SOUTHEASTERN MICHIGAN ROOFING CONTRACTORS ASSOCIATION

Great Lakes Chapter IIBEC

Winter Technical Session
February 10, 2022
Troy, Michigan

Fundamentals of vapor retarders, air barriers and attic ventilation

NRCA

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Some fundamentals

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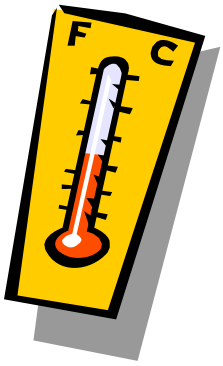
Phases of moisture

- **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.

4

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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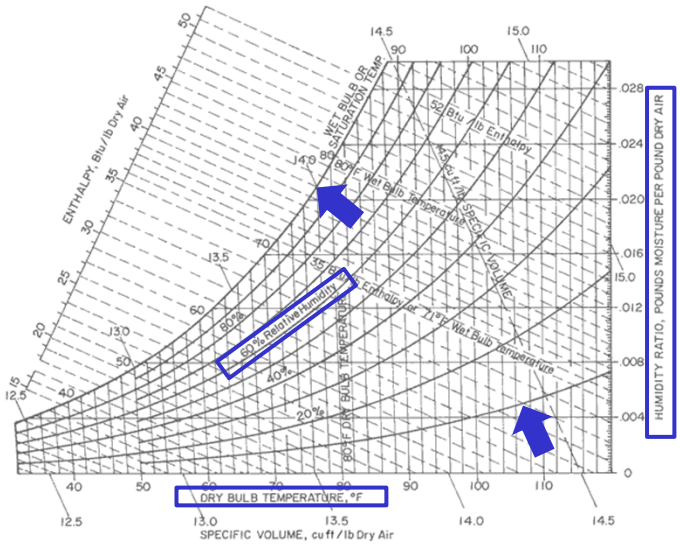
Psychrometric chart



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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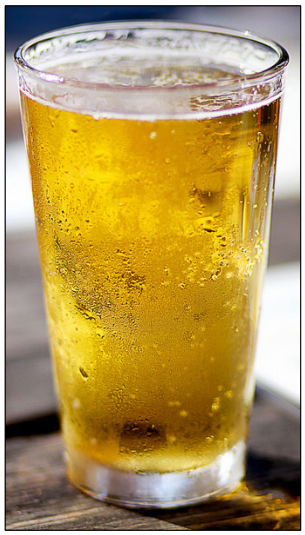
A practical application…



Is the glass “leaking”?

No… but we are studying thermodynamics

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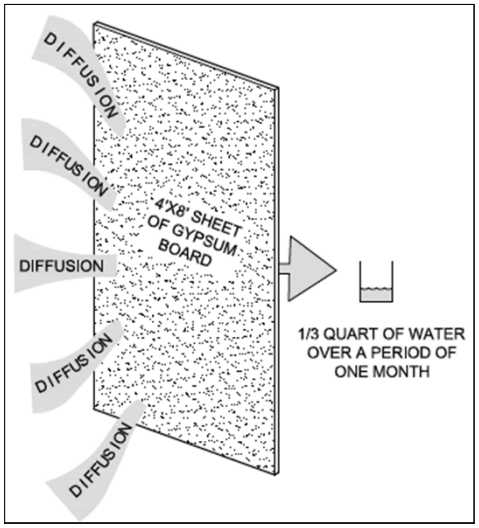
Diffusion



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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

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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

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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 (⅜ of an inch thick, plain)	50	
Hardboard (⅛ 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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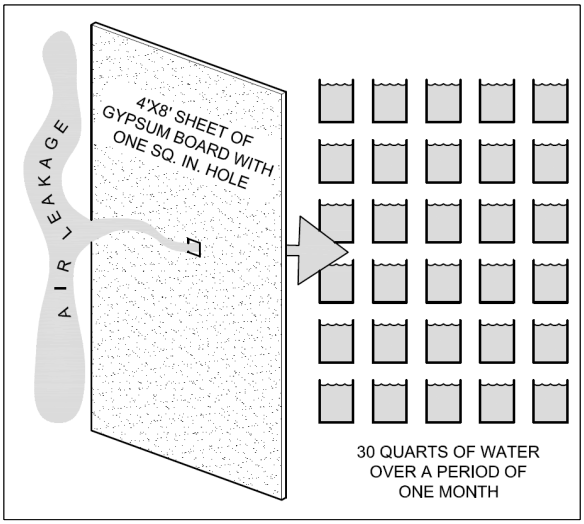
Air leakage



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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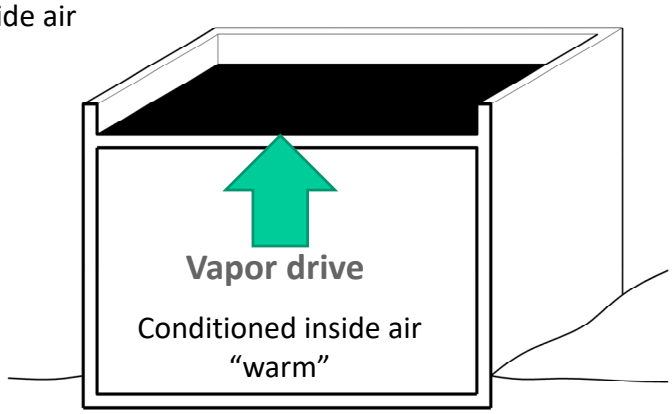
Cool outside air

Winter conditions



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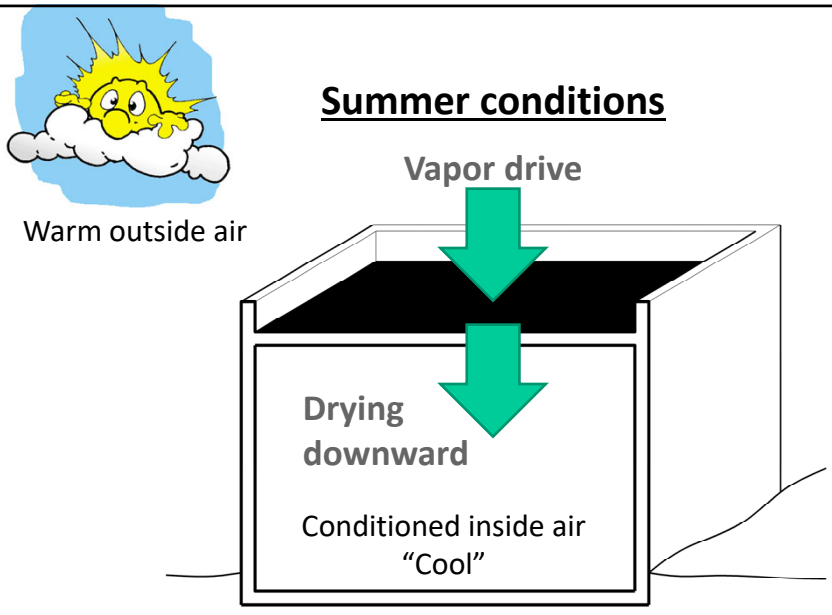

"Self-drying" roof assembly

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

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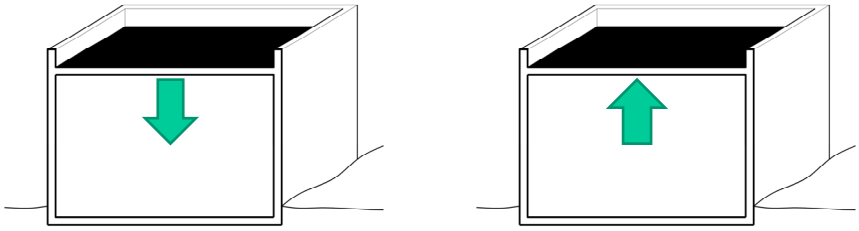
Self-drying roofs function properly if…



Downward drying ≥ Moisture pick-up

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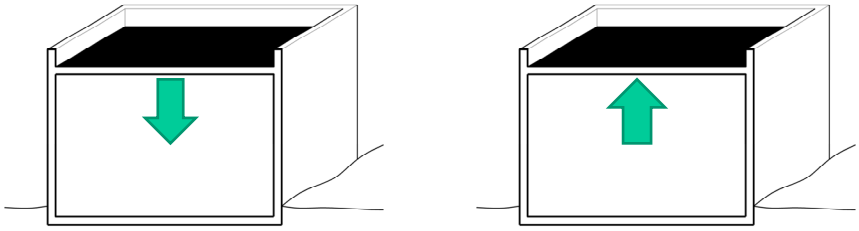
Self-drying roofs function properly if…



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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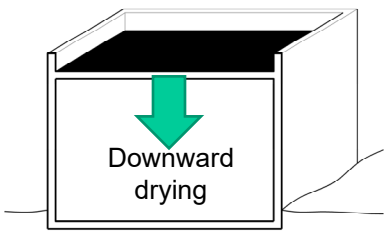
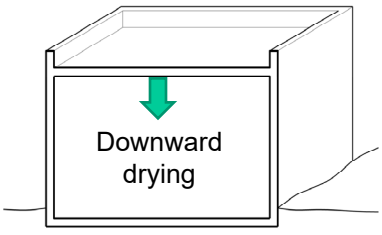


"Non-cool" roof



"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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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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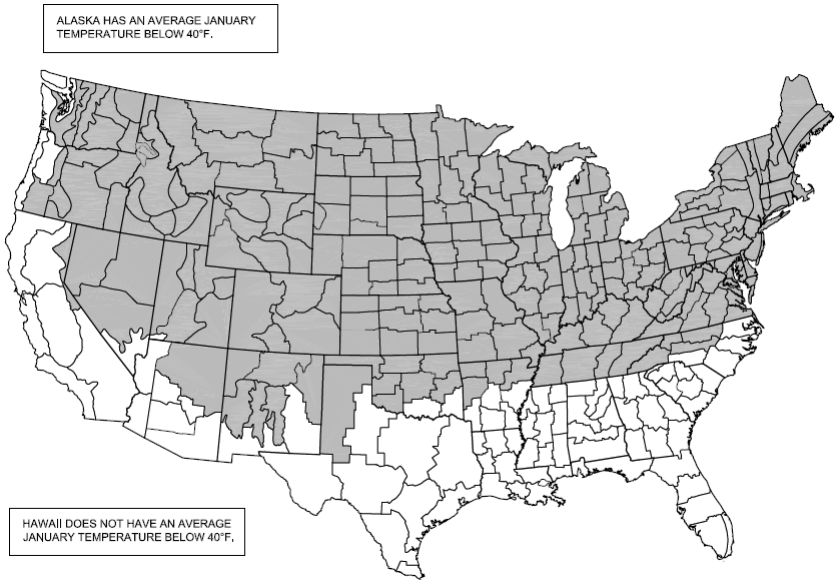
Average January temperature less than 40F



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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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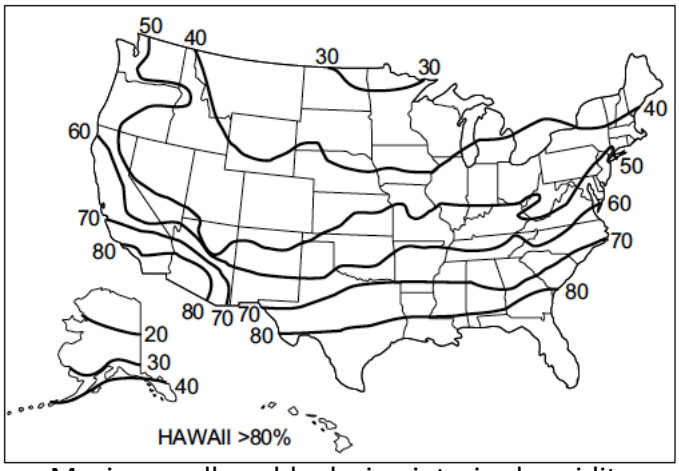
US Army CRREL method

Vapor retarder determination



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

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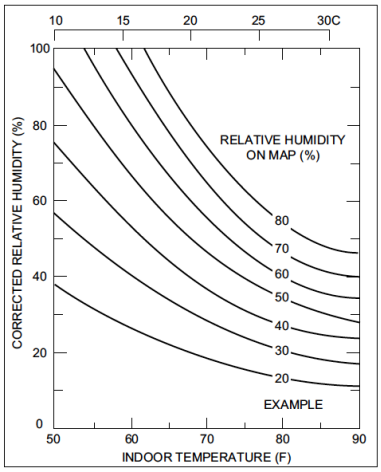
US Army CRREL method

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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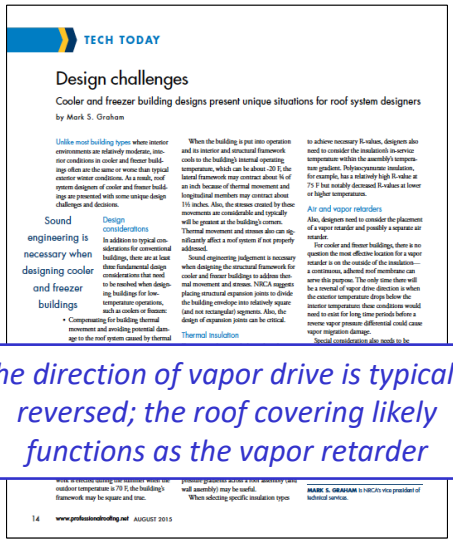
Cooler and freezer buildings



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 1½ 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.

possible gradients 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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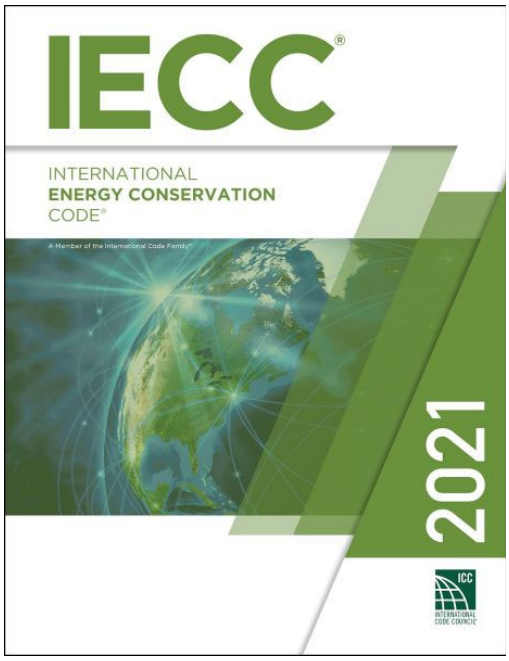

The Energy Code dictates minimum air retarder requirements

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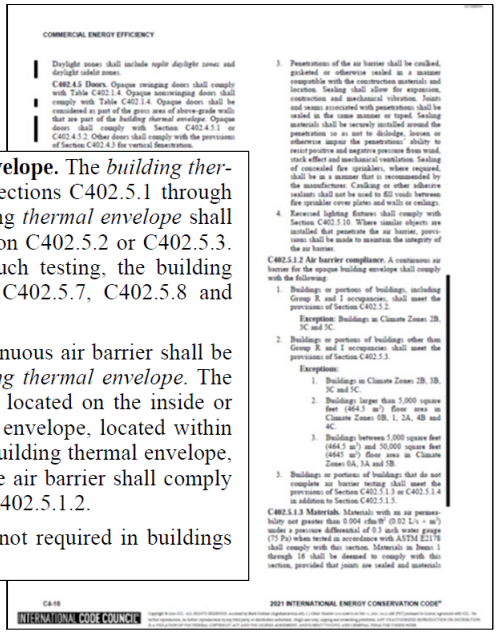
IECC 2021 Commercial – Air Retarders



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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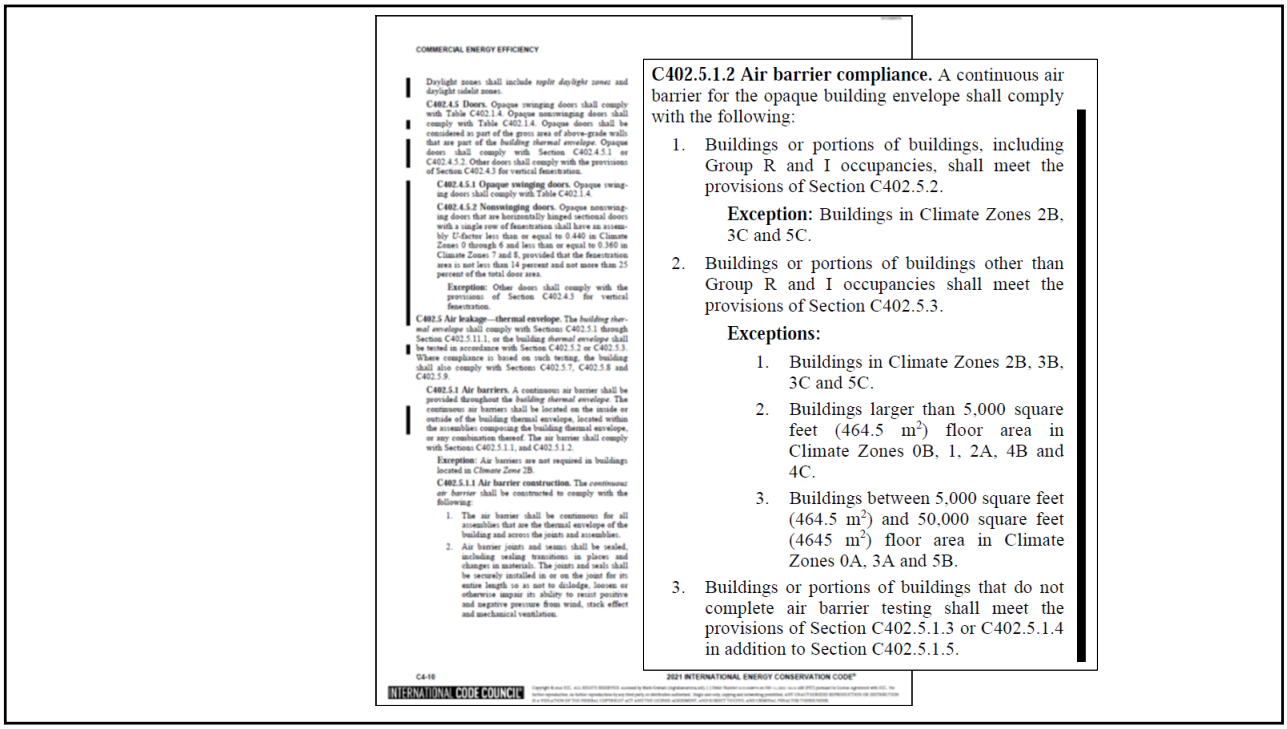

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Daylight zones shall include *toplit daylight zones* and daylight sidelit zones.

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.

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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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.

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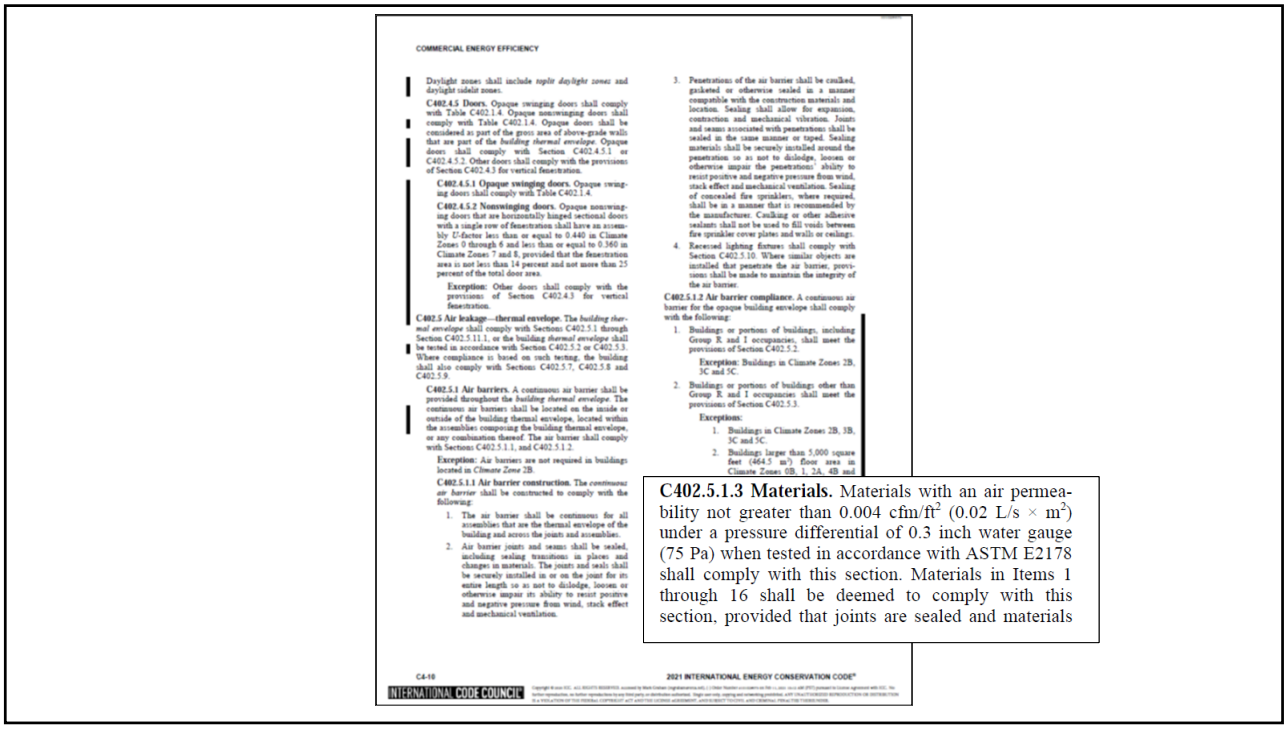

COMMERCIAL ENERGY EFFICIENCY

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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.
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.

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C402.5.1.3 Materials. Materials with an air permeability not greater than 0.004 cfm/ft^2 (0.02 L/s × m^2) 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/m^3) 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/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 $^1/_2$ 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.

C402.5.1.5 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/ft^2 (1.5 L/s·m^2) 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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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/m^3) 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/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 $^1/_2$ 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/ft^2 (0.2 L/s × m^2) 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.

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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/ft^2 (1.5 L/s·m^2) 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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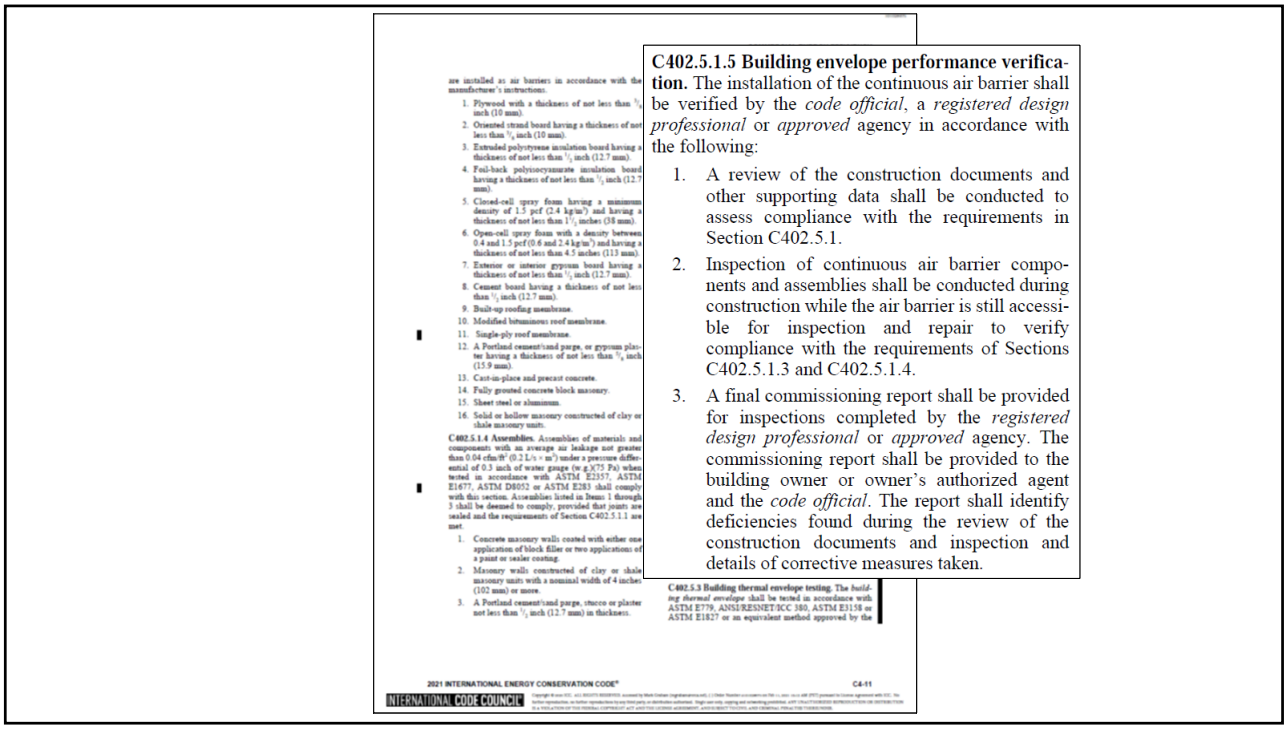

are installed as air barriers in accordance with the manufacturer's instructions.

1. Plywood with a thickness of not less than ⅜ inch (10 mm).
2. Oriented strand board having a thickness of not less than ⅜ inch (10 mm).
3. Extruded polystyrene insulation board having a thickness of not less than ½ inch (12.7 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than ½ 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 1½ 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 ½ inch (12.7 mm).
8. Cement board having a thickness of not less than ½ 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 ⅝ 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 ½ 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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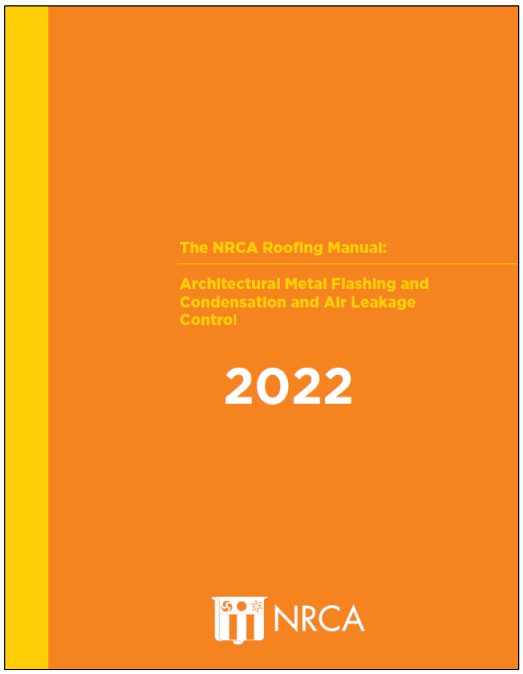

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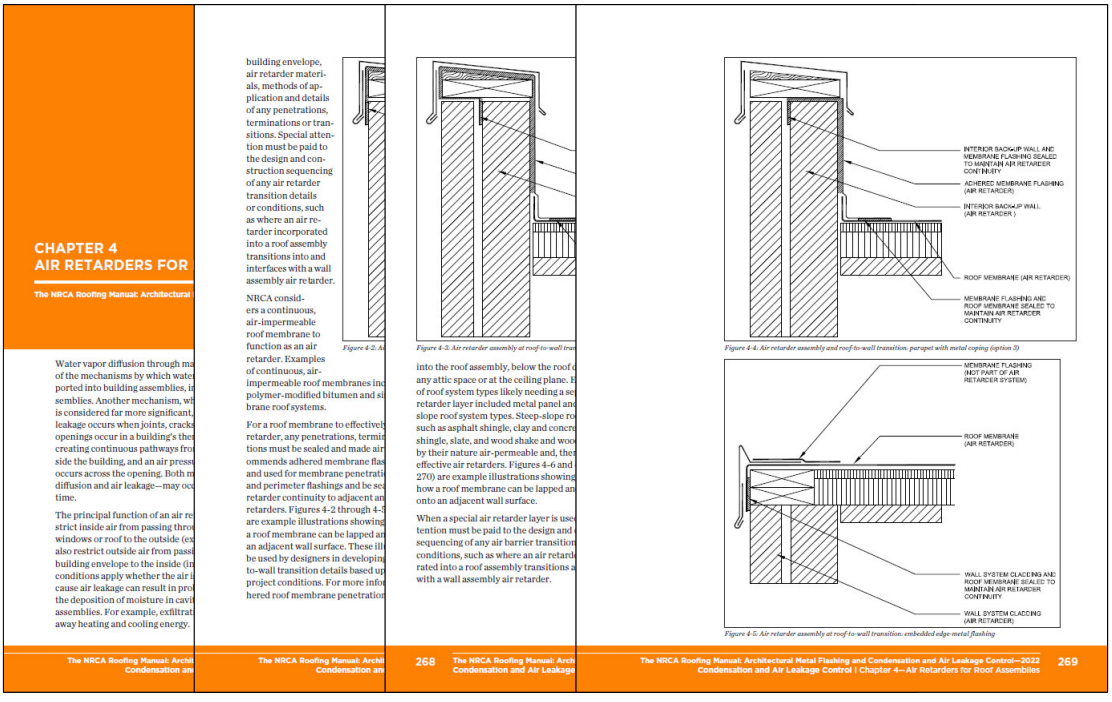

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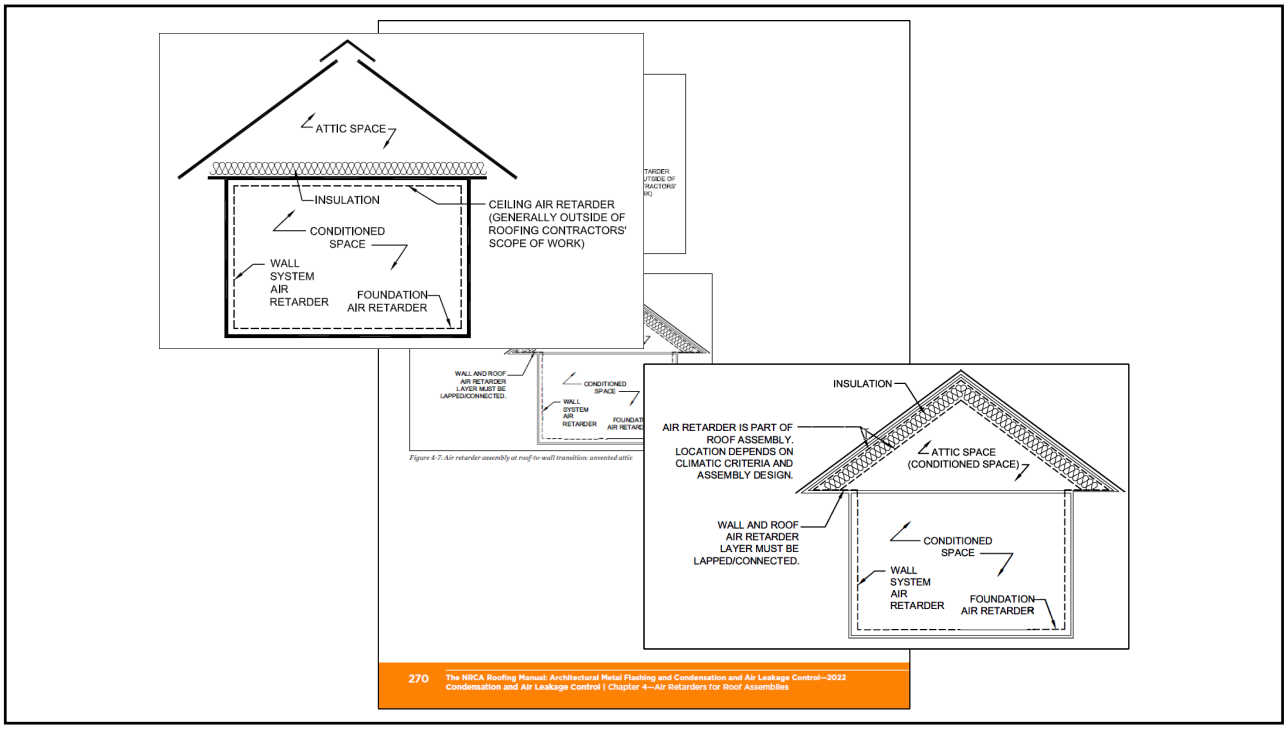

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Attic ventilation

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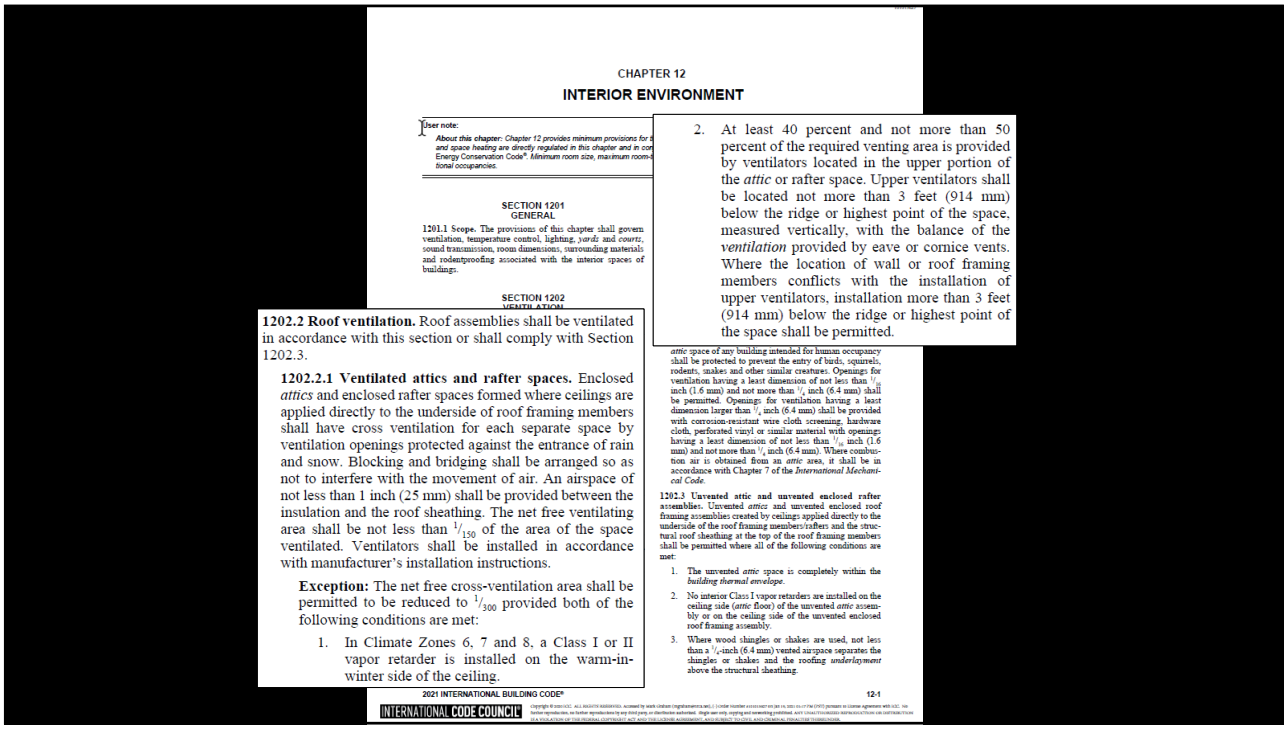

CHAPTER 12

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
VENTILATION

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 *attic* 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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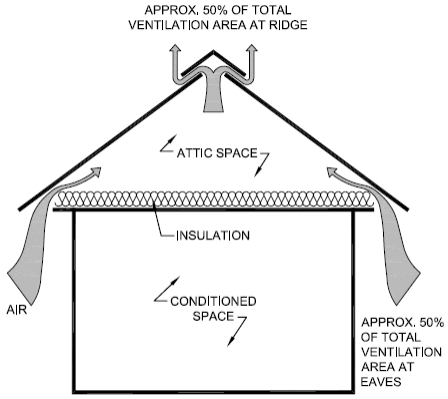
Suggested guidelines

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

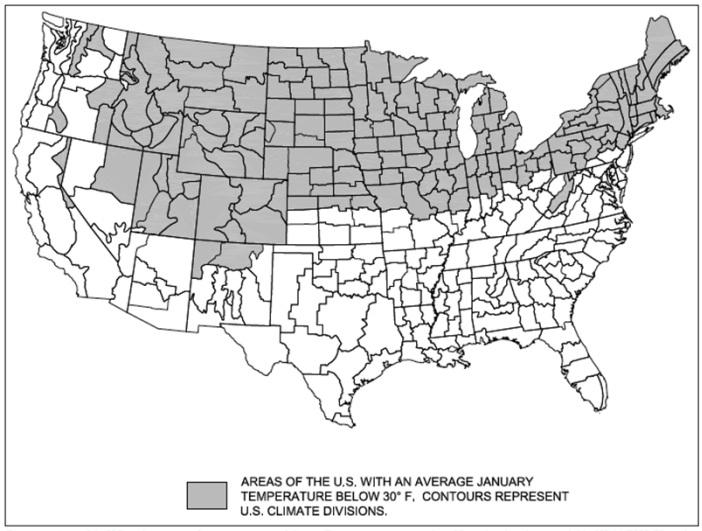

Figure 2-3: Areas of the U.S. with an average January temperature below 30 F, composite 1981-2012 data. Map is based on data provided by NOAA/ESRL Physical Sciences Division, Boulder, Colo., from its website, www.cdc.noaa.gov. Contours represent U.S. Climate Divisions.

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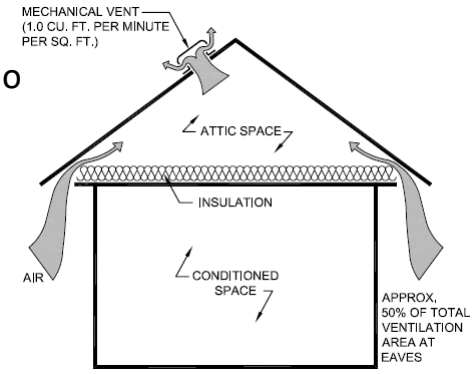
Suggested guidelines

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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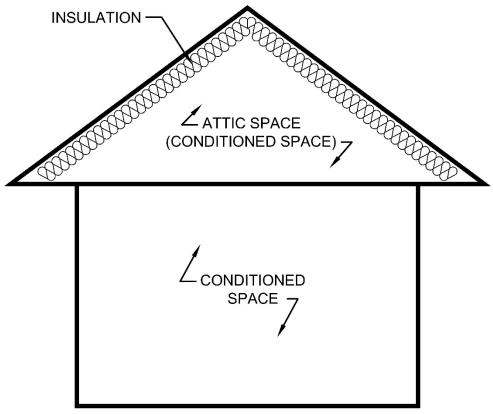
An alternative: Unvented, conditioned attic



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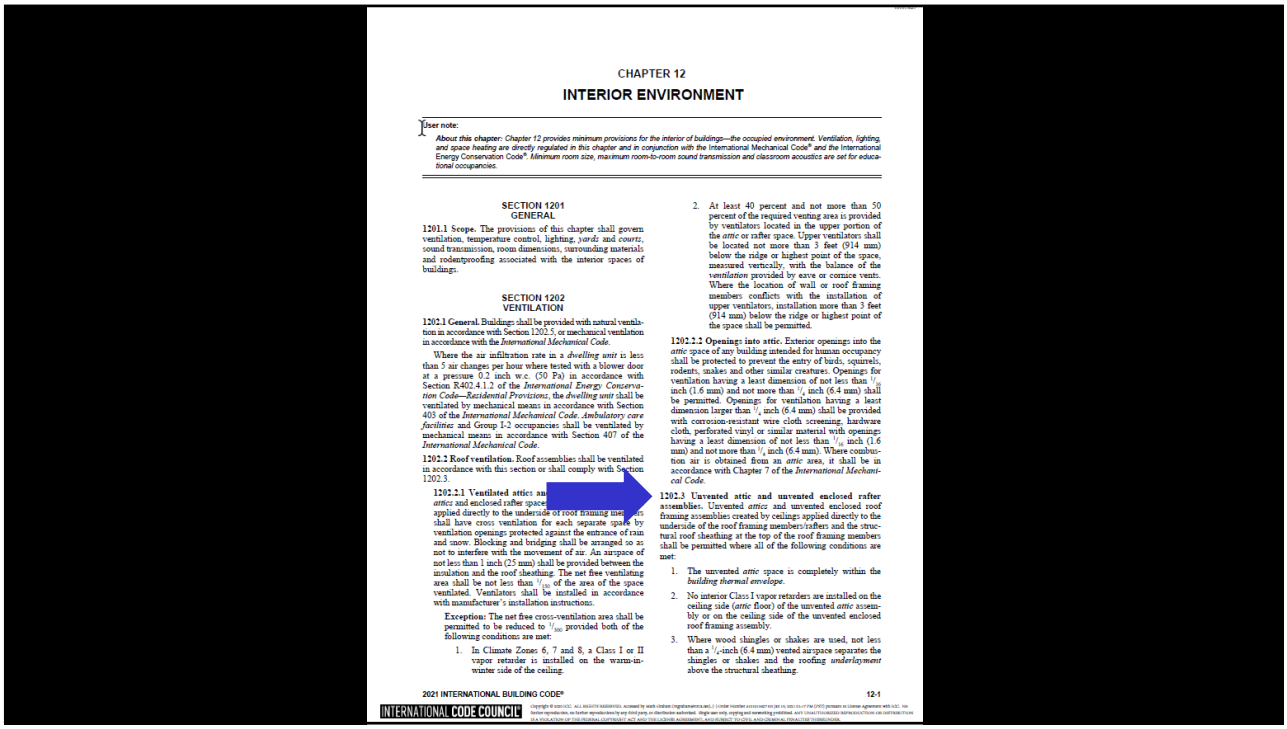

CHAPTER 12

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 when 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 mem
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 *attic* 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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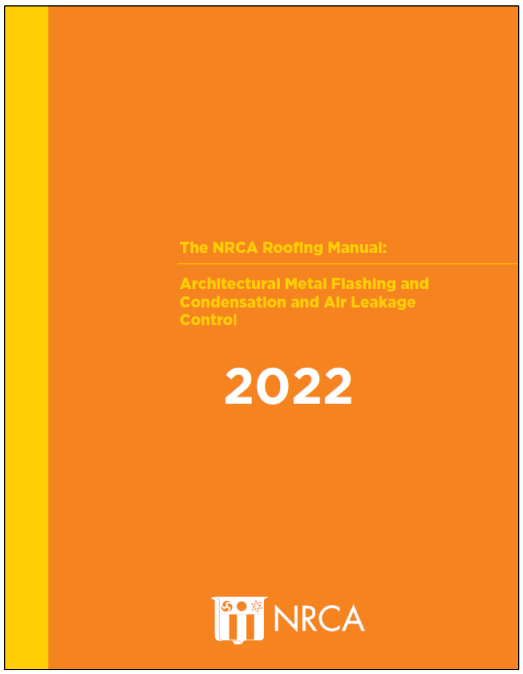

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Questions…

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