Applying Recent Building and Energy Code Advancements:

Durable and Energy-Efficient Building Enclosures

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ABTG

Applied Building Technology Group (ABTG) is committed to using sound science and generally accepted engineering practice to develop research supporting the reliable design and installation of foam sheathing. ABTG's educational program work with respect to foam sheathing is supported by the Foam Sheathing Committee (FSC) of the American Chemistry Council.

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Foam sheathing research reports, code compliance documents, educational programs and best practices can be found at www.continuousinsulation.org.

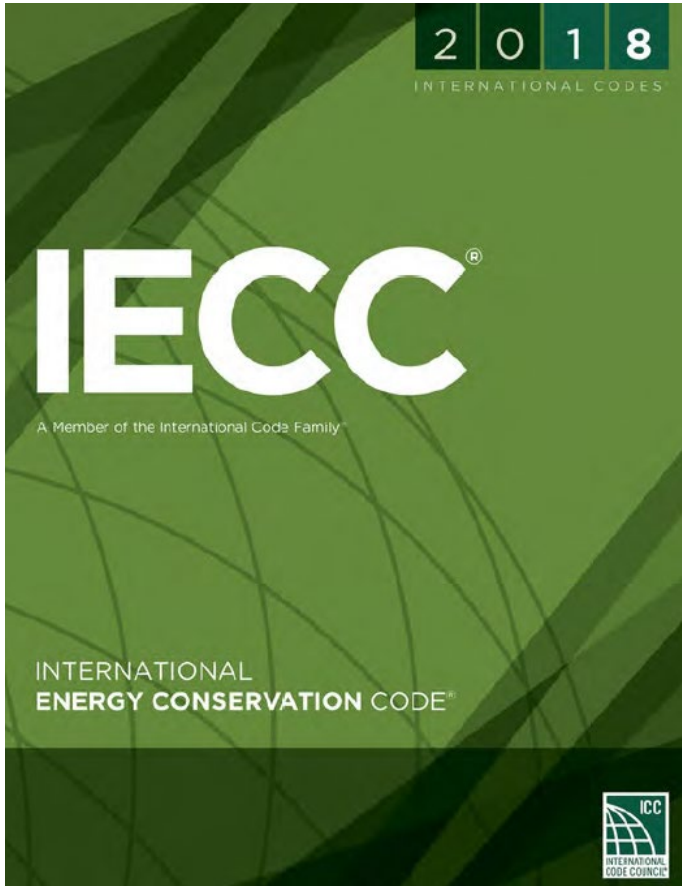
Foam Plastic Applications for Better Building

Outline

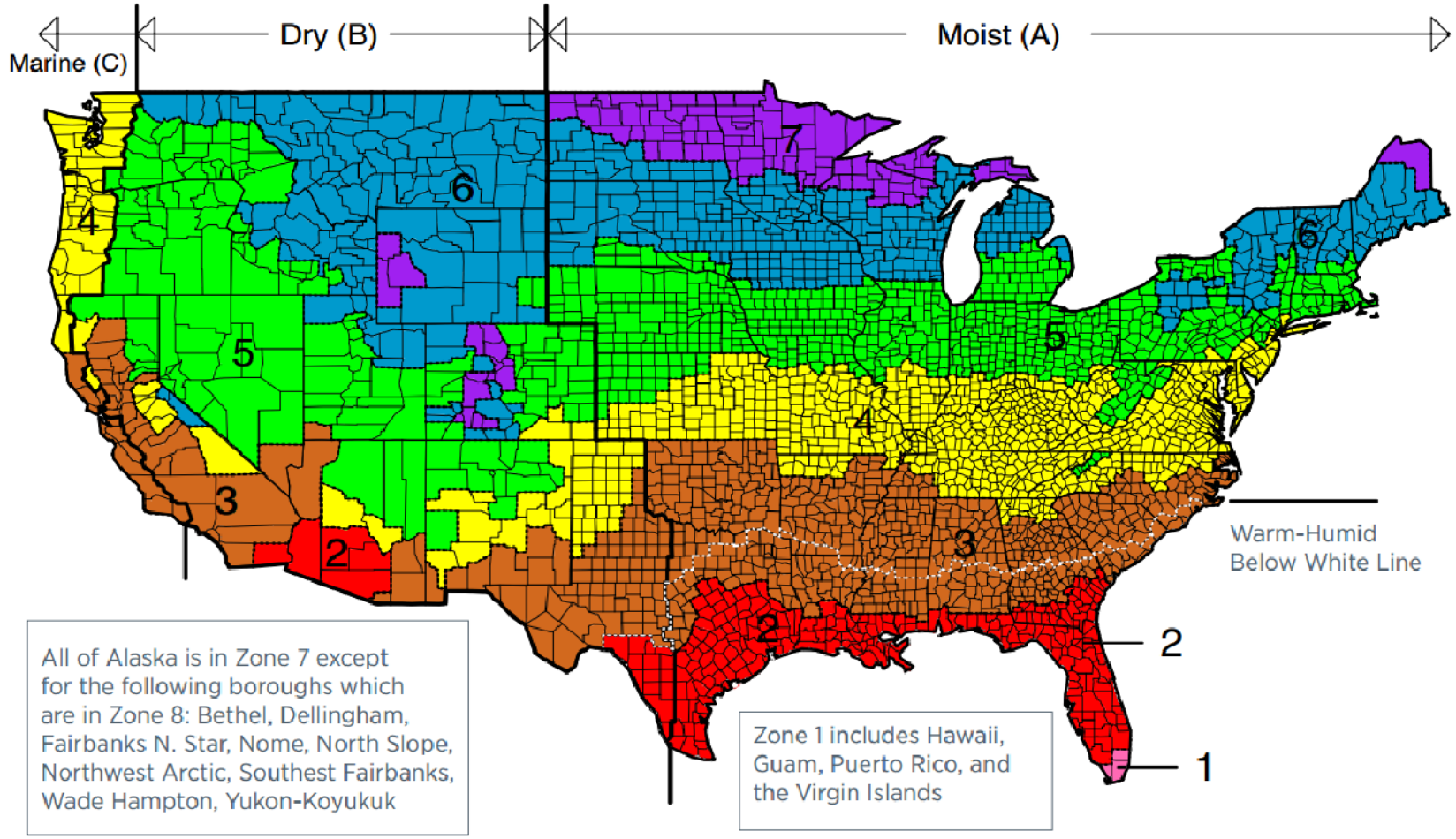
- Energy Code Advancements
- Coordinated Building Code Advancements
- Example Applications
- Conclusions & Questions
- FOCUS: Above-grade exterior walls

Energy Code Advancements

- Major advancement of building energy code occurred in 2012 (~30% increase in energy efficiency, reduction in energy use).
- Since 2012, there have been few advances in the 2015 and 2018 IECC.
- In 2021 IECC, significant additional energy efficiency improvements are expected.



Climate Zone Map

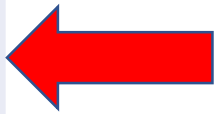


- 2021 code will use an updated map

2018 IECC-R / IRC Ch11 Wall R-value Options

(one- and two-family dwellings incl. townhouses)

Climate Zone	Wood Frame Wall R-value (16"oc)[a]
1	13+0ci or 0+10ci
2	13+0ci or 0+10ci
3	20+0ci, 13+5ci, or 0+15ci
4 except Marine	20+0ci, 13+5ci, or 0+15ci
5 and Marine 4	20+0ci, 13+5ci, or 0+15ci
6	30+0ci, 20+5ci, 13+10ci, or 0+20ci
7 and 8	30+0ci, 20+5ci, 13+10ci, or 0+20ci



Example 1 (later)

Equivalent R-value options are added as expected in 2021 code.
Not shown are expected improvements in CZ 4 & 5 to equal CZ 6, 7, & 8

2018 IECC-C Above-grade Wall R-value Options
(commercial and Group R MF residential buildings)

Example 3 (later)

Example 2 (later)

Climate Zone	Occupancy & Use	Construction Type			
		Mass	Metal Bldg	Metal Frame	Wood Frame & Other
1	Group R	R-5.7ci	R-13+R-6.5ci	R-13+R-5ci	R-13+R-3.8ci or R-20
	All Other	R-5.7ci	R-13+R-6.5ci	R-13+R-5ci	R-13+R-3.8ci or R-20
2	Group R	R-7.6ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-3.8ci or R-20
	All Other	R-5.7ci	R-13+R-6.5ci	R-13+R-5ci	R-13+R-3.8ci or R-20
3	Group R	R-9.5ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-3.8ci or R-20
	All Other	R-7.6ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-3.8ci or R-20
4 except Marine	Group R	R-11.4ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-3.8ci or R-20
	All Other	R-9.5ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-3.8ci or R-20
5 and Marine 4	Group R	R-13.3ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-7.5ci R-20+R-3.8ci
	All Other	R-11.4ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-3.8ci or R-20
6	Group R	R-15.2ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-7.5ci R-20+R-3.8ci
	All Other	R-13.3ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-7.5ci R-20+R-3.8ci
7	Group R	R-15.2ci	R-13+R-19.5ci	R-13+R15.6ci	R-13+R-7.5ci R-20+R-3.8ci
	All Other	R-15.2ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-7.5ci R-20+R-3.8ci
8	Group R	R-25ci	R-13+R-19.5ci	R-13+R-17.5ci	R-13+R-15.6ci R-20+R10ci
	All Other	R-25ci	R-13+R-13ci	R-13+R-7.5ci	R-13+R-15.6ci R-20+R10ci

Some R-values expected to increase in 2021 IECC where less stringent than ASHRAE 90.1

R-value Trade-offs

- There are several ways that alternative R-values can be determined for code compliance:
  - Use of U-factors for equivalent assemblies but different amounts and locations of insulation and building materials
  - Use of total UA trade-off, e.g., strengthening one assembly to weaken another (e.g., use REScheck or COMcheck)
  - Use of building performance methods (e.g., ERI path or building simulation path)
- Any of the approaches give flexibility to have more or less insulation or a different arrangement of the insulation for good or bad…
- CAUTION! – UNINTENDED CONSEQUENCE #1: This flexibility for energy code compliance can result in assemblies that perform differently (better or worse) from a moisture control and durability perspective.

R-value Trade-offs

- CAUTION! – UNINTENDED CONSEQUENCE #2: Value of “clean” renewable energy (e.g., solar PV) can be traded-off for reduced energy efficiency (i.e., trade-off envelope R-value).
  - WHY?
    - Doing this causes more net energy use by the building (with renewables used only to offset the increase in energy use from a weaker building envelope)
    - This works against energy conservation and wastes renewable energy resources and technology to allow a “weaker” building envelope.
    - Consequently, the use of renewable (“clean”) energy would do little or nothing to reduce the use of non-renewable (fossil) energy sources and GHG emissions.
- SOLUTION: Sustainable Energy Strategy = Conservation + Renewables
- Newer energy codes are becoming more intelligent in preventing bad “trade deals” by instituting renewable trade-off limits and/or envelope R-value backstops in the performance compliance paths (e.g., ERI or simulation).

Source: Everguardsolar.com, 2/27/2020

Coordinated Building Code Advancements

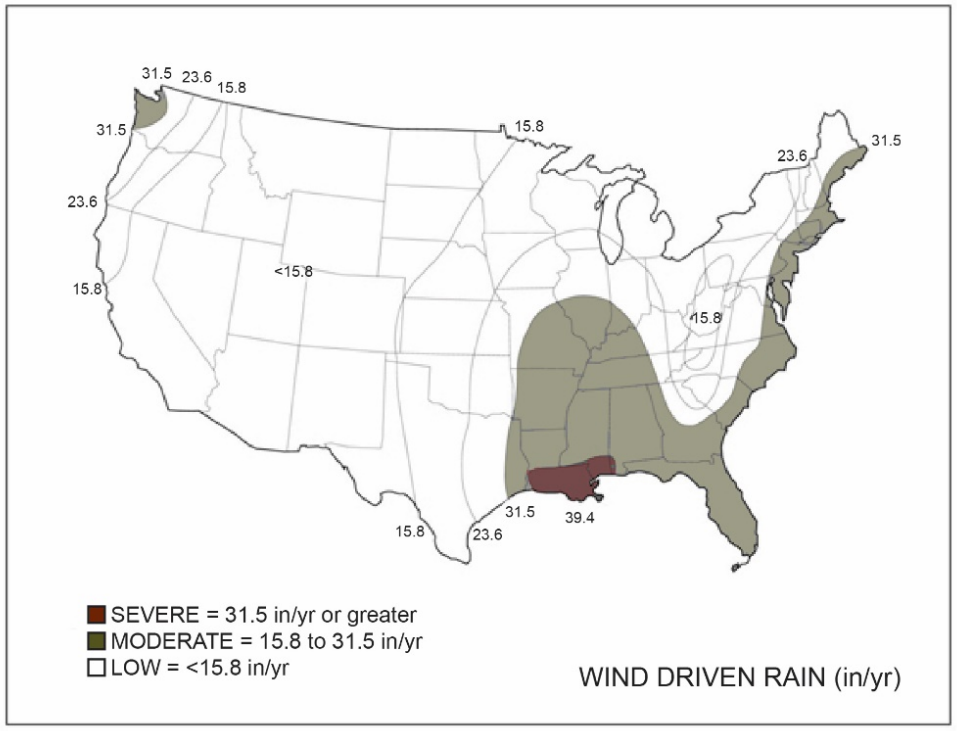
- Energy code advancements and flexibility to make “trade-offs” requires coordinating advancements in the building code’s moisture control provisions.
- Why?
  - To help avoid unintended consequences…
  - Insulation materials, amounts, and their location on a building assembly can affect moisture control, for good or bad
  - Building materials and their properties and locations within an envelope assembly also affect moisture control and durability, for good or bad.
  - Healthy and durable buildings require materials to be protected against the effects of moisture (i.e., mold, corrosion, rot, shrink/swell, degradation due to moisture cycling, etc.)
- Codes have been largely silent or incomplete on many of the key factors that govern how an assembly will perform as a system in controlling moisture.
- This is changing in the 2021 editions of the IRC and IBC…

Coordinated Building Code Advancements

- Water-resistive barriers and flashing
- Air-barriers
- Reservoir Claddings
- System-based vapor retarder provisions

Water-Resistive Barriers & Flashing

- Wind-driven rain is the water-intrusion hazard, especially for walls
- The code currently does not factor variations in WDR hazard into WRB, fenestration, and flashing requirements or assembly tests (e.g., ASTM E331)



Water-Resistive Barriers & Flashing

- 2021 IBC and IRC will expand guidance on selection of and criteria for water-resistive barriers (2021 IRC shown, IBC same except No15 felt installation instructions not included):

  R703.2 Water-resistive barrier. Not fewer than one layer of water-resistive barrier shall be applied over studs or sheathing with flashing as indicated in Section R703.4, in such a manner as to provide a continuous water-resistive barrier behind the exterior wall veneer. Water-resistive barrier materials shall comply with one of the following:

  1. No. 15 felt complying with ASTM D226, Type 1
  2. ASTM E2556, Type I or II
  3. ASTM E331 in accordance with Section R703.1.1, or
  4. Other approved materials in accordance with the manufacturer's installation instructions.

  No.15 asphalt felt and water-resistive barriers complying with ASTM E2556 shall be applied horizontally, with the upper layer lapped over the lower layer not less than 2 inches (51 mm), and where joints occur, shall be lapped not less than 6 inches (152 mm).

- Be sure to follow manufacturer's instructions (especially for "other approved materials" such as sheathing type WRBs, fluid-applied, adhered, etc.)!

Water-Resistive Barriers & Flashing

- 2021 IRC (re-organization of flashing for fenestration):

R703.4.1 Flashing installation at exterior window and door openings. Flashing at exterior window and door openings shall extend to the surface of the exterior wall finish or to the water-resistive barrier complying with Section 703.2 for subsequent drainage. Mechanically attached flexible flashings shall comply with AAMA 712. Flashing at exterior window and door openings shall be installed in accordance with one or more of the following:

1. The fenestration manufacturer's installation and flashing instructions, or for applications not addressed in the fenestration manufacturer's instructions, in accordance with the flashing manufacturer's instructions. Where flashing instructions or details are not provided, pan flashing shall be installed at the sill of exterior window and door openings. Pan flashing shall be sealed or sloped in such a manner as to direct water to the surface of the exterior wall finish or to the water resistive barrier for subsequent drainage. Openings using pan flashing shall incorporate flashing or protection at the head and sides.
2. In accordance with the flashing design or method of a registered design professional.
3. In accordance with other approved methods.

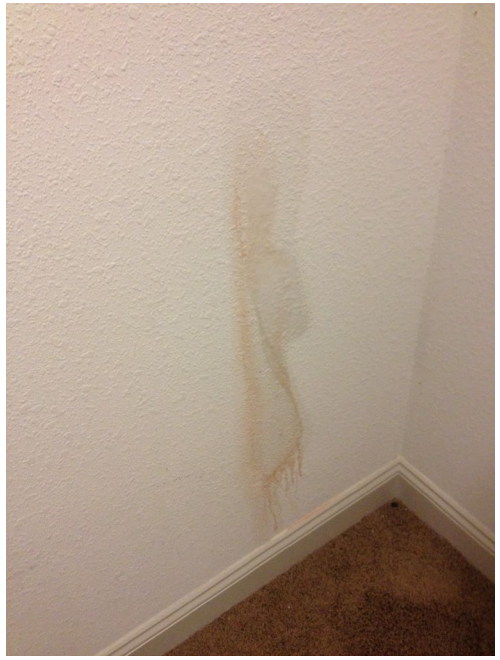
Water-Resistive Barriers & Flashing

- 2021 IBC (clarification that flashing to WRB is permissible):

1404.4 Flashing. Flashing shall be installed in such a manner so as to prevent moisture from entering the wall or to redirect that moisture to the ~~exterior.~~ surface of the exterior wall finish or to a water-resistive barrier complying with Section 1403.2 and that is part of a means of drainage complying with Section 1402.2. Flashing shall be installed at the perimeters of exterior door and window assemblies, penetrations and terminations of *exterior wall* assemblies, *exterior wall* intersections with roofs, chimneys, porches, decks, balconies and similar projections and at built-in gutters and similar locations where moisture could enter the wall. Flashing with projecting flanges shall be installed on both sides and the ends of copings, under sills and continuously above projecting *trim*. Where self-adhered membranes are used as flashings of *fenestration* in wall assemblies, those self-adhered flashings shall comply with AAMA 711. Where fluid applied membranes are used as flashing for *exterior wall* openings, those fluid applied membrane flashings shall comply with AAMA 714.

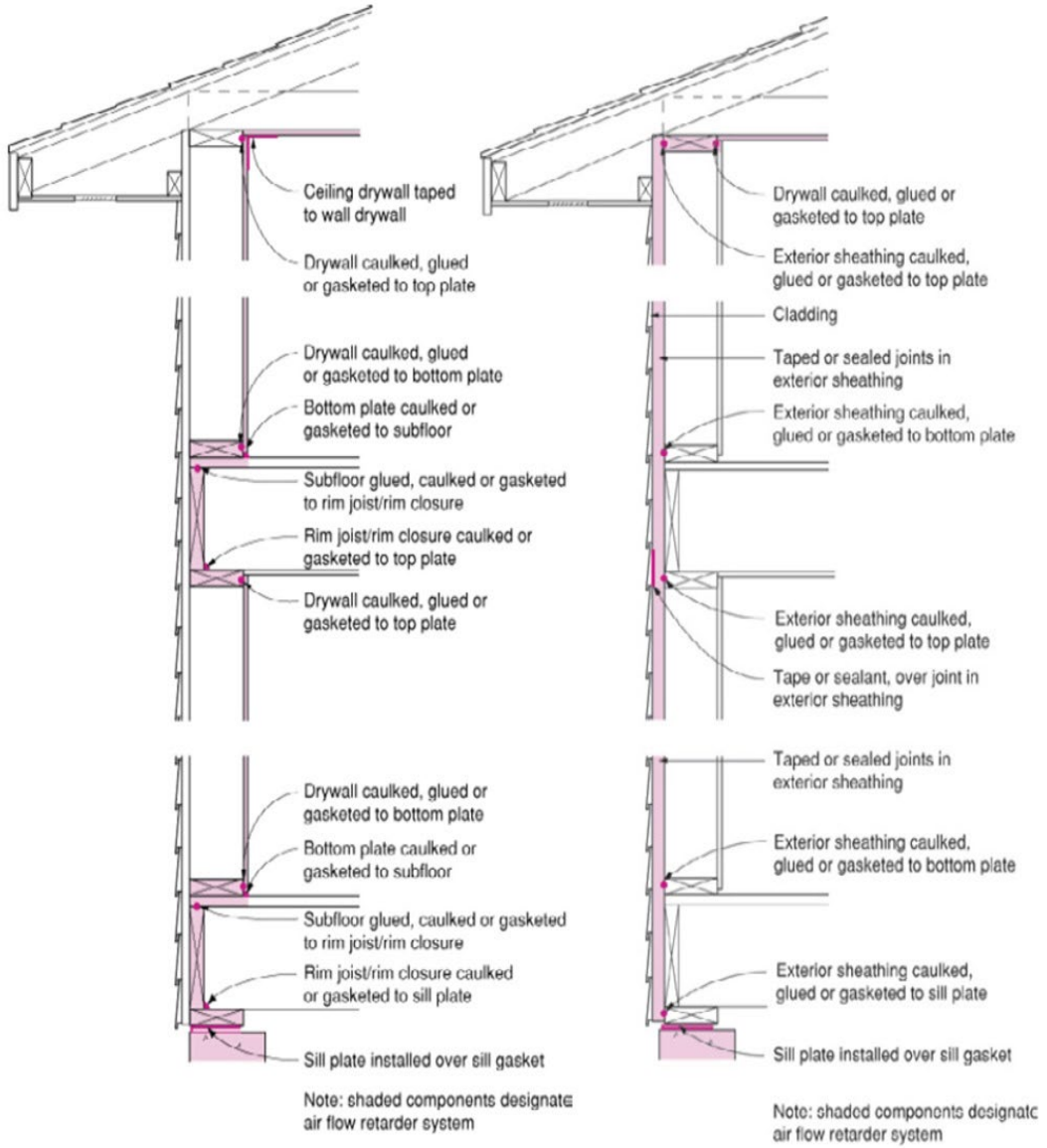
Air Barriers

- Air leakage can introduce moist air into assemblies increasing the likelihood of at least localized moisture problems
  - Similar to flashing defects resulting in a localized rain water leaks that typically cause localized moisture problems
- Air leakage, under the right circumstances, can help an assembly dry out, but this is unreliable, cuts both ways.
- It is better to prevent wetting by controlling water and air leaks.



Air Barriers

- Air barrier system installation requirements and whole building air leakage testing requirements are found in the energy code.
  - Blower door tests are only required for one- and two-family homes, but 2021 IECC is expected to require it for some commercial buildings
- There is no mention of air barriers in the building code from a moisture control perspective.



Air Barriers

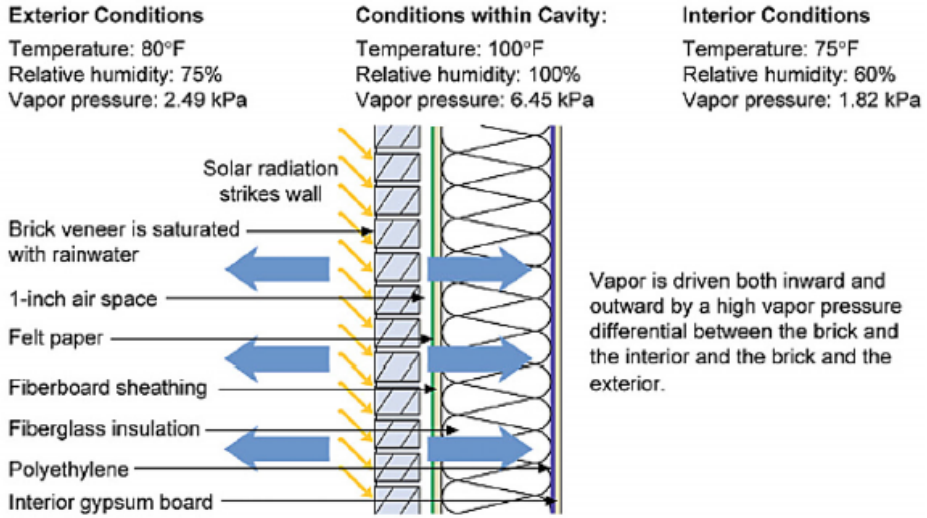
- One proposal attempted to make the link between air-barriers and moisture control, but was not approved for the 2021 I-codes:

  702.7.4 Installation. Vapor retarders shall be installed in accordance with the manufacturer's instructions or an approved design. The vapor retarder shall be installed as an air barrier or in conjunction with an air barrier.

- Vapor retarders work on the principle of controlling vapor diffusion; if they are "flanked" by air movement through the assembly the vapor retarder is bypassed or at least rendered less effective.

Reservoir Claddings

- Reservoir claddings include PC stucco and adhered veneers
- Inward vapor drives during summer, especially when solar-driven after rainfall and with AC'd buildings, can result in significant wetting of:
  - exterior sheathing
  - interior finish materials
  - Interior vapor retarder
- If combined with inadequate outward vapor control in the winter (in colder climates), then the wall never has opportunity to dry



Inward Moisture Movement Due to Solar Radiation

http://www.greenbuildingadvisor.com/blogs/dept/musings/all-about-wall-rot

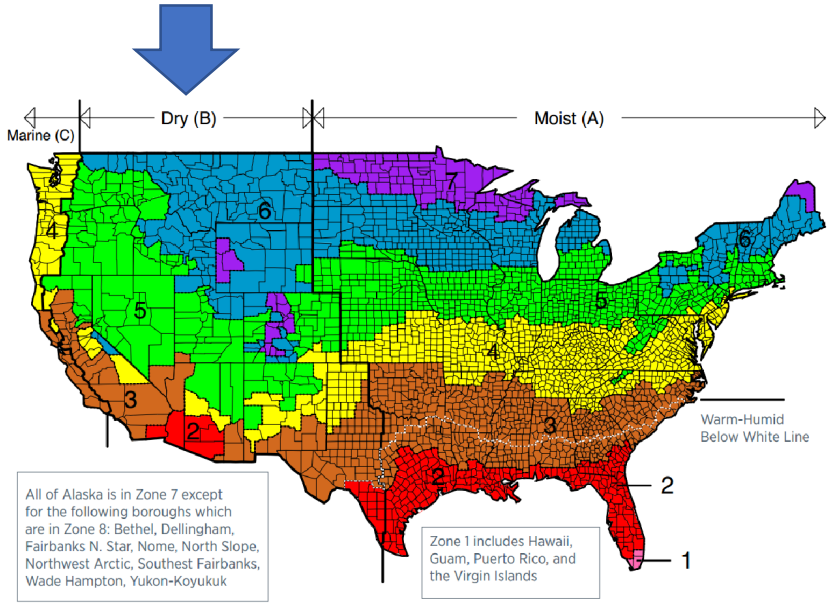
Reservoir Claddings

- The 2021 IBC and IRC significantly upgrade and clarify stucco WRB and drainage requirements to protect against inward vapor movement:

  2510.6 Water-resistive barriers. Water-resistive barriers shall be installed as required in Section 1403.2 and, where applied over wood-based sheathing, shall comply with Section 2510.6.1 or Section 2510.6.2.

Reservoir Claddings

- For “dry” climate regions, the traditional practice of two layers of 10-min Grade D paper or one layer of 60-min Grade D paper is still permitted and further clarified:

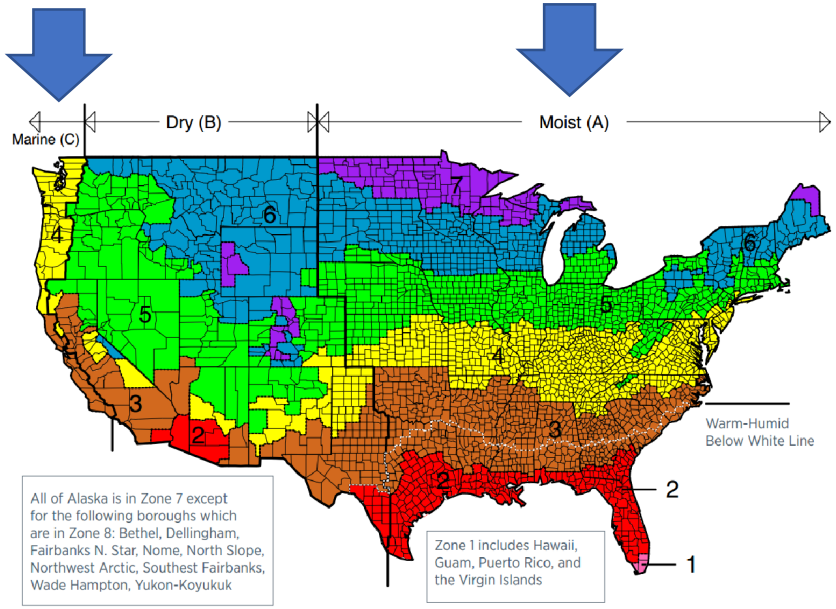


2510.6.1 Dry climates. One of the following shall apply for dry (B) climate zones:

1. The water-resistive barrier shall be two layers of 10-minute Grade D paper or have a water resistance equal to or greater than two layers of water-resistive barrier complying with ASTM E2556, Type I. The individual layers shall be installed independently such that each layer provides a separate continuous plane and any flashing, installed in accordance with Section 1404.4 and intended to drain to the water-resistive barrier, is directed between the layers.
2. The water-resistive barrier shall be 60-minute Grade D paper or have a water resistance equal to or greater than one layer of water-resistive barrier complying with ASTM E2556, Type II. The water-resistive barrier shall be separated from the stucco by a layer of foam plastic insulating sheathing or other non-water absorbing layer.

Reservoir Claddings

- In “moist” or “marine” climate regions, a drainage gap or minimum drainage efficiency is a required enhancement:

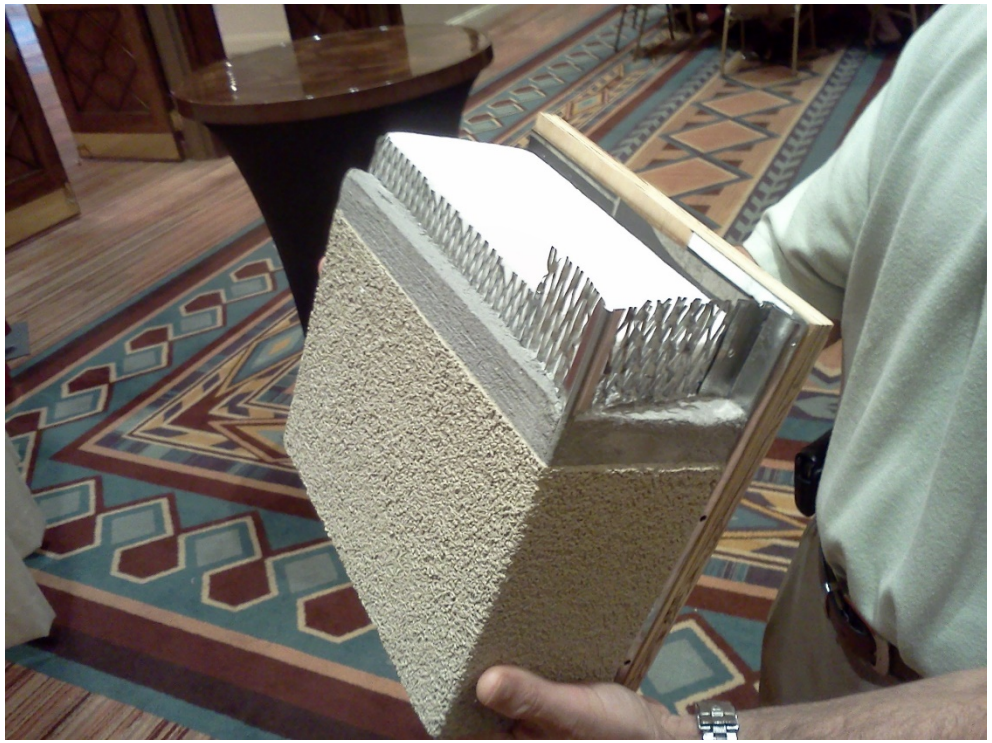


2510.6.2 Moist or marine climates. In moist (A) or marine (C) climate zones, water-resistive barrier shall comply with of one of the following:

1. In addition to complying with Item 1 or 2 of Section 2510.6.1, a minimum 3/16 inch (4.8 mm) space shall be added to the exterior side of the water-resistive barrier.
2. In addition to complying with Item 2 of Section 2510.6.1, a space with a minimum drainage efficiency of 90% as measured in accordance with ASTM E2273 or Annex A2 of ASTM E2925 is added to the exterior side of the water-resistive barrier.

Reservoir Claddings

- Example Applications

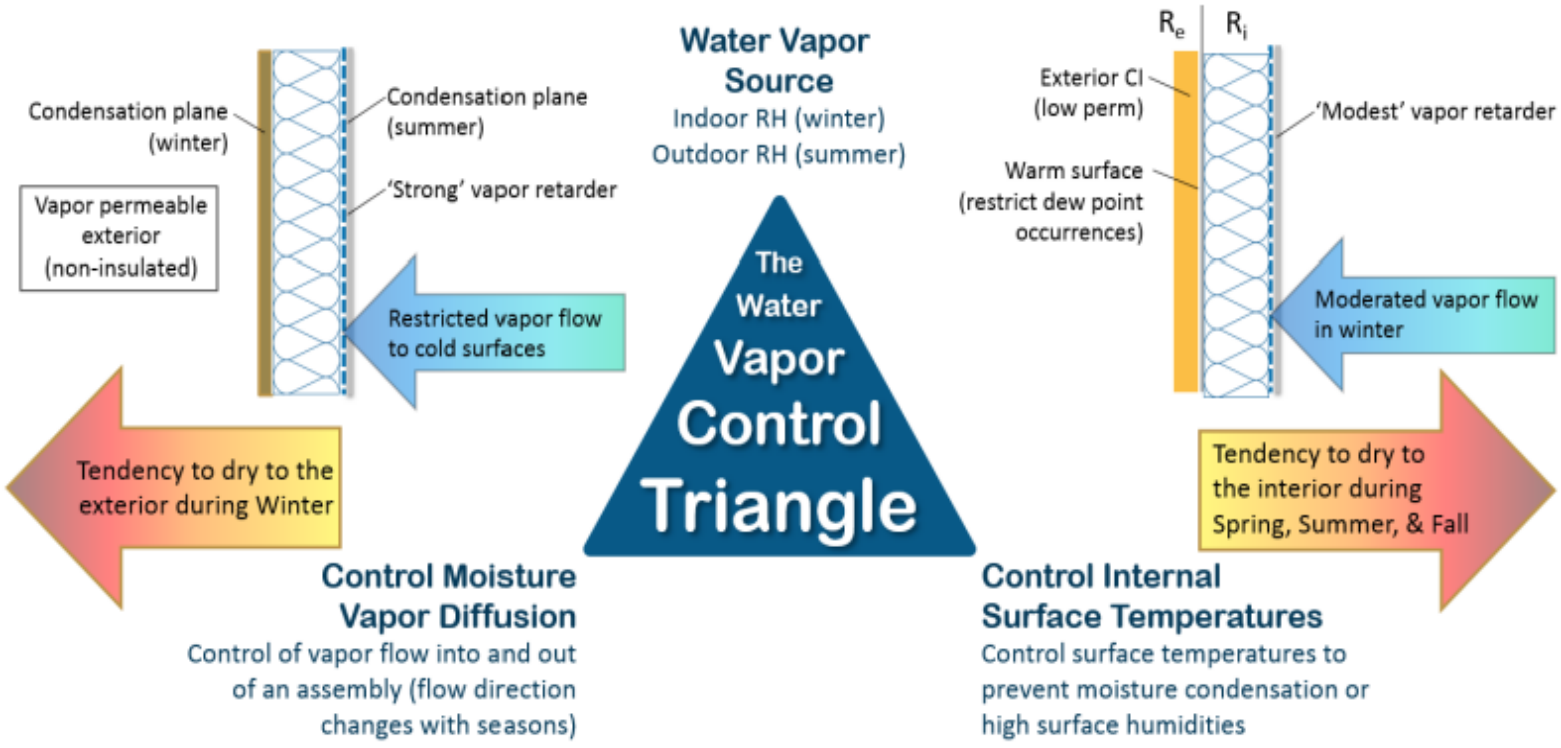


Water Vapor Retarders

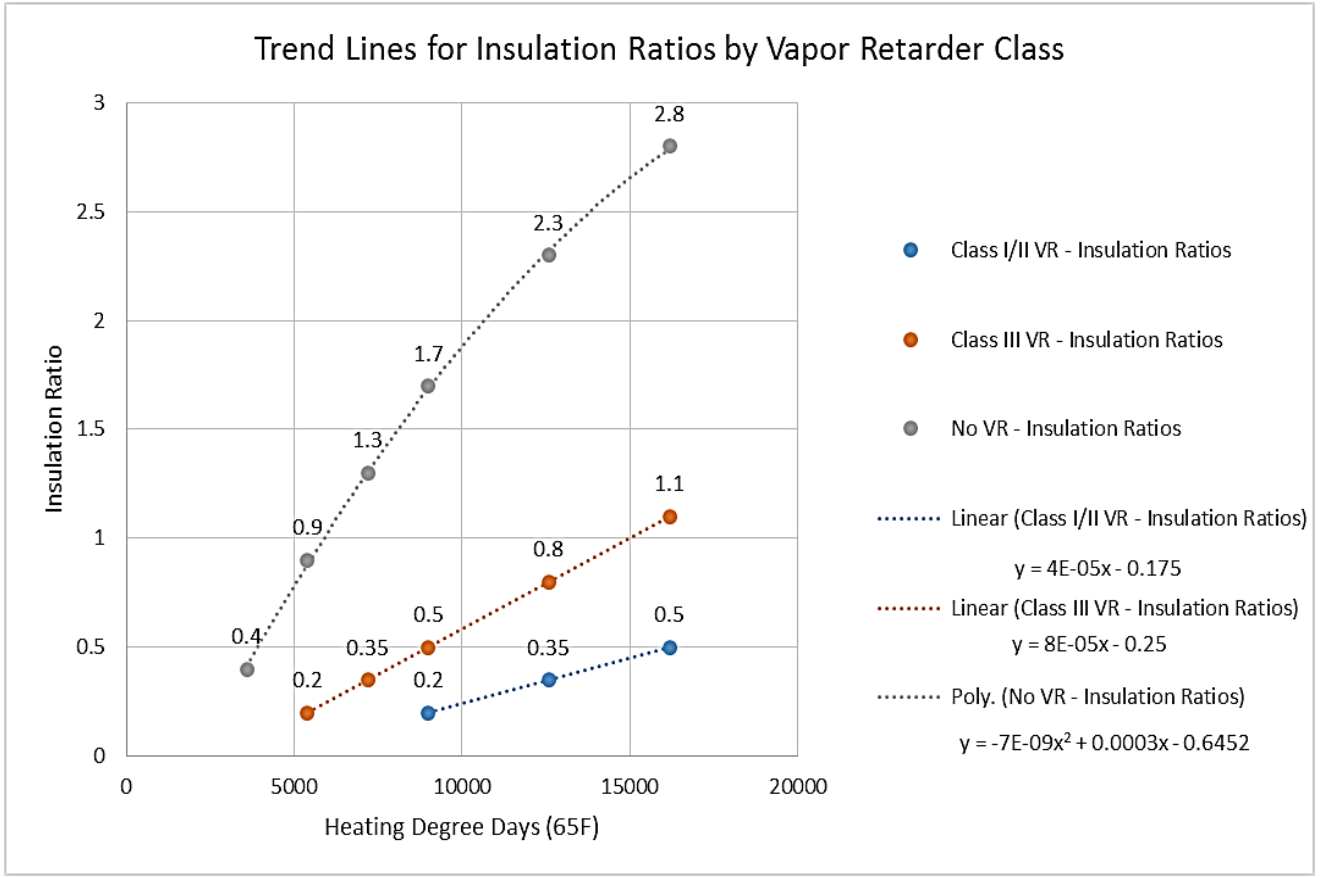
- Water vapor diffusion is the movement of water vapor through the layers of an assembly due to vapor pressure differentials caused by indoor air temperature and humidity and outdoor air temperature and humidity.
  - It's direction changes seasonally (winter vs. summer)
  - It's affect on an assembly depends on the vapor permeance of all material layers
  - It's affect depends on the temperatures within the assembly
- The old "rules of thumb" that only address a designated interior vapor retarder layer are incomplete and unreliable.
- SOLUTION: Codes must be updated to give more complete guidance.
- WHY? It affects the whole assembly area, not just localized. It controls or balances both wetting and drying effects in all seasons.

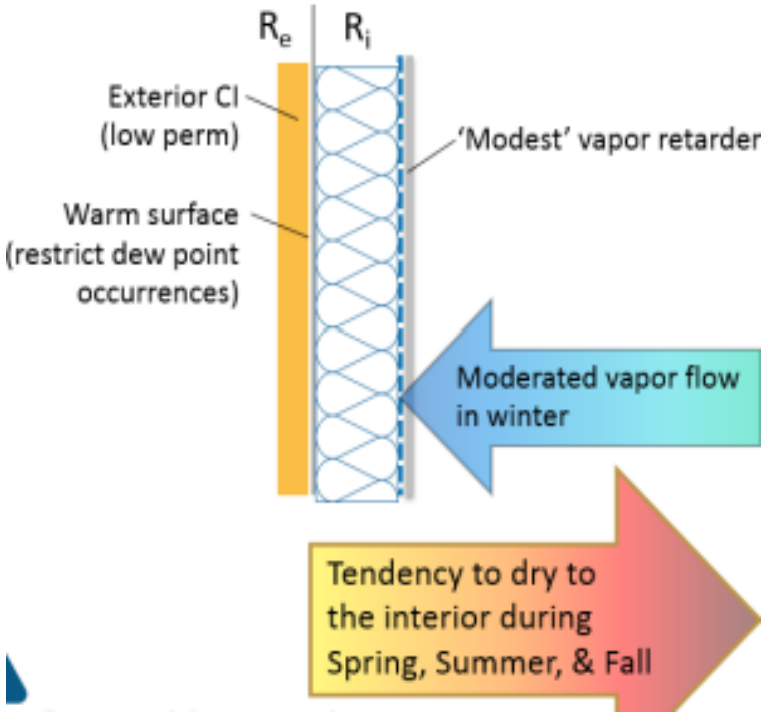
Vapor Control Principles

- Two approaches to control water vapor:
  - Permeance Controlled Design (permeance ratio)
  - Temperature Controlled Design (insulation ratio, IR = Re/Ri)



Insulation Ratio (basis of 2021 IBC and IRC)





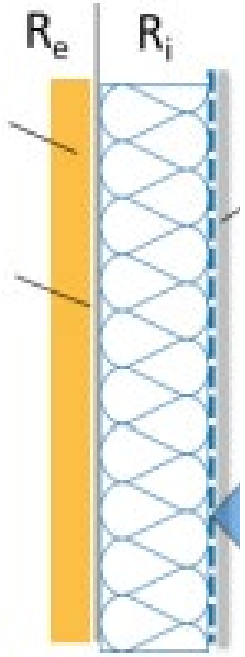
Source: http://www.appliedbuildingtech.com/rr/1410-03

Insulation Ratio (basis of 2021 IRC)

MINIMUM INSULATION RATIO OR CONTINUOUS INSULATION R-VALUE FOR LIGHT-FRAME WALLS WHERE EXTERIOR CONTINUOUS INSULATION (ci) IS USED [a,b,c,d]

Climate Zone (Fig. 2)	Maximum Heating Degree Days (65F basis)	Interior Vapor Retarder (VR) Class			
		Class I	Class II	Class III	No VR[e]
1	N/A	NP	NP[f]	R-2ci minimum	R-2ci minimum
2	N/A	NP	NP[f]	R-2ci minimum	R-2ci minimum
3	3,600	NP	R-2ci minimum	R-2ci minimum	0.4
4	5,400	NP	R-2ci minimum	0.2	0.9
5	7,200	0.2	0.2	0.35	1.3
6	9,000	0.2	0.2	0.5	1.7
7	12,600	0.35	0.35	0.8	2.3
8[g]	16,200	0.5	0.5	1.1	2.8

For SI: 1 heating degree day (65°F basis) = 0.56 heating degree days (18°C basis)
NP = indicated vapor retarder class is not permitted in the indicated Climate Zone.
Table Notes & Commentary:



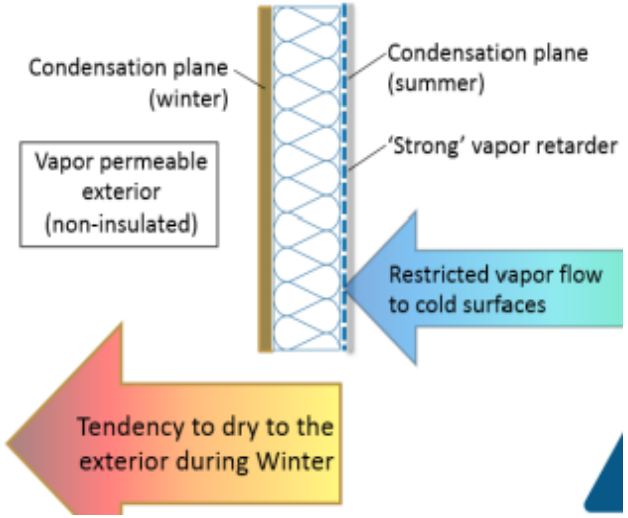
Source: http://www.appliedbuildingtech.com/rr/1701-01

Permeance Ratio (not included in 2021 IRC)

MINIMUM NET WATER VAPOR PERMEANCE (WVP) FOR MATERIAL LAYERS LOCATED ON THE EXTERIOR SIDE OF WALL STUDS [a,b,c]

Climate Zone (Fig. 2)	Interior Vapor Retarder Class		
	Class I	Class II	Class III
1	NP	NP[d]	No minimum
2	NP	NP[d]	No minimum
3	NP	No minimum	No minimum
4	0.5 perm (Marine 4) and otherwise NP	0.5 perm	3 perm
5	0.5 perm	3 perm	5 perm
6	1 perm	5 perm	15 perm
7	1 perm	15 perm	NP
8[e]	1.5 perm	NP	NP

For SI: 1 perm = 57.2 ng/s-m^2-Pa
NP = indicated vapor retarder class is not permitted in the indicated Climate Zone
Table Notes & Commentary:



NOTE: For use with cavity insulation only walls, or walls that have continuous insulation but inadequate insulation ratio.

Source: http://www.appliedbuildingtech.com/rr/1701-01

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Based on IRC proposal RB223-19 (nearly identical for IBC)
- First, vapor retarder classes are broadly defined…

TABLE R702.7(1)
VAPOR RETARDER MATERIALS AND CLASSES

CLASS	ACCEPTABLE MATERIALS
I	Sheet polyethylene, nonperforated aluminum foil, or other approved materials with a perm rating of less than or equal to 0.1.
II	Kraft-faced fiberglass batts, vapor retarder paint, or other approved materials applied in accordance with the manufacturer's installation instructions for a perm rating greater than 0.1 and less than or equal to 1.0.
III	Latex pain, enamel paint, or other approved materials applied in accordance with the manufacturer's installation instructions for a perm rating of grater than 1.0 and less than or equal to 10.0.

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Second, their application by climate zone is tabulated with footnotes addressing cases where ci is used or may be necessary to help control moisture

TABLE R702.7(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. Class I and II vapor retarders with vapor permeance greater than 1 perm when measured by ASTM E96 water method (Procedure B) shall be allowed on the interior side of any frame wall in all climate zones.
b. Use of a Class I interior vapor retarder in frame walls with a Class I vapor retarder on the exterior side shall require an approved design.
c. Where a Class II vapor retarder is used in combination with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class II vapor retarder shall have a vapor permeance of greater than 1 perm when measured by ASTM E96 water method (Procedure B).

- Footnote ‘b’ prevents double vapor barrier unless designed – generally meaning use of a Class I smart vapor retarder (see footnote ‘a’)
- Footnote ‘c’ and Table R702.7(3) provide requirements when foam sheathing (‘ci’) is used.

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Next, where the wall has a Class II VR and foam sheathing ci…

TABLE R702.7(4)
CONTINUOUS INSULATION WITH CLASS II VAPOR RETARDER

CLIMATE ZONE	CLASS II VAPOR RETARDERS PERMITTED FOR:[a]
3	Continuous insulation with R-value ≥ 2.
4, 5, and 6	Continuous insulation with R-value ≥ 3 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 5 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 10 over 2 x 6 wall.

a. The requirements of this table apply only to insulation used to control moisture in order to permit the use of Class II vapor retarders. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of Chapter 11.

- This is the “insulation ratio” in prescriptive form (same format as used in the existing Class III VR table shown in next slide)
- As noted in footnote ‘c’ the Class II VR must have a permeance of > 1 perm under “wet cup” ASTM E96 test (e.g., is a smart vapor retarder). Generically, this means a Kraft paper facer on fiberglass batts (or similar).

Updated 2021 IRC and IBC Vapor Retarder Provisions

- Finally, where a Class III VR is used…

TABLE R702.7(3)
CLASS III VAPOR RETARDERS

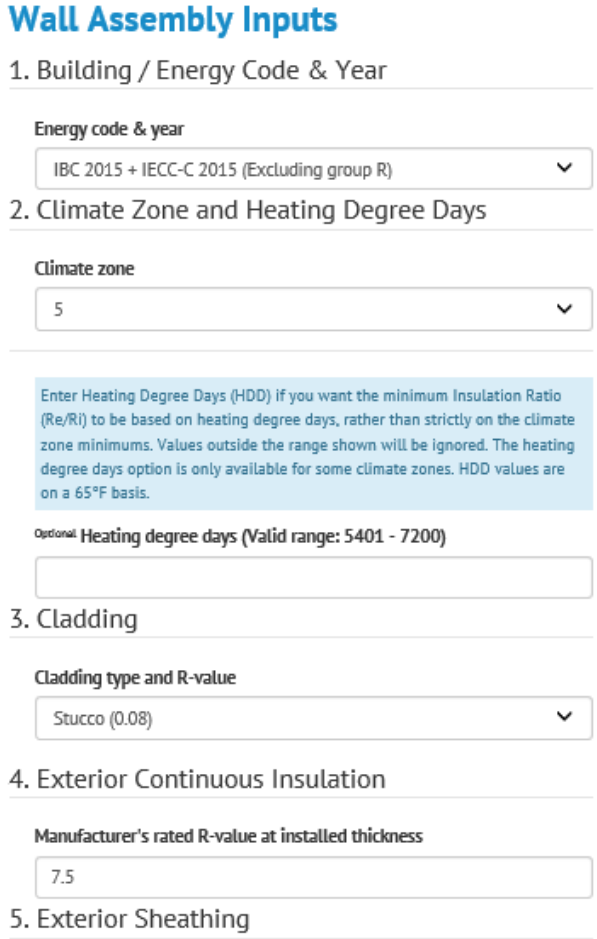
CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a,b]
Marine 4 [or all of 4 for 2021 IBC]	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 2.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 3.75 over 2 x 6 wall.
5	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
6	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 11.25 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 10 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 15 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 12.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 20 over 2 x 6 wall.

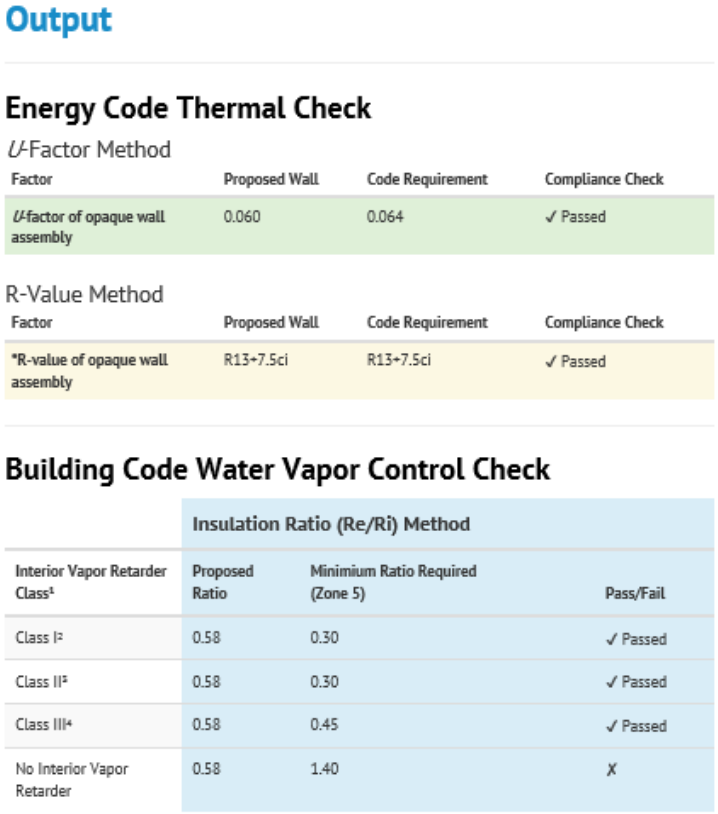
- As with the Class II VR table, the colder the climate the more ci R-value required (greater insulation ratio) – this is the temperature controlled design approach. In CZ 7 & 8, this is the only solution.
- Also, as the climate gets colder a higher exterior sheathing permeance is required if not using 'ci' to protect the wall from moisture accumulation (same should apply with use of a Class II VR, but is not currently in the code) – this is the permeance controlled design, but only for Class III VR applications.

Wall Calculator – Easy Button to IECC and IBC/IRC Coordinated Compliance

- Implements R-value and U-factor checks per IECC and also a moisture control check (including insulation and permeance ratio checks)

https://www.continuousinsulation.org





Design Examples

- Example 1 – Residential (One- and Two-Family Dwelling)

- Given: In Climate Zone 6, the energy code requires one of the following prescriptive R-value solutions for wood-frame walls:

  - 30+0ci, 20+5ci, 13+10ci, or 0+20ci

- Find: For each R-value option, what vapor retarder options are appropriate in accordance with the building code?

Design Examples

- In Climate Zone 6 any of the following vapor retarder options are permitted:

TABLE R702.7(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. Class I and II vapor retarders with vapor permeance greater than 1 perm when measured by ASTM E96 water method (Procedure B) shall be allowed on the interior side of any frame wall in all climate zones.

b. Use of a Class I interior vapor retarder in frame walls with a Class I vapor retarder on the exterior side shall require an approved design.

c. Where a Class II vapor retarder is used in combination with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class II vapor retarder shall have a vapor permeance of greater than 1 perm when measured by ASTM E96 water method (Procedure B).

Design Examples

- 30+0ci Wall Assembly (cavity insulation only – permeance based design)
  - Class I vapor retarder is permitted in CZ 6
    - Provides great protection against moisture accumulation in exterior sheathing in winter
    - Can cause moisture accumulation in summer for AC'd buildings
    - Best solution is a "smart" Class I vapor retarder
  - Class II vapor retarder is permitted in CZ 6
    - Can result in high moisture content in exterior sheathing in winter
    - While allowed by code, several studies have shown high moisture content cycling of exterior sheathing (>20% and even near saturation depending on indoor RH levels)
  - Class III vapor retarder is permitted in CZ 6
    - Must be used with vented cladding and high perm exterior sheathing (e.g., fiberboard or gypsum sheathing)
    - Wood structural panels not allowed
    - While allowed by code, will result in substantial moisture flow-through which, for cold materials like exterior sheathing or siding in winter, moisture levels will rise (this wall has no temperature control with absence of exterior ci)
  - Alternative: Use ccSPF in cavity for at least partial fill to meet insulation ratio required and it also would serve as a Class II vapor retarder.

Design Examples

- 20+5ci Wall Assembly
  - Class II vapor retarder -- permitted in accordance with footnote ‘c’ which requires compliance with continuous insulation ratios.
    - RI = 5/20 = 0.25 which is greater than 0.2 (good for CZ 6 or lower, but not CZ 7 or 8).
    - 2021 code prescriptively requires min. R5ci for 2x6 wall (max R25 vapor permeable cavity insulation) which has IR = 0.2 (OK).
    - Also requires that the Class II vapor retarder be “smart” (e.g., Kraft paper)

TABLE R702.7(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. Class I and II vapor retarders with vapor permeance greater than 1 perm when measured by ASTM E96 water method (Procedure B) shall be allowed on the interior side of any frame wall in all climate zones.

b. Use of a Class I interior vapor retarder in frame walls with a Class I vapor retarder on the exterior side shall require an approved design.

c. Where a Class II vapor retarder is used in combination with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class II vapor retarder shall have a vapor permeance of greater than 1 perm when measured by ASTM E96 water method (Procedure B).

TABLE R702.7(4)
CONTINUOUS INSULATION WITH CLASS II VAPOR RETARDER

CLIMATE ZONE	CLASS II VAPOR RETARDERS PERMITTED FOR:[a]
3	Continuous insulation with R-value ≥ 2.
4, 5, and 6	Continuous insulation with R-value ≥ 3 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 5 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 10 over 2 x 6 wall.

a. The requirements of this table apply only to insulation used to control moisture in order to permit the use of Class II vapor retarders. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of Chapter 11.

Design Examples

- 20+5ci Wall Assembly
  - Class III vapor retarder -- Minimum R-11.25ci required on 2x6 wall per code. Thus, R20+5ci wall does not work if the R20 cavity insulation is all vapor permeable.
  - Alternative:
    - Use minimum R-6.25 ccSPF in cavity with R-15 cavity insulation and R-5ci on exterior.
    - R-(15+6.25) + 5ci wall ➔ R21 + 5ci wall which meets energy code and allows use of Class III VR.
    - The R-6.25 ccSPF and R-5ci can be added together only for the purpose of meeting this table and can't be added together for energy code compliance.
    - ccSPF in cavity must be installed to thickness required for minimum 1.5 perms.

TABLE R702.7(3)
CLASS III VAPOR RETARDERS

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a,b]
Marine 4 [or all of 4 for 2021 IBC]	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 2.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 3.75 over 2 x 6 wall.
5	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
6	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 11.25 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 10 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 15 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 12.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 20 over 2 x 6 wall.

R702.7.1 Spray foam plastic insulation for moisture control with Class II and III vapor retarders. For purposes of compliance with Tables R702.7(3) and R702.7(4), spray foam with a maximum permeance of 1.5 perms at the installed thickness applied to the interior side of wood structural panels, fiberboard, insulating sheathing or gypsum shall be deemed to meet the continuous insulation moisture control requirement in accordance with one of the following conditions:

1. The spray foam R-value is equal to or greater than the specified continuous insulation R-value.
2. The combined R-value of the spray foam and continuous insulation is equal to or greater than the specified continuous insulation R-value.

Design Examples

- Example 2 – Commercial Building (Group R Residential)

- Given: In Climate Zone 5 for a Group R building, the energy code provides the following prescriptive wood-frame wall insulation options:

  - R-13+R-7.5ci
  - R-20+R-3.8ci

- Find: For each of the assembly insulation conditions above, what vapor retarder options are appropriate in accordance with the building code?

Design Examples

- In Climate Zone 5 any of the following vapor retarders are permitted:

TABLE R702.7(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. Class I and II vapor retarders with vapor permeance greater than 1 perm when measured by ASTM E96 water method (Procedure B) shall be allowed on the interior side of any frame wall in all climate zones.
b. Use of a Class I interior vapor retarder in frame walls with a Class I vapor retarder on the exterior side shall require an approved design.
c. Where a Class II vapor retarder is used in combination with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class II vapor retarder shall have a vapor permeance of greater than 1 perm when measured by ASTM E96 water method (Procedure B).

Design Examples

- R-13+R-7.5ci
  - Complies with Class II “smart” (Kraft) vapor retarder
  - Complies with use of Class III vapor retarder
- R-20+R-3.8ci
  - Does not comply with min. ci R-value for 2x6 wall in CZ 5 with Class II VR
  - Does not comply with min. ci R-value for 2x6 wall in CZ 5 with Class III vapor retarder
  - Alternate: Increase ci R-value or use ccSPF in cavity for partial fill to meet ci R-value, but ccSPF must be thick enough to meet minimum 1.5 perm

TABLE R702.7(4)
CONTINUOUS INSULATION WITH CLASS II VAPOR RETARDER

CLIMATE ZONE	CLASS II VAPOR RETARDERS PERMITTED FOR:[a]
3	Continuous insulation with R-value ≥ 2
4, 5, and 6	Continuous insulation with R-value ≥ 3 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 5 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 10 over 2 x 6 wall.

a. The requirements of this table apply only to insulation used to control moisture in order to permit the use of Class II vapor retarders. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of Chapter 11.

TABLE R702.7(3)
CLASS III VAPOR RETARDERS

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a,b]
Marine 4 [or all of 4 for 2021 IBC]	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 2.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 3.75 over 2 x 6 wall.
5	Vented cladding over wood structural panels.
	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 7.5 over 2 x 6 wall.
6	Vented cladding over fiberboard.
	Vented cladding over gypsum.
	Continuous insulation with R-value ≥ 7.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 11.25 over 2 x 6 wall.
7	Continuous insulation with R-value ≥ 10 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 15 over 2 x 6 wall.
8	Continuous insulation with R-value ≥ 12.5 over 2 x 4 wall.
	Continuous insulation with R-value ≥ 20 over 2 x 6 wall.

Design Examples

- Example 3 – Commercial Building ("All Other" – non-Residential)

- Given: In Climate Zone 2 for a non-residential metal-frame building, the energy code provides the following prescriptive wall insulation options:

  - R-13+R-5ci

- Find: For each of the assembly insulation conditions above, what vapor retarder options are appropriate in accordance with the building code

Design Examples

- In Climate Zone 2:
  - Only Class III VR is permitted
  - There is no minimum limit on ci R-value
  - Footnote ‘a’ would allow use of Class I or II “smart” vapor retarder
- Solution: use Class III VR in CZ 2 with R-13 + R-5ci assembly for maximum drying to interior in warm climate.
- Use of lower-perm ci will also help minimize inward vapor drives which are more persistent in warm climates.

TABLE R702.7(2)
VAPOR RETARDER OPTIONS

CLIMATE ZONE	VAPOR RETARDER CLASS		
	CLASS I[a]	CLASS II[a]	CLASS III
1, 2	Not Permitted	Not Permitted	Permitted
3, 4 (except Marine 4)	Not Permitted	Permitted[c]	Permitted
Marine 4, 5, 6, 7, 8	Permitted[b]	Permitted[c]	See Table R702.7(3)

a. Class I and II vapor retarders with vapor permeance greater than 1 perm when measured by ASTM E96 water method (Procedure B) shall be allowed on the interior side of any frame wall in all climate zones.

b. Use of a Class I interior vapor retarder in frame walls with a Class I vapor retarder on the exterior side shall require an approved design.

c. Where a Class II vapor retarder is used in combination with foam plastic insulating sheathing installed as continuous insulation on the exterior side of frame walls, the continuous insulation shall comply with Table R702.7(4) and the Class II vapor retarder shall have a vapor permeance of greater than 1 perm when measured by ASTM E96 water method (Procedure B).

Conclusions

- Energy Code Advancements
  - Significant advancements have been made and are continuing
  - These require improved and coordinated building code moisture control requirements as per 2021 IBC and IRC
- Coordinated Building Code Advancements
  - Significant expansion and improvement of water vapor retarder provisions
  - Still some work needed (e.g., guidance permeance controlled assemblies)
  - Major improvement for reservoir claddings
- Example Applications
  - Demonstrate coordinated energy code and building code provisions
  - Allows flexibility to optimize energy code and building code compliance