Moisture Control for Durable & Energy Efficient Cold-formed Steel Walls

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ABTG / ARES Consulting

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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.

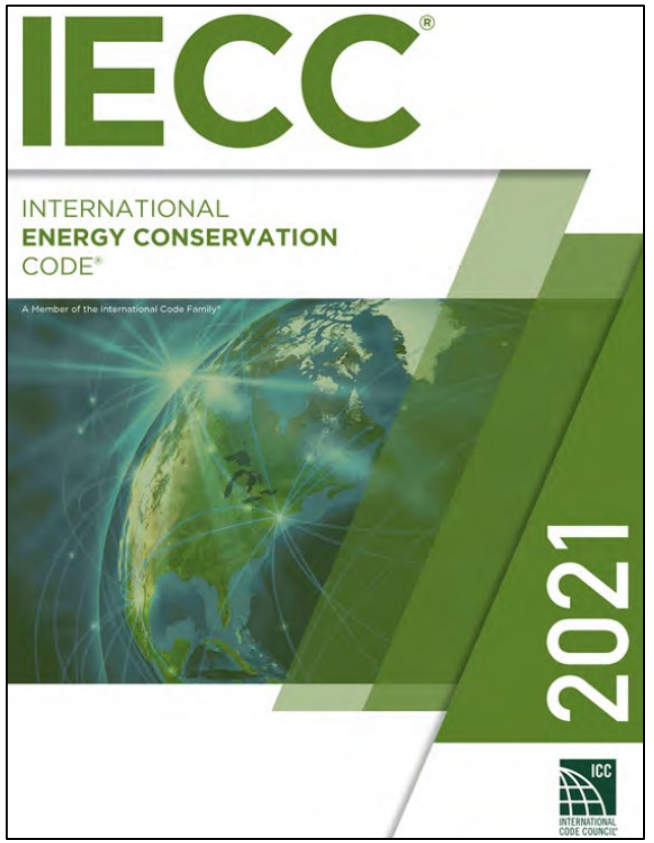
Foam Plastic Applications for Better Building

Outline

- Recent Energy Code Advancements
- 5 building science concepts
- Research supporting 2021 code for water vapor control
- New 2021 code provisions for water vapor control
- Design guides, aids, and on-line calculator tools to coordinate energy/building code compliance
- Design example

Energy Code Advancements

- Major advancement of building energy code occurred in 2012 (~30% increase in energy efficiency, reduction in energy use).
- For 2015 and 2018 IECC there were insignificant changes in envelope provisions.
- In 2021 IECC, significant but more selective energy efficiency improvements have occurred.



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IECC Prescriptive R-values & U-factors

(Light Frame Commercial Construction)

<table>
<tr><th rowspan="2">Climate Zone</th><th rowspan="2">Building Use</th><th colspan="2">Metal Framed</th><th colspan="2">Wood Framed</th></tr>
<tr><th>2018 IECC</th><th>2021 IECC</th><th>2018 IECC</th><th>2021 IECC</th></tr>
<tr><td rowspan="2">0 and 1</td><td>All other</td><td rowspan="2">R13+5ci
(U-0.077)</td><td rowspan="2">R13+5ci
(U-0.077)</td><td rowspan="8">R13+3.8ci or R20
(U-0.064)</td><td rowspan="5">R13+3.8ci or R20
(U-0.064)</td></tr>
<tr><td>Group R</td></tr>
<tr><td rowspan="2">2</td><td>All other</td></tr>
<tr><td>Group R</td><td rowspan="6">R13+7.5ci
(U-0.064)</td><td rowspan="4">R13+7.5ci
(U-0.064)</td></tr>
<tr><td rowspan="2">3</td><td>All other</td></tr>
<tr><td>Group R</td></tr>
<tr><td rowspan="2">4 Except Marine</td><td>All other</td></tr>
<tr><td>Group R</td><td rowspan="6">R13+7.5ci or
R20+3.8ci
(U-0.051)</td></tr>
<tr><td rowspan="2">5 and Marine 4</td><td>All other</td><td rowspan="2">R13+10ci
(U-0.055)</td></tr>
<tr><td>Group R</td></tr>
<tr><td rowspan="2">6</td><td>All other</td><td rowspan="2">R13+12.5ci
(U-0.049)</td></tr>
<tr><td>Group R</td></tr>
<tr><td rowspan="2">7</td><td>All other</td></tr>
<tr><td>Group R</td><td>R13+15.6ci
(U-0.052)</td><td>R13+15.6ci
(U-0.042)</td></tr>
<tr><td rowspan="2">8</td><td>All other</td><td>R13+7.5ci
(U-0.064)</td><td rowspan="2">R18+18.8ci
(U-0.037)</td><td rowspan="2">R13+15.6ci or
R20+10ci
(U-0.036)</td><td rowspan="2">R13+18.8ci
(U-0.032)</td></tr>
<tr><td>Group R</td><td>R13+17.5ci
(U-0.045)</td></tr>
</table>

Table based on IECC-Commercial Provisions, Tables C402.1.3 and C402.1.4.

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R-value Alternatives

- Alternative R-values can be determined by:
  - Use of U-factors for equivalent assemblies
    - Precalculated U-factors for various R-value assemblies (ASHRAE 90.1, Appendix A)
    - Cavity correction factor calculation method (IECC C402.1.4.2 and ASHRAE 90.1, Appendix A)
    - New AISI S250 standard (not currently recognized in codes)
  - Use of total UA method (e.g., use REScheck or COMcheck)
  - Use of building performance methods (e.g., building modeling/simulation path)
- Provides flexibility to have more options for energy code compliance
  - But, are they all really equivalent?
  - Can changing insulation amounts or locations on the assembly change the way the assembly handles moisture even if thermal performance remains the same?

UNINTENDED CONSEQUENCES!

- This flexibility can result in assemblies that perform differently (better or worse) from a moisture control and durability perspective. This may also be the case for some prescribed R-value assemblies in the code (depending on the overall wall assembly design per building code).
- More of an issue for wood framing than steel framing (due to differences in ci R-values prescribed)

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Coordinated Building Code Advancements

- **Why?**
  - To help avoid unintended consequences of complying with the energy code.
  - 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 has changed in the 2021 editions of the IRC and IBC, but first we need to cover some background…

Note errata for 2021 IBC for 1404.3

Key Building Science Concepts (BSC's)

- Successful moisture control requires an integrated approach to 5 key building science concepts:
  1. **Control Rain Water Intrusion** (e.g., continuous water-resistive barrier)
  2. **Control Air Leakage** (e.g., continuous air barrier)
  3. **Control Indoor Relative Humidity** (e.g., building ventilation & de-humidification)
  4. **Control Initial Construction Moisture** (e.g., prevent enclosure of wet materials)
  5. **Control Water Vapor** (e.g., optimized balance of wetting and drying through strategic use of insulation and vapor retarders)
- All are important, all vary in significance, all have inter-dependencies…

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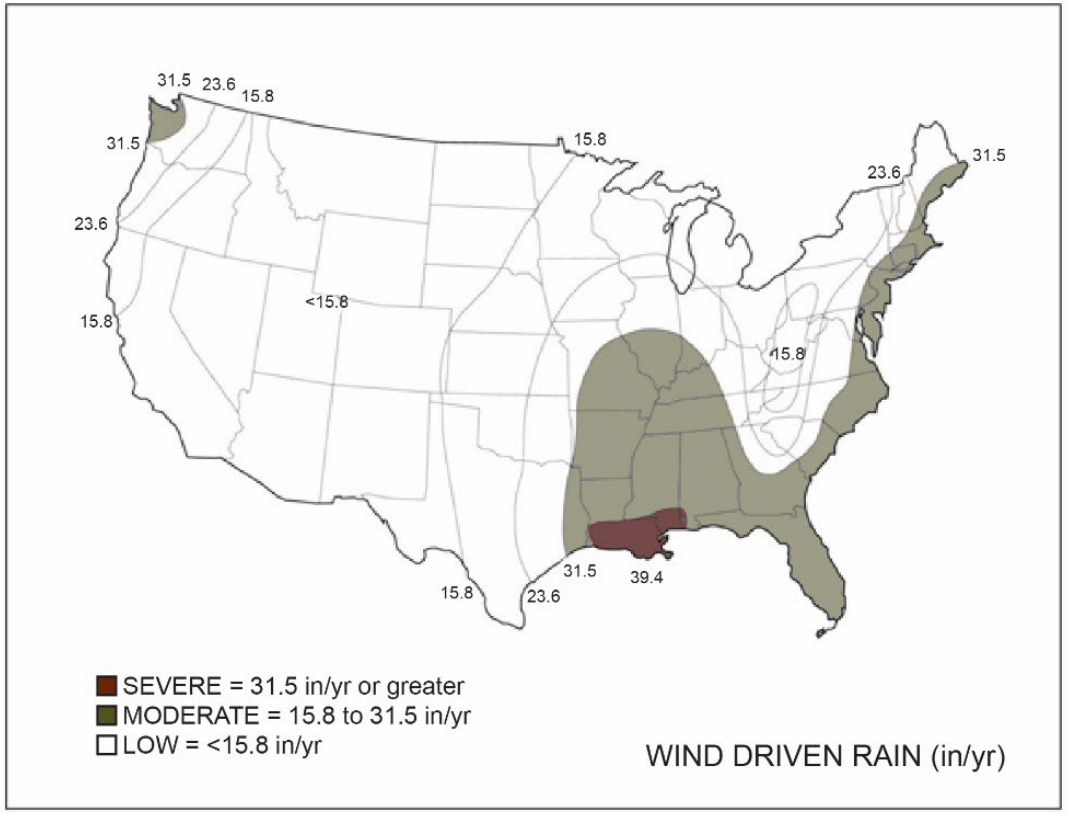
BSC #1 - Rain Water Control

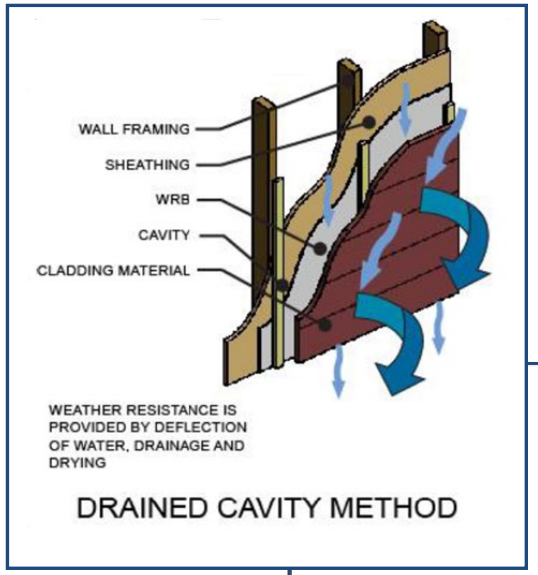
- Rain water control is often the primary factor associated with observed failure or success of moisture control.
- If rain water is not adequately controlled, other building science measures can be rendered ineffective.
- Concept is simple:
  Keep water out!

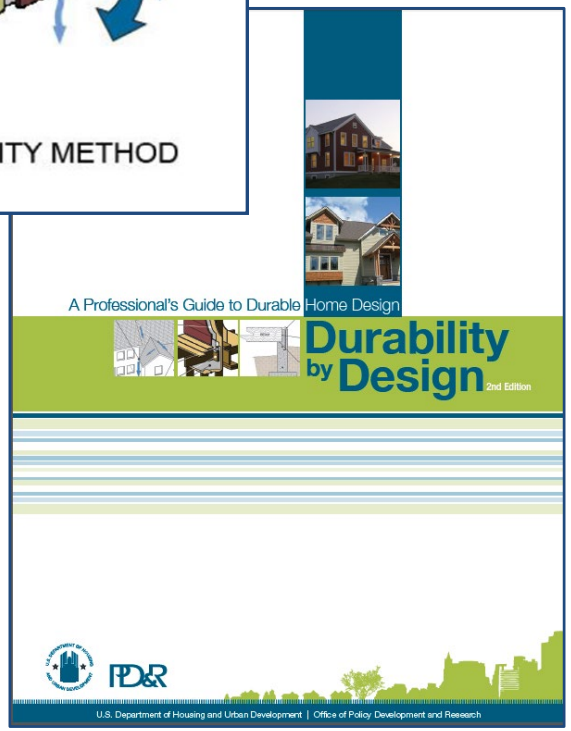


Wind driven rain is the primary hazard
(map based on UofGA research)

BSC #1 – Rain Water Control

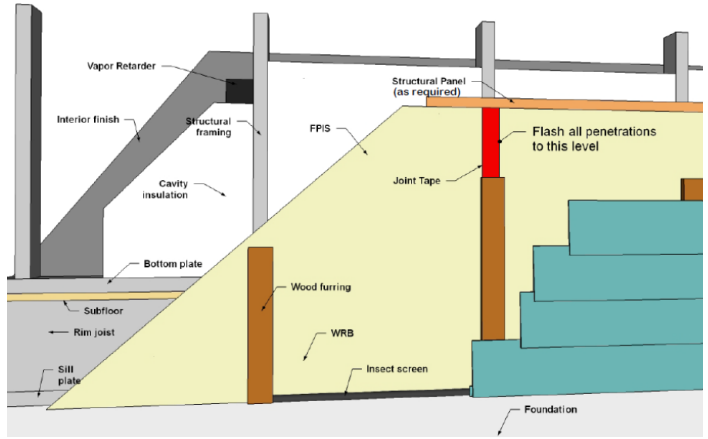
- Select cladding type, windows & doors, and installation methods best suited to the local climate wind-driven rain hazard
  - Durability by Design – 2nd Edition
- Variation in cladding material/method performance and variation in wind-driven rain hazard are not differentiated in the code.



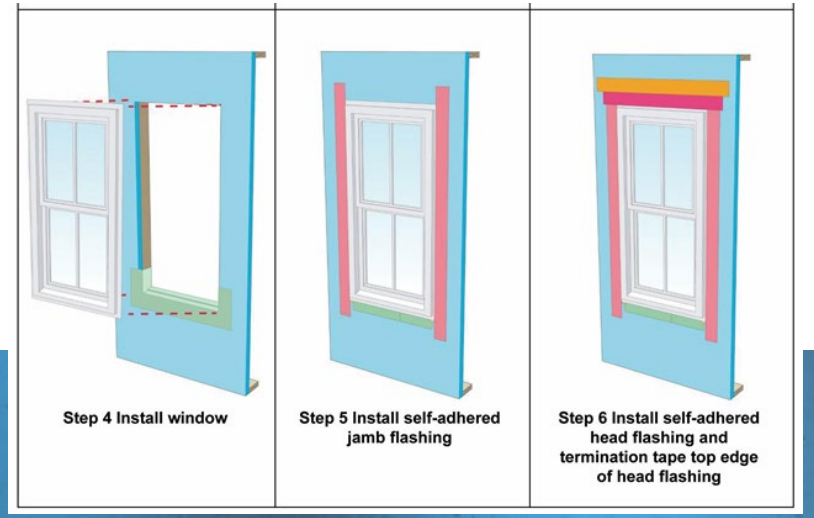


BSC #1 – Rain Water Control

- Use a code compliant water-resistive barrier (WRB) and flashing details at all penetrations for a continuous drainage plane behind the cladding
  - WHY? All claddings leak!
  - WRB is required by code.
  - But, not all WRBs are equal or subject to equivalent performance criteria. For more information, go to continuousinsulation.org/WRB.



- Robust window flashing with pan flashing strongly recommended (but not required by code)
  - WHY? Many windows/doors leak or will leak.
  - Refer to window manufacturer, WRB, and flashing manufacturer instructions. For additional information and installation guides, go to continuousinsulation.org/window-installation.
  - Standard installation
    - Window buck installation
    - Rainscreen installation

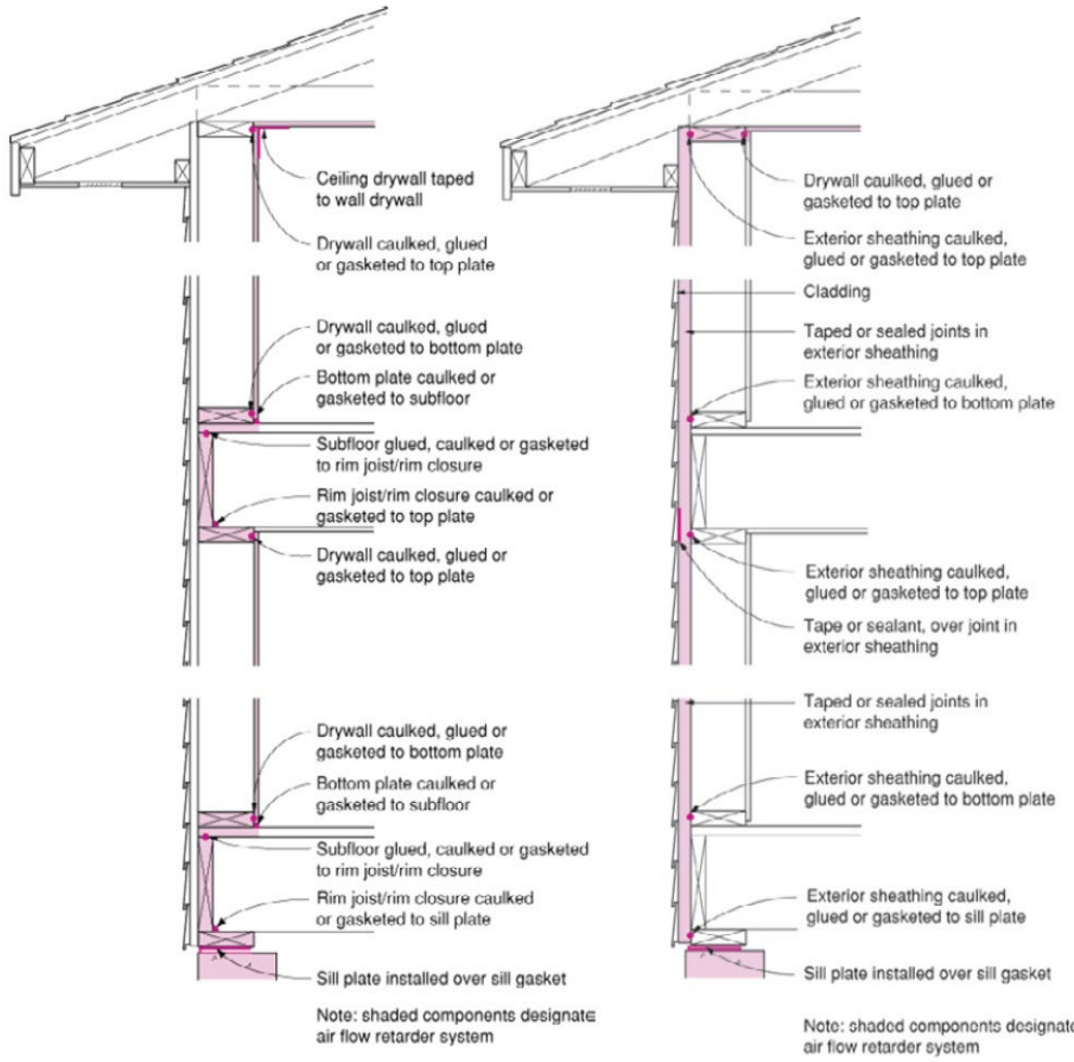


BSC #2 - Air Leakage Control

- Lack of air leakage control can allow substantial amounts of moist/humid air into and through assemblies.
  - Air can bypass vapor retarders, rendering them much less effective (increase risk of mold, condensation, rot, corrosion, etc.)
  - Air can bypass insulation, rendering insulation less effective (increased energy bills, discomfort, etc.)
- 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 and use proper vapor control to promote diffusion drying (while also minimizing seasonal diffusion wetting).

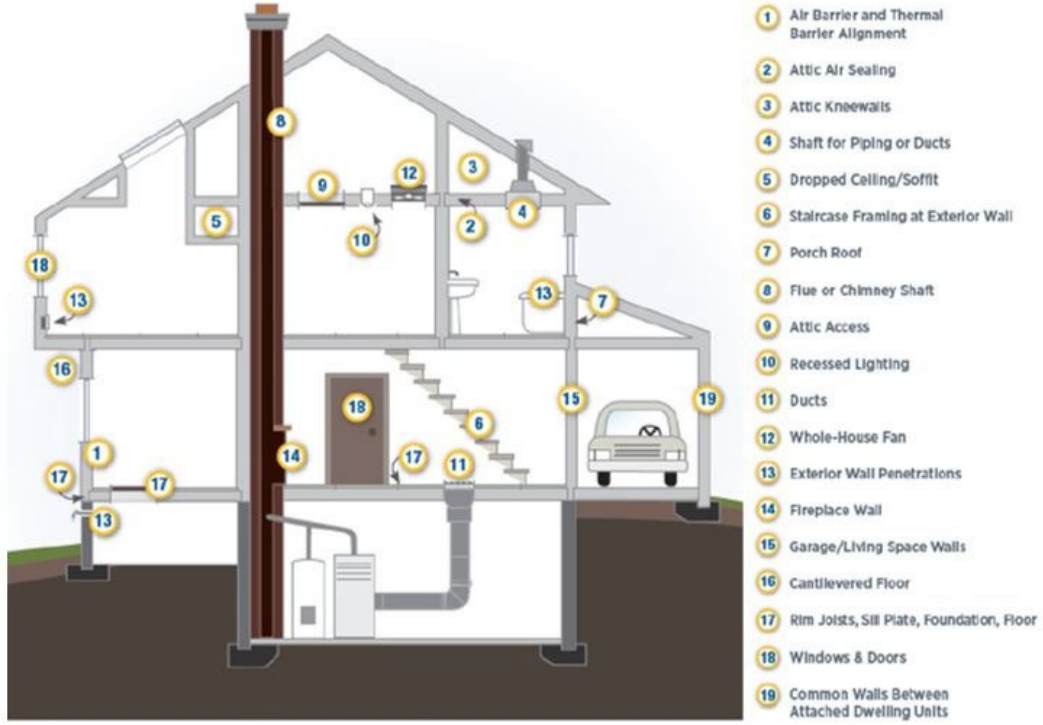
BSC #2 - Air Leakage Control

- Air barrier system installation requirements and whole building air leakage testing requirements are found in the energy code.
- The IECC does not specify where the continuous air barrier must be located
  - Can be located on the interior, inside, or to the exterior side of walls
  - EPA Energy Star* requires AB on both sides of assemblies in cold climates (best practice).
- For additional guidance refer to continuousinsulation.org/air-barrier.



BSC #2 – Air Leakage Control

- Many materials and methods of AB installation are available:
  - Exterior sheathing with sealed joints
  - Sealed drywall installation
  - Mechanically attached wraps with sealed joints
  - Adhered membranes
  - Spray-applied coatings
  - Closed-cell spray foam
- It's not just a material; it's a system!
  - As with the WRB and flashing, the AB must be properly sealed at all joints and penetrations and discontinuities.
  - Inspection & air-leakage testing are important for quality installations
- With proper design and location in an assembly, some air barrier materials may perform multiple roles (e.g., sheathing, insulation, vapor retarder, and air barrier all in one).



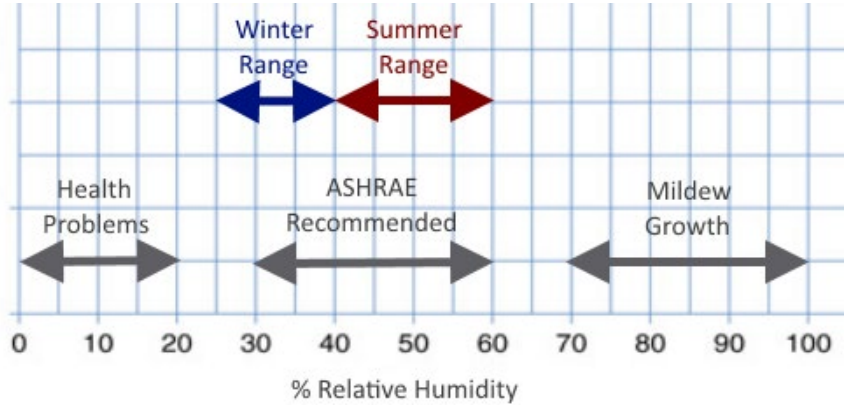
Source: U.S. Department of Energy Air Leakage Guide

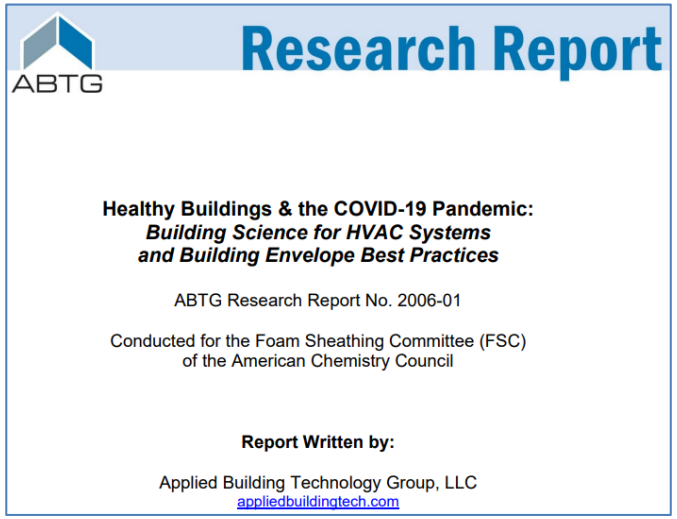
BSC #3 – Control Indoor Relative Humidity

- Excessive indoor relative humidity (RH) can overwhelm any reasonable code-compliant building envelope design
  - Acceptable indoor RH levels are not specified by the code in association with vapor retarder and insulation requirements (they are implied)
- Building ventilation requirements in the code for indoor air quality purposes can help or harm indoor RH
  - Balanced whole building ventilation methods are better than spot ventilation
  - Ventilation in winter may cause excessively dry air (may need controlled humidification)
  - Ventilation in summer may cause excessively humid air (may need controlled de-humidification)
- Proper sizing and specification of AC equipment can help control indoor RH in the summer
  - Dehumidification should be considered and used as needed

BSC #3 – Control Indoor Relative Humidity

- In general, summertime indoor RH should not exceed 60%.
- In the winter max recommended RH varies by climate (25% to 40%)
  - Lower indoor RH needed in colder climates for water vapor control (unless envelope is designed to tolerate higher RH levels)
  - Minimum 40% preferred for respiratory health and minimize disease/viral transmission
- Preferred indoor RH levels for building durability and occupant comfort and health can be in conflict
  - Must adjust water vapor control strategy accordingly
- Special conditions require special solutions (e.g., pool rooms, saunas, hot tubs, etc.)

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Research Report

Healthy Buildings & the COVID-19 Pandemic:
Building Science for HVAC Systems and Building Envelope Best Practices

ABTG Research Report No. 2006-01

Conducted for the Foam Sheathing Committee (FSC) of the American Chemistry Council

Report Written by:

Applied Building Technology Group, LLC
appliedbuildingtech.com

For more information go to continuousinsulation.org/healthy-buildings

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BSC #4 – Control Initial Construction Moisture

- Wet framing materials and wet-applied insulation materials can overwhelm the moisture tolerance of materials.
  - This issue mainly affects the initial year of building operation.
  - Can result in mold or moisture-related damage to materials such as moisture-sensitive sheathings and interior finishes.
- Solutions are simple:
  - Don’t use wet materials; and when they are wet, don’t close-in the assembly until they are dry.
  - Don’t install cavity insulation, vapor retarder, and interior finishes until the wall is dried-in (e.g., water-resistive barrier and all flashings completed).

Storm water expelled from FG batt insulation installed prior to completion of the WRB and flashing

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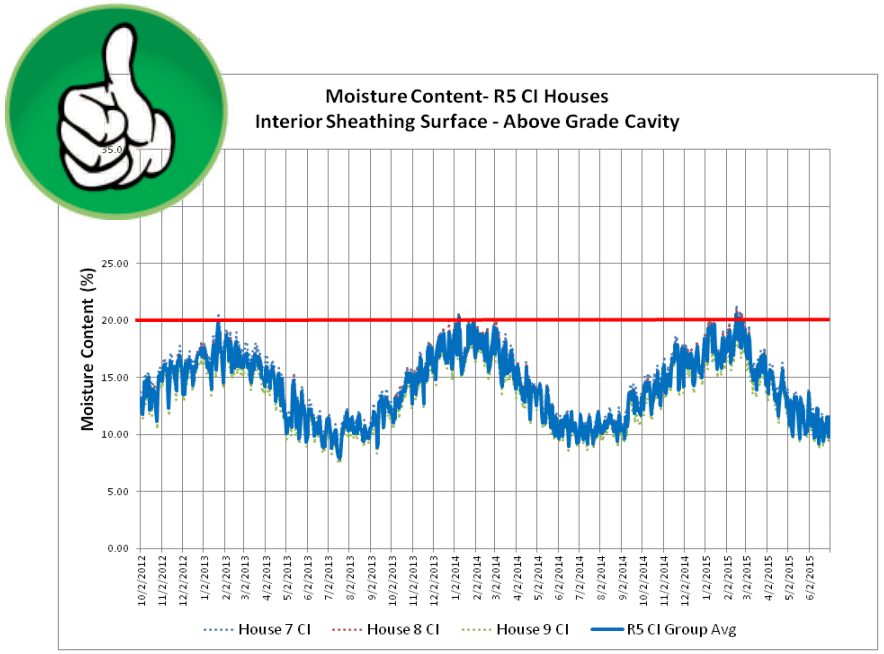
BSC #4 – Control Initial Construction Moisture

- TIP: Don't dry buildings using gas/fuel fired heaters – water vapor is a primary combustion by-product!
  - Hot/humid air creates huge vapor drives and can slow drying rather than help it.
  - Use hot/dry air instead (electric heaters, dry air ventilation, etc.)

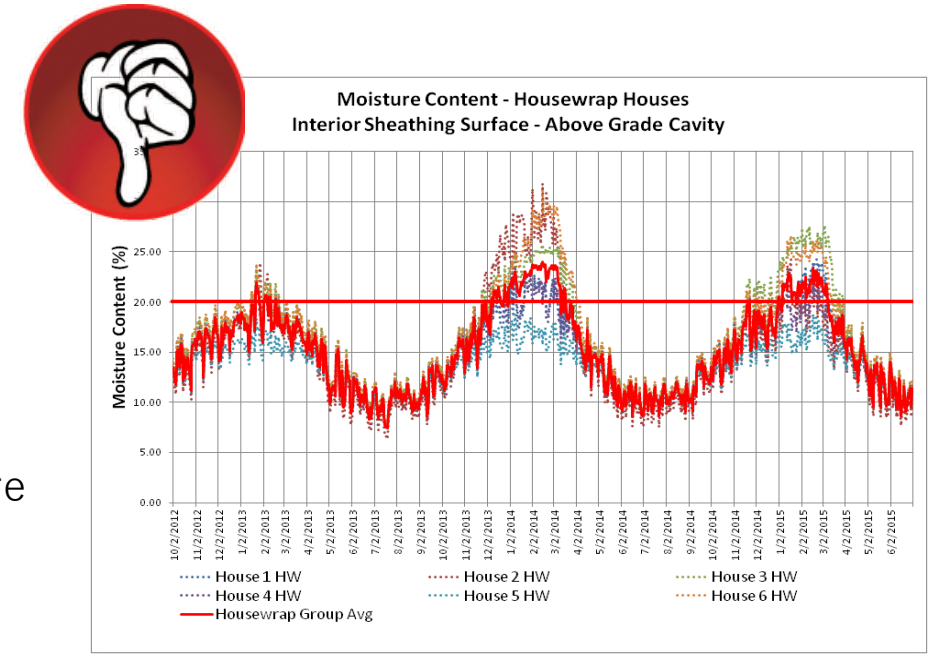
BSC #5 – Control Water Vapor

- Water vapor control involves two simple concepts:
  - Minimize the risk of the assembly getting wet due to water vapor diffusion (adsorption or condensation).
  - Optimize the ability of the assembly to dry in relation to its risk of getting wet.



Two "Code-Compliant" Walls:

- Left – moisture cycling <u>below</u> 20% MC
- Right – moisture cycling <u>above</u> 20% MC

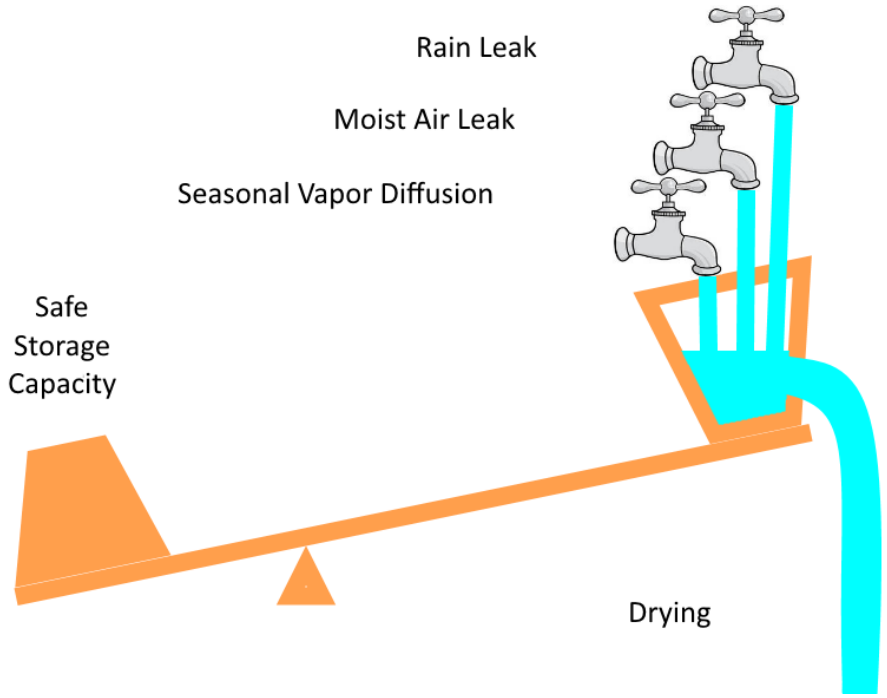


BSC #5 – Control Water Vapor

- While simple in concept, this practice involves consideration of several factors (not all addressed in code):
  - Climate and Indoor RH (boundary conditions)
  - Water vapor permeance (WVP) of exterior materials
    - Sheathing, WRB, etc.
  - WVP of interior materials
    - Interior vapor retarders in cold climates, or interior finishes in warm climates
  - Location and properties of insulation:
    - Cavity insulation R-value and its WVP
    - Exterior insulation R-value (continuous insulation) and its WVP

BSC #5 – Control Water Vapor

- It is truly a balancing act!
  - Risk of rain water wetting
  - Risk of air-leakage wetting
  - Wetting and drying by water vapor diffusion
- R-value and relative WVP of materials and their location within the assembly matters
  - Ability of materials to store and tolerate moisture also matters
- **GOAL:** Drying > wetting (in annual, not monthly/seasonal basis) to control risk of mold or water-sensitive material degradation



BSC Summary – 3 Rules for Moisture Control

Download resource at continuousinsulation.org/facts

Moisture Control for Wall Assemblies:

Building Robust Walls with Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

07.27.21

RULE #1: Keep Water Vapor (Humid Air) Away from Cool Surfaces!

When installed in accordance with modern building code and energy code requirements for continuous insulation and water vapor control (see CI's Quick Guide: Water Vapor Control and wall calculators), FPIS ci keeps water-sensitive materials inside the wall dry by maintaining a temperature above the dew point. Simply use the right R-value of FPIS ci for the wall assembly based on the climate zone and an appropriately specified interior vapor retarder (or no interior vapor retarder) to control outward vapor diffusion in the winter and maintain inward vapor diffusion (drying) in the warmer seasons. This approach results in much dryer walls with a more stable moisture content throughout all seasons of the year in comparison to walls that rely exclusively on the traditional use of interior vapor retarders without any temperature control provided by FPIS ci, as shown in Figures 1 and 2. Learn more about the use of FPIS for water vapor control here.

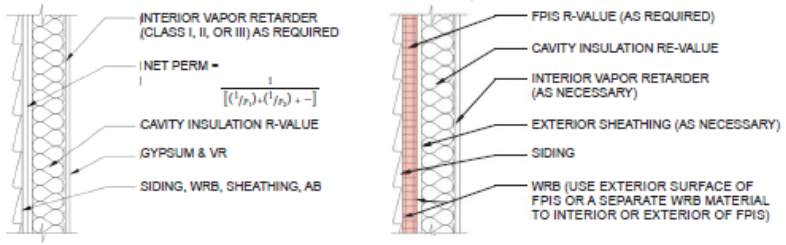
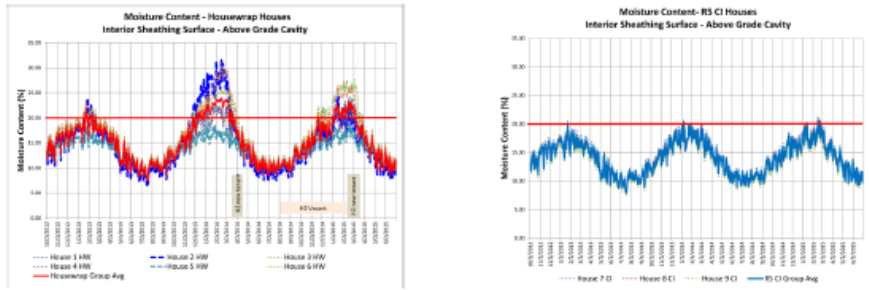


Figure 1. Cavity insulation only vs. wall with FPIS ci insulation (see Figure 2 for performance comparison)



(A) Walls with R20 cavity insulation only consistently experiencing wet OSB.

(B) Walls with R5 FPIS ci keeping OSB sheathing dry

Figure 2. Comparison of 12 actual walls with and without R5 FPIS ci

RULE #2: Minimize Air Leakage!

Leakage of moist air from the indoors or outdoors into or through a building assembly can easily override the function of vapor retarders. Minimize air leakage by following energy code requirements for use of continuous air barriers and sealing of joints and gaps. It's not just an energy code concern (although it does save a lot of energy).

When RULE #1 is followed and the FPIS ci is installed per Figure 3 as a code compliant air barrier, walls are less vulnerable to the consequence of air leakage for two reasons: (1) the FPIS ci will help limit air infiltration from the exterior (especially if it is also used as the WRB system, see RULE #3), and (2) it will also reduce the potential for moist air to condensate on or be adsorbed by moisture-sensitive materials inside the wall because it controls the temperature of those materials. Find more information on use of FPIS as an air barrier here.

RULE #3: Avoid Rain Water Intrusion!

Most importantly, keep rain water out of walls by proper use of cladding, drainage, water-resistive barrier (WRB), and flashing as required by the building code and good practice. Many FPIS ci products can be used as a code-approved WRB system when installed in accordance with the manufacturer's installation instructions. Approved FPIS WRB systems use durable joint treatments (e.g., joint tapes) and flashing materials (e.g., adhered or fluid-applied flexible flashings) as shown in Figure 4. FPIS WRB systems are subject to some of the most stringent wall assembly water-resistance test requirements. Find more information on FPIS WRB systems here.

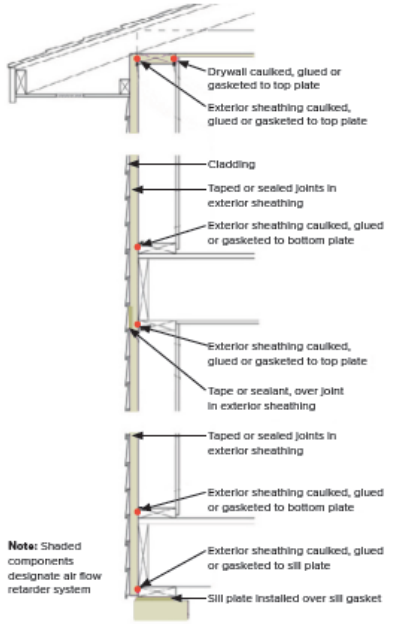


Figure 3. FPIS ci installed as an air barrier exterior sheathing.

(Source: BECP Building Energy Code Resource Guide Air Leakage Guide)

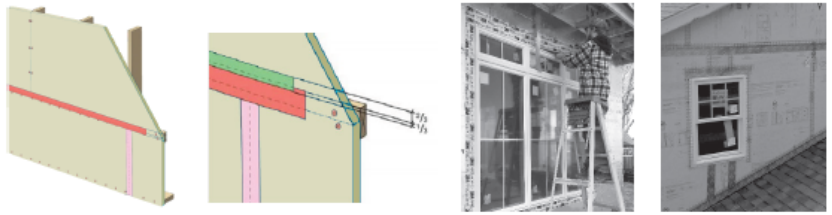


Figure 4. FPIS WRB System installation using joint tapes and adhered flashings; refer to manufacturer installation instructions for specific details.

BOTTOM LINE: Use FPIS ci as continuous insulation, vapor control, air barrier, and water-resistive barrier to create an efficient, robust, and moisture-resistant wall assembly for optimal performance and code compliance.

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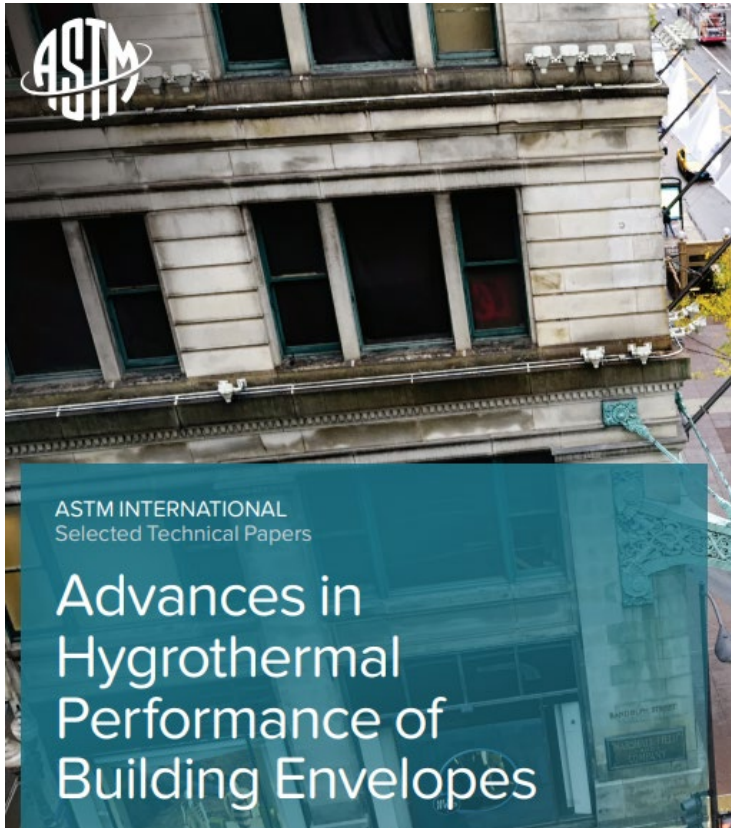
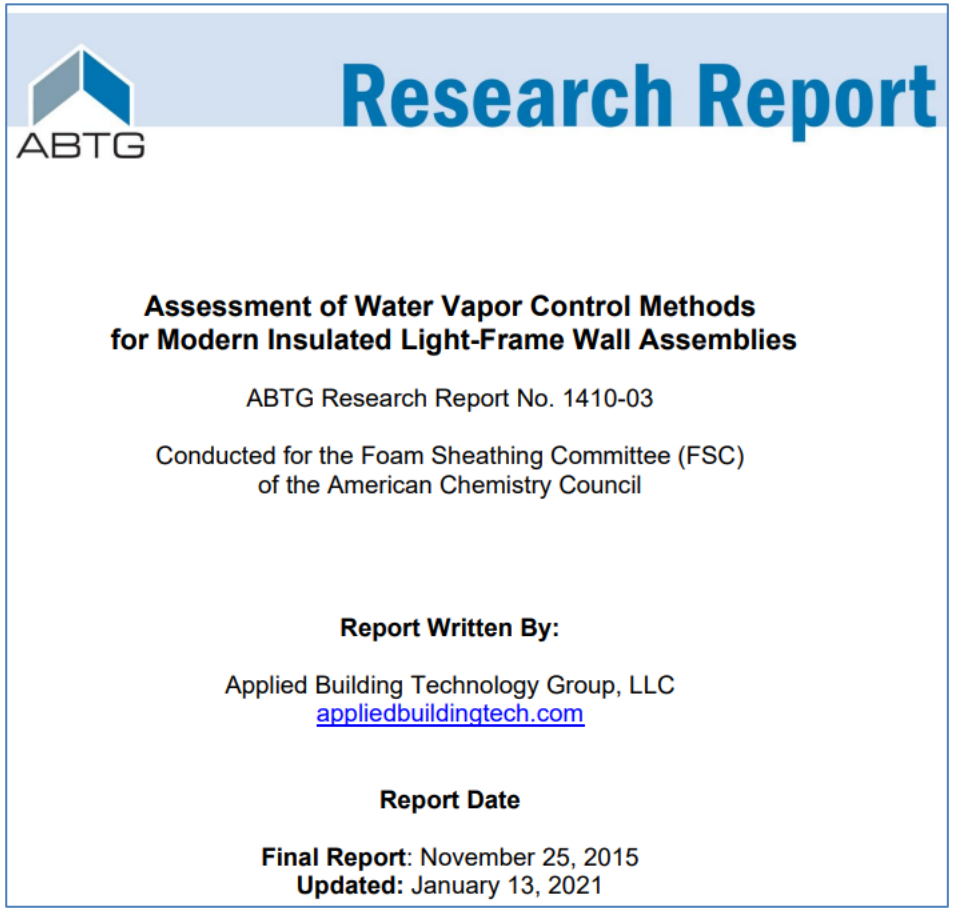
Research Leading to 2021 IRC/IBC Provisions



STP1599

Assessment of Hygrothermal Performance and Design Guidance for Modern Light-Frame Wall Assemblies

https://www.astm.org/DIGITAL_LIBRARY/STP/PAGES/STP159920160097.htm



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Research Report

Assessment of Water Vapor Control Methods for Modern Insulated Light-Frame Wall Assemblies

ABTG Research Report No. 1410-03

Conducted for the Foam Sheathing Committee (FSC) of the American Chemistry Council

Report Written By:

Applied Building Technology Group, LLC
appliedbuildingtech.com

Report Date

Final Report: November 25, 2015
Updated: January 13, 2021

https://www.appliedbuildingtech.com/rr/1410-03

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Research Findings

- Surveyed multiple field, test hut, and modeling studies
- Compared to U.S. and Canadian Code and Practices
- Confirmed where practices were working well
- Conducted analysis where refinements needed
- Peer reviewed
- Combined best of U.S. and Canadian practices to result in 2021 IBC/IRC

- Unanimous approval at code hearings including all major stakeholders

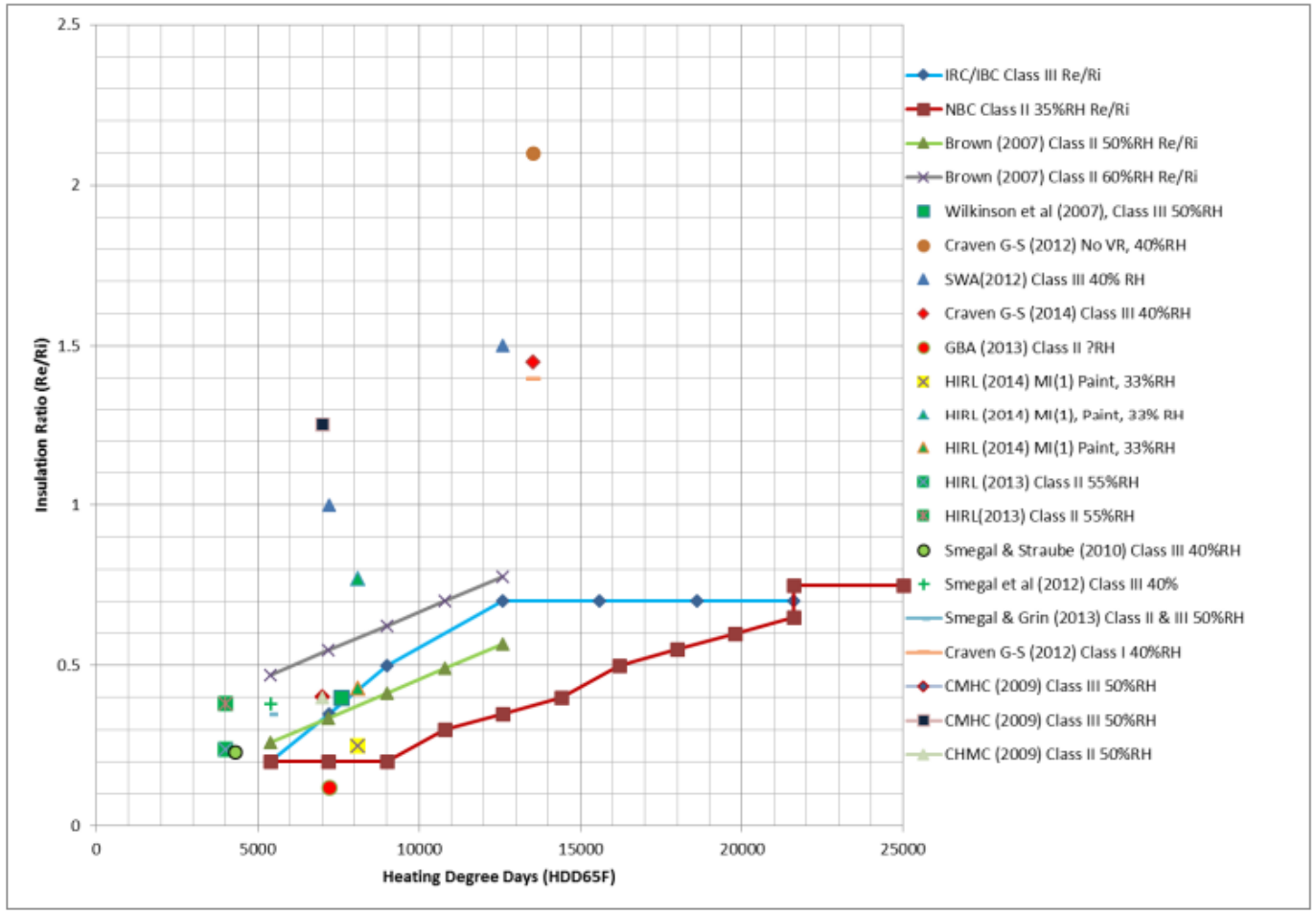

Figure 14: *IRC/IBC* and NBC Wall Insulation Ratio Requirements Compared to Data Points from Various Modeling, Test Hut, Case Studies, and Field Monitoring Studies Reported in the Literature

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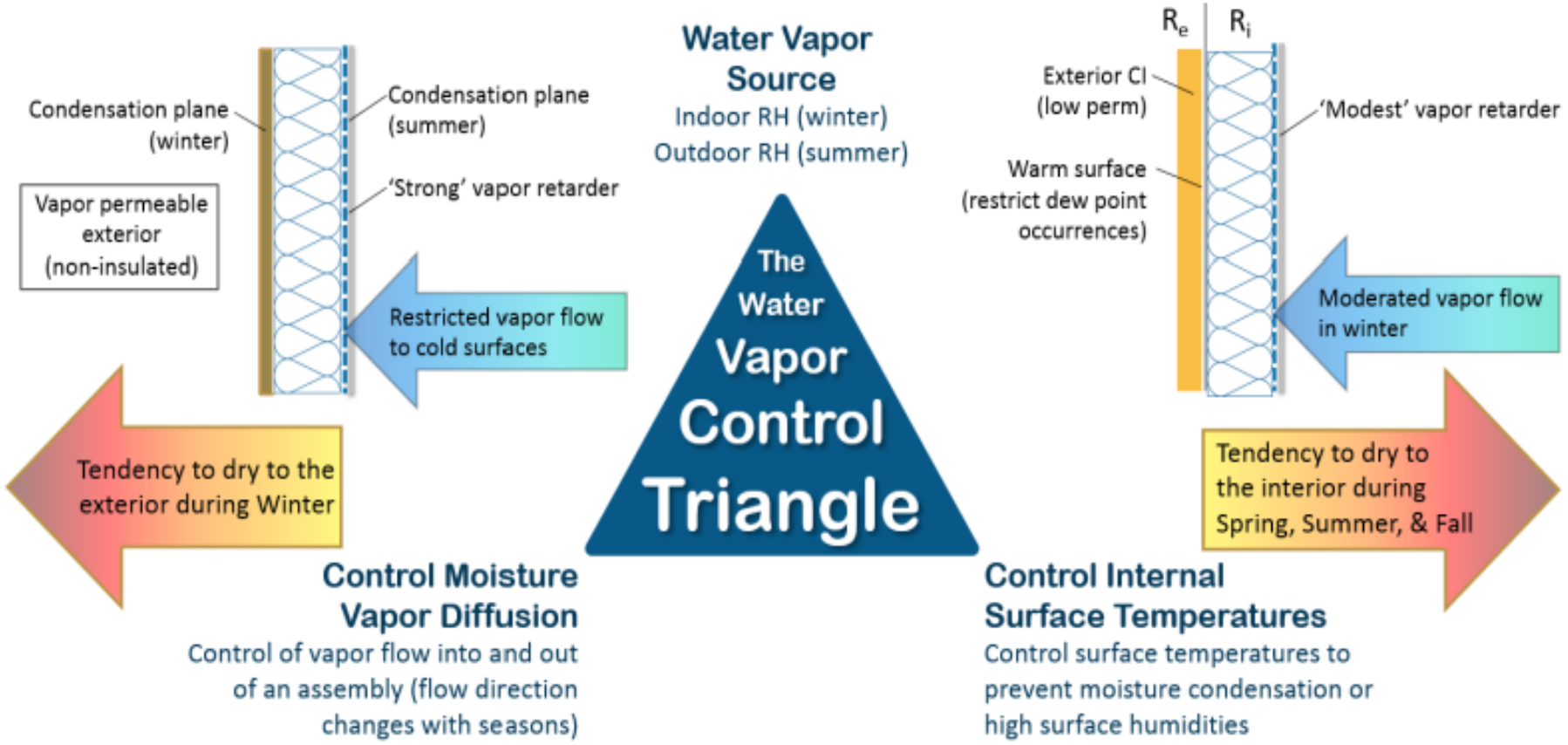
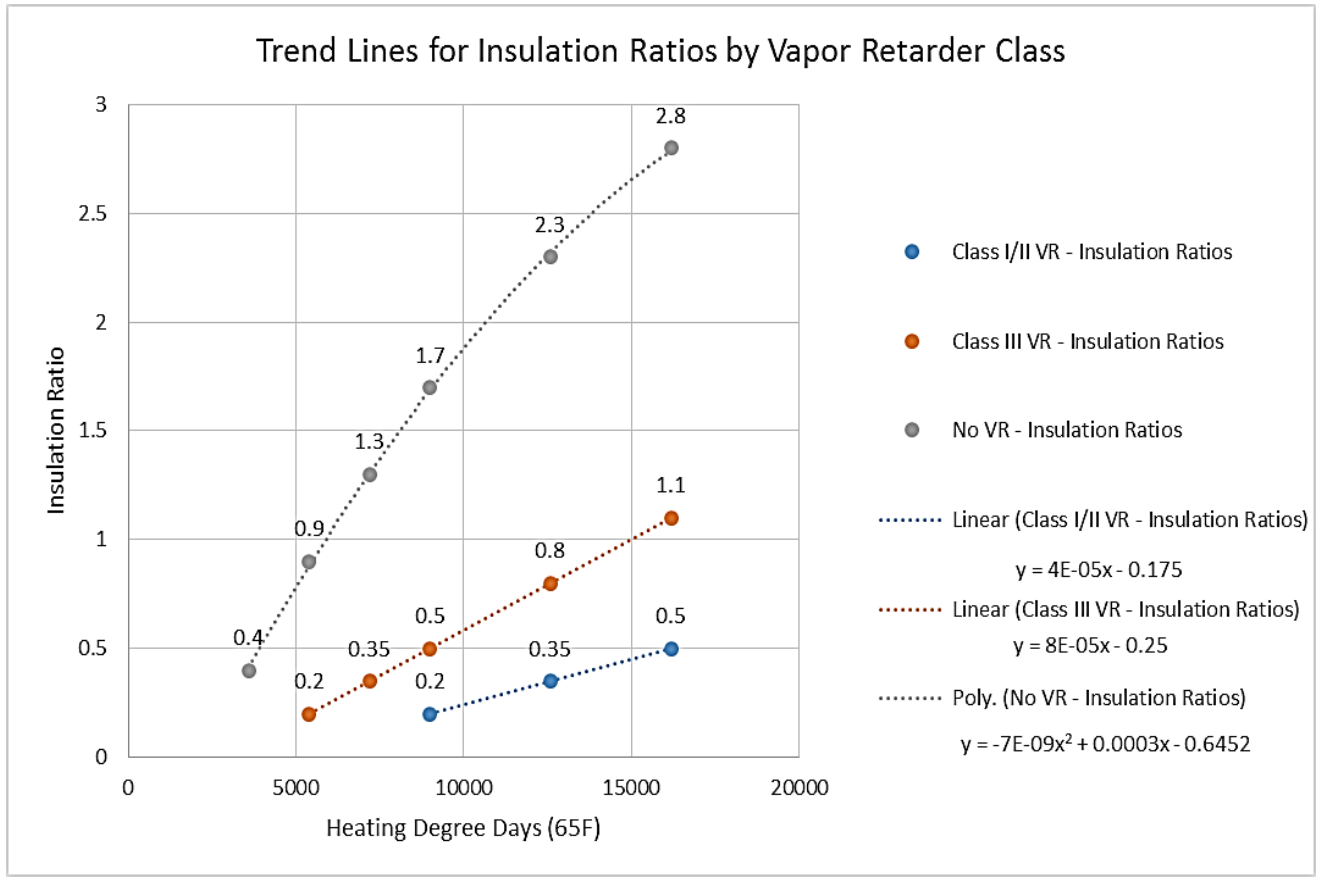
Vapor Control Principles

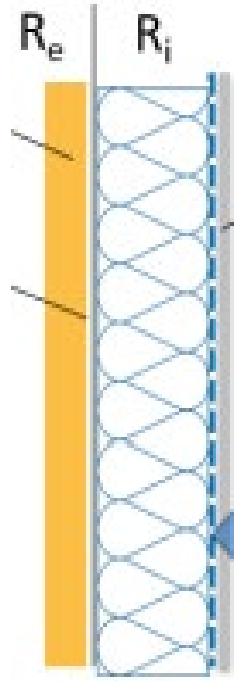
- Two approaches to control water vapor:
  - Permeance Controlled Design (permeance ratio)
  - Temperature Controlled Design (insulation ratio, IR = Re/Ri)



Insulation Ratio (Graphic Format)

(Temperature-controlled Design)





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

Insulation Ratio (Tabulated Format)

(basis of 2021 IBC and IRC for walls with continuous insulation)

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

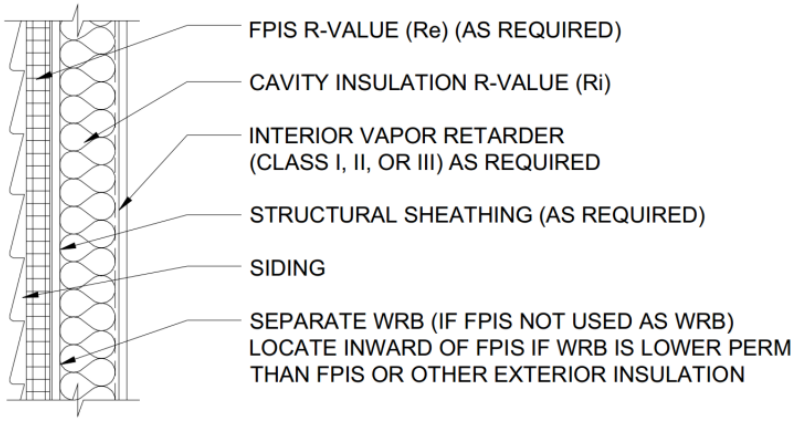
Climate Zone (Fig. 2)	Maximum Heating Degree Days (65F basis)	Interior Vapor Retarder (VR) Class			
		Class I	Class II	Class III	No VR[e]
1	N/A	NP	NP[f]	R-2ci minimum	R-2ci minimum
2	N/A	NP	NP[f]	R-2ci minimum	R-2ci minimum
3	3,600	NP	R-2ci minimum	R-2ci minimum	0.4
4	5,400	NP	R-2ci minimum	0.2	0.9
5	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



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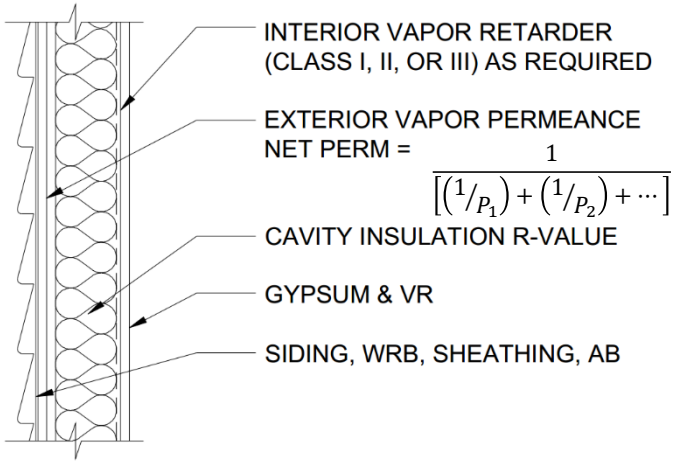
Permeance Ratio

(not included in 2021 IBC and 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

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2021 IRC & IBC Vapor Retarder Provisions

- IRC and IBC provisions are similar.
  - Refer to 2021 IBC errata for Section 1404.3
- First, the general requirements:

R702.7 Vapor retarders. Vapor retarder materials shall be classified in accordance with Table R702.7(1). A vapor retarder shall be provided on the interior side of frame walls of the class indicated in Table R702.7(2), including compliance with Table R702.7(3) or R702.7(4) where applicable. An *approved* design using accepted engineering practice for hygrothermal analysis shall be permitted as an alternative. The climate zone shall be determined in accordance with Section N1101.7.

Exceptions:

1. *Basement walls*.
2. Below-grade portion of any wall.
3. Construction where accumulation, condensation or freezing of moisture will not damage the materials.
4. A vapor retarder shall not be required in Climate Zones 1, 2 and 3.

2021 IRC & IBC Vapor Retarder Provisions

- Vapor retarder classes are broadly defined.
  - Based on static “dry cup” permeance only.
  - “Smart” (dynamic or responsive) vapor retarders are addressed separately as an “adder” to these classes.

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.

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2021 IRC & IBC Vapor Retarder Provisions

- Second, VR permitted application by climate zone is tabulated.
- Footnotes address additional conditions of use such as “smart” vapor retarders and use of foam sheathing continuous insulation with a Class II “smart” vapor retarder.

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.

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2021 IRC & 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).

2021 IRC & 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.

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2024 IBC – Ci Only, No Interior Vapor Retarder

The “Perfect Wall” – all control layers on the exterior side of the assembly; maximum protection of structure and maximum mitigation of thermal bridging.

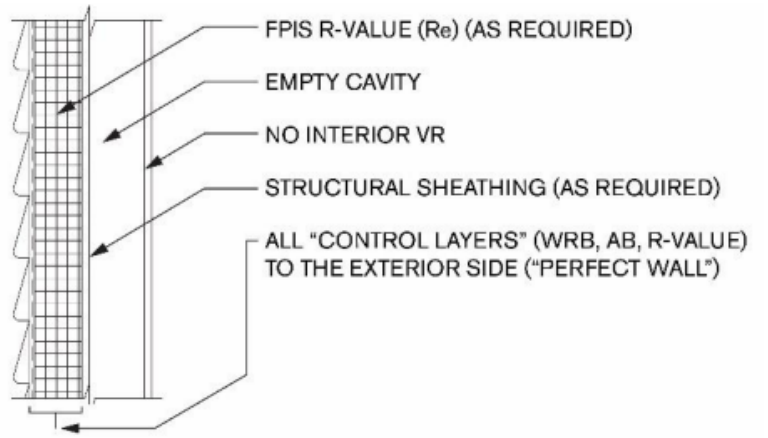


TABLE 1404.3(5)
CONTINUOUS INSULATION ON WALLS WITHOUT A CLASS I, II, OR III INTERIOR VAPOR RETARDER[a]

CLIMATE ZONE	PERMITTED CONDITIONS[b,c]
4	*Continuous insulation* with R-value ≥ 4.5
5	*Continuous insulation* with R-value ≥ 6.5
6	*Continuous insulation* with R-value ≥ 8.5
7	*Continuous insulation* with R-value ≥ 11.5
8	*Continuous insulation* with R-value ≥ 14

Generally, the energy code will require more insulation than needed for water vapor control when using all exterior continuous insulation.

Simplified Code-Compliance Guide

Download resource at continuousinsulation.org/quick-guides

QUICK GUIDE
Foam Plastic Applications for Better Building

3 STEPS FOR CODE-COMPLIANT USE OF WATER VAPOR RETARDERS and Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

07.27.21

This reference guide summarizes key requirements and options in the 2021 International Residential Code (IRC) and 2021 International Building Code (IBC) for design and construction of code-compliant and moisture-resistant frame walls using foam plastic insulating sheathing (FPIS) as continuous insulation (ci). When used in a code-compliant manner, FPIS ci protects walls against the effects of moisture by keeping walls warm to prevent condensation while maximizing drying to the interior with proper vapor retarder specification.

Follow the three steps below for code-compliant water vapor control. For greater flexibility and to automate the application of this reference guide, refer to these wall calculators. Various moisture control research reports and other practical guides are also available here.

For a summary of key concepts and principles for moisture control, refer to FACTS: Moisture Control for Wall Assemblies.

STEP 1: KNOW INTERIOR VAPOR RETARDER CLASSES

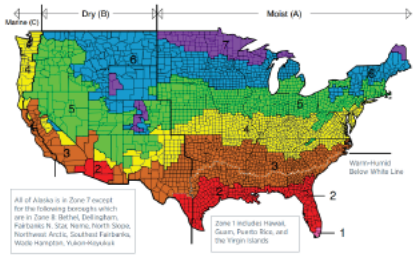
Use the following definitions for water vapor retarder classes when specifying interior vapor retarders in accordance with Steps 2 and 3:

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 paint, 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.

STEP 2: CONSIDER PERMITTED INTERIOR VAPOR RETARDERS

Select a "permitted" vapor retarder for the interior side of frame walls based on the Climate Zones as outlined in IRC Table R702.7(2), paying attention to footnotes and other table references:



U.S. Climate Zones

TABLE R702.7(3) CLASS III VAPOR RETARDERS

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).

STEP 3: DETERMINE MINIMUM R-VALUE REQUIREMENTS FOR CI

For use of FPIS ci with Class II or III interior vapor retarders (per Step 2), determine the minimum ci R-value required to control water vapor using IRC Tables R702.7(3) or R702.7(4) as applicable. The ci and cavity insulation amounts provided must also comply with the local energy code.

TABLE R702.7(3) CLASS III VAPOR RETARDERS
(only requirements for ci are shown)

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:
4 Marine	ci with R-value ≥ 2.5 over 2 x 4 wall
	ci with R-value ≥ 3.75 over 2 x 6 wall
5	ci with R-value ≥ 5 over 2 x 4 wall
	ci with R-value ≥ 7.5 over 2 x 6 wall
6	ci with R-value ≥ 7.5 over 2 x 4 wall
	ci with R-value ≥ 11.25 over 2 x 6 wall
7	ci with R-value ≥ 10 over 2 x 4 wall
	ci with R-value ≥ 15 over 2 x 6 wall
8	ci with R-value ≥ 12.5 over 2 x 4 wall
	ci with R-value ≥ 20 over 2 x 6 wall

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

CLIMATE ZONE	CLASS II VAPOR RETARDERS PERMITTED FOR:
3	ci with R-value ≥ 2
4, 5, 6	ci with R-value ≥ 3 over 2 x 4 wall
	ci with R-value ≥ 5 over 2 x 6 wall
7	ci with R-value ≥ 5 over 2 x 4 wall
	ci with R-value ≥ 7.5 over 2 x 6 wall
8	ci with R-value ≥ 7.5 over 2 x 4 wall
	ci with R-value ≥ 10 over 2 x 6 wall

NOTE: When using a Class II interior vapor retarder, it must comply with the "smart" vapor retarder requirements of footnote 'c' of IRC Table R702.7(2) above (e.g., coated kraft paper facer complies). Use of a Class I "smart" vapor retarder will provide equal or better performance. Smart vapor retarders prevent OUTWARD moisture movement into walls in the winter and become vapor permeable for increased INWARD drying potential in the summer, which compliments the "warm wall" water vapor control provided by FPIS ci. A Class III interior vapor retarder is sufficiently vapor permeable at all times such that it is not required to be a "smart" vapor retarder but it requires more FPIS ci (i.e., a warmer wall) to prevent condensation in the winter.

TIP:
While not required, using more than the code minimum ci R-values shown above will further improve water vapor control and protection of the building envelope.

YOU'RE DONE! For additional guidance on details and options for code-compliant moisture control, refer to this wall assembly illustration.

Owned and operated by the Applied Building Technology Group with support from a grant provided by the Foam Sheathing Committee (FSC) of the American Chemistry Council, **continuousinsulation.org** provides informational resources intended to assist the foam plastic insulating sheathing industry, using sound science to develop research supporting the reliable, efficient, and economic design and installation of foam sheathing.

Contact us.

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Supplemental Design Considerations

CAN YOU HAVE TOO MUCH PERMEANCE?

Yes! (in some conditions)

Recommendation:

The Net WVP of exterior layers between the cladding and sheathing (e.g., the WRB or continuous insulation) should not exceed ~10 perm.

- This prevents **solar-driven inward moisture movement**, where direct-applied (unvented) reservoir cladding (adhered veneer, stucco, etc.) is used on air-conditioned buildings.

Can also be addressed by increasing back-ventilation of reservoir cladding (more like brick veneer).

- See 2021 IBC and IRC provisions for stucco WRB (required drainage space for “Moist” and “Marine” climates)

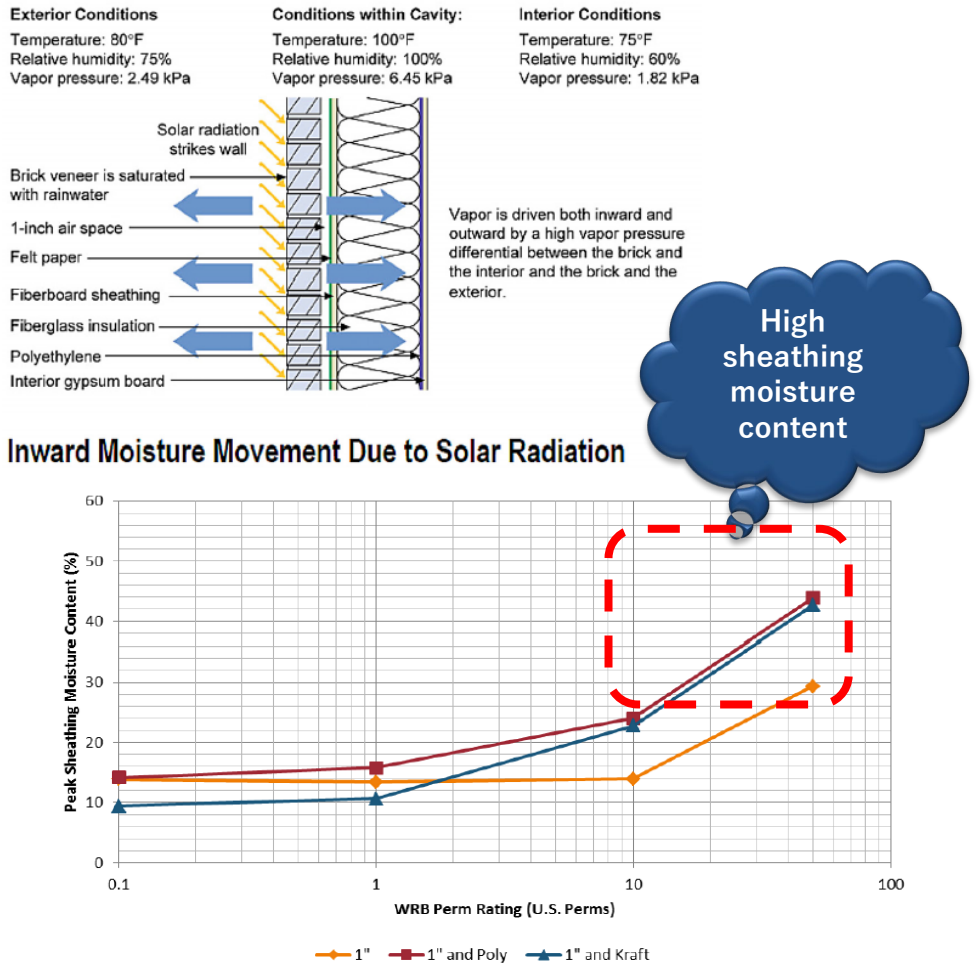

Figure 16. Peak exterior side sheathing MC for 1 in., 1 in.+ Poly, and 1in.+ Kraft at various WRB permeances.

Source: Lepage & Lstiburek (2013). Moisture Durability with Vapor-Permeable Insulating Sheathing. US DOE, Building Technologies Office, Building America Program

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Supplemental Design Considerations

CAN YOU HAVE TOO LITTLE PERMEANCE?
Yes! (in some conditions)

For all wall assembly types in climates with severe wind-driven rain hazard (see next slide), avoid use of "**double vapor barriers*"** (e.g., Class I vapor retarder on interior and << 1 perm net water vapor permeance material layers on exterior).

- Use a Class II VR (preferably a "smart" VR like Kraft paper) or Class III VR to **promote drying to interior** or high perm materials on the exterior to **promote drying to the exterior**.
- Use of **pan flashings** below window sills and door thresholds highly recommended to prevent wetting from rain intrusion in the first place. All flashings and WRB installation should be **inspected/verified** before concealment.

* The concern is not with "**double vapor retarders**." Many walls are "double vapor retarders" because both sides of typical wall assemblies provide resistance to water vapor diffusion (some more than others).

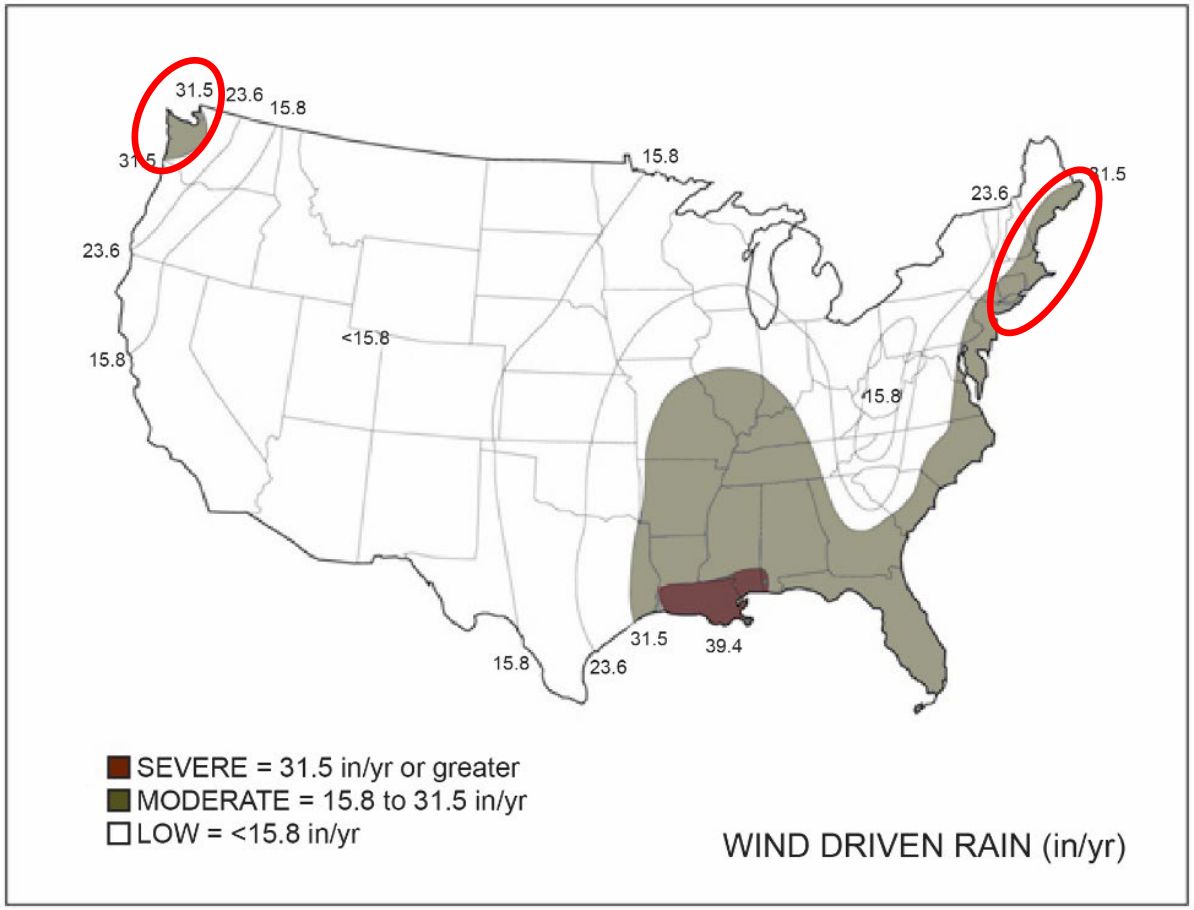
ABTG

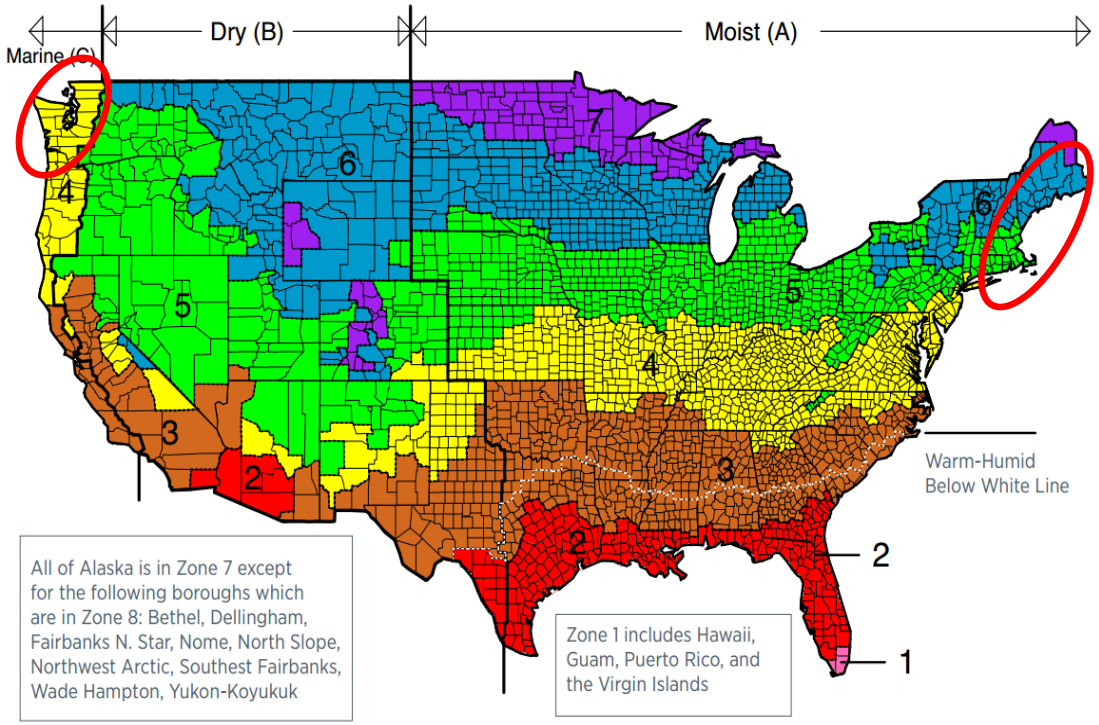
Supplemental Design Considerations

- **IMPORTANT NOTES FOR PREVIOUS SLIDE:**
  - **Drying potential (breathability)** is not a "cure all" for leaky walls and components. Taken to an extreme, it can lead to "too much permeability" or inattention to the primary concern with preventing leaks or properly specifying insulation location and vapor retarders.
  - Class I vapor retarders are not permitted in climate zones 1-4 already (except Marine 4), so this recommendation **applies mainly to the Northwest and Northeast seaboards** of the US (**see next slide**).
  - Use of a Class I or II "smart" (responsive) vapor retarder is now recognized in the 2024 codes to promote inward drying and restrict outward (winter) vapor movement.
- For additional info on **double vapor barriers**, refer to: "Doubling Down: How Come Double Vapor Barriers Work?" (Dr. Lstiburek, *ASHRAE Journal*, Jan. 2016).

ABTG

Wind-driven Rain & Climate Zone Maps





Summary – Graphic for Integrated Moisture Control

Download resource at continuousinsulation.org/water-vapor-control

MOISTURE CONTROL FOR FRAME WALLS
Code Compliant Wall Detailing

Integration of code-compliance requirements and best practices for moisture control of frame wall assemblies (based on 2021 IRC).

07.27.21

FIGURE KEY:
ci = continuous insulation
VR = vapor retarder
AB = air barrier
WRB = water-resistive barrier
FPIS = foam plastic insulating sheathing
EIFS = exterior insulation & finish system
ccSPF = closed-cell spray foam

Structural Sheathing

Specify and install structural sheathing per IRC Chapter 6 where used for wall bracing. Examples include OSB, plywood, gypsum sheathing, fiberboard, diagonal wood boards, etc. (Wood let-in and metal brace options not shown.)

Lap Sidings (vinyl, wood, aluminum, fiber-cement, etc.)

Specify and install lap sidings per IRC Section R703. In Climate Zones 4-8 where using a Class III interior VR, two options to control water vapor are provided in Table R702.7(3):

(1) Without exterior ci – siding must be back-vented (e.g., furred) or vented siding (e.g., vinyl).

(2) With exterior ci – siding not required to be back-vented or vented siding.

Back venting or vented siding is otherwise not required but is a recommended best practice, especially in in moist or marine climate regions.

Stucco, Adhered Masonry Veneer, Cement Panel Siding, etc.

Specify and install WRB per IRC Section R703.7.3. In Moist/Marine climate regions, a minimum 3/16" drainage space is required. See drainage space location options based on WRB location specified.

Alternative drainage methods include drainage matt, drain wrap, or channeled back of FPIS with separate WRB on its interior side. All alternatives must have minimum 90% drainage efficiency per ASTM E2273 or E2925.

Anchored Masonry Veneer (stone & brick)

1" ventilation and draining space required for all anchored stone or brick veneer in all climate zones (see Section R703.8).

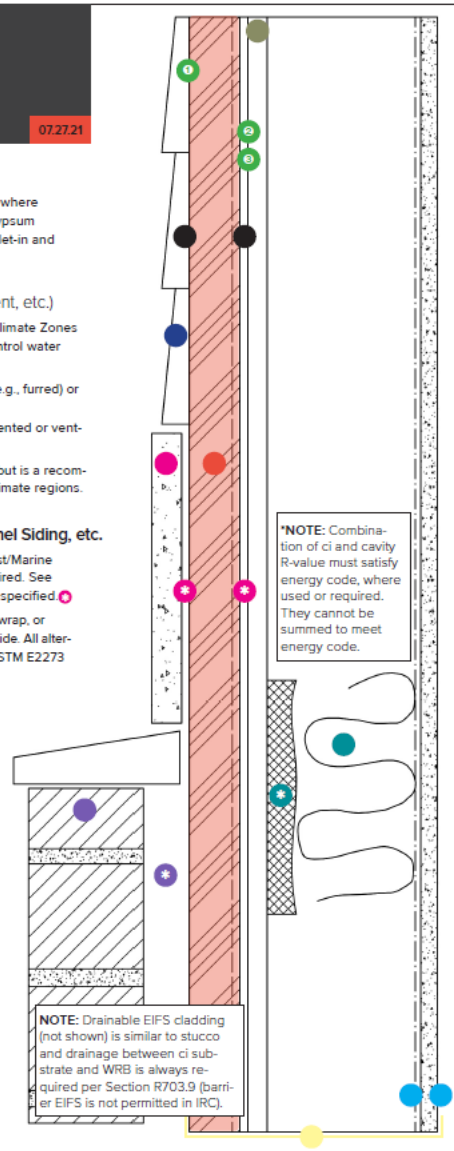
Also qualifies as vented cladding for use of Class III VR on walls without exterior ci per Table R702.7(3).

Air Barrier (AB)

A continuous AB is used in all climate zones to achieve required whole building air-change-per-hour (ACH) limits per energy code and to protect wall from moist air intrusion. The designated AB material layer must have joints, seams, gaps, intersections, and penetrations sealed. AB material can be the WRB, the ci, the structural sheathing, the ccSPF cavity insulation, the VR, or gypsum wallboard. Any material or combination thereof must meet energy code requirements for AB material properties (i.e., essentially air impermeable). Recommended best practice is to provide AB on both sides of air-permeable insulation materials (i.e., on exterior and interior sides of wall cavity) for improved thermal performance and moisture control.

Flashing (IRC Section R703.4): Flashing at siding transitions, fenestration, and other wall penetrations or details not shown; flash to the designated WRB layter (location in wall may vary) and kick-out to exterior or cladding where required at weeps, etc.

Cladding Connections (IRC Section R703.3): For connections through FPIS refer also to IRC Section R703.15.



*NOTE: Combination of ci and cavity R-value must satisfy energy code, where used or required. They cannot be summed to meet energy code.

NOTE: Drainable EIFS cladding (not shown) is similar to stucco and drainage between ci substrate and WRB is always required per Section R703.9 (barrier EIFS is not permitted in IRC).

Water-Resistive Barrier (WRB)

Specify and install a WRB in accordance with IRC Section R703.2. WRB material and location options include:

1. Surface of FPIS WRB System w/ taped joints - FPIS surface used as WRB
2. Separate WRB behing ci - Any ci insulation type not used as WRB
3. Membrane (wrap), spray-applied, or WRB wall sheathing (no ci)

Drainage Space (location based on WRB option used)

Where required, located between cladding and WRB (see above). See requirements for reservoir cladding types (brick, stucco, adhered veneer, etc.).

Where not required, use as recommended best practice.

Continuous Insulation (ci)*

Where used, ci R-value must meet IRC Table R702.7(2) and Table R702.7(3) or (4) as applicable based on Climate Zone and the interior VR Class specified. The required minimum ci R-values ensure adequate temperature control to prevent condensation and moisture accumulation within the wall. Increasing ci R-values above code-minimums will further improve thermal performance and moisture control.

Where non-vapor permeable (< 5 perm) ci is used (e.g., FPIS), it will mitigate inward vapor drive from reservoir claddings (e.g., stucco, adhered veneer, brick, etc.). For similar reasons, it is recommended to use a moderate to low perm WRB (e.g., < 20 perm) behind a vapor permeable ci material.

Cavity Insulation*

If ccSPF is used at thickness to achieve 1.5 perms or less, the R-value can be combined with ci R-value to meet ci requirements of Tables R702.7(3) or (4) to decrease the exterior ci thickness/R-value required, but ccSPF must still be treated as cavity insulation for energy code compliance.

Interior Vapor Retarder (VR)[1,2]

Use of a Class I interior VR (that is not "smart") in frame walls with a Class I exterior VR is not permitted without an approved design. Double vapor "barriers" should be avoided.

An interior vapor retarder is not required in Climate Zones 1, 2, and 3. Responsive ("smart") Class I or II VRs are allowed on interior side of any frame wall in all Climate Zones.

If ci used or required: Specify VR per Table R702.7(2) in coordination with ci and cavity insulation R-values per Tables R702.7(3) or (4) as applicable. Class I/II VR must be "smart" VR if ci is FPIS (e.g., non-vapor permeable), otherwise use Class III VR.

If ci not used: Specify VR per Table R702.7(2) with best practice recommendation to specify Class I "smart" VR in Climate Zones 5-8 and install as an air barrier. Use of a Class III VR without ci is not recommended even though permitted.

NOTES ON VAPOR RETARDER CLASSES AND RESPONSIVE VAPOR RETARDERS:

1. Vapor retarder classes are defined in Table R702.2(1) and include Class I (e.g., poly), Class II (e.g., coated kraft paper facer), and Class III (e.g., vapor retarder latex paint per manufacturer's instructions). Class I has vapor permeance of 0.1 of less, Class II is 0.1 to 1 perms, and Class III is 1 to 10 perms.
2. A responsive or "smart" vapor retarder is Class I or II (i.e., 1 perm or less) that becomes more vapor open in a humid environment such that drying occurs when needed. Regular vapor retarders are classified on the basis of "dry cup" vapor permeance measurements at low humidity conditions. Responsive vapor retarders are additionally required to have a permeance of greater than 1 perm when measured by the "wet cup" method of ASTM E96 at a moderately high humidity condition. Coated kraft paper facer is a Class II responsive vapor retarder. Class I responsive vapor retarders are typically proprietary films or membrane products.

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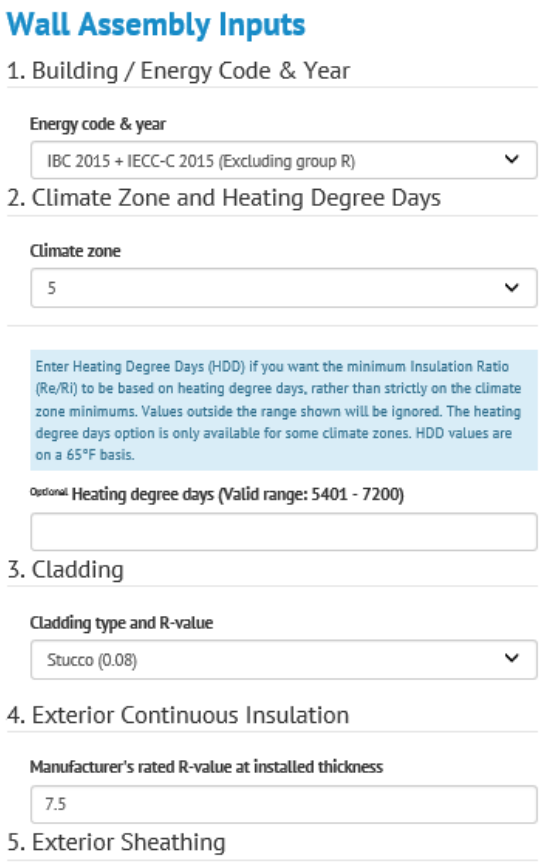
Contact us.

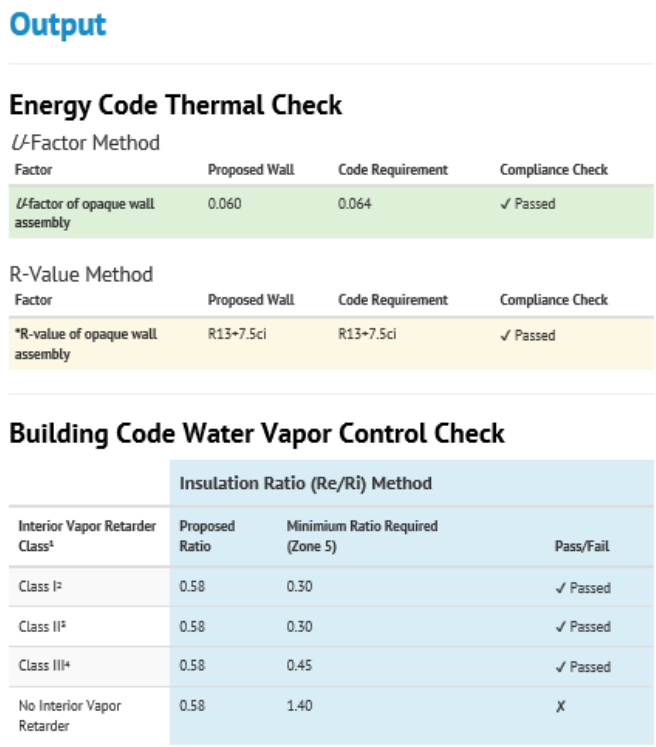
Wall Calculator

Easy Button to IECC & 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)
- Flexible, More Solutions than Code, More Precise

Access the Steel Wall Calculator at:
continuousinsulation.org/steel-wall-calculator





Design Example

Commercial Building (“All Other” – non-Residential)

- **Given:** In Climate Zone 5 for a non-residential metal-frame building, the 2018 & 2021 IECC provides the following prescriptive R-values:
  - R-13+R-7.5ci (2018 IECC)
  - R-13+R-10ci (2021 IECC)
- **Find:** Appropriate vapor retarder options in accordance with the building code.

Design Example

- **In Climate Zone 5**:
  - All vapor retarders are permitted to meet the code requirement for an interior vapor retarder in CZ 5.
  - Footnotes provide additional conditions for use.
- **Solution 1**: Class II VR with R-13 + R-3ci (minimum) works for moisture control.
  - Therefore, 2018 IECC R-13 + R-7.5ci will provide better than code minimum moisture control (greater insulation ratio).
  - 2021 IECC R-13 + R-10ci even better yet.
  - Footnote 'c' requires use of a "smart" Class II VR (e.g., Kraft paper meets criteria) for inward drying
  - Use of a "smart" Class I VR (NOT poly) will actually exceed code minimum intent of Footnote 'c' (clarified in future 2024 codes)

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.

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Design Example

- **Solution 2**: Class III VR with R-13 + R-5ci (minimum) works for moisture control.
  - Therefore, 2021 IECC R-13 + R-7.5ci will provide better than code minimum moisture control (greater insulation ratio).
  - 2021 IECC R-13 + R-10ci even better yet.
  - Class III VR is not required to be "smart" (sufficient drying potential as is)
- Use of lower-perm ci (<10 perm) will also help minimize inward vapor drives if reservoir claddings 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.

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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
  - Based on extensive, peer-reviewed research and supported unanimously at code hearings
  - Significant expansion and improvement of water vapor retarder provisions
  - Still some work needed (e.g., guidance for permeance controlled assemblies)
- Design aids are available to assist in efficiently coordinating energy code and building code compliance.
- Example design demonstrates simplicity of prescriptive energy code and building code vapor retarder compliance.

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QUESTIONS?

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Please submit any questions through the Continuous Insulation website at continuousinsulation.org/contact.