Long-Term Thermal Resistance (LTTR)

FIVE YEARS LATER

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In 2000, a new, prescriptive test method (CAN/ULC-S770, "Standard Test Method for Determination of Long-term Thermal Resistance of Closed-Cell Thermal Insulating Foams") for determining R-values of certain foam plastic insulations was adopted as a national standard in Canada, providing a long-needed definition of "aged" R-value. Aging refers to the gradual change in cell gas composition and the resulting change in R-value of a foam plastic insulation that relies on a captive blowing agent for thermal performance. This method, therefore, estimates a value that is both a 5-year, aged value and a 15-year, time-weighted thermal design value. It applies to polyurethane, polyiso, and extruded polystyrene, all of which "age." Since 2001 in Canada, and 2002 in the U.S., polyiso manufacturers have been testing products to determine their long-term thermal resistance (LTTR).

This standard derives from ASTM C 1303 ("Standard Test Method for Estimating the Long-Term Change in the Resistance of Unfaced, Rigid, Closed-cell Plastic Foams by Slicing and Scaling Under Controlled Laboratory Condition,") the first "thin slice" method. This method was developed through a government and industry initiative in 1989, and was a major step forward in estimating aged thermal values of cellular foam plastic insulations that depend on a captive blowing agent for thermal resistance.

Oak Ridge National Laboratory (ORNL) of the Department of Energy (DOE), the Polyisocyanurate Insulation Manufacturers Association (PIMA), Society of Plastics Industry (SPI), and National Roofing Contractors Association (NRCA) joined in the six-year research project, culminating in a widely read paper delivered at the 11th Conference on Roofing Technology in September 1995, in Gaithersburg, MD.

The industry, however, hesitated to embrace the standard because it was initially designed for research. Because it was not prescriptive, many considered it too complex and inappropriate for product ratings and comparisons. As a result, the industry continued to rely on the 6-month conditioning practice then in widespread use for the previous 15 years. The 6-month conditioning practice establishes a time and conditioning protocol required before measuring R-value. In its time, it too was a major step toward standardization and away from the market confusion created in the absence of an industry-recognized method, which for several years allowed the measurement of R-values at time of manufacture.

Although the 6-month conditioning method became standard practice for most foam plastic insulations and still appears in the ASTM standard specifications for polyiso (C 1289) and polystyrene (C 578), it has long been criticized for not addressing aging – the change in R-value over time caused by changes in cell gas composition. An ongoing study of extruded polystyrene (XPS) products provides a good example of this shortcoming.

Ten samples of XPS, ranging in thickness from 1 to 4 inches, were collected from the field and submitted – first to an R & D laboratory for testing over time, and then to a third-party materials testing laboratory for independent corroboration.

The samples submitted to the industry laboratory were 2.5 to 12.5 months in age. By the time they were submitted to the

Measured thickness	Measured date	Aging time (months)	Measured R-value/in.	Measured R-value full thickness	Advertised R-value full thickness	Measured % Difference from Advertised
3.94"	9/29/04 4/20/05 4/3/06 **5/19/06**	Unknown	4.85 4.66 4.65 **4.54**	17.89	20.0	-10.6
3.00"	9/29/04 4/20/05 4/3/06 **5/19/06**	8.5 15 26.5	4.87 4.76 4.76 **4.68**	14.04	15.0	-6.4
2.00"	9/8/04 4/20/05 4/3/06 **5/19/06**	5 12.5 24	4.95 4.81 4.81 **4.78**	9.56	10.0	-4.4
1.55"	9/29/04 4/20/05 4/3/06 **5/23/06**	12.5 19 30.5	5.21 5.13 5.13 **5.06**	7.84	7.5	4.5
0.99"	10/26/04 5/4/05 4/3/06 **5/19/06**	3 8.5 20	5.35 5.21 5.18 **5.12**	5.06	5.0	1.2
2.02"	9/22/04 4/20/05 4/3/06 **5/19/06**	2.5 9.5 20.5	4.78 4.74 4.69 **4.62**	9.33	10.0	-6.7
1.49"	9/22/04 4/20/05 4/3/06 **5/19/06**	6 13 24.5	4.83 4.74 4.65 **4.62**	6.88	7.5	-8.3
1.48"	9/8/04 4/20/05 4/3/06 **5/24/06**	Unknown	4.98 4.81 4.76 **4.80**	7.10	7.5	-5.3
1.01"	9/22/04 4/20/05 4/3/06 **5/19/06**	3.5 10.5 22	5.10 4.98 4.88 **4.76**	4.81	5.0	-3.8
1.03"	9/8/04 4/20/05 4/3/06 **5/24/06**	Unknown	4.55 4.46 4.42 **4.43**	4.56	5.0	-8.8
		Third-party average	**4.74**			

Table 1

Left and Below:
The "thin slice" method performed by PIMA.

third-party laboratory, they were approximately 20 to 30.5 months in age. This process provided several R-value data points over time, showing changes (i.e., aging) for products of various ages. In three cases, the exact age was unknown but exceeded 19 months, since the samples had been conditioning in a laboratory for at least that long. Refer to *Table 1* for test dates and results.

Based on the data contained in this table, the importance of an accurate, long-term thermal resistance test method is clear. In only two cases, the measured R-value met the 6-month reported value (R-5.0), which is also the S770 LTTR-value recommended by XPS manufacturers in their marketing literature. In at least two cases, the measured R-values at 2.5 to 5 months in age failed to meet the 6-month minimum value in the ASTM C 578 polystyrene material standard. In the majority of cases, the measured R-value was below the published R-5.0, especially as the samples aged. Third-party test data are identified in the table in green.

The aging phenomenon shown in this table has been recognized for years, and the "slicing and scaling" methods, such as ASTM C 1303 and CAN/ULC-S770, have attempted to account for it. For this reason, foam plastic insulation, such as polyiso and extruded polystyrene, is required by Canadian product specifications to report long-term thermal resistance values (LTTR) in accordance with CAN/ULC-S770.

After five years of experience with this test method, some researchers have identified potential positive bias (over-predicting), especially for XPS insulation. XPS manufacturers have reported over-prediction of 10-25%, presumably based on the reported value R-5.0. Based on the data shown in Table 1, the bias could be even greater if based on the average of R-4.74. Research on polyiso insulation, however, indicates a much smaller bias. The wide difference in reported bias may be related to the difference in cell gas diffusion rates between polyiso and XPS. Since diffusion rates for XPS are at least an order of magnitude higher than that for polyiso, researchers have found it difficult to establish a test method appropriate for both materials. LTTR test results and measured R-values of polyiso samples secured from the field have already been discussed in previous industry literature (Graham, 2006).

When the industry agreed to include CAN/ULC S770 in ASTM C 1289 ("Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation") as a mandatory Annex, the polyiso industry, through PIMA, initiated a bias study involving products from two manufacturers. This study is designed to determine a percentage of positive (over-prediction) or negative (under-prediction) bias that results from the CAN/ULC-S770 test method when compared to actual aged R-values at full thickness of insulation boards. After three years, the average bias according to this data is approximately +6%.

At the same time that CAN/ULC S770 was gaining recognition, the ASTM C 1303 task group in 2000 undertook revisions to that standard to add a prescriptive method to complement the existing research method. The group hoped that the prescriptive method would remove some of the less precise elements of the research method and would provide a method for widespread use in product rating for LTTR. In other words, the standard would provide standardized "cook book" instructions for users. Similar to some of the work undertaken in the S770 task group, the C 1303 task group identified slice thickness and other specimen preparation practices as potential sources for the apparent bias. Adjustments to these elements in the test method have been finalized, and the standard was recently balloted successfully at ASTM, ensuring a new version of C 1303 will be issued soon.

The industry hopes that this new portion of ASTM C 1303 proves with experience to be appropriate for both XPS and polyiso, and helps reduce the +10-25% reported bias for XPS and the +6% bias for polyiso. However, just as C 1289 initiated a bias study, C 1303 has undertaken a ruggedness test to help answer still outstanding questions about features of that test method. This ruggedness test will be completed in 2011, at which time the industry should have a greater breadth of data that may lead to further modifications. This data will be reported as the bias study concludes and the ruggedness test progresses and should provide the industry with useful insights into the success of the attempted improvements.

References

Graham, M., "Research Reveals the LTTR Method May be Over-reporting Results," *Professional Roofing*, January 2006.

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