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Fundamentals of insulation, vapor retarders, air barriers and attic ventilation

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Topics

- Some fundamentals
- Insulation
- Vapor retarders
- Air retarders
- Attic ventilation
- Questions… and other related topics

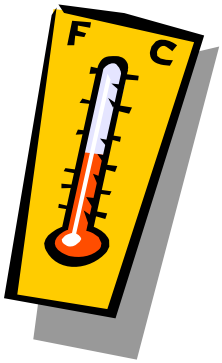
2

Some fundamentals

3

Phases of moisture

- **Gas phase** -- moisture vapor
  - Above 212 F
- **Liquid phase** -- water
  - 32 F to 212 F
- **Solid phase** -- frost or ice
  - Below 32 F



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Humidity

The amount of water vapor in the air.

Relative humidity

Relative humidity is defined as the ratio of the partial pressure of water vapor in a parcel of air to the saturated vapor pressure of water vapor at a prescribed temperature.

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Dew point

Condensation temperature

The temperature at which the air can now longer hold all of its water vapor, and some of the water vapor must condense into liquid water.

At 100% relative humidity, the dew point temperature and real temperature are the same, and condensation begins to form.

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Psychrometrics

The field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures.

Derived from the Greek *psuchron* meaning "cold" and *metron* meaning "means of measurement".

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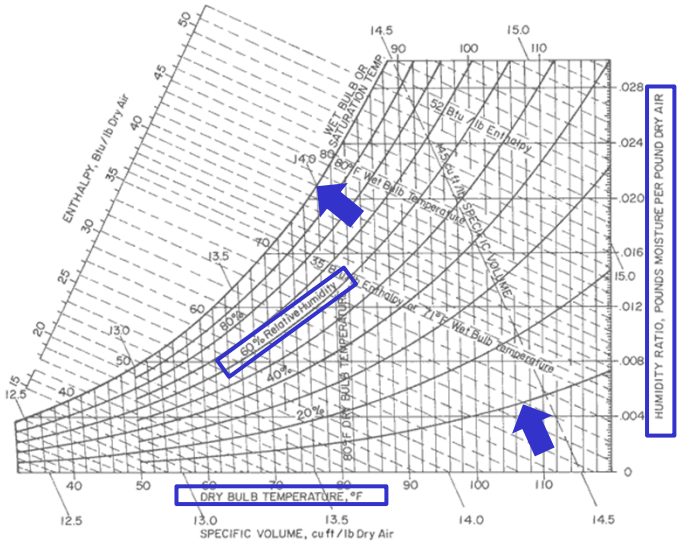
Psychrometric chart



Warm air can hold more moisture than cold air

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Thermodynamics

In physics, the study of energy conversion between heat and mechanical work, and subsequently the macroscopic variables such as temperature, volume and pressure.

Derived from the Greek *therme* meaning "heat" and *dynamis* meaning "power".

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First law of thermodynamics

Energy can be transformed (changed from one form to another), but cannot be created or destroyed.

Law of conservation of energy

Solid → Liquid → Gas → Liquid → Solid…

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Second law of thermodynamics

The entropy of an isolated system which is not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium.

Heat → Cold

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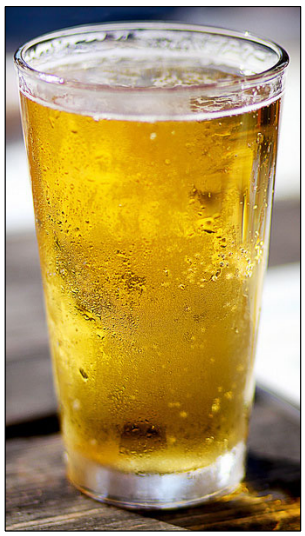
A practical application…



Is the glass "leaking"?

No… but we are studying thermodynamics

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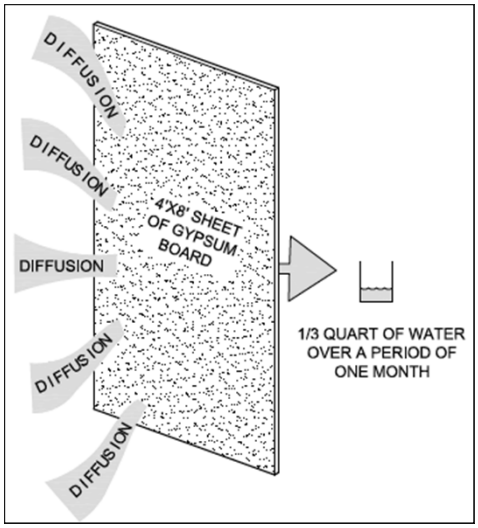
Diffusion



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Diffusion terminology

Permeability: the time rate of vapor transmission through a flat material of a unit thickness induced by vapor pressure difference between two specific surfaces under specified temperature and humidity.

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Diffusion terminology

Permeability: the time rate of vapor transmission through a flat material of a unit thickness induced by vapor pressure difference between two specific surfaces under specified temperature and humidity.

Expressed as “perm-inch” units

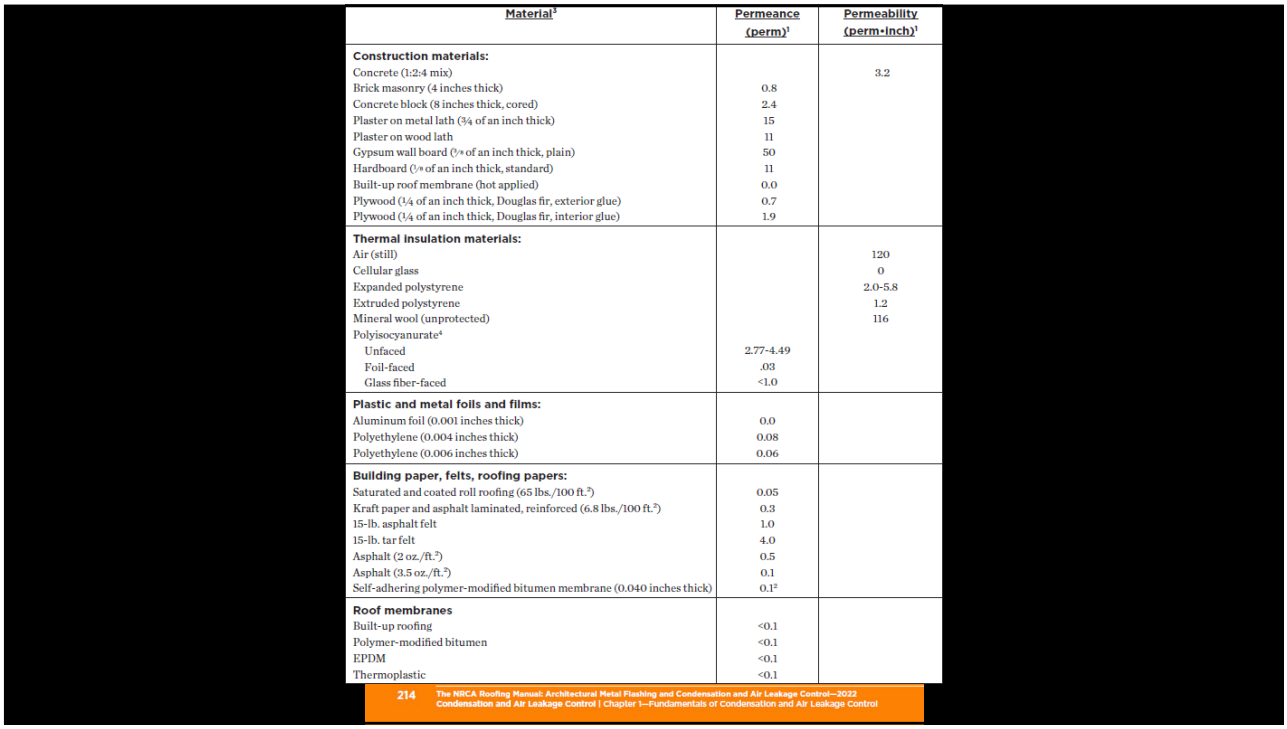
15

Diffusion terminology

Permeance: the time rate of vapor transmission through a flat material or construction assembly induced by vapor pressure difference between two specific surfaces under specified temperature and humidity.

Expressed as “perm” units

16



Material[3]	Permeance (perm)[1]	Permeability (perm•inch)[1]
Construction materials:		
Concrete (1:2:4 mix)		3.2
Brick masonry (4 inches thick)	0.8	
Concrete block (8 inches thick, cored)	2.4	
Plaster on metal lath (¾ of an inch thick)	15	
Plaster on wood lath	11	
Gypsum wall board (½ of an inch thick, plain)	50	
Hardboard (½ of an inch thick, standard)	11	
Built-up roof membrane (hot applied)	0.0	
Plywood (¼ of an inch thick, Douglas fir, exterior glue)	0.7	
Plywood (¼ of an inch thick, Douglas fir, interior glue)	1.9	
Thermal insulation materials:		
Air (still)		120
Cellular glass		0
Expanded polystyrene		2.0-5.8
Extruded polystyrene		1.2
Mineral wool (unprotected)		116
Polyisocyanurate[4]		
Unfaced	2.77-4.49	
Foil-faced	.03	
Glass fiber-faced	<1.0	
Plastic and metal foils and films:		
Aluminum foil (0.001 inches thick)	0.0	
Polyethylene (0.004 inches thick)	0.08	
Polyethylene (0.006 inches thick)	0.06	
Building paper, felts, roofing papers:		
Saturated and coated roll roofing (65 lbs./100 ft.^{2})	0.05	
Kraft paper and asphalt laminated, reinforced (6.8 lbs./100 ft.^{2})	0.3	
15-lb. asphalt felt	1.0	
15-lb. tar felt	4.0	
Asphalt (2 oz./ft.^{2})	0.5	
Asphalt (3.5 oz./ft.^{2})	0.1	
Self-adhering polymer-modified bitumen membrane (0.040 inches thick)	0.1[2]	
Roof membranes		
Built-up roofing	<0.1	
Polymer-modified bitumen	<0.1	
EPDM	<0.1	
Thermoplastic	<0.1	

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Vapor retarders

Classification	Permeance
Class I vapor retarder	0.1 per or less
Class II vapor retarder	1.0 perm or less, and greater than 0.1 perm
Class III vapor retarder	10 perm or less, and greater than 1.0 perm
Permeance determined according to ASTM E96, Test Method A (desiccant method or dry cup method)	

NRCA recommends effective vapor retarders have perm-ratings of 0.5 or less

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Continuity is critical.

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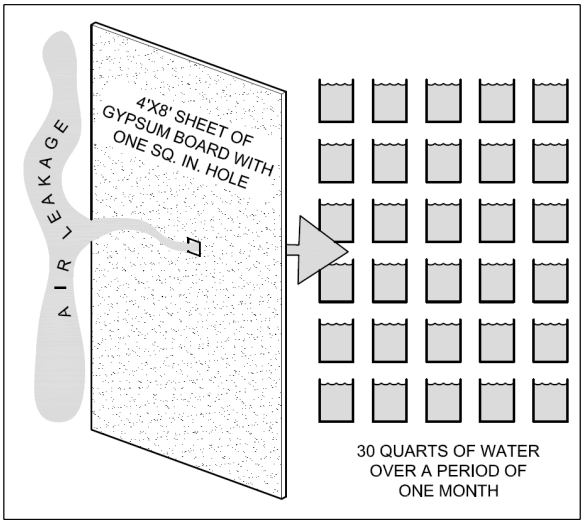
Air leakage



Note: Compared to ⅓ quart by diffusion (~100 X)

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Air leakage, not vapor diffusion, can and does cause most of the moisture problems building envelopes suffer.

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Now, pulling all these principles and fundamentals together into a roofing-specific example….

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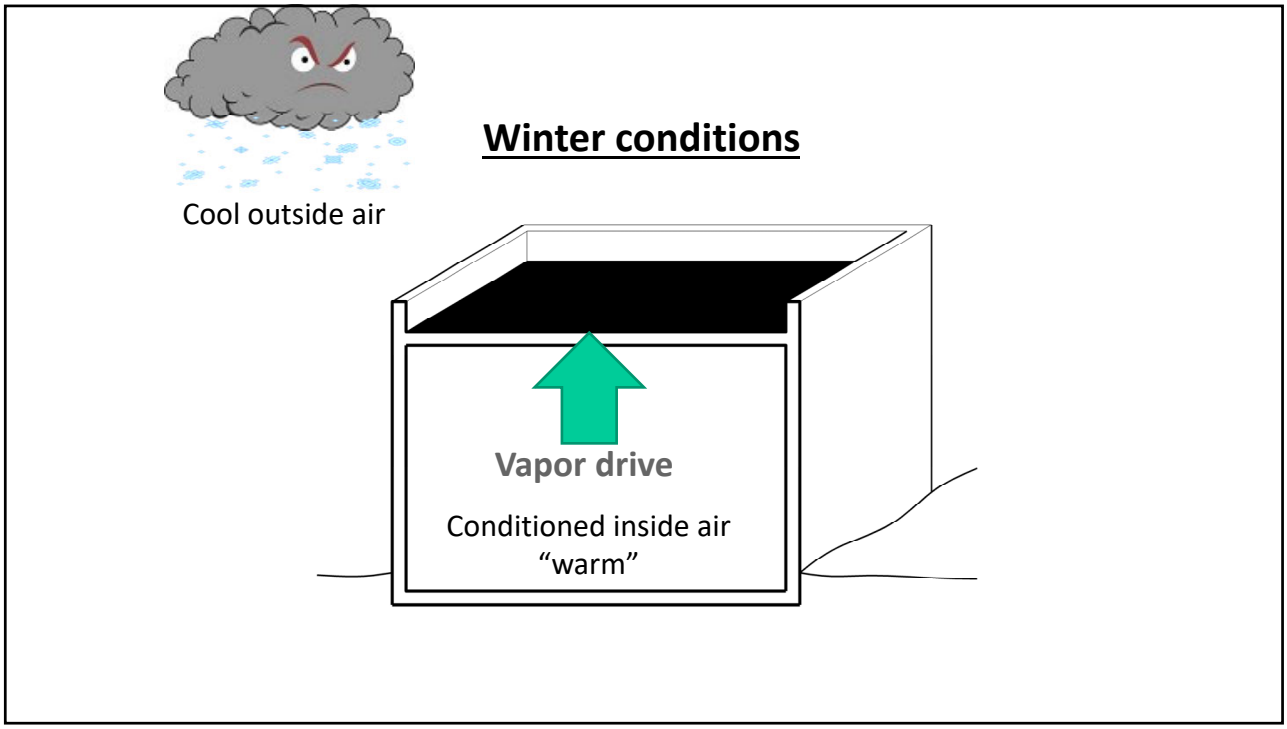
Winter conditions
Cool outside air
Vapor drive
Conditioned inside air
"warm"

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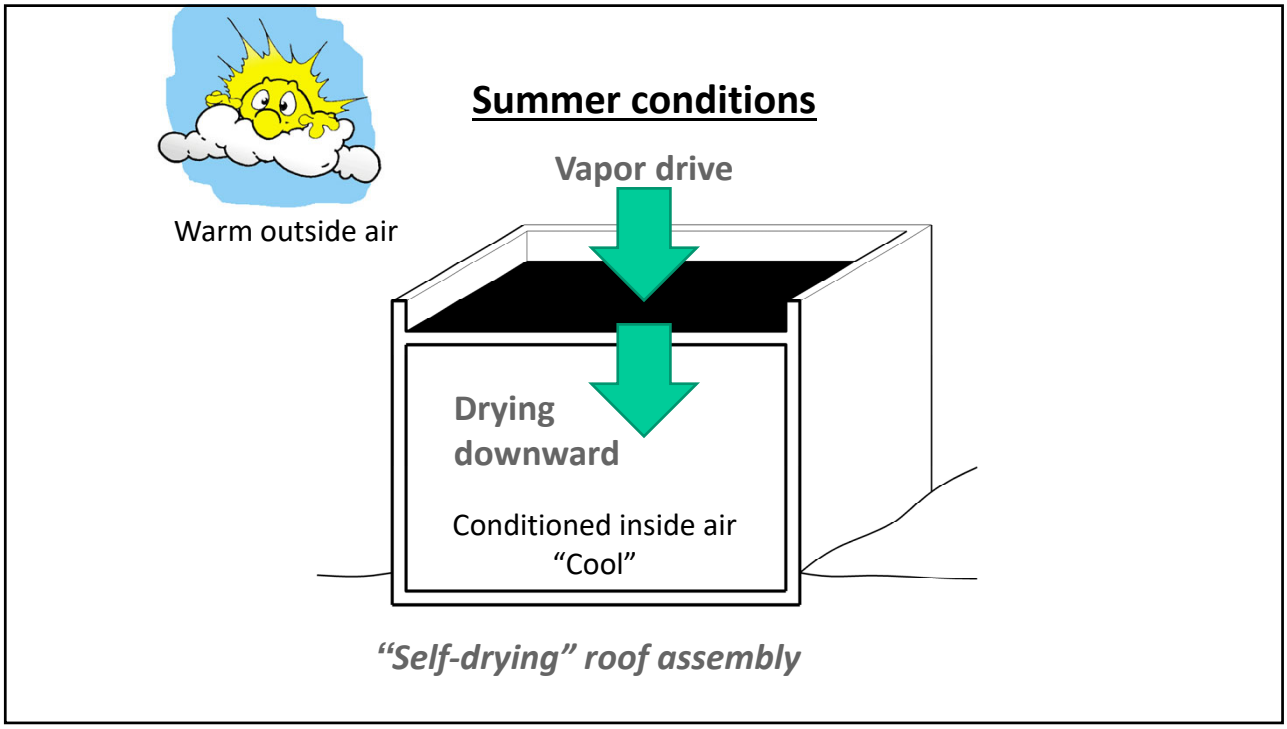
Summer conditions
Warm outside air
Vapor drive
Drying downward
Conditioned inside air
"Cool"
"Self-drying" roof assembly

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Historically, most roof systems have effectively performed as "self-drying roofs"…

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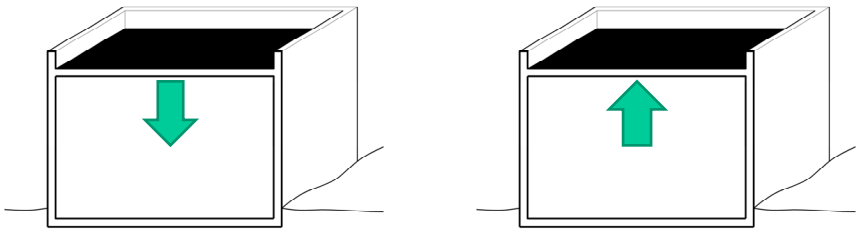
Self-drying roofs function properly if…



Downward drying ≥ Moisture pick-up

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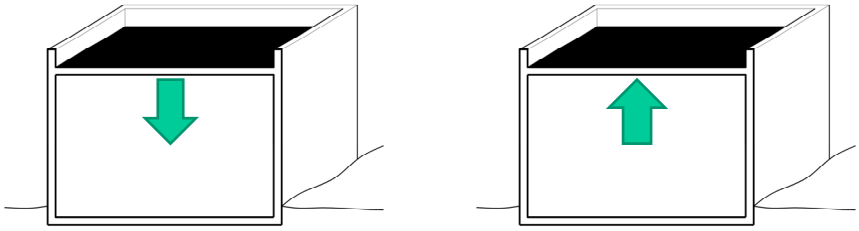
Self-drying roofs function properly if…



Downward drying ≥ Moisture pick-up

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Unintended consequences

Unintended consequences are outcomes that are not the results originally intended by a particular action.

The unintended results may be foreseen or unforeseen, but they should be the logical or likely results of the action

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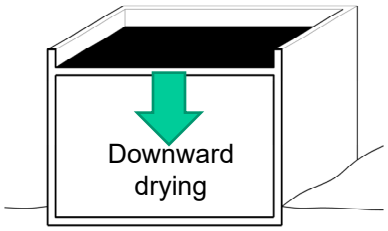
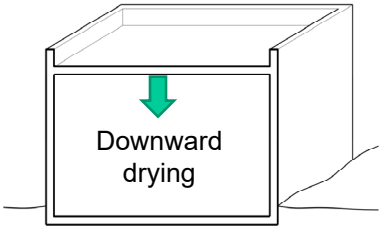


“Non-cool” roof



“Cool” roof

Cool roofs do not dry-down as efficiently as “non-cool” roofs

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NRCA’s recommendations specific to “cool” roofs

- Adhered roof covering (membrane)
- 2 or more layers of insulation
- Off-set board joints on insulation

--or--

- Don’t rely on the “self-drying” concept:
  - Consider providing for a properly-placed vapor retarder

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Thermal insulation

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Principles of thermal insulation

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

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Principles of thermal insulation

Thermal resistance (R): 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 $R_T = R_1 + R_2 + R_3 = \ldots$

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Long-term thermal resistance (LTTR)

Determined using ASTM C1303 or CAN/ULC-S770

R-value estimate based upon a 15-year time-weighted average, corresponding to the product's estimated R-value 5-years after manufacturing

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Long-term thermal resistance (LTTR)

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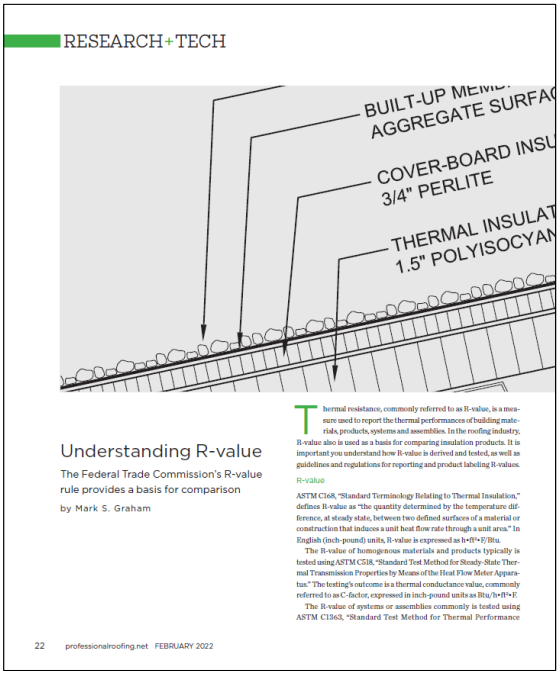
RESEARCH+TECH

Understanding R-value

The Federal Trade Commission's R-value rule provides a basis for comparison

by Mark S. Graham

Thermal resistance, commonly referred to as R-value, is a measure used to report the thermal performances of building materials, products, systems and assemblies. In the roofing industry, R-value also is used as a basis for comparing insulation products. It is important you understand how R-value is derived and tested, as well as guidelines and regulations for reporting and product labeling R-values.

R-value

ASTM C168, "Standard Terminology Relating to Thermal Insulation," defines R-value as "the quantity determined by the temperature difference, at steady state, between two defined surfaces of a material or construction that induces a unit heat flow rate through a unit area." In English (inch-pound) units, R-value is expressed as h•ft²•F/Btu.

The R-value of homogenous materials and products typically is tested using ASTM C518, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus." The testing's outcome is a thermal conductance value, commonly referred to as C-factor, expressed in inch-pound units as Btu/h•ft²•F.

The R-value of systems or assemblies commonly is tested using ASTM C1363, "Standard Test Method for Thermal Performance

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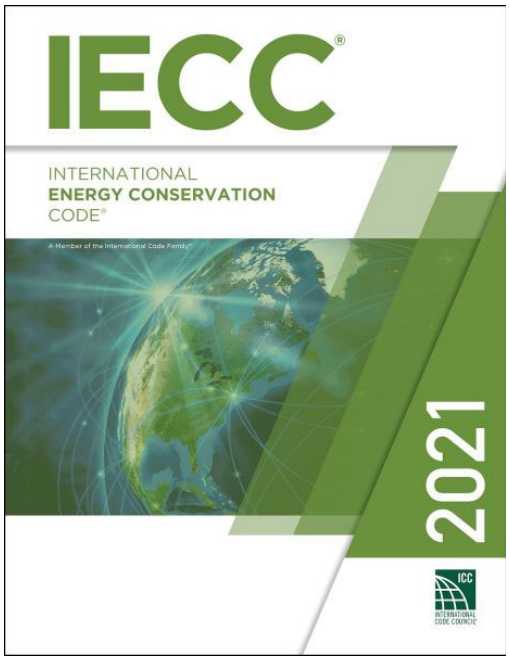

The Energy Code dictates minimum levels of thermal insulation for building energy efficiency

- The Building Code dictates minimal levels of insulation for fire classification purposes

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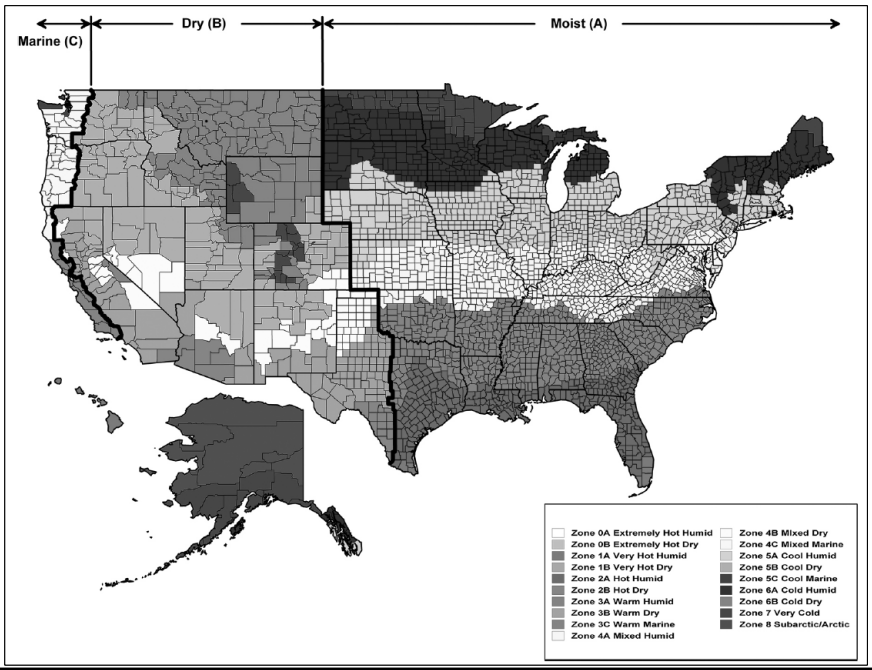
2021 IECC – Climate zone map



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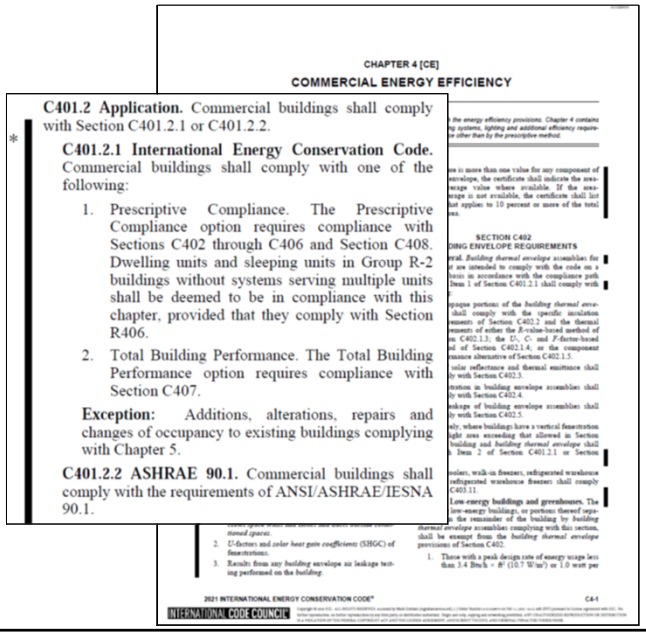
2021 IECC Commercial -- Application



CHAPTER 4 [CE]

COMMERCIAL ENERGY EFFICIENCY

C401.2 Application. Commercial buildings shall comply with Section C401.2.1 or C401.2.2.

C401.2.1 International Energy Conservation Code. Commercial buildings shall comply with one of the following:

1. Prescriptive Compliance. The Prescriptive Compliance option requires compliance with Sections C402 through C406 and Section C408. Dwelling units and sleeping units in Group R-2 buildings without systems serving multiple units shall be deemed to be in compliance with this chapter, provided that they comply with Section R406.
2. Total Building Performance. The Total Building Performance option requires compliance with Section C407.

Exception: Additions, alterations, repairs and changes of occupancy to existing buildings complying with Chapter 5.

C401.2.2 ASHRAE 90.1. Commercial buildings shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1.

SECTION C402

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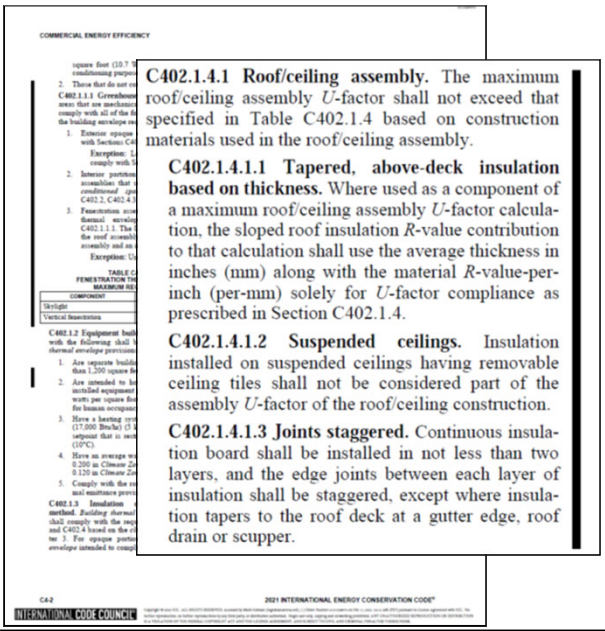
2021 IECC Commercial – U-factor Approach



COMMERCIAL ENERGY EFFICIENCY

C402.1.4.1 Roof/ceiling assembly. The maximum roof/ceiling assembly *U*-factor shall not exceed that specified in Table C402.1.4 based on construction materials used in the roof/ceiling assembly.

C402.1.4.1.1 Tapered, above-deck insulation based on thickness. Where used as a component of a maximum roof/ceiling assembly *U*-factor calculation, the sloped roof insulation *R*-value contribution to that calculation shall use the average thickness in inches (mm) along with the material *R*-value-per-inch (per-mm) solely for *U*-factor compliance as prescribed in Section C402.1.4.

C402.1.4.1.2 Suspended ceilings. Insulation installed on suspended ceilings having removable ceiling tiles shall not be considered part of the assembly *U*-factor of the roof/ceiling construction.

C402.1.4.1.3 Joints staggered. Continuous insulation board shall be installed in not less than two layers, and the edge joints between each layer of insulation shall be staggered, except where insulation tapers to the roof deck at a gutter edge, roof drain or scupper.

C4-2

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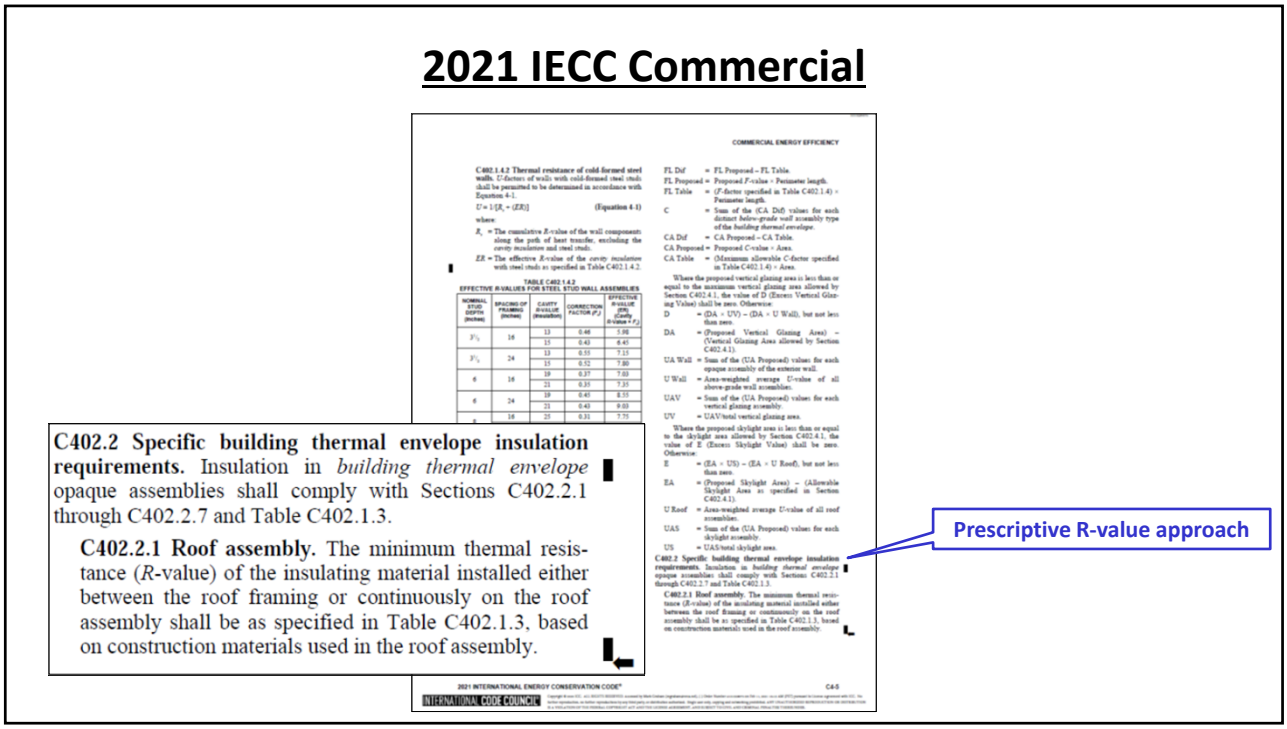

C402.2 Specific building thermal envelope insulation requirements. Insulation in *building thermal envelope* opaque assemblies shall comply with Sections C402.2.1 through C402.2.7 and Table C402.1.3.

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 C402.1.3, based on construction materials used in the roof assembly.

Prescriptive R-value approach

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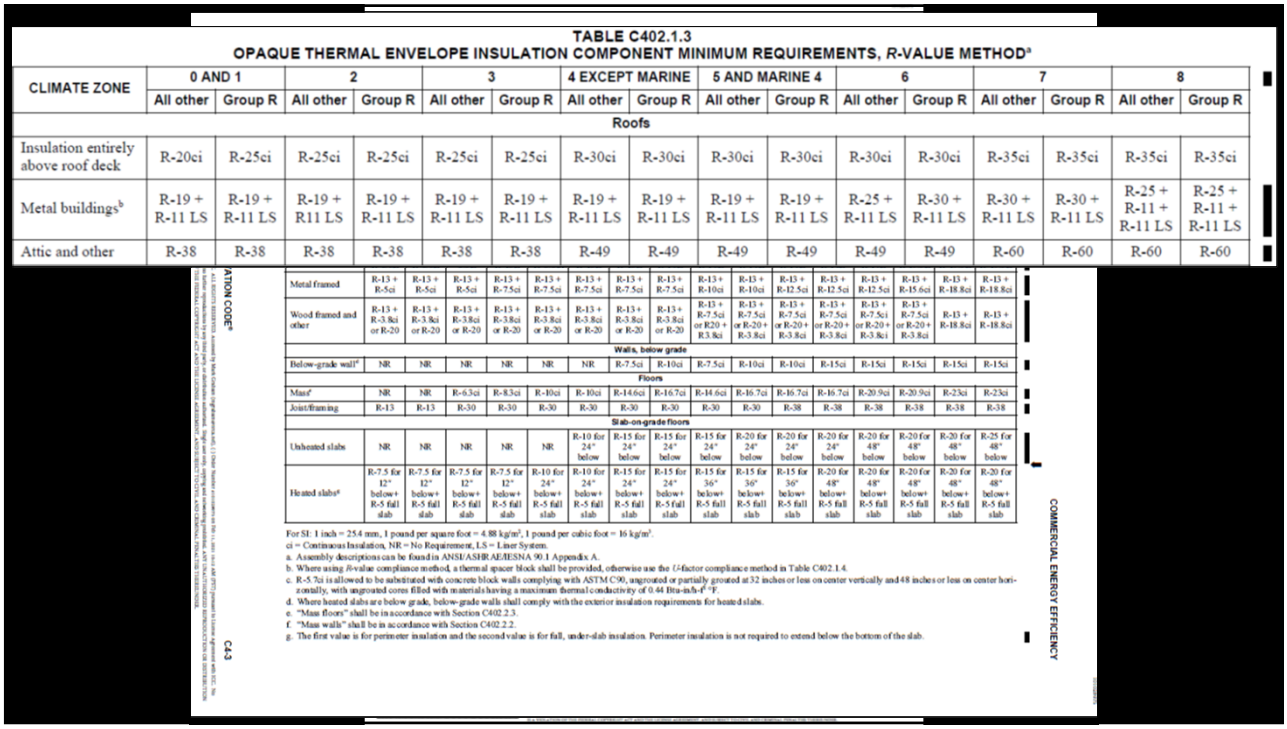

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, *R*-VALUE METHOD[a]

CLIMATE ZONE	0 AND 1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
Roofs																
Insulation entirely above roof deck	R-20ci	R-25ci	R-25ci	R-25ci	R-25ci	R-25ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-30ci	R-35ci	R-35ci	R-35ci	R-35ci
Metal buildings[b]	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-25 + R-11 + R-11 LS	R-25 + R-11 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49	R-49	R-49	R-49	R-60	R-60	R-60	R-60
Metal framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-7.5ci	R-13 + R-10ci	R-13 + R-10ci	R-13 + R-12.5ci	R-13 + R-12.5ci	R-13 + R-15.6ci	R-13 + R-18.8ci	R-13 + R-18.8ci		
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-7.5ci or R20 + R3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-7.5ci or R-20 + R-3.8ci	R-13 + R-18.8ci	R-13 + R-18.8ci		
Walls, below grade																
Below-grade wall[c]	NR	NR	NR	NR	NR	NR	NR	R-7.5ci	R-10ci	R-7.5ci	R-10ci	R-10ci	R-15ci	R-15ci	R-15ci	R-15ci
Floors																
Mass[e]	NR	NR	NR	R-6.3ci	R-8.3ci	R-10ci	R-10ci	R-14.6ci	R-16.7ci	R-14.6ci	R-16.7ci	R-16.7ci	R-16.7ci	R-20.9ci	R-20.9ci	R-23ci	R-23ci
Joist/framing	R-13	R-13	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-38	R-38	R-38	R-38	R-38	R-38
Slab-on-grade floors																
Unheated slabs	NR	NR	NR	NR	NR	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-20 for 24" below	R-20 for 24" below	R-20 for 24" below	R-20 for 48" below	R-20 for 48" below	R-20 for 48" below	R-25 for 48" below
Heated slabs[d]	R-7.5 for 12" below+ R-5 full slab	R-7.5 for 12" below+ R-5 full slab	R-7.5 for 12" below+ R-5 full slab	R-7.5 for 12" below+ R-5 full slab	R-10 for 24" below+ R-5 full slab	R-10 for 24" below+ R-5 full slab	R-15 for 24" below+ R-5 full slab	R-15 for 24" below+ R-5 full slab	R-15 for 36" below+ R-5 full slab	R-15 for 36" below+ R-5 full slab	R-15 for 36" below+ R-5 full slab	R-20 for 48" below+ R-5 full slab	R-20 for 48" below+ R-5 full slab	R-20 for 48" below+ R-5 full slab	R-20 for 48" below+ R-5 full slab	R-20 for 48" below+ R-5 full slab

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 4.88 kg/m², 1 pound per cubic foot = 16 kg/m³.
ci = Continuous Insulation, NR = No Requirement, LS = Liner System.
a. Assembly descriptions can be found in ANSI/ASHRAE/IESNA 90.1 Appendix A.
b. Where using *R*-value compliance method, a thermal spacer block shall be provided, otherwise use the *U*-factor compliance method in Table C402.1.4.
c. R-5.7ci is allowed to be substituted with concrete block walls complying with ASTM C90, ungrouted or partially grouted at 32 inches or less on center vertically and 48 inches or less on center horizontally, with ungrouted cores filled with materials having a maximum thermal conductivity of 0.44 Btu-in/h-ft² °F.
d. Where heated slabs are below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.
e. "Mass floors" shall be in accordance with Section C402.2.3.
f. "Mass walls" shall be in accordance with Section C402.2.2.
g. The first value is for perimeter insulation and the second value is for full, under-slab insulation. Perimeter insulation is not required to extend below the bottom of the slab.

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ICC 2021 Commercial – Roof Reflectivity

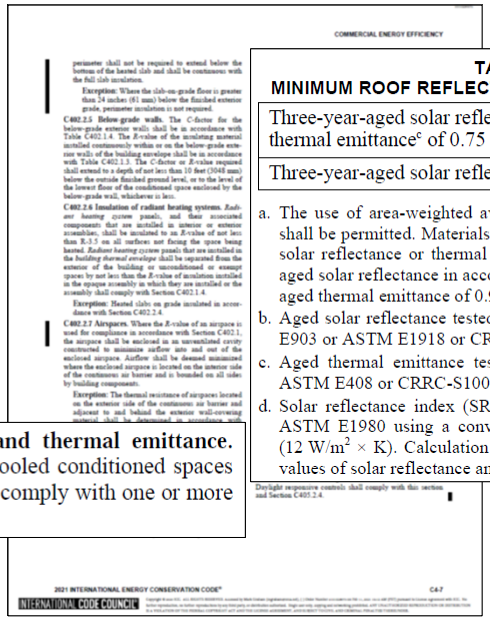

TABLE C402.3
MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS[a]

Three-year-aged solar reflectance index[b] of 55 and 3-year aged thermal emittance[c] of 0.75
Three-year-aged solar reflectance index[d] of 64

a. The use of area-weighted averages to comply with these requirements shall be permitted. Materials lacking 3-year-aged tested values for either solar reflectance or thermal emittance shall be assigned both a 3-year-aged solar reflectance in accordance with Section C402.3.1 and a 3-year-aged thermal emittance of 0.90.
b. Aged solar reflectance tested in accordance with ASTM C1549, ASTM E903 or ASTM E1918 or CRRC-S100.
c. Aged thermal emittance tested in accordance with ASTM C1371 or ASTM E408 or CRRC-S100.
d. Solar reflectance index (SRI) shall be determined in accordance with ASTM E1980 using a convection coefficient of 2.1 Btu/h × ft^2 × °F (12 W/m^2 × K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance.

C402.3 Roof solar reflectance and thermal emittance. Low-sloped roofs directly above cooled conditioned spaces in *Climate Zones* 0 through 3 shall comply with one or more of the options in Table C402.3.

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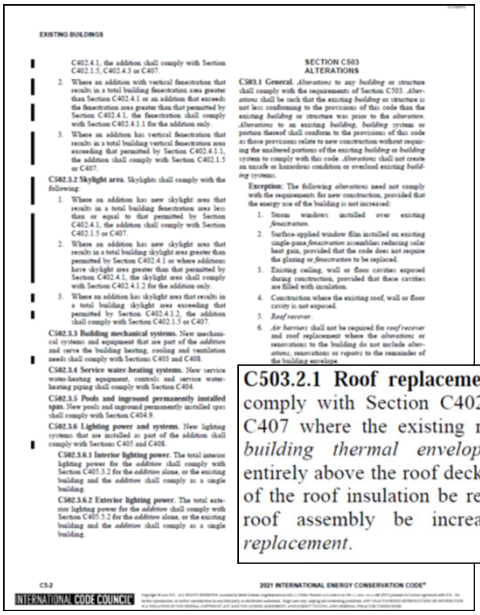
IECC 2021 Commercial-- Reroofing



C503.2.1 Roof replacement. *Roof replacements* shall comply with Section C402.1.3, C402.1.4, C402.1.5 or C407 where the existing roof assembly is part of the *building thermal envelope* and contains insulation entirely above the roof deck. In no case shall the *R*-value of the roof insulation be reduced or the *U*-factor of the roof assembly be increased as part of the *roof replacement*.

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Vapor retarders

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Vapor retarders should be considered

NRCA guidelines -- Low-slope roof assemblies

- Climate Zones 6A, 7 or 8
- High interior humidity occupancies (swimming pools)
- Coldest month < 40 F, interior RH ≥ 45%
  - US Army CRREL method enhancement
- Where there is a vapor retarder in the wall assembly

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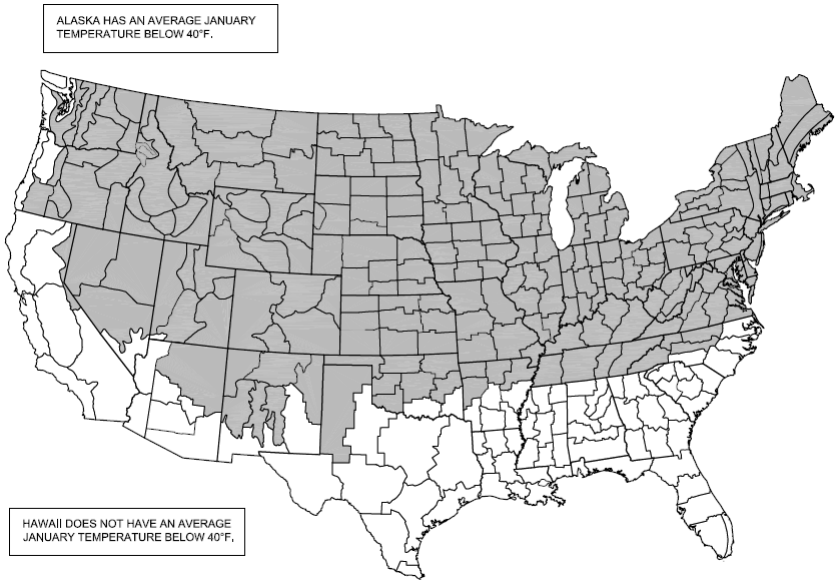
Average January temperature less than 40F



48

US Army CRREL method

Vapor retarder determination
(CRREL: Cold Regions Research and Engineering Laboratory)

Enhances the "Coldest month < 40 F, interior RH ≥ 45%" guideline:

- Applies to adhered roof coverings (only)
- Provides interior RH thresholds for throughout the U.S. (68 F design interior temperature)
- Provides RH threshold corrections for design interior temperatures other than 68 F

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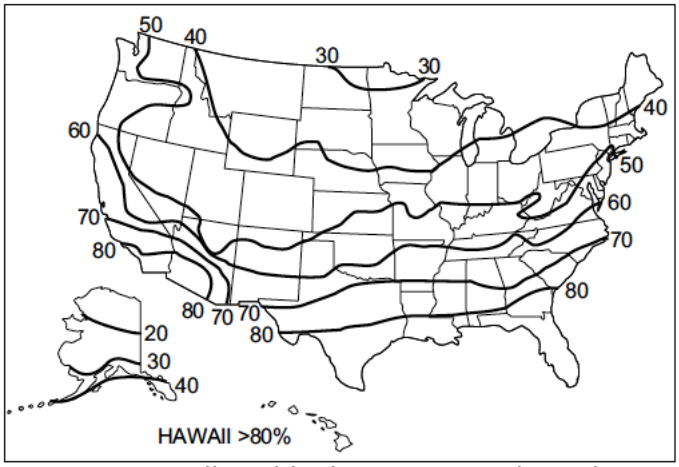
US Army CRREL method

Vapor retarder determination

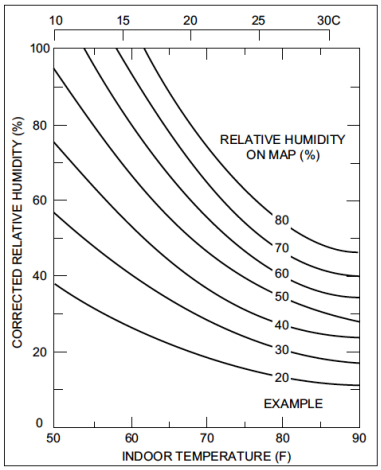


Maximum allowable design interior humidity
(before use of a vapor retarder is suggested)

50

US Army CRREL method

Vapor retarder determination



Temperature correction (other than 68 F)

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Vapor retarder fundamentals

- Evaluate the dew point temperature during winter design conditions (in North America)
- To prevent the formation of condensation on the interior side of a vapor retarder, the temperature at the vapor retarder level must be warmer than the dew point temperature.

Position the vapor retarder as close to the "warm side" as possible.

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RESEARCH+TECH

Positioning is everything

Proper vapor retarder layer placement is essential to prevent condensation

by Mark S. Graham

A vapor retarder layer sometimes is specified as an additional component in low-slope roof systems to minimize the potential for condensation to occur. When used, a vapor retarder layer can reduce water vapor diffusion from a building's interior into roof system components. For a vapor retarder layer to function as it should, it must be placed in a proper location within a low-slope roof system's cross-section. The following are some guidelines for proper vapor retarder layer placement.

Design considerations

For new construction situations, the designer of a building's mechanical system typically is best-suited for determining whether a vapor retarder layer is necessary. When sizing and designing a building's HVAC equipment, the mechanical system designer needs to consider outside conditions specific to the building's geographic location, climate conditions and desired interior design conditions. These same considerations form the basis for determining whether a vapor retarder layer is necessary for the building's exterior envelope, which includes the roof system. If a vapor retarder layer is deemed necessary for a building's exterior

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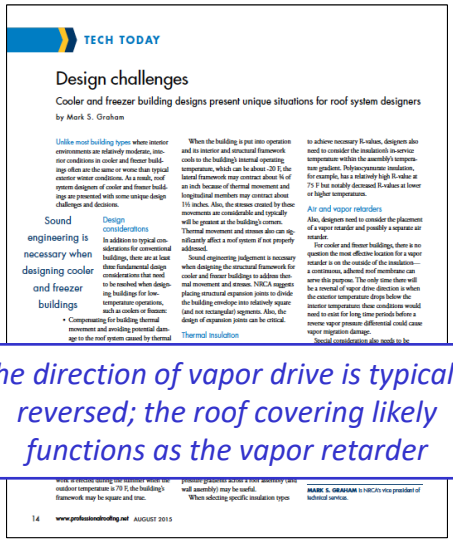
Cooler and freezer buildings



TECH TODAY

Design challenges

Cooler and freezer building designs present unique situations for roof system designers

by Mark S. Graham

Unlike most building types where interior environments are relatively moderate, interior conditions in cooler and freezer buildings often are the same or worse than typical exterior winter conditions. As a result, roof system designers of cooler and freezer buildings are presented with some unique design challenges and decisions.

Sound engineering is necessary when designing cooler and freezer buildings

Design considerations

In addition to typical considerations for conventional buildings, there are at least three fundamental design considerations that need to be resolved when designing buildings for low-temperature operations, such as coolers or freezers:

- Compensating for building thermal movement and avoiding potential damage to the roof system caused by thermal

When the building is put into operation and its interior and structural framework cools to the building's internal operating temperature, which can be about -20 F, the lateral framework may contract about ¾ of an inch because of thermal movement and longitudinal members may contract about 1¾ inches. Also, the stresses created by these movements are considerable and typically will be greatest at the building's corners. Thermal movement and stresses also can significantly affect a roof system if not properly addressed.

Sound engineering judgement is necessary when designing the structural framework for cooler and freezer buildings to address thermal movement and stresses. NRCA suggests placing structural expansion joints to divide the building envelope into relatively square (and not rectangular) segments. Also, the design of expansion joints can be critical.

Thermal insulation

to achieve necessary R-values, designers also need to consider the insulation's in-service temperature within the assembly's temperature gradient. Polyisocyanurate insulation, for example, has a relatively high R-value at 75 F but notably decreased R-values at lower or higher temperatures.

Air and vapor retarders

Also, designers need to consider the placement of a vapor retarder and possibly a separate air retarder.

For cooler and freezer buildings, there is no question the most effective location for a vapor retarder is on the outside of the insulation—a continuous, adhered roof membrane can serve this purpose. The only time there will be a reversal of vapor drive direction is when the exterior temperature drops below the interior temperature these conditions would need to exist for long time periods before a reverse vapor pressure differential could cause vapor migration damage.

Special consideration also needs to be

outdoor temperature is 70 F, the building's framework may be square and true.

pressure gradient across a roof assembly (and wall assembly) may be useful.

When selecting specific insulation types

MARK S. GRAHAM is NRCA's vice president of technical services.

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The direction of vapor drive is typically reversed; the roof covering likely functions as the vapor retarder

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Air retarders

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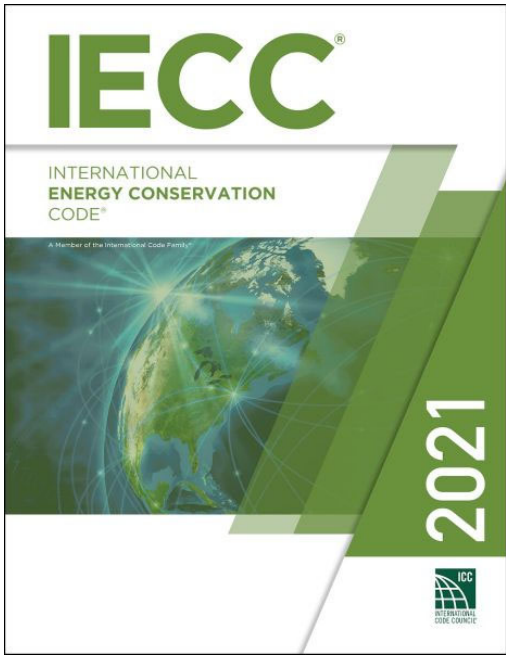

The Energy Code dictates minimum air retarder requirements

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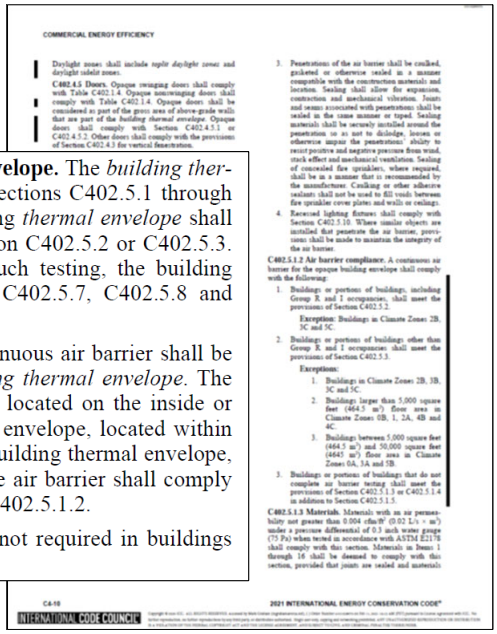
IECC 2021 Commercial – Air Retarders

C402.5 Air leakage—thermal envelope. The *building thermal envelope* shall comply with Sections C402.5.1 through Section C402.5.11.1, or the building *thermal envelope* shall be tested in accordance with Section C402.5.2 or C402.5.3. Where compliance is based on such testing, the building shall also comply with Sections C402.5.7, C402.5.8 and C402.5.9.

C402.5.1 Air barriers. A continuous air barrier shall be provided throughout the *building thermal envelope*. The continuous air barriers shall be located on the inside or outside of the building thermal envelope, located within the assemblies composing the building thermal envelope, or any combination thereof. The air barrier shall comply with Sections C402.5.1.1, and C402.5.1.2.

Exception: Air barriers are not required in buildings located in *Climate Zone* 2B.



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Daylight zones shall include *toplit daylight zones* and daylight sidelit zones.

C402.4.5 Doors. Opaque swinging doors shall comply with Table C402.1.4. Opaque nonswinging doors shall comply with Table C402.1.4. Opaque doors shall be considered as part of the gross area of above-grade walls that are part of the *building thermal envelope*. Opaque doors shall comply with Section C402.4.5.1 or C402.4.5.2. Other doors shall comply with the provisions of Section C402.4.3 for vertical fenestration.

3. Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Sealing shall allow for expansion, contraction and mechanical vibration. Joints and seams associated with penetrations shall be sealed in the same manner or taped. Sealing materials shall be securely installed around the penetration so as not to dislodge, loosen or otherwise impair the penetrations' ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation. Sealing of concealed fire sprinklers, where required, shall be in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.
4. Recessed lighting fixtures shall comply with Section C402.5.10. Where similar objects are installed that penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier.

C402.5.1.2 Air barrier compliance. A continuous air barrier for the opaque building envelope shall comply with the following:

1. Buildings or portions of buildings, including Group R and I occupancies, shall meet the provisions of Section C402.5.2.

   Exception: Buildings in Climate Zones 2B, 3C and 5C.
2. Buildings or portions of buildings other than Group R and I occupancies shall meet the provisions of Section C402.5.3.

   Exceptions:

   1. Buildings in Climate Zones 2B, 3B, 3C and 5C.
   2. Buildings larger than 5,000 square feet (464.5 m^2) floor area in Climate Zones 0B, 1, 2A, 4B and 4C.
   3. Buildings between 5,000 square feet (464.5 m^2) and 50,000 square feet (4645 m^2) floor area in Climate Zones 0A, 3A and 5B.
3. Buildings or portions of buildings that do not complete air barrier testing shall meet the provisions of Section C402.5.1.3 or C402.5.1.4 in addition to Section C402.5.1.5.

C402.5.1.3 Materials. Materials with an air permeability not greater than 0.004 cfm/ft² (0.02 L/s × m²) under a pressure differential of 0.3 inch water gauge (75 Pa) when tested in accordance with ASTM E2178 shall comply with this section. Materials in Items 1 through 16 shall be deemed to comply with this section, provided that joints are sealed and materials

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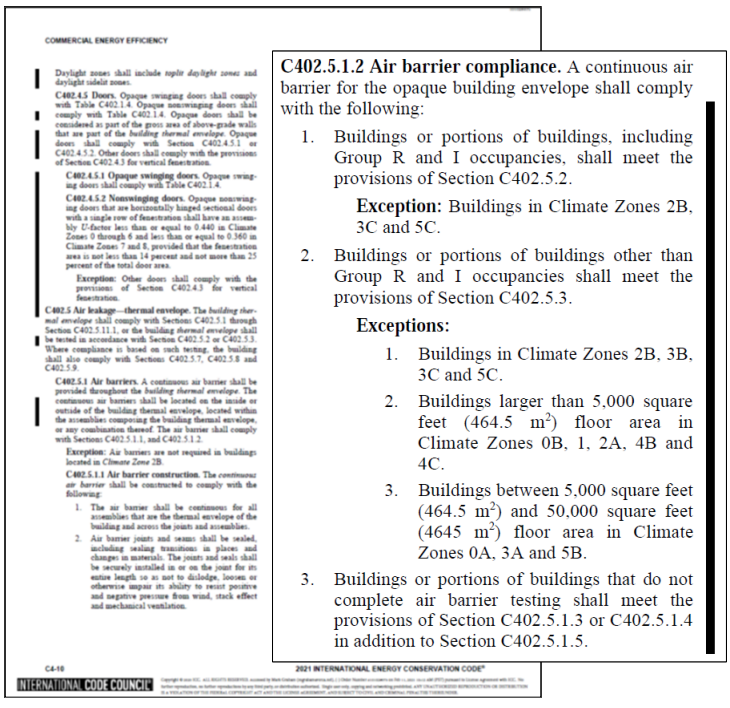

COMMERCIAL ENERGY EFFICIENCY

Daylight zones shall include *toplit daylight zones* and daylight sidelit zones.

C402.4.5 Doors. Opaque swinging doors shall comply with Table C402.1.4. Opaque nonswinging doors shall comply with Table C402.1.4. Opaque doors shall be considered as part of the gross area of above-grade walls that are part of the *building thermal envelope*. Opaque doors shall comply with Section C402.4.5.1 or C402.4.5.2. Other doors shall comply with the provisions of Section C402.4.3 for vertical fenestration.

C402.4.5.1 Opaque swinging doors. Opaque swinging doors shall comply with Table C402.1.4.

C402.4.5.2 Nonswinging doors. Opaque nonswinging doors that are horizontally hinged sectional doors with a single row of fenestration shall have an assembly *U*-factor less than or equal to 0.440 in Climate Zones 0 through 6 and less than or equal to 0.360 in Climate Zones 7 and 8, provided that the fenestration area is not less than 14 percent and not more than 25 percent of the total door area.

Exception: Other doors shall comply with the provisions of Section C402.4.3 for vertical fenestration.

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Exception: Air barriers are not required in buildings located in *Climate Zone* 2B.

C402.5.1.1 Air barrier construction. The *continuous air barrier* shall be constructed to comply with the following:

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.

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   1. Buildings in Climate Zones 2B, 3B, 3C and 5C.
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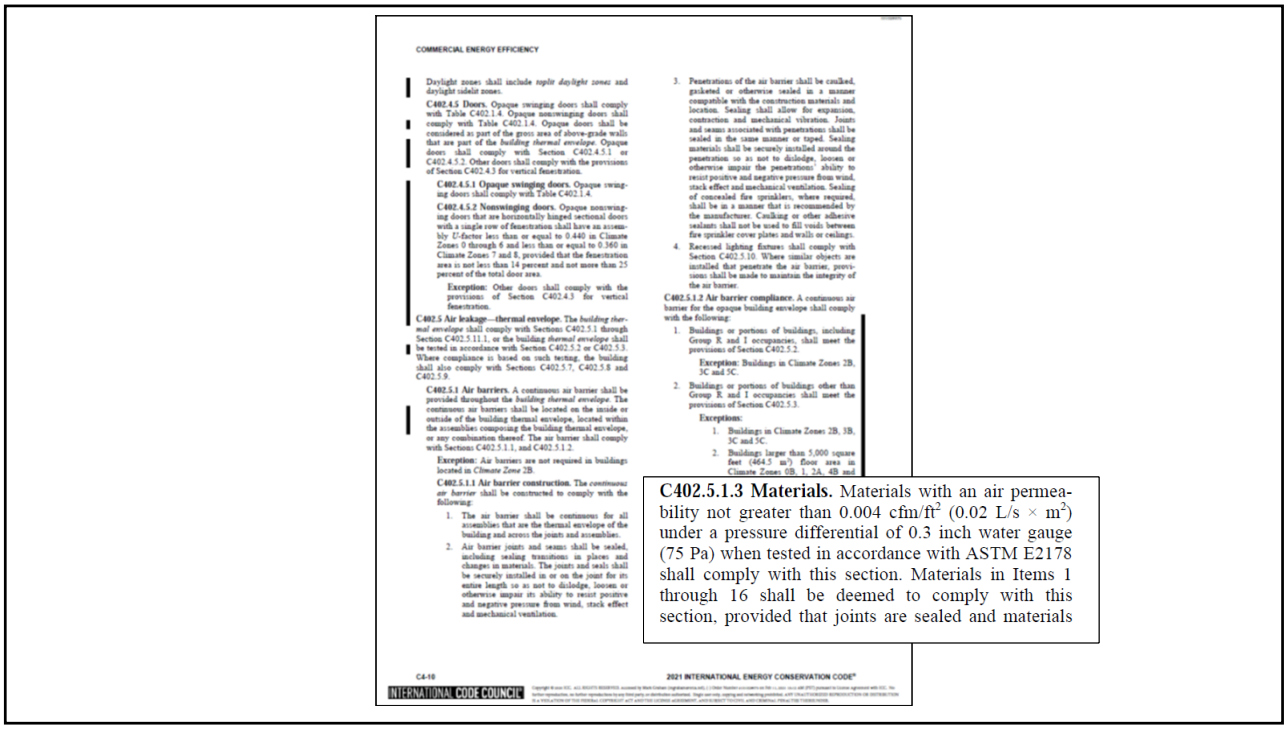

COMMERCIAL ENERGY EFFICIENCY

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2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
3. Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Sealing shall allow for expansion, contraction and mechanical vibration. Joints and seams associated with penetrations shall be sealed in the same manner or taped. Sealing materials shall be securely installed around the penetration so as not to dislodge, loosen or otherwise impair the penetrations' ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation. Sealing of concealed fire sprinklers, where required, shall be in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.
4. Recessed lighting fixtures shall comply with Section C402.5.10. Where similar objects are installed that penetrate the air barrier, provision shall be made to maintain the integrity of the air barrier.

C402.5.1.2 Air barrier compliance. A continuous air barrier for the opaque building envelope shall comply with the following:

1. Buildings or portions of buildings, including Group R and I occupancies, shall meet the provisions of Section C402.5.2.

   Exception: Buildings in Climate Zones 2B, 3C and 5C.
2. Buildings or portions of buildings other than Group R and I occupancies shall meet the provisions of Section C402.5.3.

   Exceptions:
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   2. Buildings larger than 5,000 square feet (464.5 m²) floor area in Climate Zones 0B, 1, 2A, 4B and

C402.5.1.3 Materials. Materials with an air permeability not greater than 0.004 cfm/ft² (0.02 L/s × m²) under a pressure differential of 0.3 inch water gauge (75 Pa) when tested in accordance with ASTM E2178 shall comply with this section. Materials in Items 1 through 16 shall be deemed to comply with this section, provided that joints are sealed and materials

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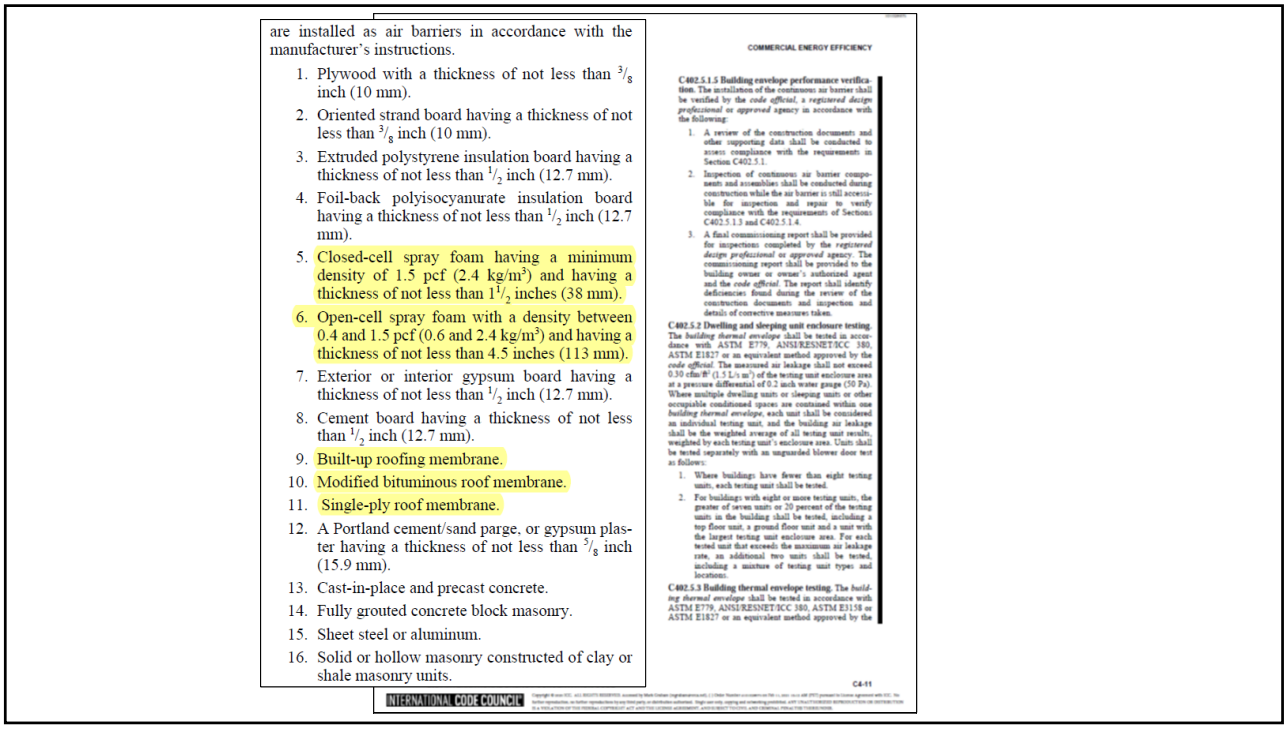

are installed as air barriers in accordance with the manufacturer's instructions.

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 (12.7 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than 1/2 inch (12.7 mm).
5. Closed-cell spray foam having a minimum density of 1.5 pcf (2.4 kg/m³) and having a thickness of not less than 1 1/2 inches (38 mm).
6. Open-cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m³) 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 1/2 inch (12.7 mm).
8. Cement board having a thickness of not less than 1/2 inch (12.7 mm).
9. Built-up roofing membrane.
10. Modified bituminous roof membrane.
11. Single-ply roof membrane.
12. A Portland cement/sand parge, or gypsum plaster having a thickness of not less than 5/8 inch (15.9 mm).
13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.
16. Solid or hollow masonry constructed of clay or shale masonry units.

COMMERCIAL ENERGY EFFICIENCY

C402.5.1.5 Building envelope performance verification. The installation of the continuous air barrier shall be verified by the *code official*, a *registered design professional* or *approved* agency in accordance with the following:

1. A review of the construction documents and other supporting data shall be conducted to assess compliance with the requirements in Section C402.5.1.
2. Inspection of continuous air barrier components and assemblies shall be conducted during construction while the air barrier is still accessible for inspection and repair to verify compliance with the requirements of Sections C402.5.1.3 and C402.5.1.4.
3. A final commissioning report shall be provided for inspections completed by the *registered design professional* or *approved* agency. The commissioning report shall be provided to the building owner or owner's authorized agent and the *code official*. The report shall identify deficiencies found during the review of the construction documents and inspection and details of corrective measures taken.

C402.5.2 Dwelling and sleeping unit enclosure testing. The *building thermal envelope* shall be tested in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E1827 or an equivalent method approved by the *code official*. The measured air leakage shall not exceed 0.30 cfm/ft² (1.5 L/s × m²) of the testing unit enclosure area at a pressure differential of 0.2 inch water gauge (50 Pa). Where multiple dwelling units or sleeping units or other occupiable conditioned spaces are contained within one *building thermal envelope*, each unit shall be considered an individual testing unit, and the building air leakage shall be the weighted average of all testing unit results, weighted by each testing unit's enclosure area. Units shall be tested separately with an unguarded blower door test as follows:

1. Where buildings have fewer than eight testing units, each testing unit shall be tested.
2. For buildings with eight or more testing units, the greater of seven units or 20 percent of the testing units in the building shall be tested, including a top floor unit, a ground floor unit and a unit with the largest testing unit enclosure area. For each tested unit that exceeds the maximum air leakage rate, an additional two units shall be tested, including a mixture of testing unit types and locations.

C402.5.3 Building thermal envelope testing. The *building thermal envelope* shall be tested in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E3158 or ASTM E1827 or an equivalent method approved by the

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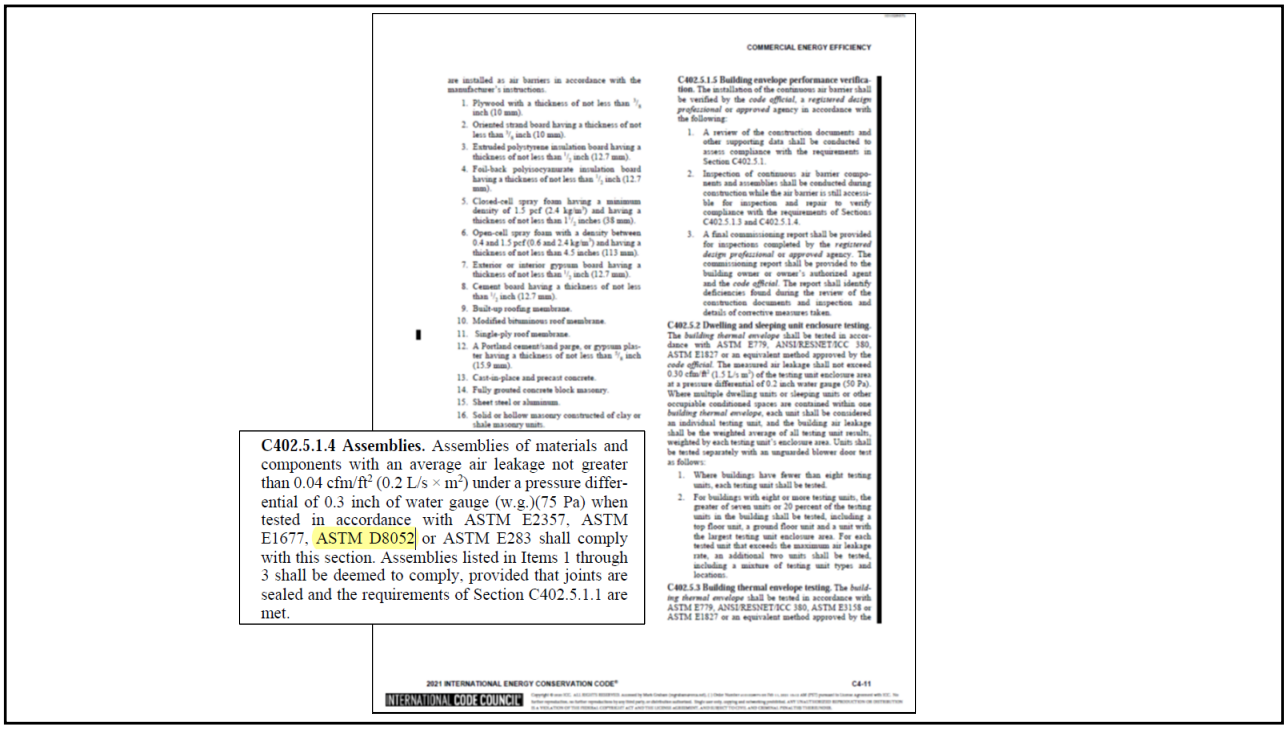

COMMERCIAL ENERGY EFFICIENCY

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).
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13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.
16. Solid or hollow masonry constructed of clay or shale masonry units.

C402.5.1.4 Assemblies. Assemblies of materials and components with an average air leakage not greater than 0.04 cfm/ft² (0.2 L/s × m²) under a pressure differential of 0.3 inch of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM D8052 or ASTM E283 shall comply with this section. Assemblies listed in Items 1 through 3 shall be deemed to comply, provided that joints are sealed and the requirements of Section C402.5.1.1 are met.

C402.5.1.5 Building envelope performance verification. The installation of the continuous air barrier shall be verified by the *code official*, a *registered design professional* or *approved* agency in accordance with the following:

1. A review of the construction documents and other supporting data shall be conducted to assess compliance with the requirements in Section C402.5.1.
2. Inspection of continuous air barrier components and assemblies shall be conducted during construction while the air barrier is still accessible for inspection and repair to verify compliance with the requirements of Sections C402.5.1.3 and C402.5.1.4.
3. A final commissioning report shall be provided for inspections completed by the *registered design professional* or *approved* agency. The commissioning report shall be provided to the building owner or owner's authorized agent and the *code official*. The report shall identify deficiencies found during the review of the construction documents and inspection and details of corrective measures taken.

C402.5.2 Dwelling and sleeping unit enclosure testing. The *building thermal envelope* shall be tested in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E1827 or an equivalent method approved by the *code official*. The measured air leakage shall not exceed 0.30 cfm/ft² (1.5 L/s × m²) of the testing unit enclosure area at a pressure differential of 0.2 inch water gauge (50 Pa). Where multiple dwelling units or sleeping units or other occupiable conditioned spaces are contained within one *building thermal envelope*, each unit shall be considered an individual testing unit, and the building air leakage shall be the weighted average of all testing unit results, weighted by each testing unit's enclosure area. Units shall be tested separately with an unguarded blower door test as follows:

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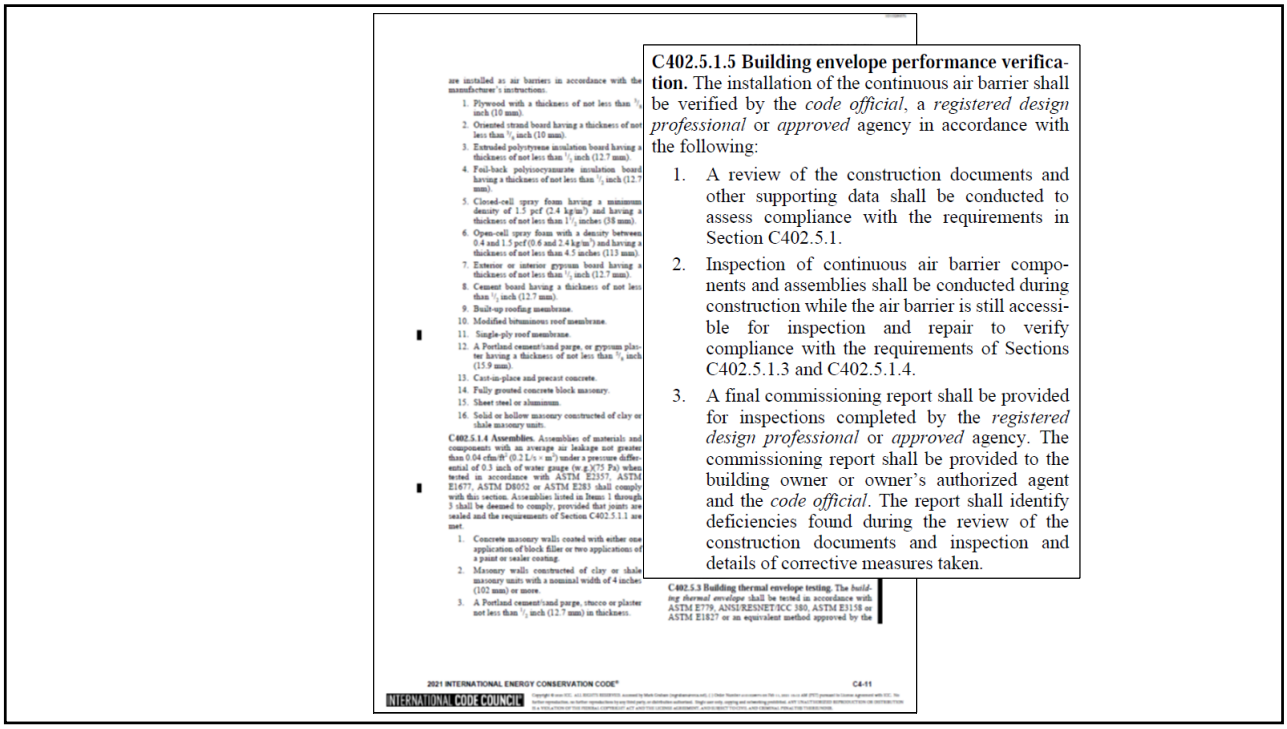

are installed as air barriers in accordance with the manufacturer's instructions.

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 (12.7 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than 1/2 inch (12.7 mm).
5. Closed-cell spray foam having a minimum density of 1.5 pcf (2.4 kg/m³) and having a thickness of not less than 1 1/2 inches (38 mm).
6. Open-cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m³) 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 1/2 inch (12.7 mm).
8. Cement board having a thickness of not less than 1/2 inch (12.7 mm).
9. Built-up roofing membrane.
10. Modified bituminous roof membrane.
11. Single-ply roof membrane.
12. A Portland cement/sand parge, or gypsum plaster having a thickness of not less than 5/8 inch (15.9 mm).
13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.
16. Solid or hollow masonry constructed of clay or shale masonry units.

C402.5.1.4 Assemblies. Assemblies of materials and components with an average air leakage not greater than 0.04 cfm/ft² (0.2 L/s × m²) under a pressure differential of 0.3 inch of water gauge (w.g.)(75 Pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM D8052 or ASTM E283 shall comply with this section. Assemblies listed in Items 1 through 3 shall be deemed to comply, provided that joints are sealed and the requirements of Section C402.5.1.1 are met.

1. Concrete masonry walls coated with either one application of block filler or two applications of a paint or sealer coating.
2. Masonry walls constructed of clay or shale masonry units with a nominal width of 4 inches (102 mm) or more.
3. A Portland cement/sand parge, stucco or plaster not less than 1/2 inch (12.7 mm) in thickness.

C402.5.1.5 Building envelope performance verification. The installation of the continuous air barrier shall be verified by the *code official*, a *registered design professional* or *approved* agency in accordance with the following:

1. A review of the construction documents and other supporting data shall be conducted to assess compliance with the requirements in Section C402.5.1.
2. Inspection of continuous air barrier components and assemblies shall be conducted during construction while the air barrier is still accessible for inspection and repair to verify compliance with the requirements of Sections C402.5.1.3 and C402.5.1.4.
3. A final commissioning report shall be provided for inspections completed by the *registered design professional* or *approved* agency. The commissioning report shall be provided to the building owner or owner's authorized agent and the *code official*. The report shall identify deficiencies found during the review of the construction documents and inspection and details of corrective measures taken.

C402.5.3 Building thermal envelope testing. The *building thermal envelope* shall be tested in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E3158 or ASTM E1827 or an equivalent method approved by the

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Roof system manufacturers should be providing air retarder information, including construction details specific to their products functioning as an air retarder.

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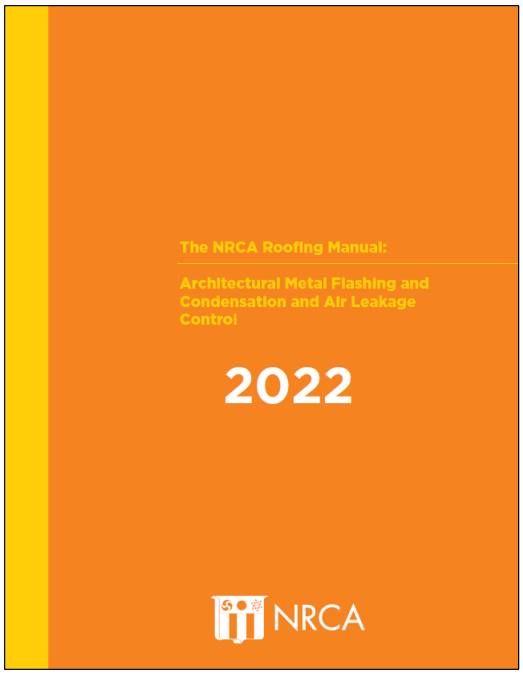

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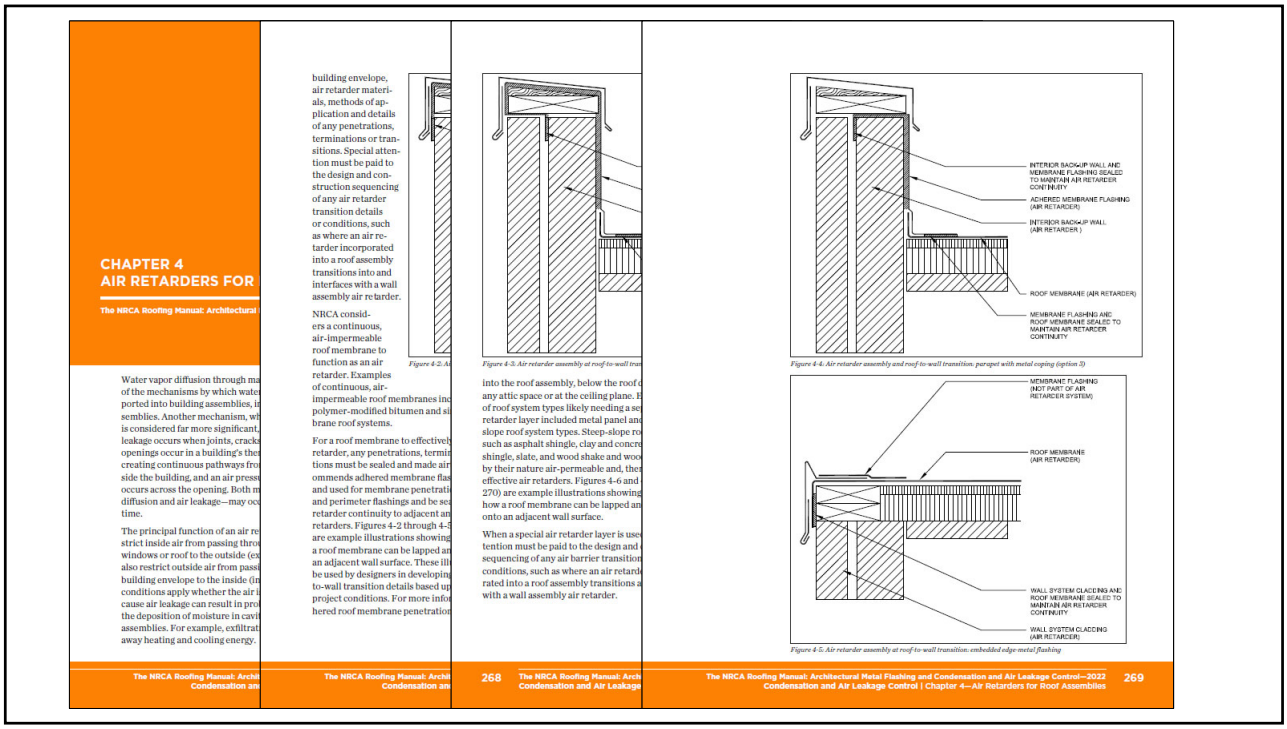

CHAPTER 4
AIR RETARDERS FOR

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Water vapor diffusion through ma
of the mechanisms by which wate
ported into building assemblies, i
semblies. Another mechanism, wh
is considered far more significant,
leakage occurs when joints, crack
openings occur in a building's the
creating continuous pathways fro
side the building, and an air presse
occurs across the opening. Both m
diffusion and air leakage—may oc
time.

The principal function of an air re
strict inside air from passing thro
windows or roof to the outside (ex
also restrict outside air from pass
building envelope to the inside (in
conditions apply whether the air l
cause air leakage can result in pro
the deposition of moisture in cavit
assemblies. For example, exfiltrat
away heating and cooling energy.

building envelope, air retarder materials, methods of application and details of any penetrations, terminations or transitions. Special attention must be paid to the design and construction sequencing of any air retarder transition details or conditions, such as where an air retarder incorporated into a roof assembly transitions into and interfaces with a wall assembly air retarder.

NRCA considers a continuous, air-impermeable roof membrane to function as an air retarder. Examples of continuous, air-impermeable roof membranes inc
polymer-modified bitumen and si
brane roof systems.

For a roof membrane to effectivel
retarder, any penetrations, termi
tions must be sealed and made air
ommends adhered membrane flas
and used for membrane penetrati
and perimeter flashings and be se
retarder continuity to adjacent ar
retarders. Figures 4-2 through 4-5
are example illustrations showing
a roof membrane can be lapped ar
an adjacent wall surface. These ill
be used by designers in developing
to-wall transition details based up
project conditions. For more infor
hered roof membrane penetration

Figure 4-2: A

Figure 4-3: Air retarder assembly at roof-to-wall tra

into the roof assembly, below the roof d
any attic space or at the ceiling plane. F
of roof system types likely needing a se
retarder layer included metal panel and
slope roof system types. Steep-slope ro
such as asphalt shingle, clay and concre
shingle, slate, and wood shake and woo
by their nature air-permeable and, thes
effective air retarders. Figures 4-6 and
270) are example illustrations showing
how a roof membrane can be lapped an
onto an adjacent wall surface.

When a special air retarder layer is use
tention must be paid to the design and
sequencing of any air barrier transition
conditions, such as where an air retard
rated into a roof assembly transitions a
with a wall assembly air retarder.

INTERIOR BACK-UP WALL AND MEMBRANE FLASHING SEALED TO MAINTAIN AIR RETARDER CONTINUITY
ADHERED MEMBRANE FLASHING (AIR RETARDER)
INTERIOR BACK-UP WALL (AIR RETARDER)
ROOF MEMBRANE (AIR RETARDER)
MEMBRANE FLASHING AND ROOF MEMBRANE SEALED TO MAINTAIN AIR RETARDER CONTINUITY

Figure 4-4: Air retarder assembly and roof-to-wall transition: parapet with metal coping (option 3)

MEMBRANE FLASHING (NOT PART OF AIR RETARDER SYSTEM)
ROOF MEMBRANE (AIR RETARDER)
WALL SYSTEM CLADDING AND ROOF MEMBRANE SEALED TO MAINTAIN AIR RETARDER CONTINUITY
WALL SYSTEM CLADDING (AIR RETARDER)

Figure 4-5: Air retarder assembly at roof-to-wall transition: embedded edge-metal flashing

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Condensation an

The NRCA Roofing Manual: Archi
Condensation an

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Condensation and Air Leakage

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Condensation and Air Leakage Control | Chapter 4—Air Retarders for Roof Assemblies

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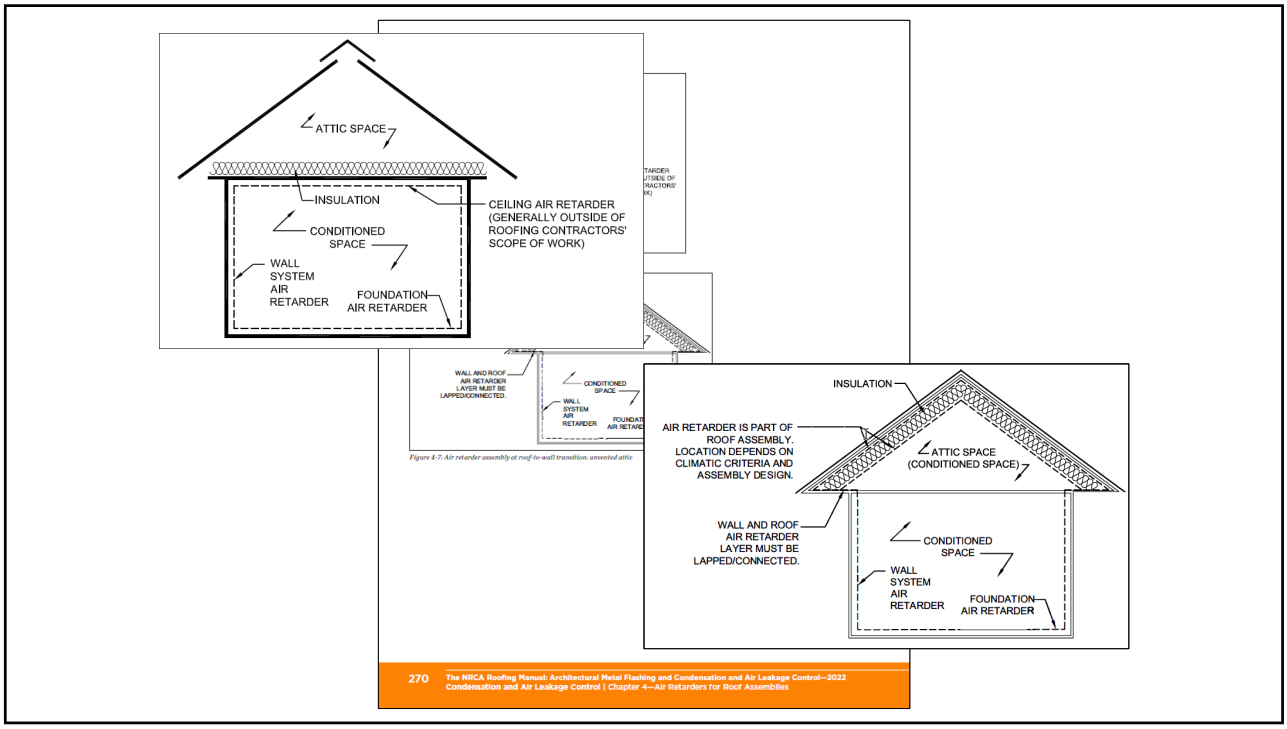

ATTIC SPACE
INSULATION
CONDITIONED SPACE
WALL SYSTEM AIR RETARDER
FOUNDATION AIR RETARDER
CEILING AIR RETARDER (GENERALLY OUTSIDE OF ROOFING CONTRACTORS' SCOPE OF WORK)

WALL AND ROOF AIR RETARDER LAYER MUST BE LAPPED/CONNECTED.
CONDITIONED SPACE
WALL SYSTEM AIR RETARDER

Figure 4-7: Air retarder assembly at roof-to-wall transition: unvented attic

INSULATION
AIR RETARDER IS PART OF ROOF ASSEMBLY. LOCATION DEPENDS ON CLIMATIC CRITERIA AND ASSEMBLY DESIGN.
ATTIC SPACE (CONDITIONED SPACE)
WALL AND ROOF AIR RETARDER LAYER MUST BE LAPPED/CONNECTED.
CONDITIONED SPACE
WALL SYSTEM AIR RETARDER
FOUNDATION AIR RETARDER

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Condensation and Air Leakage Control | Chapter 4—Air Retarders for Roof Assemblies

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Attic ventilation

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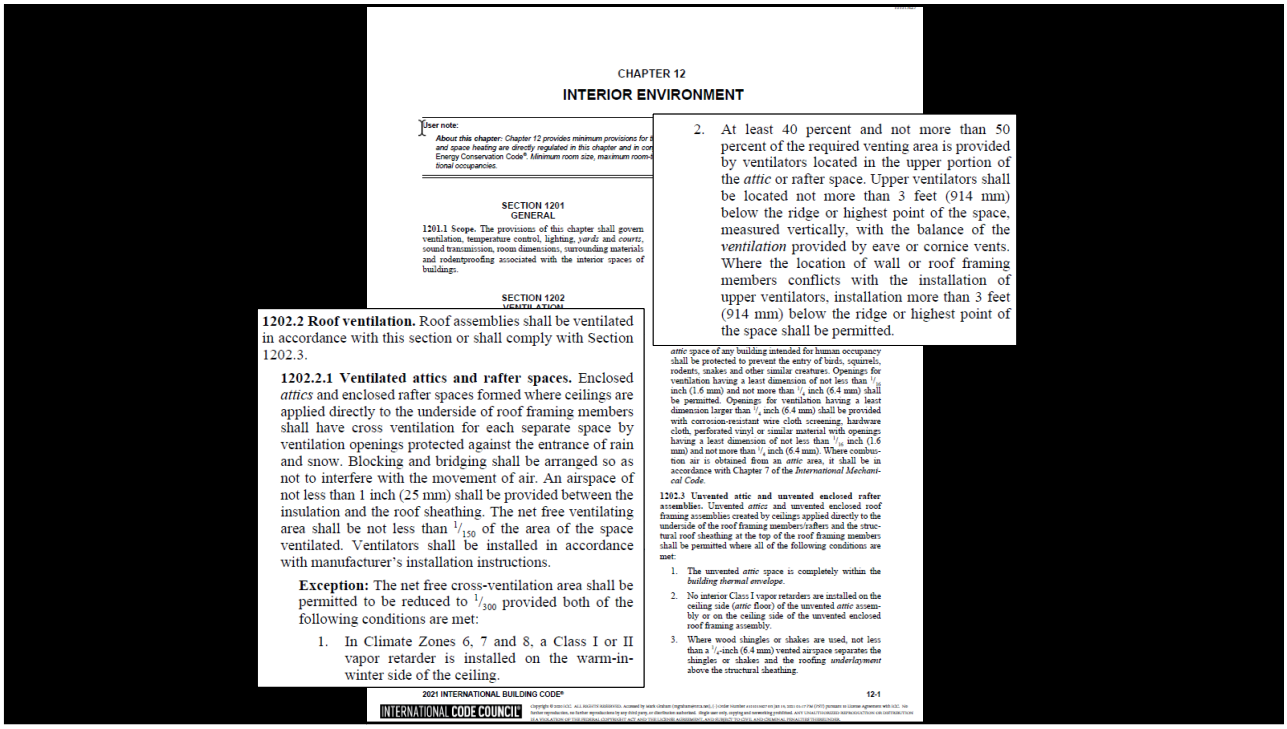

CHAPTER 12

INTERIOR ENVIRONMENT

User note:

About this chapter: Chapter 12 provides minimum provisions for t and space heating are directly regulated in this chapter and in con Energy Conservation Code®. Minimum room size, maximum room- tional occupancies.

SECTION 1201
GENERAL

1201.1 Scope. The provisions of this chapter shall govern ventilation, temperature control, lighting, *yards* and *courts*, sound transmission, room dimensions, surrounding materials and rodentproofing associated with the interior spaces of buildings.

SECTION 1202

1202.2 Roof ventilation. Roof assemblies shall be ventilated in accordance with this section or shall comply with Section 1202.3.

1202.2.1 Ventilated attics and rafter spaces. Enclosed *attics* and enclosed rafter spaces formed where ceilings are applied directly to the underside of roof framing members shall have cross ventilation for each separate space by ventilation openings protected against the entrance of rain and snow. Blocking and bridging shall be arranged so as not to interfere with the movement of air. An airspace of not less than 1 inch (25 mm) shall be provided between the insulation and the roof sheathing. The net free ventilating area shall be not less than $^1/_{150}$ of the area of the space ventilated. Ventilators shall be installed in accordance with manufacturer's installation instructions.

Exception: The net free cross-ventilation area shall be permitted to be reduced to $^1/_{300}$ provided both of the following conditions are met:

1. In Climate Zones 6, 7 and 8, a Class I or II vapor retarder is installed on the warm-in-winter side of the ceiling.
2. At least 40 percent and not more than 50 percent of the required venting area is provided by ventilators located in the upper portion of the *attic* or rafter space. Upper ventilators shall be located not more than 3 feet (914 mm) below the ridge or highest point of the space, measured vertically, with the balance of the *ventilation* provided by eave or cornice vents. Where the location of wall or roof framing members conflicts with the installation of upper ventilators, installation more than 3 feet (914 mm) below the ridge or highest point of the space shall be permitted.

attic space of any building intended for human occupancy shall be protected to prevent the entry of birds, squirrels, rodents, snakes and other similar creatures. Openings for ventilation having a least dimension of not less than $^1/_{16}$ inch (1.6 mm) and not more than $^1/_4$ inch (6.4 mm) shall be permitted. Openings for ventilation having a least dimension larger than $^1/_4$ inch (6.4 mm) shall be provided with corrosion-resistant wire cloth screening, hardware cloth, perforated vinyl or similar material with openings having a least dimension of not less than $^1/_{16}$ inch (1.6 mm) and not more than $^1/_4$ inch (6.4 mm). Where combustion air is obtained from an *attic* area, it shall be in accordance with Chapter 7 of the *International Mechanical Code*.

1202.3 Unvented attic and unvented enclosed rafter assemblies. Unvented *attics* and unvented enclosed roof framing assemblies created by ceilings applied directly to the underside of the roof framing members/rafters and the structural roof sheathing at the top of the roof framing members shall be permitted where all of the following conditions are met:

1. The unvented *attic* space is completely within the *building thermal envelope*.
2. No interior Class I vapor retarders are installed on the ceiling side (*attic* floor) of the unvented *attic* assembly or on the ceiling side of the unvented enclosed roof framing assembly.
3. Where wood shingles or shakes are used, not less than a $^1/_4$-inch (6.4 mm) vented airspace separates the shingles or shakes and the roofing *underlayment* above the structural sheathing.

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Research has shown there is little or no technical basis for these historic attic ventilation guidelines

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Also, more isn't necessarily better…

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Attic ventilation components

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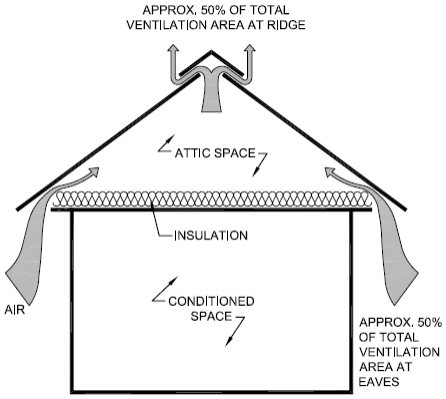
Suggested guidelines

Static ventilation configuration

- Balanced
- 1:150 ratio
- Jan. ≤ 30 F:
  - Vapor retarder
- Slope 8:12:
  - Increase ventilation



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Average January temperature less than 30F

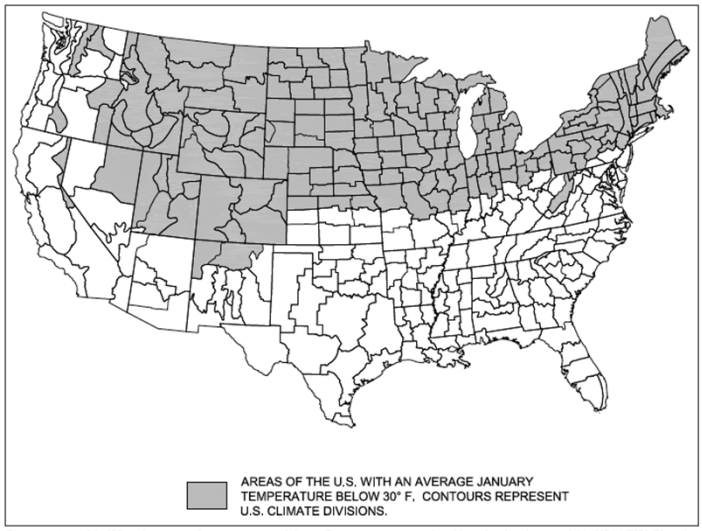

Figure 2-3: Areas of the U.S. with an average January temperature below 30 F, composite 1981-2012 data. Map is based on data provided by NOAA/ESRL Physical Sciences Division, Boulder, Colo., from its website, www.cdc.noaa.gov. Contours represent U.S. Climate Divisions.

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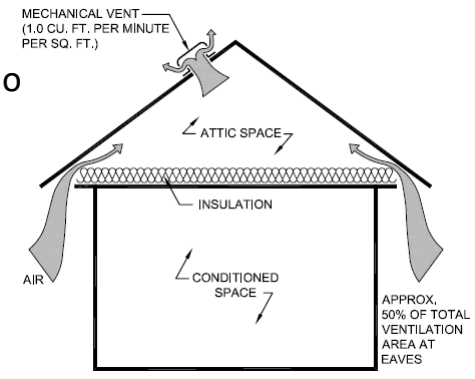
Suggested guidelines

Mechanical ventilation

- 1 CFM per sq. ft. ≈ 1:150 ratio
- Eave/soffits vents req'd.
- Jan. ≤ 30 F:
  - Vapor retarder
- Slope 8:12:
  - Increase ventilation



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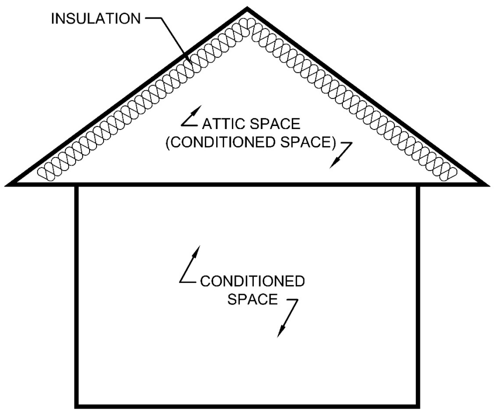
An alternative: Unvented, conditioned attic



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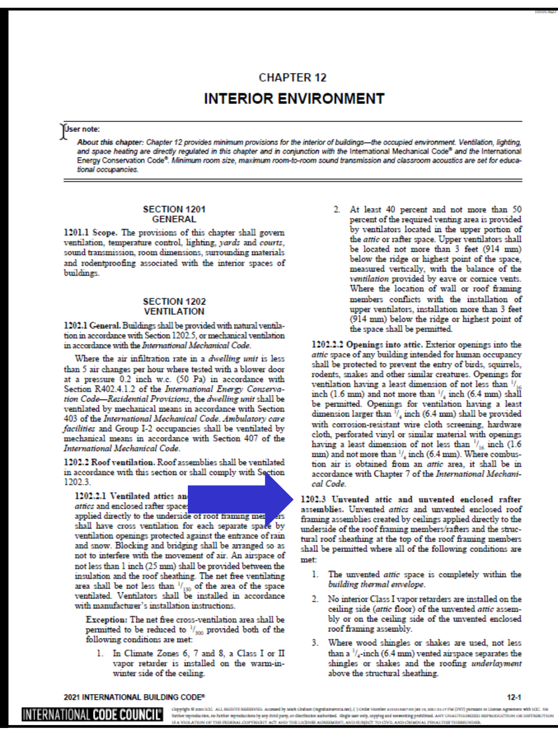

CHAPTER 12

INTERIOR ENVIRONMENT

User note:

About this chapter: *Chapter 12 provides minimum provisions for the interior of buildings—the occupied environment. Ventilation, lighting, and space heating are directly regulated in this chapter and in conjunction with the* International Mechanical Code® *and the* International Energy Conservation Code®*. Minimum room size, maximum room-to-room sound transmission and classroom acoustics are set for educational occupancies.*

SECTION 1201
GENERAL

1201.1 Scope. The provisions of this chapter shall govern ventilation, temperature control, lighting, *yards* and *courts*, sound transmission, room dimensions, surrounding materials and rodentproofing associated with the interior spaces of buildings.

SECTION 1202
VENTILATION

1202.1 General. Buildings shall be provided with natural ventilation in accordance with Section 1202.5, or mechanical ventilation in accordance with the *International Mechanical Code.*

Where the air infiltration rate in a *dwelling unit* is less than 5 air changes per hour where tested with a blower door at a pressure 0.2 inch w.c. (50 Pa) in accordance with Section R402.4.1.2 of the *International Energy Conservation Code—Residential Provisions*, the *dwelling unit* shall be ventilated by mechanical means in accordance with Section 403 of the *International Mechanical Code. Ambulatory care facilities* and Group I-2 occupancies shall be ventilated by mechanical means in accordance with Section 407 of the *International Mechanical Code.*

1202.2 Roof ventilation. Roof assemblies shall be ventilated in accordance with this section or shall comply with Section 1202.3.

1202.2.1 Ventilated attics an[...] *attics* and enclosed rafter space[...] applied directly to the underside of roof framing me[...]ers shall have cross ventilation for each separate space by ventilation openings protected against the entrance of rain and snow. Blocking and bridging shall be arranged so as not to interfere with the movement of air. An airspace of not less than 1 inch (25 mm) shall be provided between the insulation and the roof sheathing. The net free ventilating area shall be not less than $^1/_{150}$ of the area of the space ventilated. Ventilators shall be installed in accordance with manufacturer's installation instructions.

Exception: The net free cross-ventilation area shall be permitted to be reduced to $^1/_{300}$ provided both of the following conditions are met:

1. In Climate Zones 6, 7 and 8, a Class I or II vapor retarder is installed on the warm-in-winter side of the ceiling.
2. At least 40 percent and not more than 50 percent of the required venting area is provided by ventilators located in the upper portion of the *attic* or rafter space. Upper ventilators shall be located not more than 3 feet (914 mm) below the ridge or highest point of the space, measured vertically, with the balance of the *ventilation* provided by eave or cornice vents. Where the location of wall or roof framing members conflicts with the installation of upper ventilators, installation more than 3 feet (914 mm) below the ridge or highest point of the space shall be permitted.

1202.2.2 Openings into attic. Exterior openings into the *attic* space of any building intended for human occupancy shall be protected to prevent the entry of birds, squirrels, rodents, snakes and other similar creatures. Openings for ventilation having a least dimension of not less than $^1/_{16}$ inch (1.6 mm) and not more than $^1/_4$ inch (6.4 mm) shall be permitted. Openings for ventilation having a least dimension larger than $^1/_4$ inch (6.4 mm) shall be provided with corrosion-resistant wire cloth screening, hardware cloth, perforated vinyl or similar material with openings having a least dimension of not less than $^1/_{16}$ inch (1.6 mm) and not more than $^1/_4$ inch (6.4 mm). Where combustion air is obtained from an *attic* area, it shall be in accordance with Chapter 7 of the *International Mechanical Code.*

1202.3 Unvented attic and unvented enclosed rafter assemblies. Unvented *attics* and unvented enclosed roof framing assemblies created by ceilings applied directly to the underside of the roof framing members/rafters and the structural roof sheathing at the top of the roof framing members shall be permitted where all of the following conditions are met:

1. The unvented *attic* space is completely within the *building thermal envelope.*
2. No interior Class I vapor retarders are installed on the ceiling side (*attic* floor) of the unvented *attic* assembly or on the ceiling side of the unvented enclosed roof framing assembly.
3. Where wood shingles or shakes are used, not less than a $^1/_4$-inch (6.4 mm) vented airspace separates the shingles or shakes and the roofing *underlayment* above the structural sheathing.

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The conditioned, unvented attic is considered a viable alternative to attic ventilation

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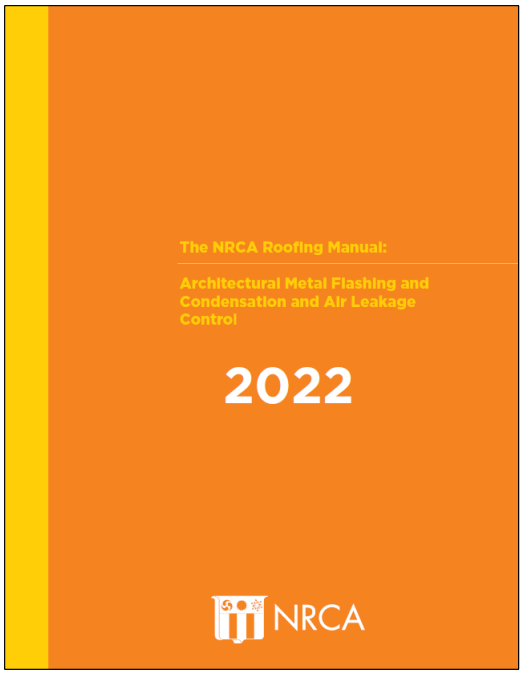

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Questions…

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