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NRCA University Webinar
November 21, 2013

"R" You Aware?
Understanding R-values for Polyiso

presented by

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Some terminology

R-value: See "thermal resistance (R)"

thermal resistance: The quantity determined by the temperature difference at steady state between two defined surfaces or a material or construction that induces a unit heat flow rate through a unit area. In English (inch·pound) units, it is expressed as $F \cdot ft^2 \cdot hr/Btu$.

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About thermal resistance (R)

- A thermal resistance (R) value applies to a specific thickness of material or construction.
- The thermal resistance (R) of a material is the reciprocal of the thermal conductance (C) of the same material (i.e., R = 1/C).
- Thermal resistance (R) values can be added, subtracted, multiplied and divided by mathematically appropriate methods.

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Thermal resistance (R)

ASTM C518, " Standard Test Method for Steady-state Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus"

-- Originally published in 1963
Current edition is 2010

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Theory of foam aging

ASTM C1303, Appendix X3-Theory of Foam Aging

- R-value of most foam insulations is affected by the gas mixture in the foam
  - R-value of most blowing agents is greater than that of air.
  - R-value of foam insulation is greater when there is more blowing agent and less air

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Theory of foam aging -- continued

ASTM C1303, Appendix X3-Theory of Foam Aging

- For rigid, closed-cell foams, diffusion plays a role:
  - Air diffuses into cells
  - Blowing agent diffuses out of cells or partially dissolves into the polymer matrix
- Diffusion rate depends upon:
  - Type of polymer
  - Type of gas
  - Foam structure
  - Temperature
  - Pressure

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Long-term thermal resistance (LTTR)

R-value: same

thermal resistance: same

long-term: for the purpose of the Prescriptive Method, long term refers to five years

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Long-term thermal resistance (LTTR)

- ASTM C1303, "Standard Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation"
- CAN/ULC-S770, "Standard Test Method for Determination of Long-Term Thermal Resistance of Closed-Cell Thermal Insulating Foams

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PIMA Quality Mark^{cm} program

- Established in 2003
- Implemented on January 1, 2004
- Report LTTR values based upon CAN/ULC-S770-03
- Third party administration by FM Global

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Insulation thickness	LTTR
1.0 inch (25 mm)	6.0
1.5 inches (38 mm)	9.0
1.7 inches (43 mm)	10.3
1.8 inches (46 mm)	10.9
2.0 inches (51 mm)	12.1
2.5 inches (64 mm)	15.3
2.7 inches (69 mm)	16.6
3.0 inches (76 mm)	18.5
3.3 inches (84 mm)	20.4
3.5 inches (89 mm)	21.7
4.0 inches (102 mm)	25.0

"Tech today," *Professional Roofing,* November 2002

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Revision to the PIMA Quality Mark^{cm} program

- Report LTTR values based upon:
  - ASTM C1303-11
  - CAN/ULC-S770-09
- Effective date of January 1, 2014

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New minimum LTTR values

PIMA Quality Mark^{cm} program (minimum values)

Revised LTTR values		
Thickness (inches)	**New LTTR values per inch thickness**	**New LTTR values per thickness**
1	5.6	5.6
2	5.7	11.4
3	5.8	17.4
4	5.9	23.6

"Tech today," *Professional Roofing,* August 2013

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Comparing existing vs. new LTTR values

Thickness	LTTR (2004 – 2013)	New LTTR (2014 –)
1 inch	6.0	5.6
1.5 inches	9.0	8.6
2 inches	12.1	11.4
3 inches	18.5	17.4
4 inches	25.0	23.6

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Some concerns

Design/bid/construction scenarios:

- Projects designed in 2013, but will be constructed in 2014
- Projects bid in 2013, but will be constructed in 2014
- Projects designed and bid in 2014 using outdated LTTR values

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NRCA recommends designers specify polyisocyanurate insulation by thickness – not R-value or LTTR.

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<u>Some words of caution…</u>

Do not use the terms “R-value” and “LTTR” interchangeably.

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Some additional cautions…

- Is the "long-term" in LTTR really long term in the context of a roof system service life?
- LTTR may not appropriate for use for vapor retarder design.
- LTTR may not be appropriate for use for building energy calculations.

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NRCA has not endorsed the LTTR concept

"Although the LTTR method of R-value determination and reporting may be appropriate for laboratory analysis, research comparison and procurement purposes, NRCA does not consider LTTR to be appropriate for design and in-service purposes…"

--The NRCA Roofing Manual: Membrane Roof Systems-2011

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NRCA's recommended design R-values

The NRCA Roofing Manual: Membrane Roof System-2011

Polyisocyanurate			
Thickness, in.	LTTR	NRCA Recommended Design R-values	
		Heating Conditions	Cooling Conditions
1.0	6.0	5.0	5.6
1.25	7.5	6.3	7.0
1.5	9.0	7.5	8.4
1.75	10.5	8.8	9.8
2.0	12.1	10.0	11.2
2.3	14.0	11.5	12.9
2.5	15.3	12.5	14.0
2.8	17.2	14.0	15.7
3.0	18.5	15.0	16.8
3.25	20.1	16.3	18.2
3.5	21.7	17.5	19.6
3.75	23.4	18.8	21.0
4.0	25.0	20.0	22.4

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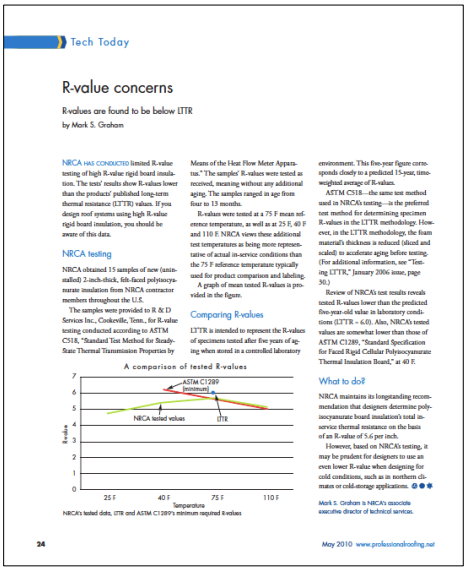

Tech Today

R-value concerns

R-values are found to be below LTTR

by Mark S. Graham

NRCA has conducted limited R-value testing of high R-value rigid board insulation. The tests' results show R-values lower than the products' published long-term thermal resistance (LTTR) values. If you design roof systems using high R-value rigid board insulation, you should be aware of this data.

NRCA testing

NRCA obtained 15 samples of new (uninstalled) 2-inch-thick, felt-faced polyisocyanurate insulation from NRCA contractor members throughout the U.S.

The samples were provided to R & D Services Inc., Cookeville, Tenn., for R-value testing conducted according to ASTM C518, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus." The samples' R-values were tested as received, meaning without any additional aging. The samples ranged in age from four to 13 months.

R-values were tested at a 75 F mean reference temperature, as well as at 25 F, 40 F and 110 F. NRCA views these additional test temperatures as being more representative of actual in-service conditions than the 75 F reference temperature typically used for product comparison and labeling.

A graph of mean tested R-values is provided in the figure.

Comparing R-values

LTTR is intended to represent the R-values of specimens tested after five years of aging when stored in a controlled laboratory environment. This five-year figure corresponds closely to a predicted 15-year, time-weighted average of R-values.

ASTM C518—the same test method used in NRCA's testing—is the preferred test method for determining specimen R-values in the LTTR methodology. However, in the LTTR methodology, the foam material's thickness is reduced (sliced and scaled) to accelerate aging before testing. (For additional information, see "Testing LTTR," January 2006 issue, page 30.)

Review of NRCA's test results reveals tested R-values lower than the predicted five-year-old value in laboratory conditions (LTTR – 6.0). Also, NRCA's tested values are somewhat lower than those of ASTM C1289, "Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board," at 40 F.

A comparison of tested R-values

NRCA's tested data, LTTR and ASTM C1289's minimum required R-values

What to do?

NRCA maintains its longstanding recommendation that designers determine polyisocyanurate board insulation's total in-service thermal resistance on the basis of an R-value of 5.6 per inch.

However, based on NRCA's testing, it may be prudent for designers to use an even lower R-value when designing for cold conditions, such as in northern climates or cold-storage applications.

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May 2010 www.professionalroofing.net

"Tech today," *Professional Roofing*, May 2010

NRCA 2009 R-value testing:

- 15 samples of new 2-inch polyiso. were testing according to ASTM C518
- Tested R-values at 75 F were lower than LTTR
- R-value of polyiso. is temperature sensitive
- R-values at 25 F, 40 F and 110 F are lower than R-value at laboratory conditions

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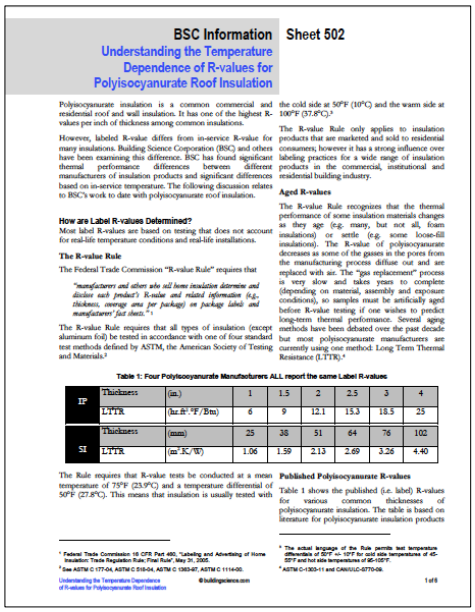

BSC Information Sheet 502

Understanding the Temperature Dependence of R-values for Polyisocyanurate Roof Insulation

Polyisocyanurate insulation is a common commercial and residential roof and wall insulation. It has one of the highest R-values per inch of thickness among common insulations.

However, labeled R-value differs from in-service R-value for many insulations. Building Science Corporation (BSC) and others have been examining this difference. BSC has found significant thermal performance differences between different manufacturers of insulation products and significant differences based on in-service temperature. The following discussion relates to BSC's work to date with polyisocyanurate roof insulation.

How are Label R-values Determined?

Most label R-values are based on testing that does not account for real-life temperature conditions and real-life installations.

The R-value Rule

The Federal Trade Commission "R-value Rule" requires that

> *"manufacturers and others who sell home insulation determine and disclose each [product's] R-value and related information (e.g., thickness, coverage area per package) on package labels and manufacturers' fact sheets."* [1]

The R-value Rule requires that all types of insulation (except aluminum foil) be tested in accordance with one of four standard test methods defined by ASTM, the American Society of Testing and Materials.[2]

Table 1: Four Polyisocyanurate Manufacturers ALL report the same Label R-values

IP	Thickness	(in.)	1	1.5	2	2.5	3	4
	LTTR	(hr.ft².°F/Btu)	6	9	12.1	15.3	18.5	25
SI	Thickness	(mm)	25	38	51	64	76	102
	LTTR	(m².K/W)	1.06	1.59	2.13	2.69	3.26	4.40

The Rule requires that R-value tests be conducted at a mean temperature of 75°F (23.9°C) and a temperature differential of 50°F (27.8°C). This means that insulation is usually tested with the cold side at 50°F (10°C) and the warm side at 100°F (37.8°C).[3]

The R-value Rule only applies to insulation products that are marketed and sold to residential consumers, however it has a strong influence over labeling practices for a wide range of insulation products in the commercial, institutional and residential building industry.

Aged R-values

The R-value Rule recognizes that the thermal performance of some insulation materials changes as they age (e.g. many, but not all, foam insulations) or settle (e.g. some loose-fill insulation). The R-value of polyisocyanurate decreases as some of the gases in the pores from the manufacturing process diffuse out and are replaced with air. The "gas replacement" process is very slow and takes years to complete (depending on material, assembly and exposure conditions), so samples must be artificially aged before R-value testing if one wishes to predict long-term thermal performance. Several aging methods have been debated over the past decade but most polyisocyanurate manufacturers are currently using one method: Long Term Thermal Resistance (LTTR).[4]

Published Polyisocyanurate R-values

Table 1 shows the published (i.e. label) R-values for various common thicknesses of polyisocyanurate insulation. The table is based on literature for polyisocyanurate insulation products

[1] Federal Trade Commission 16 CFR Part 460, "Labeling and Advertising of Home Insulation: Trade Regulation Rule; Final Rule", May 31, 2005.
[2] See ASTM C 177-04, ASTM C 518-04, ASTM C 1363-97, ASTM C 1114-00.
[3] The actual language of the Rule permits test temperature differentials of 50°F +/- 10°F for cold side temperatures of 40-50°F and hot side temperatures of 90-100°F.
[4] ASTM C-1303-11 and CAN/ULC-S770-09.

Understanding the Temperature Dependence of R-values for Polyisocyanurate Roof Insulation ©buildingscience.com 1 of 8

BCS Info. Sheet 502:

- Replicated NRCA's 2009 R-value testing
- Similar results
- Suggests a "climate-based" R-value approach
- Suggests use of a hybrid insulation approach

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In review…

- New LTTR values as of January 1, 2014
- Implementation concerns
- LTTR may not be appropriate for design purposes
- NRCA is maintaining it's longstanding design R-value recommendation

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Future NRCA webinars

- Nov. 26 - Understanding OSHA's Proposed Silica Rule
- Dec. 19 - Errors & Omissions and Pollution: Understanding Your Exposures
- Jan 23 - NRCA Leadership: Industry Update
- Feb 20 - Engaging the Latino Labor Force
- March 20 - Exploring EnergyWise

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