Polyiso's R-value

NRCA recommends polyisocyanurate insulation be specified by its desired thickness

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This month, U.S. polyisocyanurate insulation manufacturers will begin reporting long-term thermal resistance (LTTR) values based on updated and revised test methods. As a result, LTTR values will be less than values previously used.

Theory of foam aging

The R-value of closed-cell, polyisocyanurate insulation is affected by the amount of gas in the foam's cells. Because the R-value of most blowing agents (gases) is greater than that of air, polyisocyanurate insulation's R-value is greatest when there is more blowing agent and less air in the foam's cells.

During polyisocyanurate insulation's service life, air diffuses into the foam's cells and the blowing agent diffuses out or partially dissolves into the cell's polymer matrix. Each of these processes occurs at rates dependent upon temperature, pressure and the foam's polymer type, gas type and cell structure. Generally, the inward diffusion of air occurs at a much faster rate than the outward diffusion of the captive blowing agent. Diffusion rates also are affected by the foam's thickness and type of facer sheets.

Because of this phenomenon, the R-value of polyisocyanurate insulation is not constant. Its R-value is highest soon after manufacturing and decreases at a relatively significant rate during the earliest portion of its service life. As polyisocyanurate insulation ages further, its R-value decreases at a slower rate until the gas concentration in the foam's cells equals the gas concentration in air, at which point its R-value no longer changes with time.

R-value testing

The R-value of most insulation products used in the roofing industry is tested using ASTM C518, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus," originally published in 1963.

When urethane foam and later polyisocyanurate insulation boards were introduced to the U.S. roofing industry, their R-values typically were reported using ASTM C518 testing conducted immediately after manufacturing and before the cell gas had diffused from the foam's cells and been replaced with air. As a result, R-values of 7.2 or higher per inch thickness were reported.

Beginning in the 1980s, the Roof Insulation Committee of the Thermal Insulation Manufacturers Association's (RIC/TIMA's) conditioning procedure (RIC/TIMA 281-1) and later the Polyisocyanurate Insulation Manufacturers Association's (PIMA's) conditioning procedure (PIMA 101) called for preconditioning foam samples at room conditions (75 F) for 180 days before R-value testing. This preconditioning was an early attempt at addressing polyisocyanurate insulation's R-value loss over time. Using RIC/TIMA 281-1 or PIMA 101 conditioning, R-values of about 6.6 per inch thickness were reported.

In 1987, based on extensive testing of in-service R-values, NRCA and the Midwest Roofing Contractors Association issued a joint technical bulletin regarding the in-service R-values of polyisocyanurate and polyurethane insulation. The bulletin recommended using an in-service R-value of 5.6 per inch of foam thickness. This in-service R-value was intended to account for polyisocyanurate insulation's R-value losses over time and provides a more realistic design R-value for polyisocyanurate insulation during a roof system's entire design life.

LTTR

During the early 1990s, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tenn., in cooperation with NRCA, PIMA and The Society of the Plastics Industry, conducted research that led to the development of a new methodology for assessing aged R-values for closed-cell plastic foam insulation. This methodology involves thin slicing and accelerated aging of polyisocyanurate insulation specimens and testing their R-values using ACTM C518—a process called LTTR.

In 1995, ASTM International published an LTTR test method, ASTM C1303, "Standard Test Method for Estimating the Long-Term Change in the Thermal Resistance of Unfaced Rigid Closed-Cell Plastic Foams by Slicing and Scaling Under Controlled Laboratory Conditions," based upon this new methodology.

In 1998, the Standards Council of Canada and Underwriters Laboratories of Canada published CAN/ULC-S770, "Standard Test Method for Determination of Long Term Thermal Resistance of Closed-Cell Thermal Insulation Foams." CAN/ULC-S770 is based on ORNL's research and ASTM C1303 and provides R-value data based on a 15-year time-weighted average, corresponding to a product's R-value five years after manufacturing.

Beginning in 2003, U.S. polyisocyanurate insulation manufacturers began reporting LTTR values using a third-party certification program, referred to as PIMA's QualityMark[cm] program. This program used the 2003 edition of CAN/ULC-S770 for LTTR determination. LTTR values applicable in the QualityMark program from 2003 through 2013 are shown in Figure 1.

In 2009, CAN/ULC-770 was updated. ASTM C1303 also has been updated several times since its original publication; the current edition is ASTM C1303-12.

Polyiso thickness (inches)	LTTR
1.0	6.0
1.5	9.0
2.0	12.1
2.5	15.3
3.0	18.5
3.5	21.7
4.0	25.0

Figure 1: 2003-13 LTTR values

In June 2013, PIMA announced its QualityMark-certified LTTR program was being updated to incorporate using either CAN/ULC-S770-09 or ASTM C1303-11 for LTTR determination. The updated test methods are reported to result in a more accurate determination and reporting of LTTR values. The effective date for this change was Jan. 1, 2014. The new minimum LTTR values are slightly less than those from 2003 through 2013 and shown in Figure 2. The slightly increasing LTTR values per inch thickness are an indication of the slightly lower cell gas diffusion rate with thicker products.

Polyiso thickness (inches)	LTTR
1.0	5.6
1.5	8.4
2.0	11.4
2.5	14.3
3.0	17.4
3.5	20.3
4.0	23.6

Figure 2: 2014 LTTR values

NRCA recommendations

Although NRCA participated in the ORNL research and continues to participate in the task group responsible for the LTTR test method, NRCA does not recommend using LTTR for roof system design. The LTTR method for determining and reporting R-values may be considered appropriate for laboratory analysis and research comparisons; however, NRCA does not consider LTTR to be appropriate for roof system design where actual in-service R-values can be an important aspect of roof system performance.

ASTM C1303 is performed after accelerated aging test specimens under controlled laboratory conditions, indicated as 72 F ± 10 F. ASTM C1303 also defines "long term" as five years, which is intended as the time-weighted average of a 15-year period. The implication of this time-weighted average approach is actual R-values may be higher than the LTTR value for an initial five-year period, but R-values also will be less than the LTTR value from years five through 15.

The design service lives for most roof systems is longer than the five-year time-weighted average because 20-year and longer expected roof system service lives and roof system guarantees now are commonplace. Also, rooftop temperature conditions typically vary significantly from ASTM C1303's prescribed laboratory conditions. Therefore, NRCA does not view LTTR as being representative of design intentions or actual rooftop conditions.

In 2005, NRCA participated in a limited testing program that showed a majority of polyisocyanurate insulation samples tested one to four years after manufacturing had actual R-values less than their LTTR values.

In 2009, NRCA conducted R-value testing of polyisocyanurate insulation obtained through distributors; samples ranged in age from four to 13 months. R-values were tested at a 75 F mean reference temperature as well as 25 F, 40 F and 110 F and found to be less than their published LTTR values.

In 2011, with the publication of *The NRCA Roofing Manual: Membrane Roof Systems—2011*, NRCA revised its 1987 design R-value recommendations to account for polyisocyanurate insulation's R-values at different temperatures.

NRCA recommends designers use the design R-values shown in Figure 3 for polyisocyanurate insulation based upon the predominant condition for the climate where the specific building being considered is located. One way to evaluate whether the heating or cooling condition is predominant is by comparing heating degree day (HDD) values with cooling degree day (CDD) values for a specific climatic location. HDD and CDD values are provided in the ASHRAE Fundamentals Handbook.

Polyisocyanurate thickness (inches)	Heating conditions	Cooling conditions
1.0	5.0	5.6
1.5	7.5	8.4
2.0	10.0	11.2
2.5	12.5	14.0
3.0	15.0	16.8
3.5	17.5	19.6
4.0	20.0	22.4

Figure 3: NRCA's recommended design R-values

In 2013, Building Science Corp., Somerville, Mass., published Information Sheet 502, "Understanding the Temperature Dependence of R-values for Polyisocyanurate Roof Insulation," which replicated NRCA's 2009 testing with similar results.

Whether designers use LTTR or NRCA's predominant temperature condition-based design R-values, NRCA recommends designers specify polyisocyanurate insulation by its desired thickness—not its R-value or LTTR—to avoid possible confusion during procurement.

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