NRCA Regional Conference
Arlington, TX – March 18, 2014

Code changes and technical issues

Mark S. Graham
Associate Executive Director, Technical Services
National Roofing Contractors Association

Topics

- Code issues:
  - Why is code compliance a concern?
  - What code is applicable?
  - International Building Code
  - International Energy Conservation Code
- Asphalt shingles
- Asphalt
- New LTTR values
- Concrete roof decks
- Slip-resistance of roofing products

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Code issues -- Some background

- The I-Codes are "model codes" developed by the International Code Council (ICC)
- Model codes serve as the technical basis for state or local code adoption
- The code provides the minimum legal requirements for building construction…and operation
- The code is enforced by the "authority having jurisdiction" (AHJ)
- The code can also provide a basis for construction claims-related litigation

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Legal considerations

"In most states, a building code violation is considered to be evidence of negligence. In some situations, a building code violation may be considered *negligence per se…*"

--Stephen M. Phillips
Hendrick, Phillips, Salzman & Flatt

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Texas code adoptions

- State-mandated level:
  - *International Building Code, 2006 Edition*
  - *International Residential Code, 2000 Edition*
  - *International Energy Conservation Code, 2009 Edition*
- Individual jurisdictions can adopt more stringent requirements (later editions)

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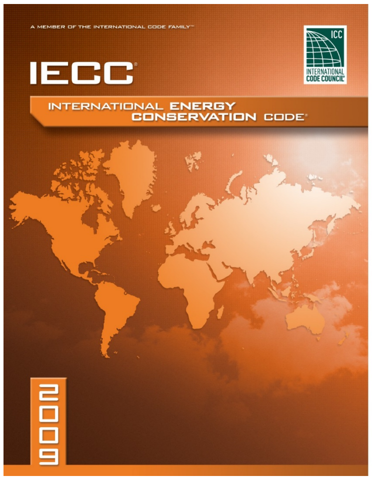
International Energy Conservation Code, 2009 Edition (IECC 2009)



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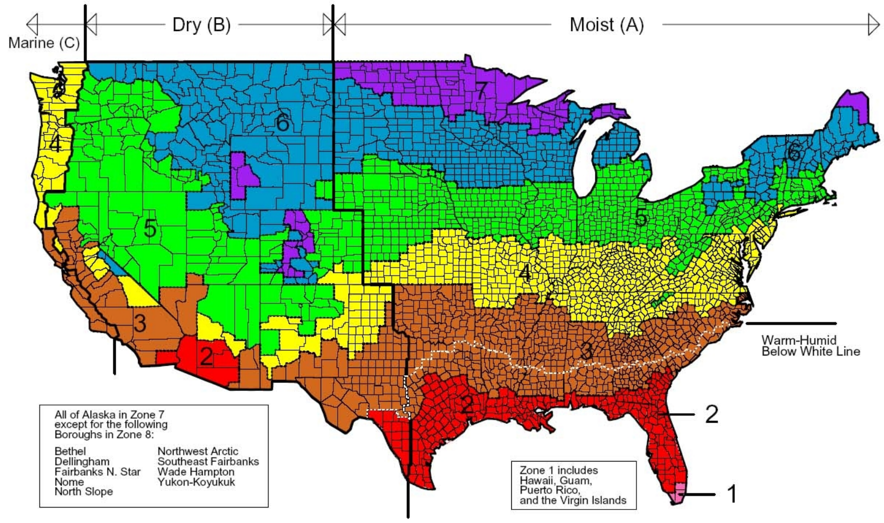
Climate zones

IECC 2012, Section C301 and Sec. R301—Climate Zones



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Roofing-specific adaptation of Table 402.1.1

International Energy Conservation Code, 2009 Edition **(Residential buildings)**

Insulation and Fenestration Requirements by Component[a]	
Climate zone	**Ceiling R-value**
1	30
2	
3	
4	38
5	
6	49
7	
8	

[a] R-values are minimums. …
[Other footnotes omitted for clarity]

8

Roofing-specific adaptation of Table 502.2(1)

International Energy Conservation Code, 2009 Edition ***(Commercial buildings)***

<table>
<tr><th colspan="4">Opaque Thermal Envelope Assembly Requirements</th></tr>
<tr><th rowspan="2">Climate zone</th><th colspan="3">Roof assembly configuration</th></tr>
<tr><th>Insulation entirely above deck</th><th>Metal buildings (with R-5 thermal blocks)</th><th>Attic and other</th></tr>
<tr><td>1</td><td>R-15ci</td><td>R-19</td><td>R-30</td></tr>
<tr><td>2</td><td rowspan="5">R-20ci</td><td rowspan="4">R-13 + R-13</td><td rowspan="6">R-38</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td rowspan="3">R-13 + R-19</td></tr>
<tr><td>7</td><td rowspan="2">R-25ci</td></tr>
<tr><td>8</td><td>R-49</td></tr>
</table>

ci = Continuous insulation
LS = Liner system (a continuous membrane installed below the purlins and uninterrupted by framing members; uncompressed, faced insulation rests on top of the membrane between the purlins)

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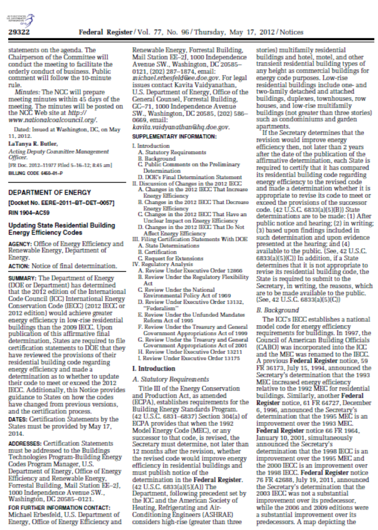
Federal Register, May 17, 2012


29322 Federal Register / Vol. 77, No. 96 / Thursday, May 17, 2012 / Notices

DEPARTMENT OF ENERGY

[Docket No. EERE–2011–BT–DET–0057]

RIN 1904–AC59

Updating State Residential Building Energy Efficiency Codes

Key points:

- US DOE has determined IECC 2012 will achieve greater energy efficiency in low-rise residential buildings than IECC 2009
- States must certify by May 17, 2014 their energy code meets or exceeds the levels of IECC 2012

This triggers most states to update their state energy code

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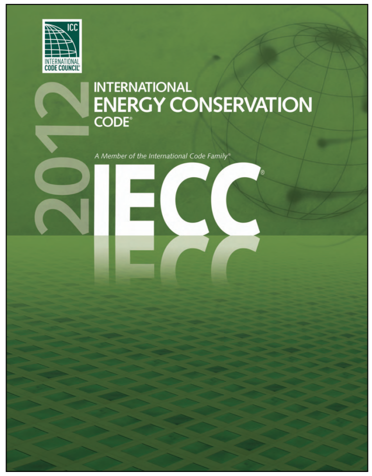
International Energy Conservation Code, 2012 Edition (IECC 2012)



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Roofing-specific adaptation of Table R402.1.1

International Energy Conservation Code, 2012 Edition

Insulation and Fenestration Requirements by Component[a]	
Climate zone	**Ceiling R-value**
1	30
2	38
3	
4	49
5	
6	
7	
8	

[a] R-values are minimums. …
[Other footnotes omitted for clarity]

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Roofing-specific adaptation of Table C402.2

International Energy Conservation Code, 2012 Edition

Opaque Thermal Envelope Assembly Requirements			
Climate zone	Roof assembly configuration		
	Insulation entirely above deck	Metal buildings (with R-5 thermal blocks)	Attic and other
1	R-20ci	R-19 + R-11 LS	R-38
2			
3			
4	R-25 ci		
5			
6	R-30ci	R-25 + R-11 LS	R-49
7	R-35ci	R-30 + R-11 LS	
8			

ci = Continuous insulation
LS = Liner system (a continuous membrane installed below the purlins and uninterrupted by framing members; uncompressed, faced insulation rests on top of the membrane between the purlins)

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TABLE C402.2.1.1
MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS[a]

Three-year aged solar reflectance[b] of 0.55 and three-year aged thermal emittance of 0.75
Initial solar reflectance[b] of 0.70 and initial thermal emittance[c] of 0.75
Three-year-aged solar reflectance index[d] of 64
Initial solar reflectance index[d] of 82

[Footnotes omitted for clarity]

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Tapered insulation

International Energy Conservation Code, 2012 Edition

C402.2.1 Roof assembly. The minimum thermal resistance (R-value) of the insulating material installed either between the roof framing or continuously on the roof assembly shall be as specified in Table C402.2, based on construction materials used in the roof assembly. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

Exceptions:

1. Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25 mm) or less and where the area-weighted *U-factor is* equivalent to the same assembly with the *R-value* specified in Table C402.2.
2. …

IECC Commentary indicates Exception 1 applies to tapered insulation systems.

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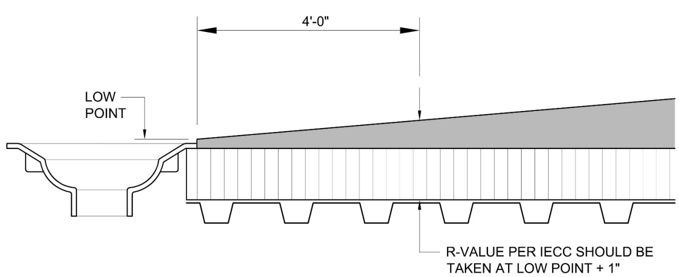
Graphically depicted…



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Summary – IECC 2012 – Commercial Provisions

- R-value increases
- Mandatory reflectivity requirements in Climate Zones 1-3
- Air barriers requirements in Climate Zones 4-8

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So….

- Do increased R-values make sense?
- Is there a realistic payback?

…we've done some calculations

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In a cooling climate

10,000 sq. ft. single-story building in Dallas, TX

R-value increase	Annual Btu savings	Payback time
R-10 to R-15	27,291,307 Btu	13.6 years
R-15 to R-20	15,107,897 Btu	27.9 years
R-20 to R-25	8,711,683 Btu	44.9 years
R-25 to R-30	6,150,345 Btu	97.6 years

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Asphalt shingles

- ~~ASTM D225 (organic shingles)~~
- ASTM D3462 (fiberglass shingles)
- ICC-ES AC 438 (alternative asphalt shingles)

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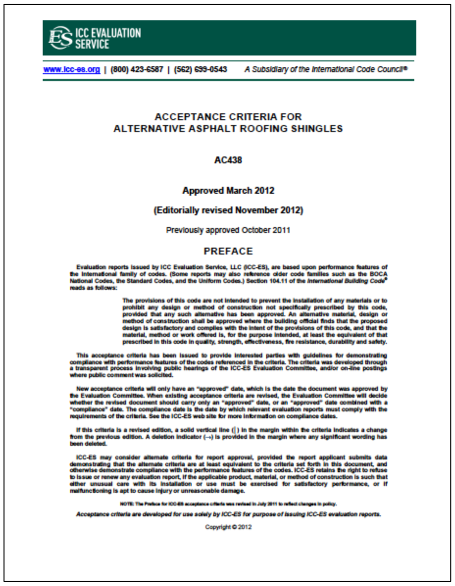
ICC-ES AC438


ICC EVALUATION SERVICE

www.icc-es.org | (800) 423-6587 | (562) 699-0543 *A Subsidiary of the International Code Council®*

ACCEPTANCE CRITERIA FOR
ALTERNATIVE ASPHALT ROOFING SHINGLES

AC438

Approved March 2012

(Editorially revised November 2012)

Previously approved October 2011

PREFACE

Evaluation reports issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the International family of codes. (Some reports may also reference older code families such as the BOCA National Codes, the Standard Codes, and the Uniform Codes.) Section 104.11 of the *International Building Code®* reads as follows:

> The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

This acceptance criteria has been issued to provide interested parties with guidelines for demonstrating compliance with performance features of the codes referenced in the criteria. The criteria was developed through a transparent process involving public hearings of the ICC-ES Evaluation Committee, and/or on-line postings where public comment was solicited.

New acceptance criteria will only have an "approved" date, which is the date the document was approved by the Evaluation Committee. When existing acceptance criteria are revised, the Evaluation Committee will decide whether the revised document should carry only an "approved" date, or an "approved" date combined with a "compliance" date. The compliance date is the date by which relevant evaluation reports must comply with the requirements of the criteria. See the ICC-ES web site for more information on compliance dates.

If this criteria is a revised edition, a solid vertical line (|) in the margin within the criteria indicates a change from the previous edition. A deletion indicator (→) is provided in the margin where any significant wording has been deleted.

ICC-ES may consider alternate criteria for report approval, provided the report applicant submits data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. ICC-ES retains the right to refuse to issue or renew any evaluation report, if the applicable product, material, or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause injury or unreasonable damage.

NOTE: The Preface for ICC-ES acceptance criteria was revised in July 2011 to reflect changes in policy.

Acceptance criteria are developed for use solely by ICC-ES for purpose of issuing ICC-ES evaluation reports.

Copyright © 2012

- Alternative acceptance
- No weight/mass testing
- No tear strength testing
- ASTM E108 Class C
- ASTM D7158 Class D
- Weather resistance
  - Break strength
- Temperature cycling
- Wind-driven rain

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Asphalt testing

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Some terminology…

Flash point (FP): the lowest temperature at which asphalt vapors above a volatile combustible substance can ignite in air when exposed to an ignition source; tested using ASTM D92.

Equiviscous temperature (EVT): the temperature at which asphalt attains proper viscosity (flow rate) for built-up membrane application; tested using ASTM D4402 – 125 cP (mop application) and 75 cP (mechanical spreader application).

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Some more terminology…

EVT application range: the recommended bitumen application range. The range is approximately 25 F above or below the EVT, thus giving a range of approximately 50 F. The EVT is measured in the mop cart pr mechanical spreader just prior to application of bitumen to the substrate.

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NRCA recommends…

"…NRCA recommends designers specify asphalt with a sufficiently high enough FP temperature top provide a minimum 125-degree differential between an asphalt's EVT and FP temperature to allow for proper application of built-up membranes."

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NRCA asphalt testing -- 1989

- 26 asphalt samples
- EVTs:
  - Type III (mop) 375 – 450 F
  - Type III (spreader) 400 – 500 F
  - Type IV (mop) 395 – 475 F
  - Type IV (spreader) 425 – 505 F
- FPs:
  - Not reported

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NRCA asphalt testing -- 2000

- 19 asphalt lots sampled
- EVTs:
  - Type III (mop) 390 – 440 F
  - Type III (spreader) 415 – 470 F
- FPs: 585 – 640 F
- ASTM D312 compliance:
  - 10 of 19 did not comply

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NRCA asphalt testing – 2014 (to date)

- 14 asphalt lots (7 suppliers) sampled
- EVTs:
  - Type III (mop) 424 – 462 F
  - Type III (spreader) 452 – 486 F
  - Type IV (mop) 455 – 482 F
  - Type IV (spreader) 480 – 506 F
- FPs: 615 – 660 F
- 10 of 14 do not comply with ASTM D312's physical property requirements

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Proposed revision to ASTM D312

- Maximum heating temp.: 550 F (575 F min. FP)
- Maximum EVTs:
  - Type III (mop) 430 F
  - Type III (spreader) 455 F
  - Type IV (mop) 470 F
  - Type IV (spreader) 485 F
- Lot-specific package labeling of EVT

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NRCA's interim recommendations

- Consult manufacturers' installation requirements and MSDS.
- Carefully select asphalt
- Beware of actual FPs; max. heating temp. should be FP – 25 F
- Beware of actual EVTs
- Make field crews aware

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New LTTR values

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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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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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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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Polyiso. thicknesses/layers

R-20: 2 layers of 1.8-inch-thick polyiso.

R-25: 2 layers of 2.2-inch-thick polyiso.

R-30: 2 layers of 2.6-inch-thick polyiso.

R-35: 2 layers of 3.1-inch-thick polyiso.

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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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Industry Issue Update, January 2014

INDUSTRY ISSUE UPDATE

NRCA Member Benefit

Polyiso's R-value

NRCA recommends polyisocyanurate insulation be specified by its desired thickness

Jan. 1, 2014

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℠ program. This program used the 2003 edition of CAN/ULC-S770 for LTTR

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Concrete Roof Decks

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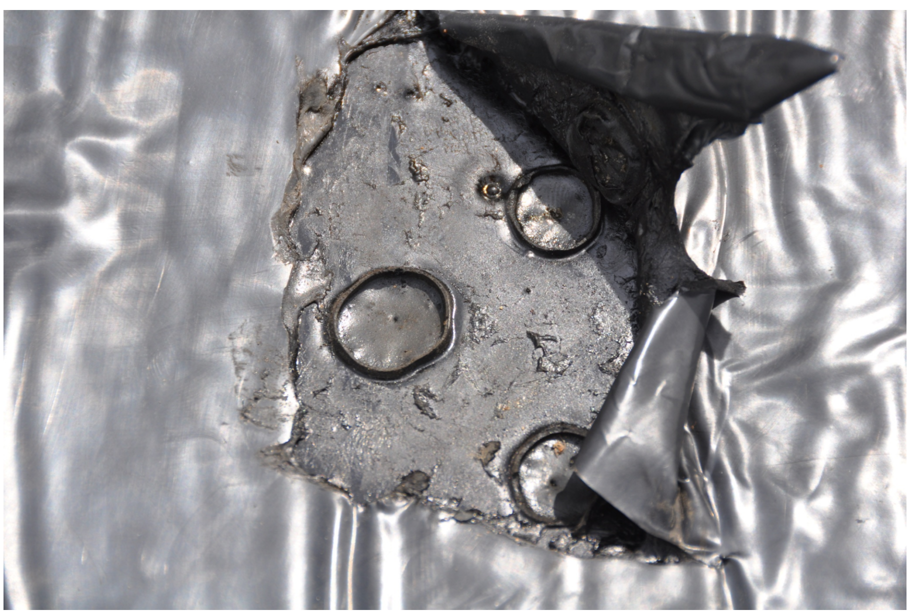

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Reported roofing-related problems

- Moisture within the roof system
- Loss of adhesion
- Insulation facer delamination
- Adhesive curing issues
- Mold growth
- Fastener/metal corrosion
- R-value loss

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Some terminology

- **Structural concrete (normal weight)**
  - 150 lbs/ft^3
- **Lightweight structural concrete**
  - 85–120 lbs/ft^3
- **Lightweight insulating concrete**
  - 20-40 lbs/ft^3

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Some terminology

- **Structural concrete (normal weight)**
  - 150 lbs/ft^3
- **Lightweight structural concrete**
  - 85–120 lbs/ft^3
- ~~**Lightweight insulating concrete**~~
  - ~~20-40 lbs/ft^3~~

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Concrete Aggregates

60-80% of Concrete Mix Design

- Normal-weight aggregates (stone):
  - Dense
  - Absorb about 2% by weight
- Light-weight aggregates (expanded shale):
  - Porous
  - Absorbs from 5 - 25% by weight

Lightweight structural concrete inherently contains more moisture

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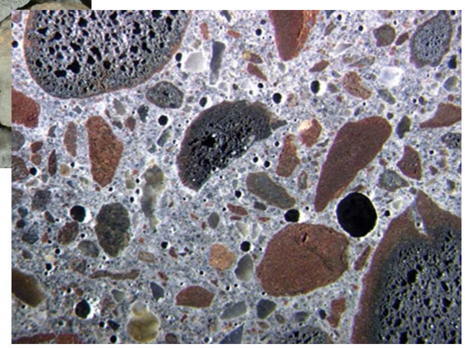
An up-close look



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When is it OK to roof?

Historical guidelines

- After 28 days
- Application of hot bitumen
- Plastic film test
  - ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method"

These are not appropriate for current generations of concrete mixes

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Conclusions

- Concrete roof decks – normal weight and light-weight structural – present challenging moisture-related considerations.
- Further complicated by the use of admixtures and method of finishing.
- NRCA does not support the 28-day drying period or the plastic sheet test

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Conclusions - continued

- Roofing contractors can only visually assess the dryness of the concrete's top surface
- Roofing contractors cannot readily assess any remaining free moisture within concrete or its likely release

Roofing contractors are not privy to and may not be knowledgeable about the information necessary to make "…when to roof…" decisions

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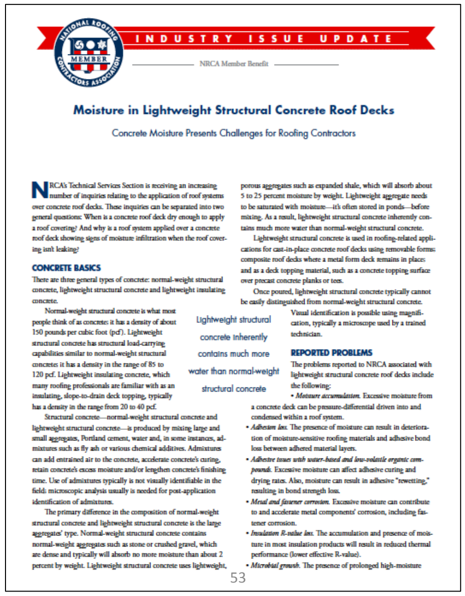
NRCA Industry Issue Update, August 2013



INDUSTRY ISSUE UPDATE

NRCA Member Benefit

Moisture in Lightweight Structural Concrete Roof Decks

Concrete Moisture Presents Challenges for Roofing Contractors

NRCA's Technical Services Section is receiving an increasing number of inquiries relating to the application of roof systems over concrete roof decks. These inquiries can be separated into two general questions: When is a concrete roof deck dry enough to apply a roof covering? And why is a roof system applied over a concrete roof deck showing signs of moisture infiltration when the roof covering isn't leaking?

CONCRETE BASICS

There are three general types of concrete: normal-weight structural concrete, lightweight structural concrete and lightweight insulating concrete.

Normal-weight structural concrete is what most people think of as concrete; it has a density of about 150 pounds per cubic foot (pcf). Lightweight structural concrete has structural load-carrying capabilities similar to normal-weight structural concrete; it has a density in the range of 85 to 120 pcf. Lightweight insulating concrete, which many roofing professionals are familiar with as an insulating, slope-to-drain deck topping, typically has a density in the range from 20 to 40 pcf.

Structural concrete—normal-weight structural concrete and lightweight structural concrete—is produced by mixing large and small aggregates, Portland cement, water and, in some instances, admixtures such as fly ash or various chemical additives. Admixtures can add entrained air to the concrete, accelerate concrete's curing, retain concrete's excess moisture and/or lengthen concrete's finishing time. Use of admixtures typically is not visually identifiable in the field; microscopic analysis usually is needed for post-application identification of admixtures.

The primary difference in the composition of normal-weight structural concrete and lightweight structural concrete is the large aggregates' type. Normal-weight structural concrete contains normal-weight aggregates such as stone or crushed gravel, which are dense and typically will absorb no more moisture than about 2 percent by weight. Lightweight structural concrete uses lightweight, porous aggregates such as expanded shale, which will absorb about 5 to 25 percent moisture by weight. Lightweight aggregate needs to be saturated with moisture—it's often stored in ponds—before mixing. As a result, lightweight structural concrete inherently contains much more water than normal-weight structural concrete.

Lightweight structural concrete is used in roofing-related applications for cast-in-place concrete roof decks using removable forms; composite roof decks where a metal form deck remains in place; and as a deck topping material, such as a concrete topping surface over precast concrete planks or tees.

Once poured, lightweight structural concrete typically cannot be easily distinguished from normal-weight structural concrete. Visual identification is possible using magnification, typically a microscope used by a trained technician.

Lightweight structural concrete inherently contains much more water than normal-weight structural concrete

REPORTED PROBLEMS

The problems reported to NRCA associated with lightweight structural concrete roof decks include the following:

- *Moisture accumulation.* Excessive moisture from a concrete deck can be pressure-differential driven into and condensed within a roof system.
- *Adhesion loss.* The presence of moisture can result in deterioration of moisture-sensitive roofing materials and adhesive bond loss between adhered material layers.
- *Adhesive issues with water-based and low-volatile organic compounds.* Excessive moisture can affect adhesive curing and drying rates. Also, moisture can result in adhesive "rewetting," resulting in bond strength loss.
- *Metal and fastener corrosion.* Excessive moisture can contribute to and accelerate metal components' corrosion, including fastener corrosion.
- *Insulation R-value loss.* The accumulation and presence of moisture in most insulation products will result in reduced thermal performance (lower effective R-value).
- *Microbial growth.* The presence of prolonged high-moisture

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Slip-resistance testing of roofing products

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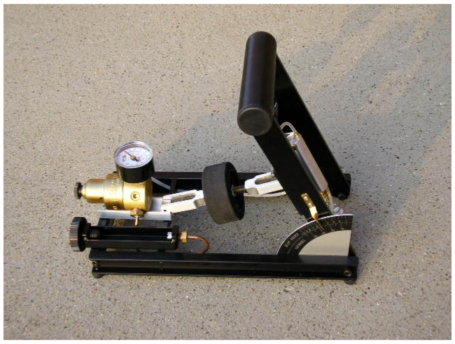
Slip resistance of roofing products

Variable Incidence Tribometer



Applicable standards:
- ASTM F1679, "Standard Test Method for Using a Variable Incidence Tribometer (VIT)"
- ASTM F2508, "Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces"

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Slip index results

Steep-slope underlayment products (new products)

Product	Dry	Wet
No. 15 underlayment	1.0	0.60
No. 30 underlayment	1.0 +	0.86
Smooth SA	1.0+	1.0+
Sanded-surface SA	0.88	0.78
Smooth-film SA	0.89	0.82
Textured SA	0.85	0.75
Textured SA	0.89	0.66

Tested on horizontal surfaces

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Slip index results

Single-ply membrane products (new products)

Product	Dry	Wet
EPDM	0.96	0.29
TPO	0.82	0.18
PVC	0.93	0.10

Tested on horizontal surfaces

A slip index of 0.25 to 0.35 is generally required for safe ambulation of the general population on horizontal surfaces

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Some NRCA programs to be aware of…

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CERTA

- Established by MRCA in 1986
- Joint agreement with NRCA beginning in 2003
- 1,600+ trainers
- 21,000+ applicators
- Substantially improved fire safety record

59 NRCA

roofwinddesigner.com

$q_h = 0.00256(K_h)(K_{zt})(K_d)(V^2)(I)$

- Developed jointly by NRCA, MRCA and NERCA
- No cost to users
- Determine building-specific wind loads:
  - ASCE 7-05
  - ASCE 7-10
- Determine required wind resistances
- 14,827 projects

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EnergyWise Roof Calculator

energywise.nrca.net

- Developed by NRCA in cooperation with the Roofing Industry Alliance for Progress
- Determine R-value requirements:
  - IECC 2006 and 2012
  - IgCC 2012
  - ASHRAE 90.1-99, -04, -07, -10 and -13
  - ASHRAE 189.1-09
- Calculates heating/cooling costs
- Verifies proper vapor retarder placement
- 7,457 projects

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Mark S. Graham
Associate Executive Director, Technical Services
National Roofing Contractors Association
10255 West Higgins Road, 600
Rosemont, Illinois 60018-5607

(847) 299-9070
mgraham@nrca.net
www.nrca.net

Twitter: @MarkGrahamNRCA
Personal website: www.marksgraham.com

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Moisture in Lightweight Structural Concrete Roof Decks

Concrete Moisture Presents Challenges for Roofing Contractors

NRCA's Technical Services Section is receiving an increasing number of inquiries relating to the application of roof systems over concrete roof decks. These inquiries can be separated into two general questions: When is a concrete roof deck dry enough to apply a roof covering? And why is a roof system applied over a concrete roof deck showing signs of moisture infiltration when the roof covering isn't leaking?

CONCRETE BASICS

There are three general types of concrete: normal-weight structural concrete, lightweight structural concrete and lightweight insulating concrete.

Normal-weight structural concrete is what most people think of as concrete; it has a density of about 150 pounds per cubic foot (pcf). Lightweight structural concrete has structural load-carrying capabilities similar to normal-weight structural concrete; it has a density in the range of 85 to 120 pcf. Lightweight insulating concrete, which many roofing professionals are familiar with as an insulating, slope-to-drain deck topping, typically has a density in the range from 20 to 40 pcf.

Structural concrete—normal-weight structural concrete and lightweight structural concrete—is produced by mixing large and small aggregates, Portland cement, water and, in some instances, admixtures such as fly ash or various chemical additives. Admixtures can add entrained air to the concrete, accelerate concrete's curing, retain concrete's excess moisture and/or lengthen concrete's finishing time. Use of admixtures typically is not visually identifiable in the field; microscopic analysis usually is needed for post-application identification of admixtures.

The primary difference in the composition of normal-weight structural concrete and lightweight structural concrete is the large aggregates' type. Normal-weight structural concrete contains normal-weight aggregates such as stone or crushed gravel, which are dense and typically will absorb no more moisture than about 2 percent by weight. Lightweight structural concrete uses lightweight, porous aggregates such as expanded shale, which will absorb about 5 to 25 percent moisture by weight. Lightweight aggregate needs to be saturated with moisture—it's often stored in ponds—before mixing. As a result, lightweight structural concrete inherently contains much more water than normal-weight structural concrete.

Lightweight structural concrete is used in roofing-related applications for cast-in-place concrete roof decks using removable forms; composite roof decks where a metal form deck remains in place; and as a deck topping material, such as a concrete topping surface over precast concrete planks or tees.

Once poured, lightweight structural concrete typically cannot be easily distinguished from normal-weight structural concrete. Visual identification is possible using magnification, typically a microscope used by a trained technician.

Lightweight structural concrete inherently contains much more water than normal-weight structural concrete

REPORTED PROBLEMS

The problems reported to NRCA associated with lightweight structural concrete roof decks include the following:

- *Moisture accumulation.* Excessive moisture from a concrete deck can be pressure-differential driven into and condensed within a roof system.
- *Adhesion loss.* The presence of moisture can result in deterioration of moisture-sensitive roofing materials and adhesive bond loss between adhered material layers.
- *Adhesive issues with water-based and low-volatile organic compounds.* Excessive moisture can affect adhesive curing and drying rates. Also, moisture can result in adhesive "rewetting," resulting in bond strength loss.
- *Metal and fastener corrosion.* Excessive moisture can contribute to and accelerate metal components' corrosion, including fastener corrosion.
- *Insulation R-value loss.* The accumulation and presence of moisture in most insulation products will result in reduced thermal performance (lower effective R-value).
- *Microbial growth.* The presence of prolonged high-moisture

contents in contact with organic-based materials, such as wood fiberboard, perlite board and some insulation facer sheets, can support microbial growth.

DETERMINING CONCRETE'S DRYNESS

The roofing industry historically has used rather rudimentary methods for determining concrete roof decks' dryness and suitability for roof system application.

One method is to apply roofing materials to concrete roof decks only after a minimum of 28 days after concrete is placed. For concrete, 28 days is the standard time for testing and evaluating concrete's compressive strength. There is minimal correlation between concrete's compressive strength and its dryness or suitability to be covered by a roof system.

Another method often used is to mop or pour hot bitumen on a concrete's surface and monitor it for splattering or bubbling caused by excessive moisture in the concrete substrate. Experience has shown this method is unreliable, particularly with current generation concrete mix designs because the test only evaluates empirical moisture levels at the concrete's top surface and not moisture levels throughout the concrete's thickness.

> NRCA recommends designers not specify lightweight structural concrete for roof decks

A third method involves taping or otherwise sealing the perimeter of a small, transparent sheet or glass pane to the concrete surface and monitoring it over time for developing condensation. This method is standardized as ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method." Experience has shown this method also is unreliable. An airtight seal at the test panel's edges is difficult to achieve, and unless temperatures on the top and bottom sides of the concrete deck are nearly identical, the resulting pressure difference can result in false "dry" indications.

The flooring industry has developed a test method, ASTM F2170, "Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes," that, in NRCA's opinion, holds some promise for the roofing industry to use when determining dryness in concrete roof decks. Using this test method, small moisture probes are drilled, placed and sealed into a concrete roof deck for a minimum of 48 hours. Each probe measures the concrete's internal temperature and relative humidity.

The ASTM F2170 test method does not provide specific pass-fail values for concrete; however, in the flooring industry, manufacturers of resilient and textile floor coverings and coatings establish maximum acceptable humidity levels for their products. Maximum relative humidity values range from 65 to 85 percent depending on the floor covering type and manufacturer; a 75 percent maximum value appears to be the most common.

NRCA has conducted limited ASTM F2170 testing on existing lightweight structural concrete roof decks where roof systems had been installed and moisture-related problems were reported. These roof systems ranged from 4 to 7 years old at the time of testing. Internal concrete relative humidity values ranged from 89 to 99 percent, indicating extremely high moisture levels.

Concrete industry research shows newly placed normal-weight structural concrete will reach internal relative humidity values of 75 percent in less than 90 days under controlled laboratory conditions (no rewetting); lightweight structural concrete will reach this humidity value in about six months.

CONTRACTORS' RESPONSIBILITIES

Project contract, specification or manufacturers' installation requirements often attempt to place the responsibility on roofing contractors for determining structural concrete decks' dryness and suitability to be covered with roofing materials.

NRCA considers the decision of when it is appropriate to cover newly placed concrete substrates with roofing materials to be beyond roofing contractors' control. Because of the numerous variables associated with concrete mix design, placement, curing and drying, roofing contractors are not privy to and may not be knowledgeable of the information necessary to make such a decision.

Also, though a roofing contractor can visually assess the dryness of concrete's uppermost surface, he or she cannot readily assess any remaining free moisture within the concrete and its likely release.

NRCA RECOMMENDATIONS

NRCA recommends the decision of when a newly placed concrete substrate is ready to be covered with a new roof system be made by the building's structural engineer, general contractor, concrete supplier and concrete placement contractor, each of whom likely will have more knowledge than the roofing contractor about the particular concrete's curing and moisture release rates. It also may be useful to consult the building's project or roof system designer and roof system manufacturer.

NRCA's premise and position is consistent with the flooring industry. For resilient tile and textile floor coverings and coatings, floor covering manufacturers generally require quantitative moisture testing be performed before floor covering installation on concrete. ASTM F2170 testing often is used for this purpose.

Furthermore, in new construction, NRCA recommends designers not specify—and construction managers and general contractors not use—lightweight structural concrete for roof decks or as toppings for roof decks. In NRCA's opinion, the risks of moisture-related problems associated with lightweight structural concrete roof decks outweigh the possible benefits.

In the event lightweight structural concrete is used, NRCA recommends designers clearly specify the concrete's drying parameters. ASTM F2170 can be used for this purpose. Until recognized pass-fail criteria applicable for determining concrete's internal humidity is developed, NRCA suggests a maximum 75 percent relative humidity value be used; lower values may be necessary when using organic-based materials, such as wood fiberboard, perlite board and some insulation facer sheets, as roof system components.

For reroofing situations where the existing roof deck is known to be lightweight structural concrete or where there is evidence of concrete deck-related moisture problems, NRCA recommends two alternative roof system designs be considered.

An above-deck venting design, such as a venting base sheet, using a loosely laid ballasted roof system with perimeter venting may allow release of the concrete deck's moisture without adversely affecting roof system components. Or sealing the concrete's moisture into the deck by using a high-bond strength vapor retarder adhered directly to the deck followed by an adhered roof system is another option. A high-quality, 12- to 15-mil-thick two-part epoxy has successfully been used as a vapor retarder in the flooring industry.

CLOSING THOUGHTS

NRCA remains committed to keeping members informed of further developments relating to moisture-related problems with lightweight structural concrete roof decks and encourages you to notify NRCA's Technical Services Section about moisture-related problems regarding lightweight structural concrete roof decks. Also, we encourage you to share with us any ASTM F2170 testing, relative humidity or moisture content data developed for projects you encounter.

MARK S. GRAHAM is NRCA's associate executive director of technical services.

INDUSTRY ISSUE UPDATE

NRCA Member Benefit

Polyiso's R-value

NRCA recommends polyisocyanurate insulation be specified by its desired thickness

Jan. 1, 2014

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.

Mark S. Graham is NRCA's associate executive director of technical services.

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