plants, the plant personnel did not have a gauge on how well the product being made was going to resist facer delamination. Now, there is a gauge and we have seen marked improvement in all plants since it was first installed.

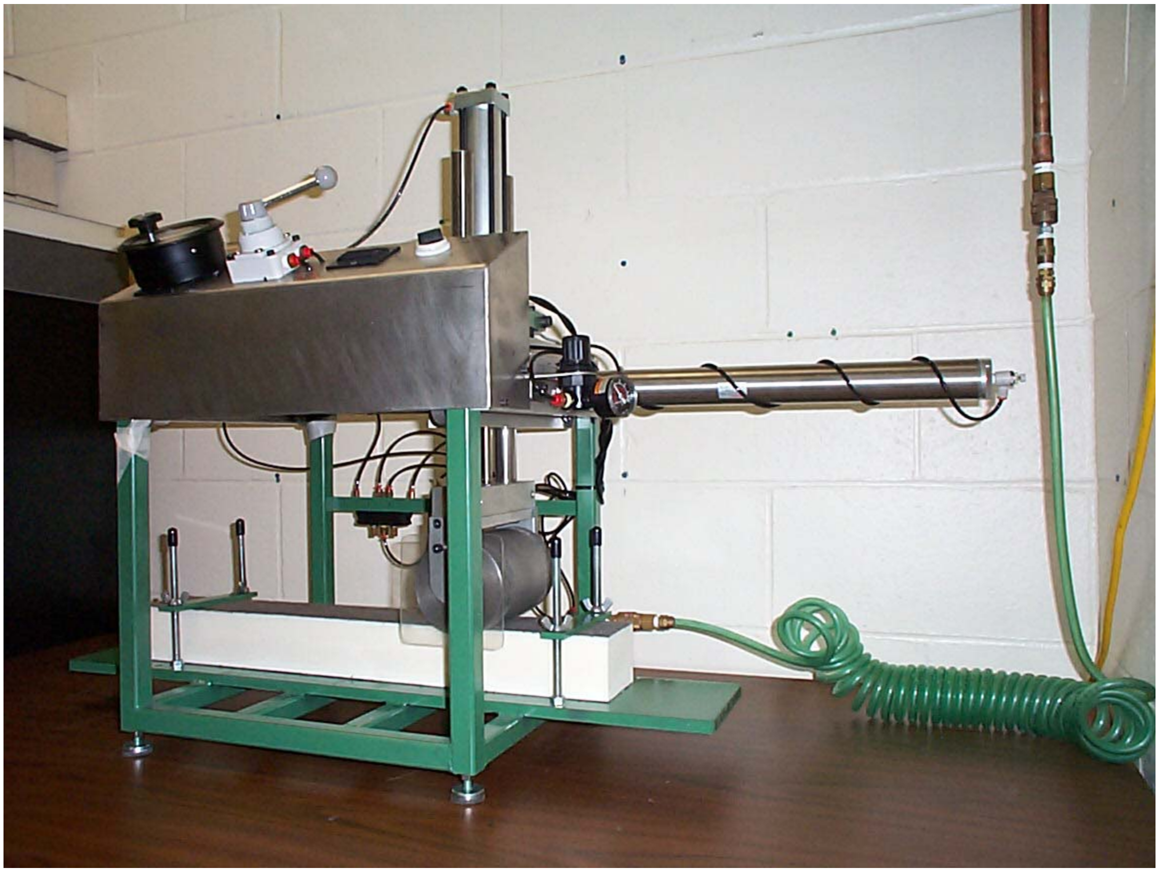

Figure 1

The method used in the authors' plants is to conduct passes over a board at 20 psi (138 kPa) and record the percent delamination, if any. A sample is deemed to pass if there is less than 25 percent delamination after 100 passes.

In cooperation with PIMA (Polyisocyanurate Insulation Manufacturers Association) and others, the authors' board manufacturing company is working with ASTM (American Society for Testing and Materials) International to develop it as a standard test method. A task force has been set up, two meetings have been held, and a procedure in standard ASTM format has been submitted for review and comment.

Results in Tables 2 and 3 with pentane and HCFC-141b boards showed no delamination after 100 passes.

The RLE is discussed more fully in an accompanying paper in the 12th International Roofing and Waterproofing Conference titled "Study of Polyisocyanurate Rigid Foam Board Facer Behavior Using the Rolling Load Emulator" by René Dupuis, John B. Letts, and Tim D. Tackett.

R-Value Performance

When polyurethane boards were first introduced in the 1960s the aging process was not well understood and board manufacturers marketed their R-Values as manufactured, which is what they could get their hands around initially. As knowledge and experience increased, board manufacturers adopted PIMA Technical Bulletin, which measured the R-Value after 180 days conditioning at 73° F (23° C)and 50 percent relative humidity. This approximated the point at which a majority of the aging had been completed and any additional aging was small and difficult to quantify.

Long Term Thermal Resistivity (LTTR)

During the past few years, the technical background has been laid to accurately predict the long term R-Value of polyiso insulation boards [10]. Essentially, by measuring the R-Value of a thin sample of a board as a function of time the long term R-Value can be determined. This is also known colloquially as the slicing and scaling technique. The general method along with the theory and background are described in ASTM C 1303 and other publications [11]. A prescriptive method for determining the long term R-Value using the slicing and scaling method, CAN/ULC-S770-00 [12], has been recently investigated and approved for use in Canada. In this method, 15-year, time-weighted average R-Values are measured.

The method, S770, takes thin samples between 6 mm (0.24 inches) and 12 mm (0.47 inches) from the core and the surface and ages them. R-Value measurements of these thin samples are taken initially and after various times that correspond to different product thickness. The thicker the full product, the shorter time it takes to obtain results; the thinner the product, the longer it takes to obtain results, which is counterintuitive. The reason for this is the acceleration for the thicker product is greater than for the thinner product. A ratio of final R-Value divided by initial R-Values for these slices at different times for different product thicknesses is developed and applied to the initial full thickness R-Value. This method requires a board from the middle of the thickness range to be used as the test sample. All LTTR numbers are derived from this sample.

Today, it is possible to confidently specify and order polyiso with long-term, design R-Values. In fact, board manufacturers in Canada have begun publishing LTTR numbers as per S770 with pentane expanded boards and also with HCFC-141b expanded boards. Although they are somewhat lower than the 180 days number, these numbers more closely approximate the useful life of a roof assembly. Work in the authors' laboratories has shown that the LTTR numbers for most pentane boards are similar to those expanded with HCFC-141b. Generally, a HCFC-141b board starts out at a higher R-Value as manufactured but ages faster than comparable boards expanded with pentane. In contrast, most pentane expanded boards start out as manufactured at a lower R-Value but age slower. This is because the cell size of pentane expanded foam is generally finer than corresponding foam expanded with HCFC-141b. This is illustrated in Figure 2. Also, pentane diffuses slower than HCFC-141b at the nominal use temperatures of boards [7]. The net effect with most pentane expanded boards is the LTTR numbers as per S770 are similar to those with HCFC-141b.

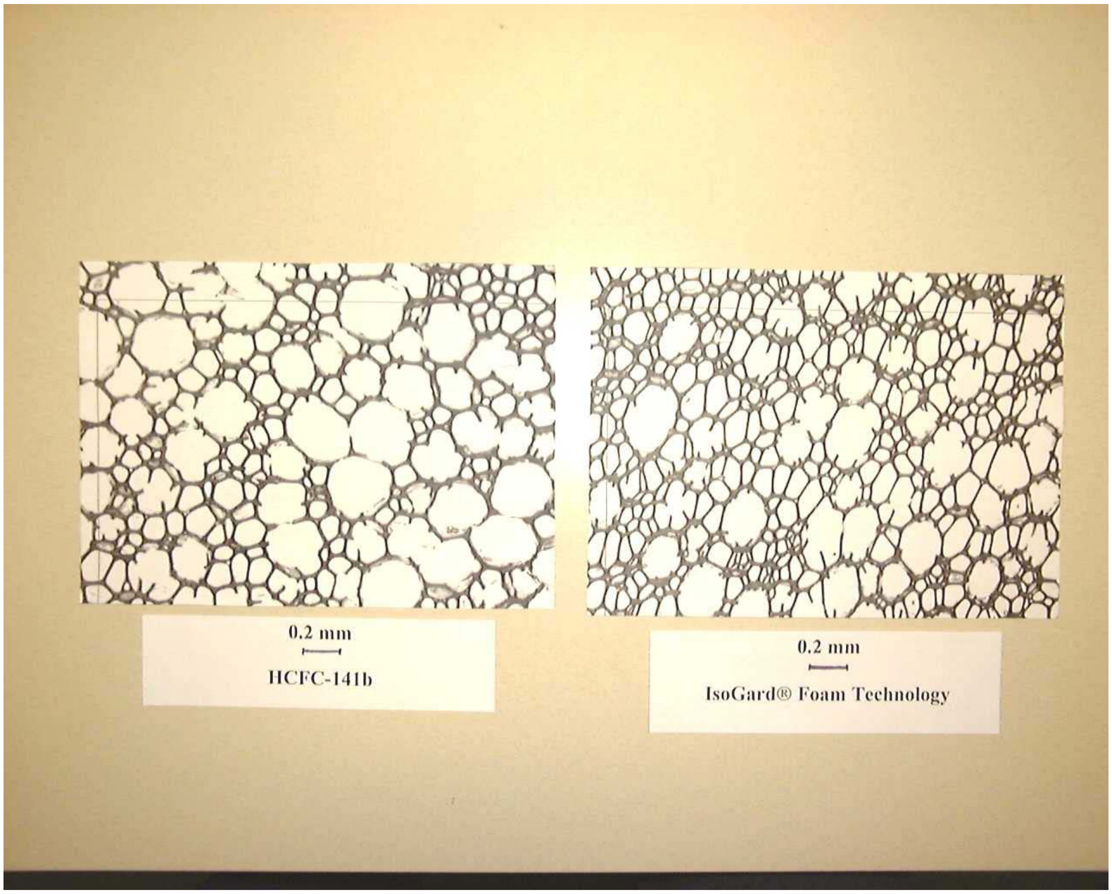

Figure 2

Tables 2 and 3 give typical values for various thickness products. Although the R-Values are a little lower than the corresponding PIMA 101 values, the time period covered is significantly longer. The LTTR numbers in these tables agree with recent independently derived results from three companies in Canada that PIMA recently reported at the NRCA Convention in San Antonio.

Review of the data in Table 3 also reveals that the LTTR per inch increases as the product thickness increases, which is expected. Essentially, it takes years for air to completely diffuse into cell walls and decades to centuries, depending on cell / board thickness for the blowing agent, to completely leave the cells. The thicker the product, the longer it takes these diffusion processes to complete. Hence, this is the reason for the increase in LTTR per inch as product thickness increases.

Fire Performance

High index polyiso boards have excellent flammability properties compared to other plastic foams. These thermosetting plastic foams readily form a char layer when exposed to flames or excessive heat. Although pentanes are inherently more flammable than HCFC-141b, this increased flammability is offset by the introduction of or increases in flame retardant, and an increase in isocyanate index. Additionally, there is approximately 40 percent less pentane by weight than HCFC-141b in a typical foam sample. HCFC-141b is also flammable but less so than pentanes.

The char layer formed by polyiso products will swell or intumesce when sufficient heat is applied. The higher the index and, typically, the higher the flame retardant level (with most flame retardants), the more intumescent char there is. Pentane expanded polyiso boards have exhibited this action.

Pentane expanded boards have passed exterior flame tests (UL 790), a standard flame spread and smoke development test (ASTM E 84), foam degradation tests (ASTM E 108), and both the interior flame spread (UL 1256 – Steiner tunnel) and the demanding Factory Mutual Research Calorimeter test (FM 4450).

Wind Uplift Performance

In many roofing applications, roof insulation board is an integral part of the system holding the roof assembly to the roof deck. The foam with the facer can be attached to the roof with fasteners and plates or with adhesives, such as asphalt and polyurethane systems. The membrane is then attached to the insulation board with bonding adhesives as with EPDM fully adhered roofs, for example. It is important for the foam / facer to distribute the load in the presence of a wind event. The more the load can be spread, the stronger the overall roof system.

The wind uplift test is typically performed on 5- by 9-foot (1.5- by 2.7-m) or 12- by 24-foot (3.7- by 7.3-m) wind uplift tables to evaluate this property. Insulation boards expanded with pentane have passed equivalent and appropriate wind uplift table tests, such as, FM 1-90 in the reduced fastener pattern at 2.0-inch (51-mm) board thickness. A number of the physical properties of the board, such as, pull-through tests, flexural strength, tensile strength, and compressive strength, correlate to some degree with wind uplift performance. The higher the number, the better the performance. Generally, it has been observed that these properties are somewhat higher with pentane expanded boards. This may be related to the higher index and the lower amount of blowing agent by weight in pentane expanded boards.

Field Performance

Test Roofs

Millions of square feet of insulation with pentane expanded boards have been used on roofs primarily in the Southeast and the western states from the authors' plants, although selected jobs have been done in the Midwest. The boards are dimensionally stable and meet the appropriate building codes. Installation and handling on the roofs are identical to boards made with HCFC-141b.

Compatibility with Other Components on the Roof

Part of the reason Polyiso has been successful as the insulation board of choice is the board's wide compatibility with other roofing components. It is resistant to most common solvents in fully adhered situations; can be used with asphalt systems; can accommodate fasteners and plates; and although not a structural element of a roof assembly, it can accommodate modest amounts of roof installation traffic. And because it is a thermoset plastic insulation, it is not only resistant to most solvents, it can also withstand temperatures as high as 210 F and higher if necessary. By comparison, thermoplastic insulations can degrade in the presence of many common solvents.

Pentane expanded boards have been evaluated in asphalt systems, fully adhered EPDM and other single ply systems and appear to be more heat resistant than polyiso boards expanded with HCFC-141b.

Storage and Handling

As per current standard practice, the product should be protected from the elements by storing on pallets or risers at least 4 inches above the ground and fully tarped. The product must be maintained and installed in a dry condition at all times.

These insulation products are nonstructural, nonload bearing materials. A finished roof assembly should be protected from excessive roof traffic with proper walkway materials.

Like other plastic materials, polyiso foam will burn if exposed to a flame of high heat and intensity.

Comparison of Roofing Insulation Alternatives

Pentane blown Polyiso boards offer advantages in insulating performance compared with other commonly used roofing insulation. Several other advantages include the environmentally green properties of the board (CFC and HCFC free) and higher compressive strength. Table 5 shows a comparison of different roofing insulation materials. Pentane polyiso boards are the superior insulation choice when comparing the different features of the competing products.

Table 5: Comparison of pentane blown polyiso vs. other roofing insulation

	Pentane polyiso	HCFC-141b polyiso	EPS	XPS	Spray 141b	Fiber-glass	Mineral wool
Ozone Depleting Potential (ODP)	+++	+	+++	+	+	+++	+++
Global Warming Potential (GWP)	+++	-	+++	-	-	+++	+++
Thermal Resistance (R-value/in)	+++	+++	+	++	+++	-	-
Compressive Strength	+++	++	+ / -	+++	+++	-	-
Dimensional Stability	++	++	+	+	++	+++	+++
Moisture Resistance	++	++	-	+++	++	-	-
Fire safety in use	++	++	-	-	++	+++	+++

+ = good **++ = better**
+++ = best **- = poor**

Conclusions

The polyiso board industry is expected to complete the conversion to pentane polyiso boards by January 1, 2003. These boards have zero ozone depletion potential, minimal global warming impact and equal or better performance. This change is consistent with the United Nations, Montreal Protocol of 1987, on which the United States was a signatory, and with Title VI of the U.S. Clean Air Act. Firestone Building Products has been successfully producing pentane expanded boards at the Jacksonville facility for more than two years, and the boards have equal or better in performance relative to the HCFC-141b boards.

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