Low Slope Roofing Systems
The University of Wisconsin Madison
Madison, Wisconsin – December 3-5, 2014

Roof Insulation

presented by

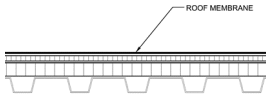
Mark S. Graham
Associate Executive Director, Technical Services
National Roofing Contractors Association
Rosemont, Illinois

Topics

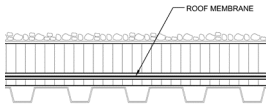
- Principles of insulation (for roofing)
- Insulating materials
- Code requirements (Energy Code)

2

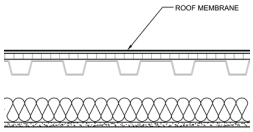
Roof assembly configurations



Conventional
Insulation above deck



Protected membrane
Insulation above membrane



Attic (or "other")
Insulation below deck

THE UNIVERSITY OF WISCONSIN MADISON

3

Purpose(s) for insulation

Low-slope roof systems

- Thermal performance
- Condensation control
- Smooth substrate
- Deck stability
  - Reduce temperature variations
  - Control thermal expansion and contraction
- Fire resistance
- Roof slope
  - Above-deck tapered insulation

THE UNIVERSITY OF WISCONSIN MADISON

4

Principles of thermal insulation

British thermal unit (Btu): the energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit (F).

5

Principles of thermal insulation

Thermal conductivity (k): the amount of heat is transmitted by conduction through 1 square foot of 1-inch-thick homogenous material in 1 hour where there is a difference of 1 degree Fahrenheit (F) across the two surfaces of the material.

$$k = Btu \bullet inch / ft^2 \bullet hr \bullet F$$

6

Principles of thermal insulation

Thermal conductance (C): the amount of heat is transmitted by conduction through 1 square foot of a specified thickness of material in 1 hour where there is a difference of 1 degree Fahrenheit (F) across the two surfaces of the material.

$$C = Btu / ft^2 \bullet hr \bullet F$$

7

Principles of thermal insulation

Thermal tranmittance (U): the amount of heat is transmitted by conduction through 1 square foot of an assembly and its boundary layers in 1 hour where there is a difference of 1 degree Fahrenheit (F) across the two surfaces of the assembly.

$$U = Btu / ft^2 \bullet hr \bullet F$$

8

Principles of thermal insulation

Thermal resistance: a relative measure of a material's or an assembly's resistance to heat flow; the reciprocal of the material's thermal conductance (C) or an assembly's thermal transmittance (U).

$$R = 1 / C \text{ or } R = 1 / U$$

R-values are readily additive (unlike k-values and C-values). Therefore $R_T = R_1 + R_2 + R_3 = \ldots$

9

R-values of boundary layer air films

Applicable to the inside and outside surfaces of assemblies

Surface	Condition	Resistance
Outside air film (f_o)	15 mph wind (winter) 7.5 mph wind (summer)	0.17 °F•ft²•h/Btu 0.25 °F•ft²•h/Btu
Inside air film (f_i)	Still air—horizontal surface[3] Heat flow upward (winter) Heat flow downward (summer)	 0.61 °F•ft²•h/Btu 0.92 °F•ft²•h/Btu

1. Values derived from Table 1, *2001 ASHRAE Handbook—Fundamentals,* page 25.4.
2. Surface air films exist on every surface. They are invisible layers of air that cling to the surface on a material and have some resistance to heat flow. Outside air films vary in thickness according to wind velocity; inside air films vary in effectiveness according to the direction of heat flow.
3. Inside air film values listed are for horizontal inside surfaces only. If the inside surface being evaluated is sloping or vertical, other thermal resistance values may apply; refer to Table 1, *2001 ASHRAE Handbook—Fundamentals,* page 25.4.

Figure 3-1: Thermal resistance values for air films

10

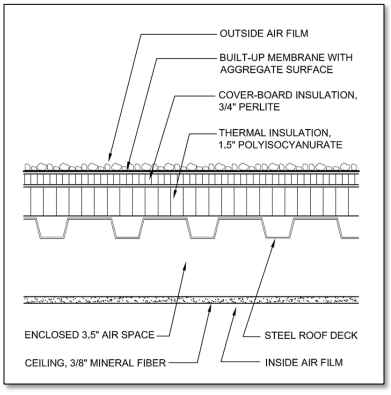
R-values of enclosed spaces

Position of Air Space[3]	Condition[3]	Thickness of Air Space[4]	Thermal Resistance of Air Space[5]		
			Highly Reflective Roof Surface[6]	Moderately Reflective Roof Surface[7]	Non-Reflective Roof Surface[8]
Horizontal	Heat flow upward (winter)	0.75 inch 1.5 inches 3.5 inches	1.70°F•ft²•h/Btu 1.81°F•ft²•h/Btu 1.95°F•ft²•h/Btu	1.16°F•ft²•h/Btu 1.21°F•ft²•h/Btu 1.28°F•ft²•h/Btu	0.87°F•ft²•h/Btu 0.89°F•ft²•h/Btu 0.93°F•ft²•h/Btu
Horizontal	Heat flow downward (summer)	0.75 inch 1.5 inches 3.5 inches	2.41°F•ft²•h/Btu 3.27°F•ft²•h/Btu 4.09°F•ft²•h/Btu	1.45°F•ft²•h/Btu 1.73°F•ft²•h/Btu 1.93°F•ft²•h/Btu	1.02°F•ft²•h/Btu 1.15°F•ft²•h/Btu 1.24°F•ft²•h/Btu

1. Values derived from Tables 2 and 3, *2001 ASHRAE Handbook—Fundamentals,* pages 25.2 and 25.4.
2. Any air space where the air is not ventilated or otherwise allowed to freely move has some thermal resistance to heat flow. If the air space is ventilated or if the space is used as a plenum, the thermal resistance of the space and inside air film must be considered zero.
3. The thermal resistance values listed are for horizontal air spaces with the direction of heat flow either in an upward (winter) or downward (summer) direction. If the air space being evaluated is oriented in a sloping or vertical direction, other thermal resistance values may apply; refer to Tables 2 and 3, *2001 ASHRAE Handbook—Fundamentals,* pages 25.2 and 25.4.
4. Interpolation and moderate extrapolation for air spaces other than those listed is permissible.
5. Thermal resistance values based on 50 F mean temperature and 10 F temperature difference.
6. Values based on an Effective Emittance (ϵ_{eff}) of 0.20 with one surface with a reflectivity of 75-84 percent and the other surface with ϵ=0.90 (e.g., foil-surfaced modified bitumen membrane, mill finish aluminum panels).
7. Values based on an ϵ_{eff} of 0.50 with one surface with a reflectivity of 30-70 percent and the other surface with ϵ=0.90 (e.g., white membranes, smooth-surfaced membrane with a reflective coating).
8. Values based on an ϵ_{eff} of 0.82 with surfaces with a reflectivity of 5-15 percent (e.g., most aggregate-surfaced roofs, smooth-surfaced built-up roofs).

Figure 3-2: Thermal resistance values for enclosed air spaces

R-value calculations



Component	Heating Condition R-value	Cooling Condition R-value
Outside air film	0.17	0.25
Built-up membrane, aggregate surfaced	0.33	0.33
Insulation cover board, ¾-inch perlite board	2.08	2.08
Primary insulation, 1½-inch polyisocyanurate	7.50	8.40
Roof deck, steel	0.00	0.00
Enclosed air space, 3½ inches	0.93	1.24
Ceiling, ⅜-inch mineral fiber	1.56	1.56
Inside air film	0.61	0.92
Total (R_T):	13.18	14.78

Desirable properties for roof insulation

- Attachment capability
- Compatible with adhesives
- Compatible with other roof assembly components
- Compressive strength
- Dimensionally stable
- Fire resistant
- Impact resistance
- Moisture resistant
- Thermal resistant (low k-value or C-value/high R-value)
- Thermal resistance stability

13

So, what is the "ideal" roof insulation

There is no "ideal" roof insulation…
roof insulation selection and use is a compromise

14

Roof insulation types

Rigid board insulation

- Cellular glass
- Expanded polystyrene (EPS)
- Extruded polystyrene (XPS)
- Faced gypsum
- Fiber-reinforced gypsum
- Mineral fiber (stone wool)
- Perlite
- Polyisocyanurate
- High-density polyisocyanurate
- Wood fiberboard

15

Cellular glass

- Crushed glass and hydrogen sulfide gas heated to 950 F
- ASTM C552, Type IV
- 12” x 18”, 18” x 24” and 2’ x 4’
- 1½” to 6” and tapered
- R = 3.44 per inch

16

Expanded polystyrene (EPS)

- Polystyrene polymer, foaming agent and heat
- ASTM C578 (many types)
- 4’ x 4’ and 4’ and 8’
- ⅜” to 24”and tapered
- R = 3.1 to 4.3 per inch based upon density

17

EPS types

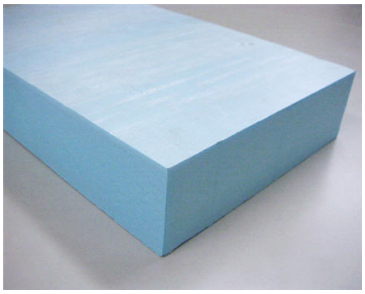
ASTM C578, Type __

EPS type	Density, min. (pounds per cubic foot)	Compressive strength, min. (psi)	R-value
Type I	0.90 (1.0 nominal)	10.0	3.6
Type II	1.35 (1.5 nominal)	15.0	4.0
Type VIII	1.15 (1.25 nominal)	13.0	3.8
Type IX	1.80 (2.0 nominal)	25.0	4.2
Type XI*	0.70 (0.75 nominal)	5.0	3.1
Type XIV	2.40 (2.5 nominal)	40.0	4.2
Type XV	2.85 (3.0 nominal)	60.0	4.3

* Type XI is generally not intended to be used in roofing applications

18

Extruded polystyrene (XPS)



- Polystyrene polymer is heated and extruded
- ASTM C578 (many types)
- 2’ x 4’ and 2’ x 8’
- 1”, 1½”, 2”, 2½”, 3” & 4”
- R = 4.6 to 5.0 per inch

19

XPS types

ASTM C578, Type __

XPS type	Density, min. (pounds per cubic foot)	Compressive strength, min. (psi)	R-value
Type IV	1.55	25.0	5.0
Type V	3.00	100.0	5.0
Type VI	1.80	40.0	5.0
Type VII	2.20	60.0	5.0
Type X	1.30	15.0	5.0
Type XII*	1.20	15.0	4.6

* Type XII is generally not intended to be used in roofing applications

20

Faced gypsum

- Gypsum core between paper or fiberglass-mat facers
- ASTM C1396 (paper)
- ASTM C1177 (glass-mat)
- 4’ x 4’ and 4’ x 8’
- ¼”, ½” and ⅝” thick
- R = 1.12 per inch

21

Fiber-reinforced gypsum

- Cellulose-fiber reinforced gypsum
- ASTM C1278
- 4’ x 4’ and 4’ x 8’
- ¼”, ⅜”, ½” and ⅝” thick
- R = 1.0 per inch

22

Mineral fiber (stone wool)

- Rock, slag or glass heated and spun into fibers with a binding agent
- ASTM C726 or ASTM C612
- 4’ x 4’
- Up to 6” thick
- R = 4 per inch (10 pcf density)

23

Perlite

- Expanded volcanic minerals, organic fibers and binders
- ASTM C728 (various types)
- 2’ x 4’ and 4’ x 4’
- ½”, ¾”, 1”, 1½”, 2” and tapered
- R = 2.78 per inch

24

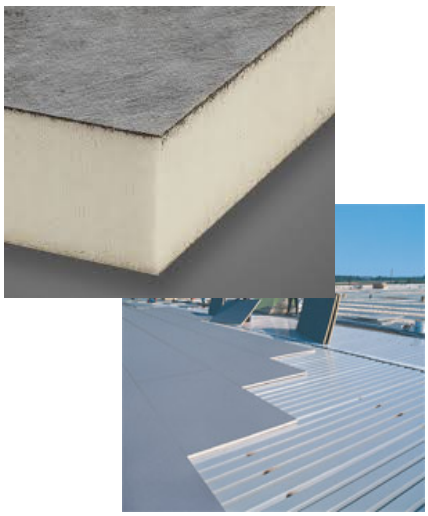
Perlite types

ASTM C728, Type __

- Type 1: Roof insulation board
- Type 2: Recover board
- Type 3: Recover board (higher physical properties)

25

Polyisocyanruate



- Polysiocyanurate foam and facers
- ASTM C1289 (multiple types, grades and classes)
- 4’ x 4’ and 4’ x 8’
- Thicknesses range from 1” to 4”
- R = 5.0-6.0 per inch
- LTTR = 5.6 to 5.9 per inch

26

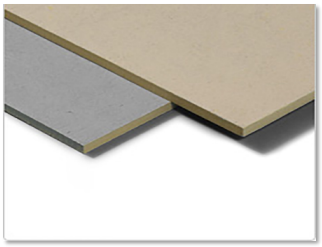
Polyiso. type, grades and classes

ASTM C1289, Type II, Class __, Grade __

- Type II:
  - Class 1: organic/glass facer:
    - Grade 1: 16 psi (min.) compressive strength
    - Grade 2: 20 psi (min.) compressive strength
    - Grade 3: 25 psi (min.) compressive strength
  - Class 2: coated glass facer
  - Class 3: uncoated glass facer

27

High density polyisocyanurate



- Polyisocyanurate foam and facers
- ASTM C1289, Type II, Class 4 (multiple grades)
- 4’ x 4’ and 4’ x 8’
- ¼” and ½” thick
- R = 1.0 for ¼” thick
  R = 2.0 for ½” thick

28

HD polyiso. type, class and grades

ASTM C1289, Type III, Class 4, Grade __

- Type III:
  - Class 4: coated or uncoated glass mats:
    - Grade 1: 80 psi (min.) compressive strength
    - Grade 2: 110 psi (min.) compressive strength
    - Grade 3: 140 psi (min.) compressive strength

29

Wood fiberboard

- Wood or cane fibers and binders; may be coated
- ASTM C208, Type II (two grades)
- 2’ x 4’, 4’ x 4’ and 4’ x 8’
- ½”, 1” and 2’ thick
- R = 2.78 per inch

30

Wood fiberboard grades

ASTM C208, Type II, Grade __

- ASTM C208, Type II:
  - Grade 1: For BUR and MB systems
  - Grade 2: For single-ply systems

31

Composite boards

- EPS and plywood/OSB
- Polyiso. and perlite, wood fiberboard, plywood/OSB or glass-mat-faced gypsum

32

Board joints

Heat loss through gaps at the joints between insulation boards can represent up to a 10% reduction in effective R-value

A two-layer application rigid board insulation with staggered and offset board joints is recommended

33

Mechanical fasteners

Mechanical fasteners through the cross-section of rigid board insulation can represent 3% to 8% losses in effective R-values.

Mechanically-attach the bottommost layer and adhere subsequent layers is preferred.

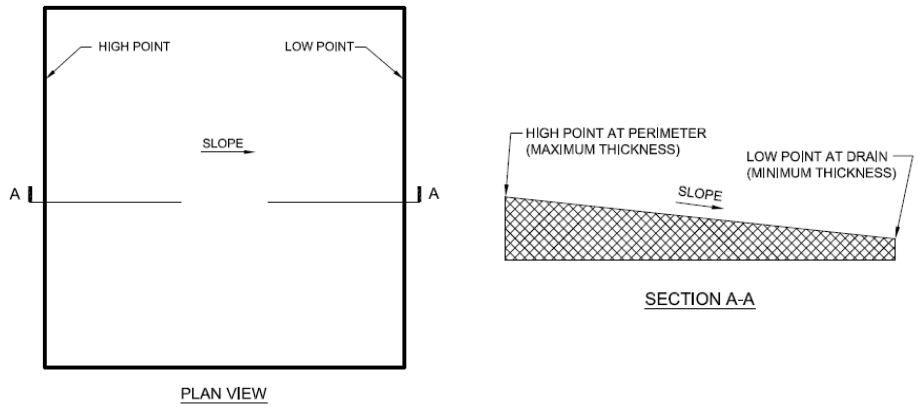
34

Tapered insulation

- Common materials:
  - EPS
  - XPS
  - Perlite
  - Polyisocyanurate
- Common slopes:
  - ⅛" per foot
  - ¼" per foot
  - ½" per foot

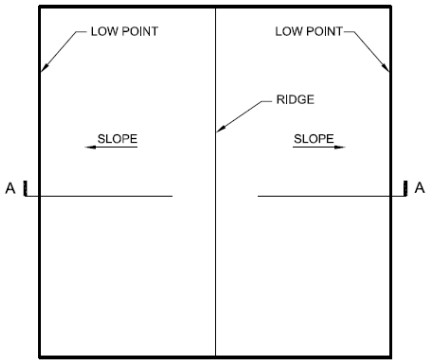
35

One-way slope

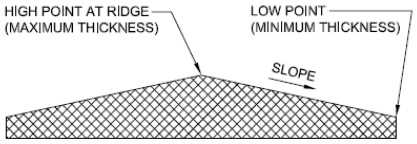


36

Two-way slope



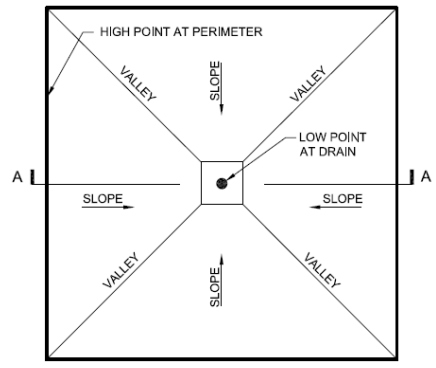
PLAN VIEW



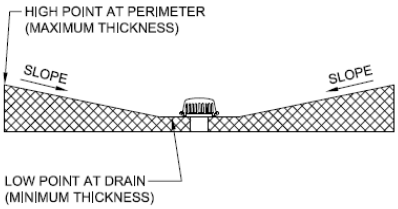
SECTION A-A

37

Four-way slope



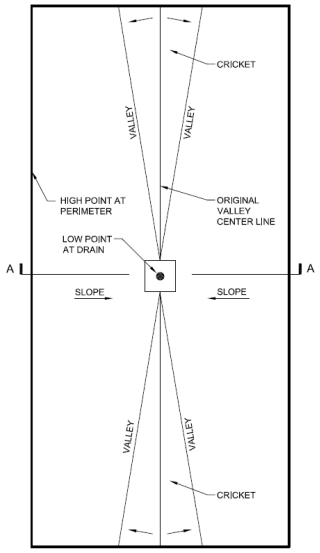
PLAN VIEW



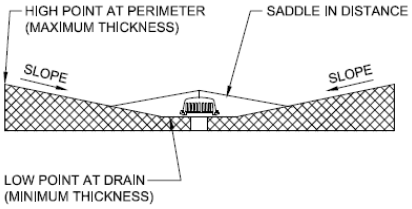
SECTION A-A

38

Two-way slope crickets



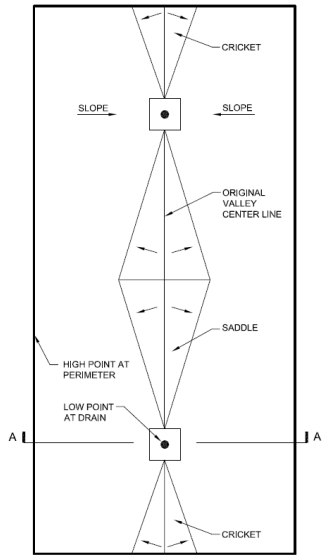
PLAN VIEW



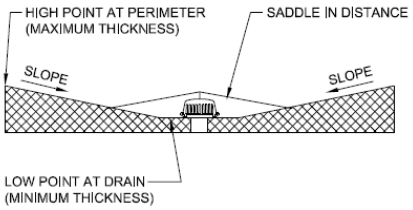
SECTION A-A

39

Two-way slope with saddle and crickets



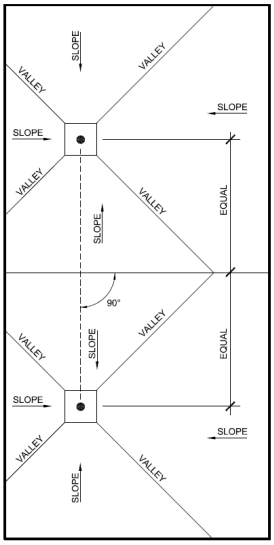
PLAN VIEW



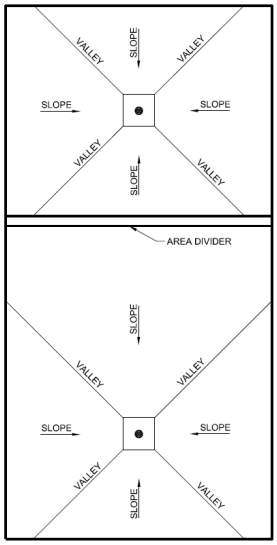
SECTION A-A

40

Ridge/area divider configurations



Common ridge



Area divider

41

R-value determination

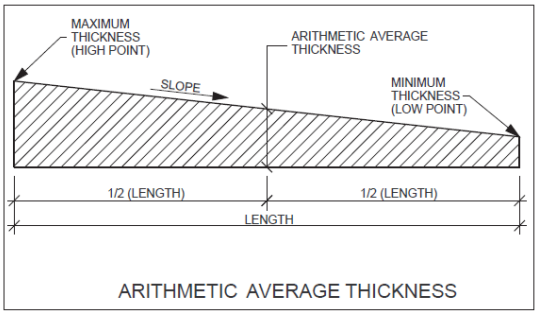
Tapered insulation systems

- Low point
- Average R-value
  - Arithmetic average thickness
  - Volumetric average thickness (cross section)
  - Volumetric average thickness (total material)

42

Average R-value

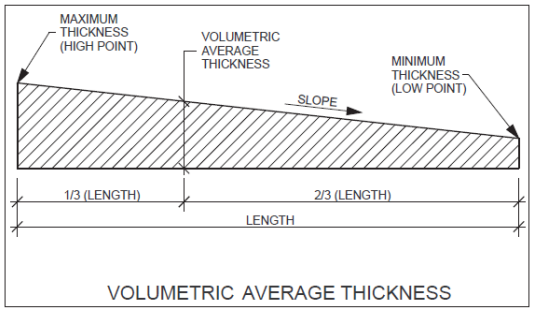
Arithmetic average thickness method



Arithmetic average thickness = LP + [½(HP - LP)]

Average R-value

Volumetric average thickness-cross section method



Volumetric average thickness = LP +[⅔(HP - LP)]

Average R-value

Volumetric average thickness total material method

Volumetric average thickness = volume of insulation / roof surface area

Energy code requirements applicable to roof assemblies

Some history…

Energy efficiency of buildings

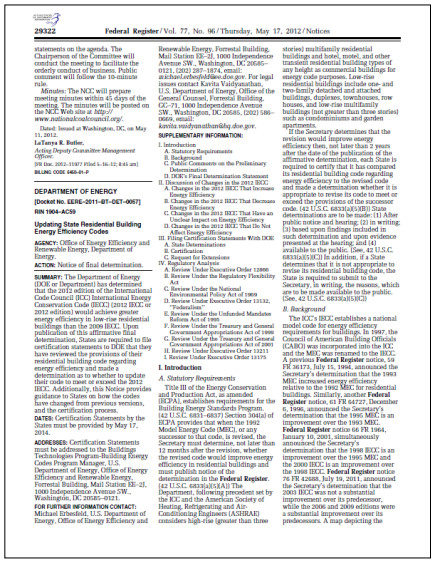
- 1973: Arab oil embargo
- 1974: NBS Interim Report 74-452 (prelim. criteria)
- 1975: ASHRAE 90-75 (energy-efficiency std.)
- 1977: BOCA/ICBO/SBCCI code (CABO *MEC*)
- 1980: ASHRAE 90-80
- 1989: ASHRAE 90.1-89
- 1992: Energy Policy Act (EPAct)
- 1998: *International Energy Conservation Code*
- 1999: ASHRAE 90.1-99

More recent history…

Energy efficiency in buildings

- 2004: ASHRAE 90.1-04
- 2006: *International Energy Conservation Code, 2006 Edition*
- 2007: ASHRAE 90.1-07
- 2009: *International Energy Conservation Code, 2009 Edition*
- 2009: ASHRAE 189.1-09
- 2010: ASHRAE 90.1-10
- 2011: *International Energy Conservation Code, 2012 Edition*
- 2013: ASHRAE 90.1-13
- 2014: *International Energy Conservation Code, 2015 Edition*

Federal Register, May 17, 2012



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

statements on the agenda. The Chairperson of the Committee will conduct the meeting to facilitate the orderly conduct of business. Public comment will follow the 10-minute rule.

Minutes: The NCC will prepare meeting minutes within 45 days of the meeting. The minutes will be posted on the NCC Web site at *http://www.nationalcouncil.org/*.

Dated: Issued at Washington, DC, on May 11, 2012.

LaTanya R. Butler,
Acting Deputy Committee Management Officer.

[FR Doc. 2012-11977 Filed 5-16-12; 8:45 am]
BILLING CODE 6450-01-P

DEPARTMENT OF ENERGY

[Docket No. EERE–2011–BT–DET–0067]

RIN 1904–AC59

Updating State Residential Building Energy Efficiency Codes

AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy.

ACTION: Notice of final determination.

SUMMARY: The Department of Energy (DOE or Department) has determined that the 2012 edition of the International Code Council (ICC) International Energy Conservation Code (IECC) (2012 IECC or 2012 edition) would achieve greater energy efficiency in low-rise residential buildings than the 2009 IECC. Upon publication of this affirmative final determination, States are required to file certification statements to DOE that they have reviewed the provisions of their residential building code regarding energy efficiency and made a determination as to whether to update their code to meet or exceed the 2012 IECC. Additionally, this Notice provides guidance to States on how the codes have changed from previous versions, and the certification process.

DATES: Certification Statements by the States must be provided by May 17, 2014.

ADDRESSES: Certification Statements must be addressed to the Buildings Technologies Program-Building Energy Codes Program Manager, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Forrestal Building, Mail Station EE–2J, 1000 Independence Avenue SW., Washington, DC 20585–0121.

FOR FURTHER INFORMATION CONTACT: Michael Ebbehold, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Forrestal Building, Mail Station EE–2J, 1000 Independence Avenue SW., Washington, DC 20585–0121, (202) 287–1874, email: *michael.ebbehold@ee.doe.gov*. For legal issues contact Kavita Vaidyanathan, U.S. Department of Energy, Office of the General Counsel, Forrestal Building, GC–71, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586–0669, email: *kavita.vaidyanathan@hq.doe.gov*.

SUPPLEMENTARY INFORMATION:

I. Introduction
A. Statutory Requirements
B. Background
C. Public Comments on the Preliminary Determination
D. DOE's Final Determination Statement
II. Discussion of Changes in the 2012 IECC
A. Changes in the 2012 IECC That Increase Energy Efficiency
B. Changes in the 2012 IECC That Decrease Energy Efficiency
C. Changes in the 2012 IECC That Have an Unclear Impact on Energy Efficiency
D. Changes in the 2012 IECC That Do Not Affect Energy Efficiency
III. Filing Certification Statements With DOE
A. Format and Submissions
B. Certification
C. Request for Extensions
IV. Regulatory Analysis
A. Review Under Executive Order 12866
B. Review Under the Regulatory Flexibility Act
C. Review Under the National Environmental Policy Act of 1969
D. Review Under Executive Order 13132, Federalism
E. Review Under the Unfunded Mandates Reform Act of 1995
F. Review Under the Treasury and General Government Appropriations Act of 1999
G. Review Under the Treasury and General Government Appropriations Act of 2005
H. Review Under Executive Order 13211
I. Review Under Executive Order 13175

I. Introduction

A. Statutory Requirements

Title III of the Energy Conservation and Production Act, as amended (ECPA), establishes requirements for the Building Energy Standards Program. (42 U.S.C. 6831–6837) Section 304(a) of ECPA provides that when the 1992 Model Energy Code (MEC), or any successor to that code, is revised, the Secretary must determine, not later than 12 months after the revision, whether the revised code would improve energy efficiency in residential buildings and must publish notice of the determination in the **Federal Register**. (42 U.S.C. 6833(a)(5)(A)) The Department, following precedent set by the ICC and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) considers high-rise (greater than three stories) multifamily residential buildings and hotel, motel, and other transient residential building types of any height as commercial buildings for energy code purposes. Low-rise residential buildings include one- and two-family detached and attached buildings, duplexes, townhouses, row houses, and low-rise multifamily buildings (not greater than three stories) such as condominiums and garden apartments.

If the Secretary determines that the revision would improve energy efficiency then, not later than 2 years after the date of the publication of the affirmative determination, each State is required to certify that it has compared its residential building code regarding energy efficiency to the revised code and made a determination whether it is appropriate to revise its code to meet or exceed the provisions of the successor code. (42 U.S.C. 6833(a)(5)(B)) State determinations are to be made: (1) After public notice and hearing; (2) in writing; (3) based upon findings included in such determination and upon evidence presented at the hearing; and (4) available to the public. (See, 42 U.S.C. 6833(a)(5)(C)) In addition, if a State determines that it is not appropriate to revise its residential building code, the State is required to submit to the Secretary, in writing, the reasons, which are to be made available to the public. (See, 42 U.S.C. 6833(a)(5)(C))

B. Background

The ICC's IECC establishes a national model code for energy efficiency requirements for buildings. In 1997, the Council of American Building Officials (CABO) was incorporated into the ICC and the MEC was renamed to the IECC. A previous **Federal Register** notice, 59 FR 36173, July 15, 1994, announced the Secretary's determination that the 1993 MEC increased energy efficiency relative to the 1992 MEC for residential buildings. Similarly, another **Federal Register** notice, 61 FR 64727, December 6, 1996, announced the Secretary's determination that the 1995 MEC is an improvement over the 1993 MEC. **Federal Register** notice 66 FR 1964, January 10, 2001, simultaneously announced the Secretary's determination that the 1998 IECC is an improvement over the 1995 MEC and the 2000 IECC is an improvement over the 1998 IECC. **Federal Register** notice 76 FR 42688, July 19, 2011, announced the Secretary's determination that the 2003 IECC was not a substantial improvement over its predecessor, while the 2006 and 2009 editions were a substantial improvement over its predecessors. A map depicting the

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 5/17/14 their energy code meets or exceeds the levels of IECC 2012

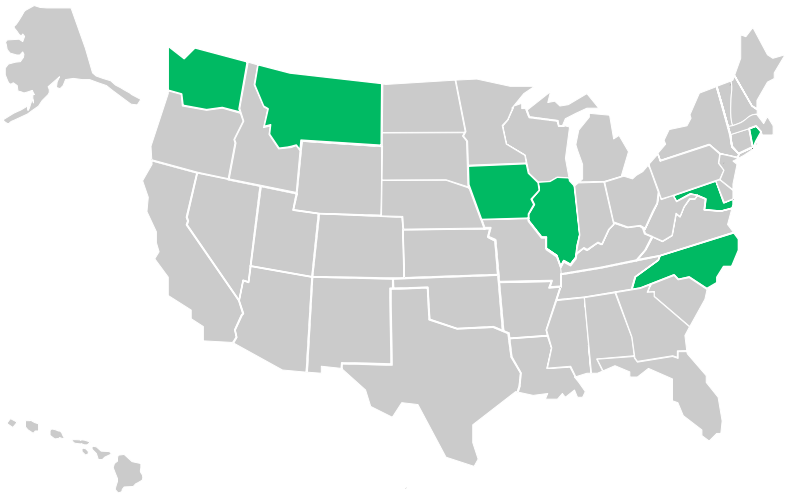
This triggers most states to update their state energy code

THE UNIVERSITY OF WISCONSIN MADISON

49

Status of states' adoptions

Adoption of IECC 2012 before May 17, 2014



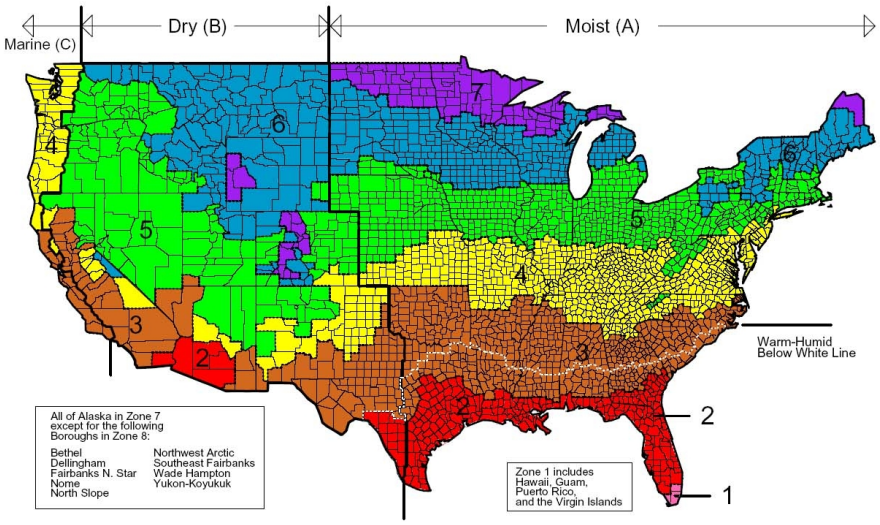
THE UNIVERSITY OF WISCONSIN MADISON

Status of states' adoptions

Adoption of IECC 2012 between May 17, 2014 and Jan. 1, 2015

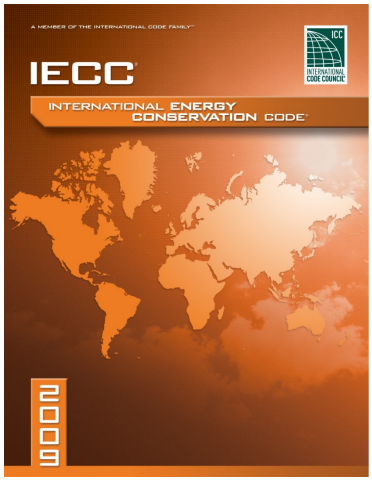
Climate zones

IECC 2009 and IECC 2012



52

International Energy Conservation Code, 2009 Edition (IECC 2009)



53

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]	

54

Roofing-specific adaptation of Table 502.2(1)

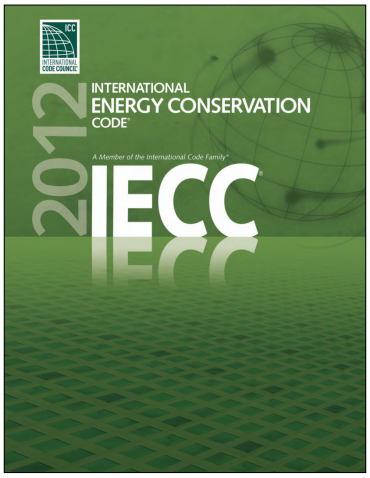
International Energy Conservation Code, 2009 Edition (Commercial buildings)

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-15ci	R-19	R-30
2	R-20ci	R-13 + R-13	R-38
3			
4			
5			
6		R-13 + R-19	
7	R-25ci		
8			R-49

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)

55

International Energy Conservation Code, 2012 Edition (IECC 2012)



56

Format of IECC 2012

IECC – Commercial	***IECC – Residential***
Ch. 1[CE]: Scope and Admin.	Ch. 1[RE]: Scope and Admin.
Ch. 2[CE]: Definitions	Ch. 2[RE]: Definitions
Ch. 3[CE]: General Req.	Ch. 3[RE]: General Req.
Ch. 4[CE]: Commercial Energy Efficiency	Ch. 4[RE]: Residential Energy Efficiency
Ch. 5[CE]: Referenced Stds.	Ch. 5[RE]: Referenced Stds.
Index	Index

57

Commercial vs. Residential

- Commercial unless Residential
- R202-General Definitions:

  Residential Building. For this code, includes detached one- and two-family dwellings and multiple single-family dwellings (townhouses) as well as Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane

58

IECC – Residential Provisions

Ch. 4[RE]—Residential Energy Efficiency

International Energy Conservation Code, 2012 Edition

- Sec. R401—General
- Sec. R402—Building Thermal Envelope
- Sec. R403—Systems
- Sec. R404—Electrical Power and Lighting Systems
- Sec. R405—Simulated Performance Alternative

Minimum thermal insulation requirements

IECC 2012, Section R402-Building Thermal Envelope

R402.1 General (Prescriptive). The *building thermal envelope* shall meet the requirements of Sections R402.1.1 through R402.1.4.

R402.1.1 Insulation and fenestration criteria. The building thermal envelope shall meet the requirements of Table R402.1.1 based upon the climate zone specified in Chapter 3.

R402.1.2 *R*-value computation. Insulation material used in layers, such as framing cavity insulation and insulated sheathing, shall be summed to compute the component *R*-value. The manufacturer's settled *R*-value shall be used for blown insulation. Computed *R*-values shall not include an R-value for other building materials or air films

61

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]	

62

R402.2 Specific insulation requirements (Prescriptive). In addition to the requirements of Section R402.1, insulation shall meet the specific requirements of Sections R402.2.1 through R402.2.12.

R402.2.1 Ceilings with attic spaces. When Section R402.1.1 would require R-38 in the ceiling, R-30 shall be deemed to satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Similarly, R-38 shall be deemed to satisfy the requirement for R-49 wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the U-factor alternative approach in Section R402.1.3 and the total UA alternative in Section R402.1.4.

63

R402.2.2 Ceilings without attic spaces. Where Section R402.1.1 would require insulation levels above R-30 and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation for such roof/ceiling assemblies shall be R-30. This reduction of insulation from the requirements of Section R402.1.1 shall be limited to 500 square feet (46 m^2) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the U-factor alternative approach in Section R402.1.3 and the total UA alternative in Section R402.1.4.

R402.2.3 Eave baffle. For air permeable insulations in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain an opening equal or greater than the size of the vent. The baffle shall extend over the top of the attic insulation. The baffle shall be permitted to be any solid material.

64

Air retarders

IECC 2012, Section R402.4-Air Leakage (Mandatory)

R402.4 Air leakage (Mandatory). The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.

R402.4.1 Building thermal envelope. The building thermal envelope shall comply with Sections R402.4.1.1 and R402.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

R402.4.1.1 Installation. The components of the building thermal envelope as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction. Where required by the code official, an approved third party shall inspect all components and verify compliance.
R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 5 air changes per hour in Climate Zones 1 and 2, and 3 air changes per hour in Climate Zones 3 through 8. Testing shall be conducted…

65

Roofing-specific adaptation of Table R402.4.1.1

International Energy Conservation Code, 2012 Edition

Air Barrier and Insulation Installation	
Component	**Criteria**
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints sin the bar barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.

66

IECC – Commercial Provisions

Ch. 4[CE]—Commercial Energy Efficiency

International Energy Conservation Code, 2012 Edition

- Sec. C401—General
- Sec. C402—Building Envelope Requirements
- Sec. C403—Building Mechanical Systems
- Sec. C404—Service Water Heating
- Sec. C405—Electrical Power and Lighting Systems
- Sec. C406—Additional Efficiency Package Options
- Sec. C407—Total Building Performance

Ch. 4—Commercial Energy Efficiency

International Energy Conservation Code, 2012 Edition

C401.2 Application. Commercial buildings shall comply with one of the following:

1. The requirements of ANSI/ASHRAE/IESNA 90.1
2. The requirements of Sections C402, C403, C404 and C405. In addition, commercial buildings shall comply with either Section C406.2, C406.3 or C406.4
3. The requirements of Section C407, C402.4, C403.2, C404, C405.2, C405.3, C405.4, C405.6 and C405.7. The building energy cost shall be equal to or less than 85 percent of the standard reference design building.

[Continued…]

69

C401.2.1 Application to existing buildings. Additions, alterations and repairs to existing buildings shall comply with one of the following:

1. Sections C402, C403, C404 and C405; or
2. ANSI/ASHRAE/IESNA 90.1

70

Minimum thermal insulation requirements

IECC 2009, Section C402.2—Specific insulation Requirements (Prescriptive)

C402.2 Specific insulation requirements (Prescriptive). Opaque assemblies shall comply with Table C402.2. Where two or more layers of continuous insulation board are used in a construction assembly, the continuous insulation boards shall be installed in accordance with Section C303.2. If the continuous insulation board manufacturer's installation instructions do not address installation of two or more layers, the edge joints between each layer of continuous insulation boards shall be staggered.

71

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. Unit skylight curbs included as a component of an NFRC 100 rated assembly shall not be required to be insulated.

Insulation installed on a suspended ceiling with removable ceiling tiles shall not be considered part of the minimum thermal resistance of the roof insulation.

72

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)

73

R-value determination

IECC 2012, Section C303.1.4-Insulation Product Rating

C303.14 Insulation product rating. The thermal resistance (R-value) of insulation shall be determined in accordance with the U.S. Federal Trade commission R-value rule (CFR Title 16, Part 460) in units of h x ft^2 x °F/Btu at a mean temperature of 75°F (24°C).

What about tapered insulation?

74

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.

75

2012 IECC Code and Commentary

Tapered insulation

"…The exception to this section permits a roof that is "continuously insulated" to have areas that do not meet the required *R*-values, provided that the area-weighted values are equivalent to the specified insulation values. This type of insulation referred to as tapered insulation is where the roof insulation varies to provide slope for drainage…."

[continued…]

76

2012 IECC Code and Commentary

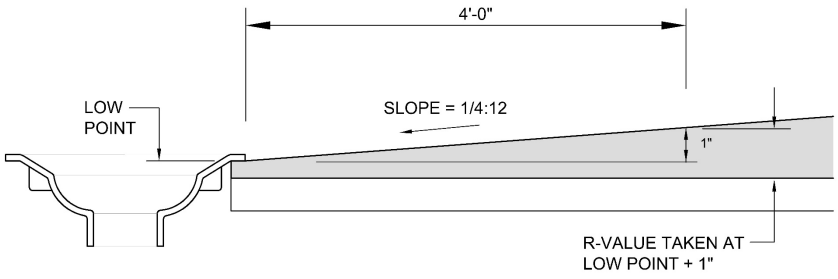
Tapered insulation

"…This 1-inch (25 mm) limitation does not prevent the provisions from being applied to roofs that have a greater variation; it simply does not allow the additional thickness to be factored into the average insulation values. Where the variation exceeds 1 inch (25 mm), it would be permissible to go to the thinnest spot and measure the *R*-value at that point (for the example call this Point "a"). Then go to a point that is 1 inch (25 mm) thicker than Point "a" and measure the *R*-value there (for the example, call this Point "b"). The remaining portions of the roof that are thicker than the additional 1-inch (25 mm) portion (Point "b") would simply be assumed to have the same *R*-value that Point "b" had. All portions of the roof that meet or exceed the Point "b" *R*-value would simply use the Point "b" *R*-value when determining the area weighted *U*-factor for the roof. "

77

What about tapered insulation…?

IBC 2012, Sec. C402.2-Roof Assembly , Exception 1
allows a 1-inch insulation thickness variation



78

Solar reflectance and thermal emittance

IECC 2012, Section C402.2.1.1

C402.2.1.1 Roof solar reflectance and thermal emittance. Low-sloped roofs, with a slope less than 2 units vertical in 12 horizontal, directly above cooled *conditioned spaces* in Climate Zones 1, 2, and 3 shall comply with one or more of the options in Table C402.2.1.1.

Exceptions: The following roofs and portions of roofs are exempt from the requirements in Table C402.2.1.1:

1. Portions of roofs that include or are covered by:
   - 1.1 Photovoltaic systems or components.
   - 1.2 Solar air or water heating systems or components.
   - 1.3 Roof gardens or landscaped roofs.
   - 1.4 Above-roof decks or walkways.
   - 1.5 Skylights.
   - 1.6 HVAC systems, components, and other opaque objects mounted above…

[Continued…]

79

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]

80

Air retarders

IECC 2012, Section C402.4-Air Leakage (Mandatory)

C402.4 Air leakage (Mandatory). The thermal envelope of buildings shall comply with Sections C402.4.1 through C402.4.8.

C402.4.1 Air barriers. A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.4.1.1 and C402.4.1.2.

Exception: Air barriers are not required in buildings located in Climate Zones 1, 2 and 3.

[Continued…]

81

C402.4.1.2 Air barrier compliance options. A continuous air barrier for the opaque building envelope shall comply with Section C402.4.1.2.1, C402.4.1.2.2, or C402.4.1.2.3.

C402.4.1.2.1 Materials. Materials with an air permeability no greater than 0.004 cfm/ft^2 (0.02 L/s · m^2) under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2178 shall comply with this section. Materials in Items 1 through 15 shall be deemed to comply with this section provided joints are sealed and materials are installed as air barriers in accordance with the manufacturer's instructions.

1. Plywood with a thickness of not less than 3/8 inch (10 mm).
2. Oriented strand board having a thickness of not less than 3/8 inch (10 mm).
3. Extruded polystyrene insulation board having a thickness of not less than 1/2 inch (12 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than 1/2 inch (12 mm).
5. Closed cell spray foam a minimum density of 1.5 pcf (2.4 kg/m^3) having a thickness of not less than 1-1/2 inches (36 mm).

[Continued….]

82

6. Open cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m^3) and having a thickness of not less than 4.5 inches (113 mm).
7. Exterior or interior gypsum board having a thickness of not less than ½ inch (12 mm).
8. Cement board having a thickness of not less than 1/2 inch (12 mm).
9. Built up roofing membrane.
10. Modified bituminous roof membrane.
11. Fully adhered single-ply roof membrane.
12. A Portland cement/sand parge, or gypsum plaster having a thickness of not less than 5/8 inch (16 mm).
13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.

[Continued…]

83

C402.4.1.2.2 Assemblies. Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft^2 (0.2 L/s · m^2) under a pressure differential of 0.3 inches of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283 shall comply with this section. Assemblies listed in Items 1 and 2 shall be deemed to comply provided joints are sealed and requirements of Section C402.4.1.1 are met.

1. Concrete masonry walls coated with one application either of block filler and two applications of a paint or sealer coating;

2. A Portland cement/sand parge, stucco or plaster minimum 1/2 inch (12 mm) in thickness.

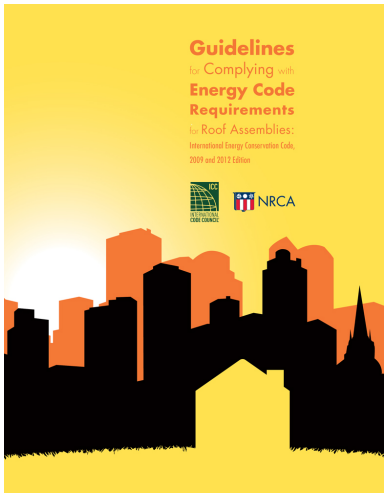
C402.4.1.2.3 Building test. The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft^2 at a pressure differential of 0.3 inches water gauge (2.0 L/s · m^2 at 75 Pa) in accordance with ASTM E 779 or an equivalent method approved by the code official.

[Continued…]

84

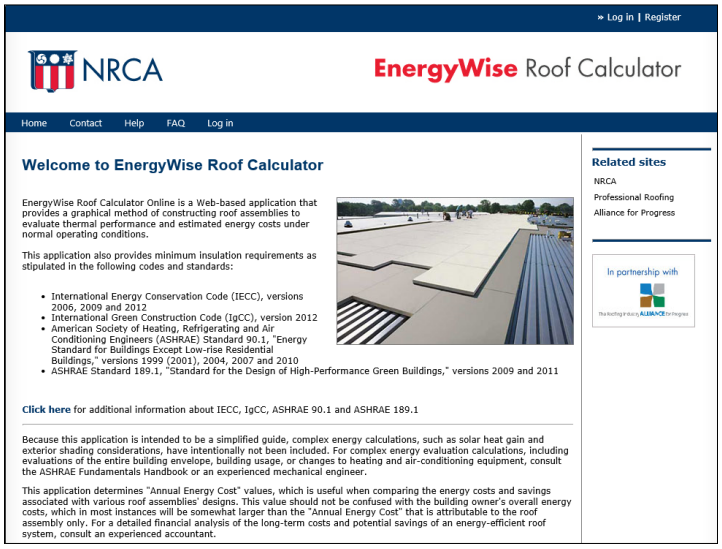
"…IECC 2012's air barrier requirements significantly limit roof system designs…"

Energy Codes Manual (2009 & 2012 Codes)



- Based upon IECC 2012 with ASHRAE 90.1-07 option and IECC 2012 with ASHRAE 90.1-10 option
- Includes roofing-related code text and NRCA commentary on each section
- Appendix has county-specific prescriptive R-value tables
- Co-branded with ICC; NRCA promotes to industry and ICC promotes to code officials

energywise.nrca.net



87

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.MarkGrahamNRCA.com

88