Water, Wind, Windows, & Walls with Continuous Insulation

IIBEC • March 2022

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.

ABTG is a professional engineering firm, an approved source as defined in Chapter 2 and independent as defined in Chapter 17 of the IBC.

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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

- Background
- Evolving Codes
- Fenestration Installation and Performance
- Thermal Bridging Impacts of Fenestration Installation
- Wind-driven Rain Research
- Conclusion & Questions

BACKGROUND

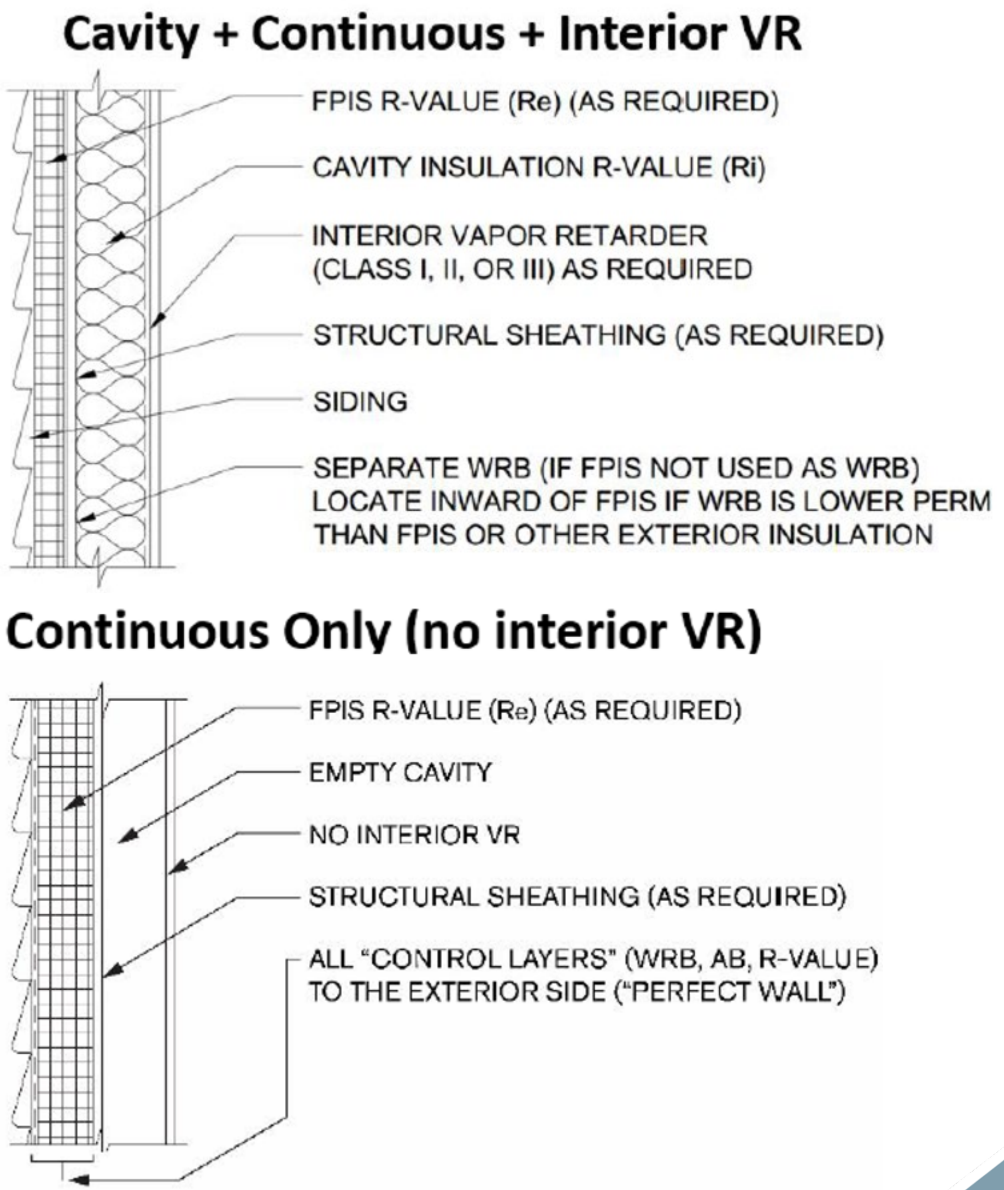
- *Continuous Insulation* (ci):
  - Insulation that is <u>uncompressed</u>

    …and <u>continuous</u> across all structural members

    …<u>without thermal bridges</u>*

    …*other than fasteners and service openings.

(based on IECC and ASHRAE 90.1 definition)



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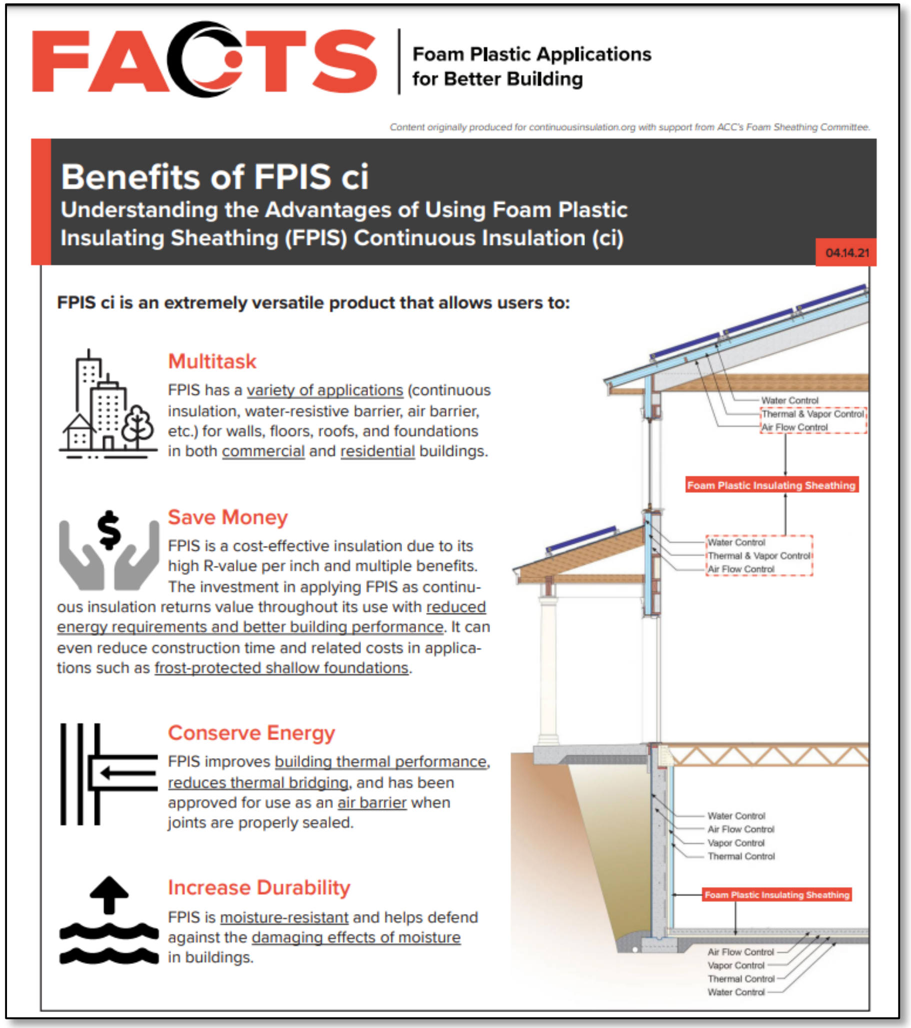
BACKGROUND

- Foam plastic insulating sheathing (FPIS) is one type of ci; others include wood fiberboard and mineral fiber.
- FPIS has applications for all parts of the building envelope (foundations, walls, floors, and roofs).
- FPIS can be multi-functional including ci, water-resistive barrier (WRB), air barrier (AB), vapor control (inward and outward), and even structural.
- Prior IIBEC and RCI papers addressed many of these topics.
- For additional information refer to: https://www.continuousinsulation.org/resources/benefits-fpis-ci


FACTS | Foam Plastic Applications for Better Building

Content originally produced for continuousinsulation.org with support from ACC's Foam Sheathing Committee.

Benefits of FPIS ci

Understanding the Advantages of Using Foam Plastic Insulating Sheathing (FPIS) Continuous Insulation (ci)

04.14.21

FPIS ci is an extremely versatile product that allows users to:

Multitask

FPIS has a variety of applications (continuous insulation, water-resistive barrier, air barrier, etc.) for walls, floors, roofs, and foundations in both commercial and residential buildings.

Save Money

FPIS is a cost-effective insulation due to its high R-value per inch and multiple benefits. The investment in applying FPIS as continuous insulation returns value throughout its use with reduced energy requirements and better building performance. It can even reduce construction time and related costs in applications such as frost-protected shallow foundations.

Conserve Energy

FPIS improves building thermal performance, reduces thermal bridging, and has been approved for use as an air barrier when joints are properly sealed.

Increase Durability

FPIS is moisture-resistant and helps defend against the damaging effects of moisture in buildings.

EVOLVING CODES

- 2018 & 2021 IECC prescriptive R-values
- 2024 IBC water vapor retarders
- 2024 IBC water-resistive barriers
- 2024 IBC fenestration flashing

CODE-REFERENCED STANDARDS FOR FPIS

- ASTM C578
  - Expanded polystyrene (EPS)
  - Extruded polystyrene (XPS)
- ASTM C1289
  - Polyisocyanurate (Polyiso, PIC, PIR, etc.)
- ANSI/ABTG FS100
  - Applies to all types of FPIS where applied over open stud cavities (wind pressure rating is required in this special case)
- Fire Properties & Requirements
  - —IBC Chapter 26 & 14
  - —See manufacturer data, code compliance reports, and material labels

IECC PRESCRIPTIVE R-VALUES & U-FACTORS
(light frame commercial buildings)

<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="3">R13+5ci
(U-0.077)</td><td rowspan="3">R13+5ci
(U-0.077)</td><td rowspan="9">R13+3.8ci or R20
(U-0.064)</td><td rowspan="8">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="10">R13+7.5ci
(U-0.064)</td><td rowspan="5">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></tr>
<tr><td rowspan="2">5 and Marine 4</td><td>All other</td><td rowspan="2">R13+10ci
(U-0.055)</td><td rowspan="6">R13+7.5ci or R20+3.8ci
(U-0.051)</td></tr>
<tr><td>Group R</td><td rowspan="5">R13+7.5ci or R20+3.8ci
(U-0.051)</td></tr>
<tr><td rowspan="2">6</td><td>All other</td><td rowspan="3">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>

- **Metal Framed**
  (Cold-formed Steel)

2021 > 2018 for CZ 5-8 & Marine 4

- **Wood Framed**

2021 > 2018 for CZ 5 & Marine 4 (only for "all other")

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

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IECC PRESCRIPTIVE R-VALUES & U-FACTORS

(one- and two-family dwellings & apartments ≤ 3 stories)

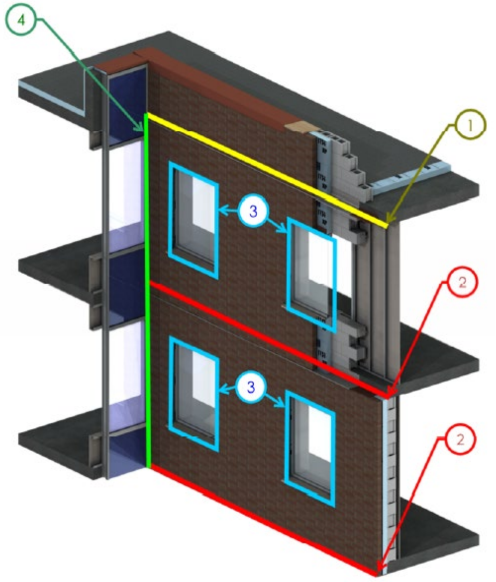
<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="2">Wood Frame Walls</th></tr>
<tr><th>2018 IECC</th><th>2021 IECC</th></tr>
<tr><td>0, 1 and 2</td><td>R13
(U-0.084)</td><td>R13 or R0+10ci
(U-0.084)</td></tr>
<tr><td>3</td><td rowspan="3">R20 or R13+5ci
(U-0.060)</td><td>R20 or R13+5ci or R0+15ci
(U-0.060)</td></tr>
<tr><td>4 except Marine</td><td rowspan="4">R30 or R20+5ci or R13+10ci or R20ci
(U-0.045)</td></tr>
<tr><td>5 and Marine 4</td></tr>
<tr><td>6</td><td rowspan="2">R20+5ci or R13+10ci
(U-0.045)</td></tr>
<tr><td>7 and 8</td></tr>
</table>

- **Wood frame walls**
  2021 > 2018 for CZ 4 and 5

- All climates have multiple equivalent R-value solutions:
  - Cavity insulation only
  - Cavity + Continuous Insulation
  - Continuous Insulation Only

2021 IECC-C ABOVE-GRADE WALL DEFINITION

WALL, ABOVE-GRADE. A wall associated with the *building thermal envelope* that is more than 15 percent above grade and is on the exterior of the building or any wall that is associated with the *building thermal envelope* that is not on the exterior of the building. <u>This includes, but is not limited to, between-floor spandrels, peripheral edges of floors, roof knee walls, dormer walls, gable end walls, walls enclosing a mansard roof and skylight shafts.</u>



Source: BC Hydro BETB Guide / Morrison Hershfield LTD

2021 IECC-C ABOVE-GRADE WALL DEFINITION

- Clarifies thermal bridges must be considered in determining wall overall U-factor and compliance, usually with one of the following approaches:
  1. Use of ci and appropriate detailing is often the most efficient way to mitigate thermal bridges
  2. Simply adding more insulation to compensate (without mitigating thermal bridges) is another approach, but generally less efficient use of insulation.
- Future code development intends to provide explicit thermal bridging provisions to more fully implement the above two approaches
  - ASHRAE 90.1 has required consideration of “uninsulated assemblies” (including thermal bridges) in the performance path
  - Prescriptive path of IECC and 90.1 has generally assumed no thermal bridges other than those addressed within assemblies (e.g., studs, etc.)
- For additional information on thermal bridging, refer to: https://www.continuousinsulation.org/applications/prevent-thermal-bridging

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IBC/IRC IMPROVED WATER VAPOR CONTROL

- See Appendix A in paper (2024 IBC provisions)
  - Formatting clean-ups
  - IRC/IBC consistency
  - Complete resolution of errata to 2021 IBC
  - Addition of "Responsive Vapor Retarder" definition
  - Expand ci vapor control options to better coordinate with energy code insulation options
    - —First, some background may be helpful…

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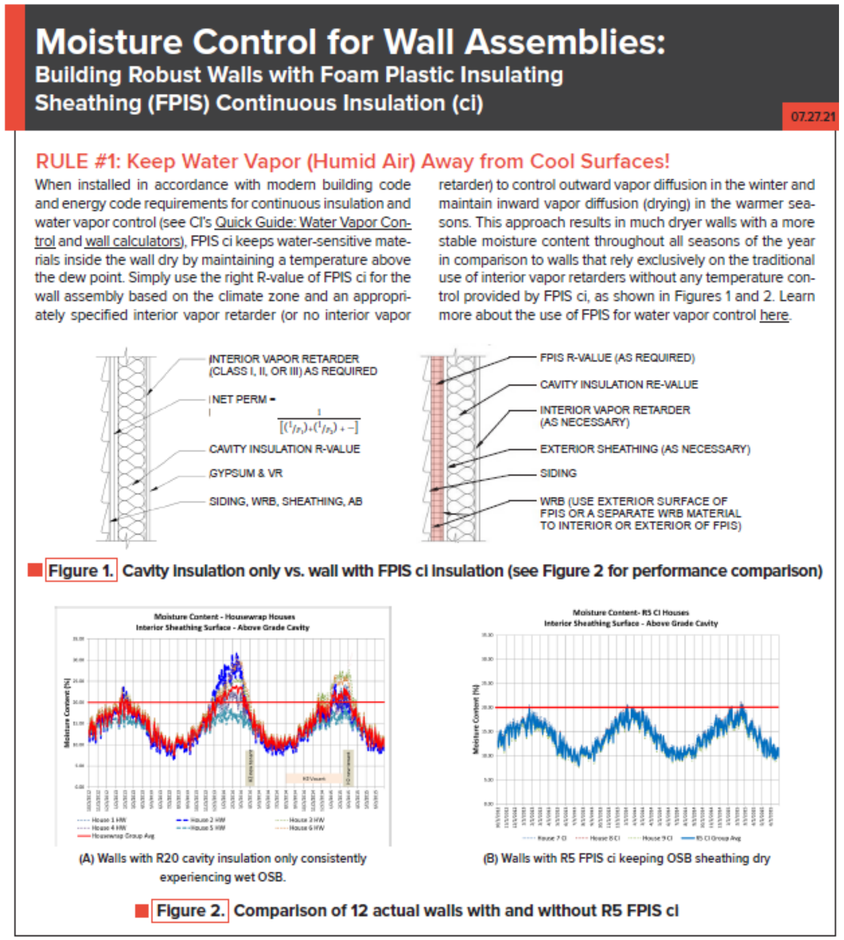
5 BUILDING SCIENCE CONCEPTS FOR MOISTURE CONTROL

- 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…

3 RULES FOR MOISTURE CONTROL



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!

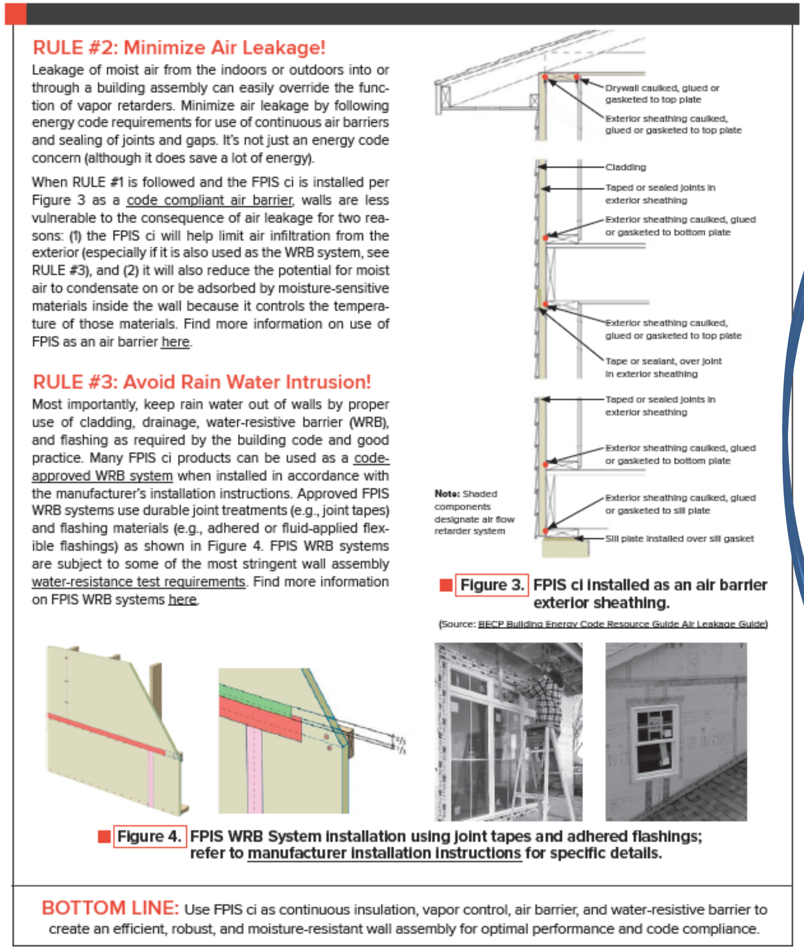
When installed in accordance with modern building code and energy code requirements for continuous insulation and water vapor control (see CI's Quick Guide: Water Vapor Control and wall calculators), FPIS ci keeps water-sensitive materials inside the wall dry by maintaining a temperature above the dew 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.

https://www.continuousinsulation.org/resources/facts-ci

RULE #1 – Keep water (humid air) away from cool surfaces!
BSC 3, 4, & 5

RULE #2 – Minimize air leakage!
BSC 2

RULE #3 – Avoid rain water intrusion!
BSC 1

SUMMARY GRAPHIC FOR INTEGRATED, CODE-COMPLIANT MOISTURE CONTROL （“CHEAT SHEET”）

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).

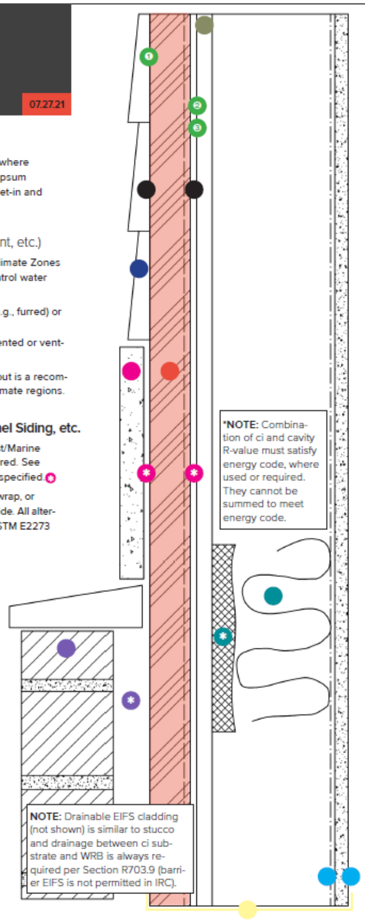
Also qualifies as vented cladding for use of Class III VR on walls without exterior ci per Table R702.7(3).

Air Barrier (AB)

A continuous AB is used in all climate zones to achieve required whole buildilng 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.



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:

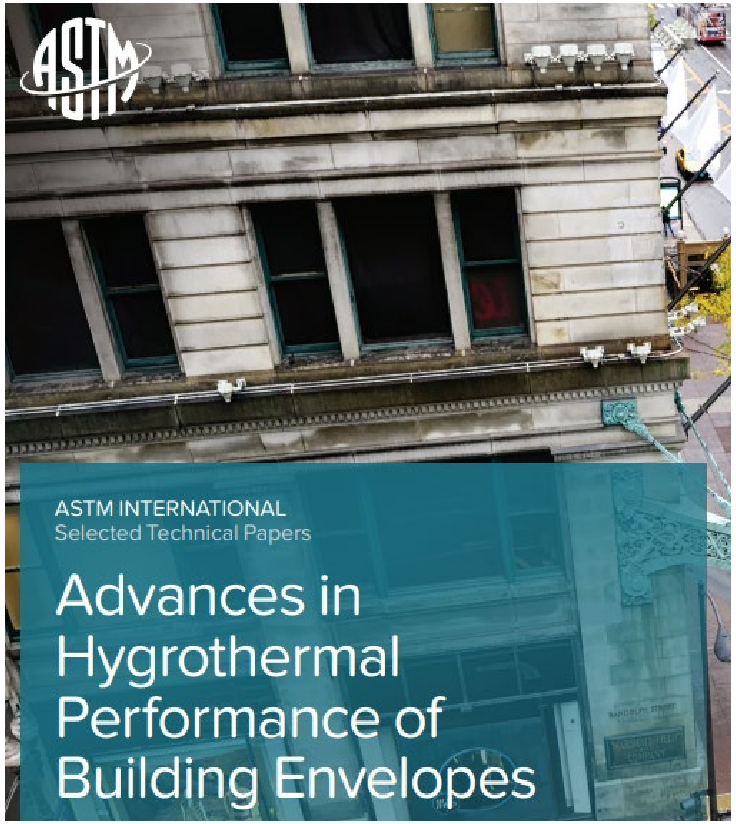
1. Vapor retarder classes are defined in Table R702.2(1) and include Class I (e.g., poly), Class II (e.g., coated kraft paper facer), and Class III (e.g., vapor retarder latex paint per manufacturer's instructions). Class I has vapor permeance of 0.1 of less, Class II is 0.1 to 1 perms, and Class III 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.

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.

https://www.continuousinsulation.org/applications/water-vapor-control

RESEARCH LEADING TO 2021/2024 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

ABTG **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

- Assumed worst-case low permeance conditions for ci and/or exterior material layers to ensure robust prescriptive provisions
- Unanimous approval at code hearings including major stakeholders

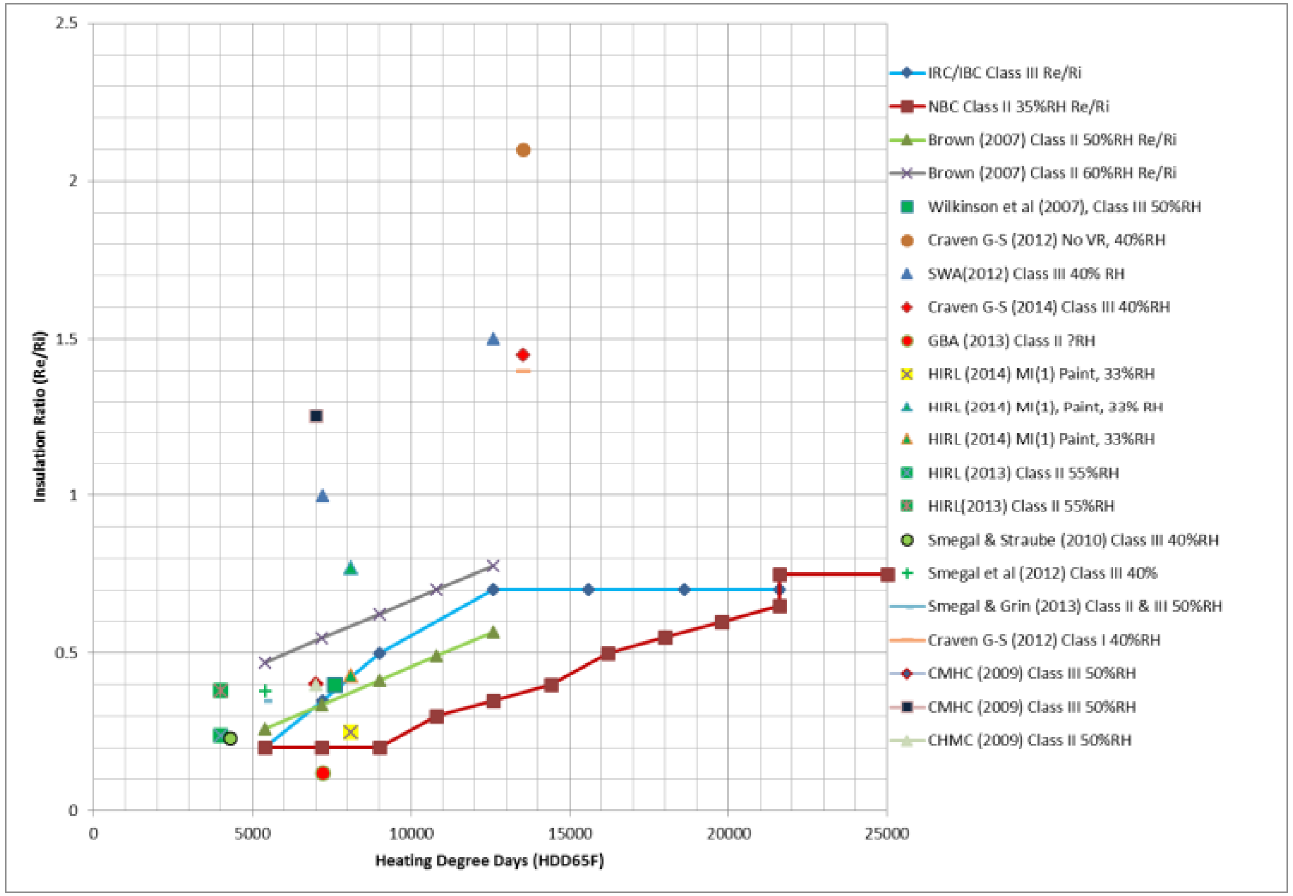

Figure 14: *IRC/IBC* and NBC Wall Insulation Ratio Requirements Compared to Data Points from Various Modeling, Test Hut, Case Studies, and Field Monitoring Studies Reported in the Literature

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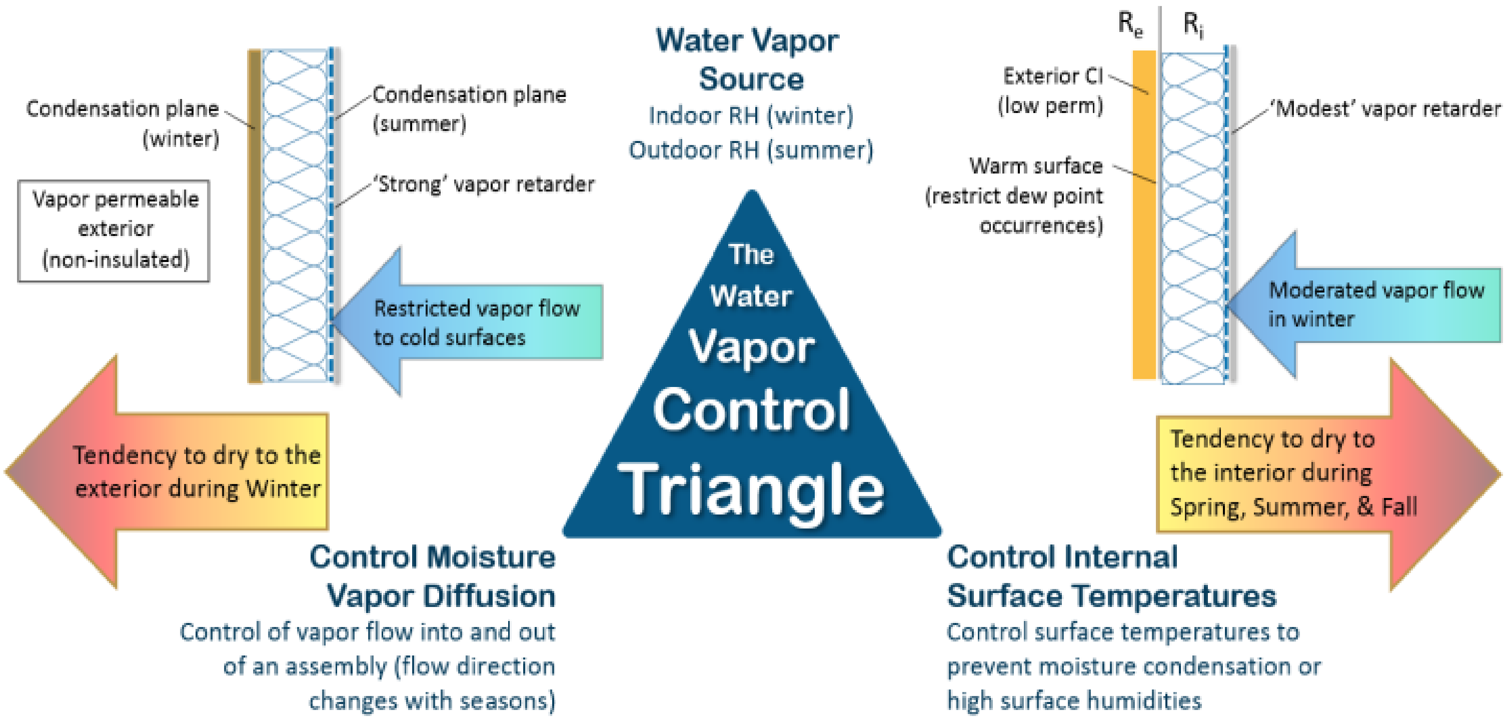
VAPOR CONTROL PRINCIPLES

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



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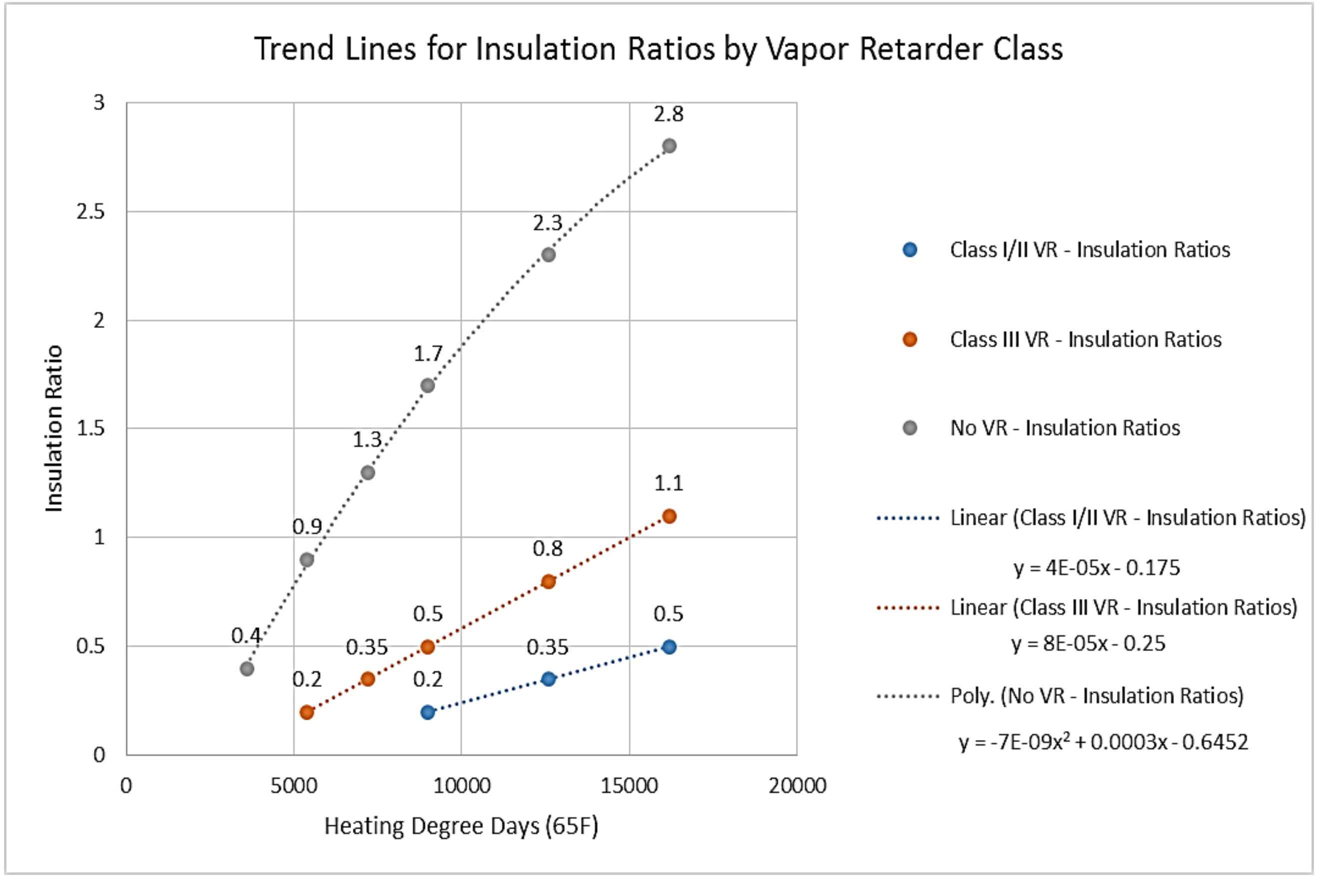
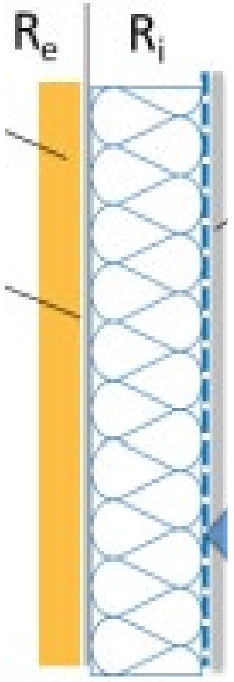
INSULATION RATIO (GRAPHIC FORMAT)
(Temperature-controlled Design)





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

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INSULATION RATIO (TABULATED FORMAT)

(basis of 2021/2024 IBC and IRC for walls with continuous insulation)

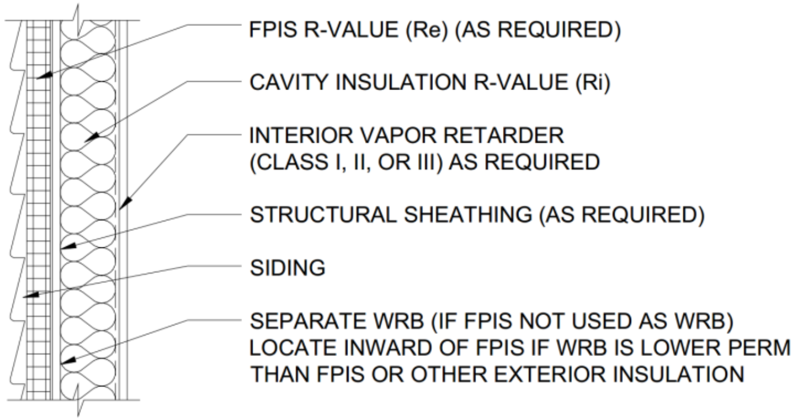
MINIMUM INSULATION RATIO OR CONTINUOUS INSULATION R-VALUE FOR LIGHT-FRAME WALLS WHERE EXTERIOR CONTINUOUS INSULATION (ci) IS USED [a,b,c,d]

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

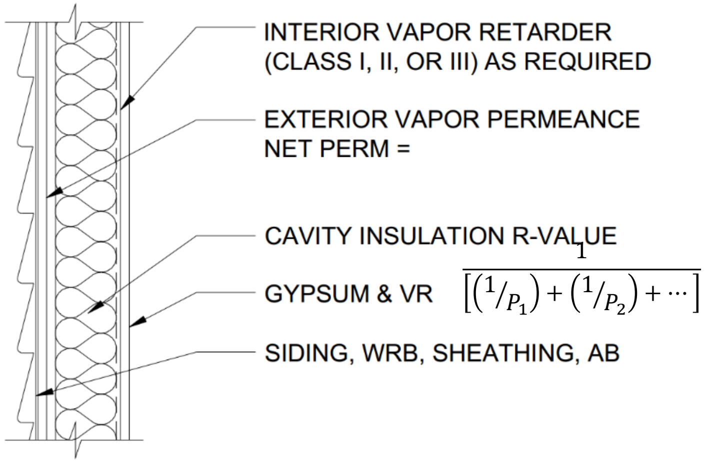
PERMEANCE RATIO

(not included in 2021 or 2024 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

2024 IBC SECTION 1404.3 PROVISIONS

- New definition added:

  RESPONSIVE VAPOR RETARDER. A vapor retarder material complying with a vapor retarder class of Class I or Class II but which also has a vapor permeance of 1 perms or greater in accordance with ASTM E96, water method (Procedure B).
- RVR's allowed on interior side of assembly in any climate
- Required when using a Class I or II interior VR with FPIS ci on the exterior
  - Examples: Class II RVR = coated Kraft paper; Class I RVR = proprietary "smart" vapor retarder (not poly)

2024 IBC SECTION 1404.3 PROVISIONS

1404.3 Vapor retarders. Vapor retarder materials shall be classified in accordance with Table 1404.3(1). A vapor retarder shall be provided on the interior side of frame walls in accordance with Table 1404.3(2) and Tables 1404.3(3) or 1404.3(4) as applicable, or an approved design using accepted engineering practice for hygrothermal analysis. Vapor retarders shall be installed in accordance with 1404.3.3. The appropriate climate zone shall be selected in accordance with Chapter 3 of the *International Energy Conservation Code*.

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.
5. In Climate Zones 4 through 8, a vapor retarder on the interior side of frame walls shall not be required where the assembly complies with Table 1404.3(5).

2024 IBC SECTION 1404.3 PROVISIONS

1404.3.1 Spray foam plastic insulation for moisture control with Class II or III vapor retarders. For purposes of compliance with Tables 1404.3(3) and 1403.3(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 meets or exceeds 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.

2024 IBC SECTION 1404.3 PROVISIONS

1404.3.2 Vapor retarder installation. Vapor retarders shall be installed in accordance with the manufacturer's instructions or an approved design. Where a vapor retarder also functions as a component of a continuous air barrier, the vapor retarder shall be installed as an air barrier in accordance with the *International Energy Conservation Code*.

2024 IBC SECTION 1404.3 PROVISIONS

TABLE 1404.3(1)
VAPOR RETARDER MATERIALS AND CLASSES

VAPOR RETARDER 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 or vapor retarder paint or other approved materials, applied in accordance with the manufacturer's 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 instructions for a perm rating of greater than 1.0 and less than or equal to 10

NOTE: These classes are based purely on "dry cup" vapor permeance by definition. Responsive vapor retarders add a requirement that the "wet cup" vapor permeance be greater than 1 perm. For example, while Kraft-faced FG is a Class II VR with "dry cup" permeance of about 0.6 perms, it is also a Class II RVR because it has a "wet cup" permeance of about 2 perms (proprietary RVR's even greater x10).

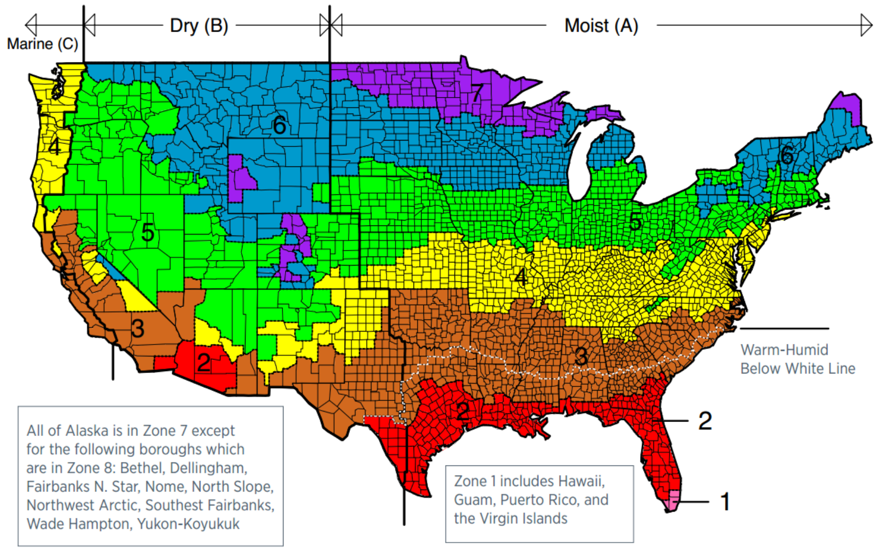
ABTG

2024 IBC Section 1404.3 Provisions

TABLE 1404.3(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	Not Permitted	Permitted[c]	Permitted
4 (except Marine 4)	Not Permitted	Permitted[c]	See Table 1404.3(3)
Marine 4, 5, 6, 7, 8	Permitted[b,c]	Permitted[c]	

a. A *responsive vapor retarders* shall be allowed on the interior side of any frame wall in all climate zones.
b. Use of a Class I interior vapor retarder, that is not a *responsive vapor retarder*, in frame walls with a Class I vapor retarder on the exterior side shall require an *approved* design.
c. Where a Class I or 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 1404.3(4) and the Class I or II vapor retarder shall be a *responsive vapor retarder*.



2024 IBC SECTION 1404.3 PROVISIONS

TABLE 1404.3(3)
CLASS III VAPOR RETARDERS

CLIMATE ZONE	CLASS III VAPOR RETARDERS PERMITTED FOR:[a, b]
4	Vented cladding over wood structural panels Vented cladding over fiberboard Vented cladding over gypsum *Continuous insulation* with *R*-value ≥ R2.5 over 2 × 4 wall *Continuous insulation* with *R*-value ≥ R3.75 over 2 × 6 wall
5	Vented cladding over wood structural panels Vented cladding over fiberboard Vented cladding over gypsum *Continuous insulation* with *R*-value ≥ R5 over 2 × 4 wall *Continuous insulation* with *R*-value ≥ R7.5 over 2 × 6 wall
6	Vented cladding over fiberboard Vented cladding over gypsum *Continuous insulation* with *R*-value ≥ R7.5 over 2 × 4 wall *Continuous insulation* with *R*-value ≥ R11.25 over 2 × 6 wall
7	*Continuous insulation* with *R*-value ≥ R10 over 2 × 4 wall *Continuous insulation* with *R*-value ≥ R15 over 2 × 6 wall
8	*Continuous insulation* with *R*-value ≥ R12.5 over 2 × 4 wall *Continuous insulation* with *R*-value ≥ R20 over 2 × 6 wall

a. Vented cladding shall include vinyl lap siding, polypropylene, or horizontal aluminum siding, brick veneer with airspace as specified in this code, rainscreen systems, and other approved vented claddings.

b. The requirements in this table apply only to insulation used to control moisture in order to permit the use of Class III vapor retarders. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of the International Energy Conservation Code.

ABTG

2024 IBC SECTION 1404.3 PROVISIONS

TABLE 1404.3(4)
CONTINUOUS INSULATION WITH A CLASS I OR II RESPONSIVE VAPOR RETARDER

CLIMATE ZONE	PERMITTED CONDITIONS[a]
3	*Continuous insulation* with R-value ≥2
4, 5, and 6	*Continuous insulation* with R-value ≥3 over 2x4 wall. *Continuous insulation* with R-value ≥5 over 2x6 wall
7	*Continuous insulation* with R-value ≥5 over 2x4 wall. *Continuous insulation* with R-value ≥7.5 over 2x6 wall
8	*Continuous insulation* with R-value ≥7.5 over 2x4 wall. *Continuous insulation* with R-value ≥10 over 2x6 wall

a. The requirements in this table apply only to insulation used to control moisture in order to permit the use of Class I or II vapor retarders. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of the *International Energy Conservation Code*.

2024 IBC SECTION 1404.3 PROVISIONS

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

a. The total insulating value of materials to the interior side of the exterior *continuous insulation*, including any cavity insulation, shall not exceed R-5. Where the R-value of materials to the interior side of the exterior *continuous insulation* exceed R-5 an *approved* design shall be required.

b. A water vapor control material layer having a permeance not greater than 1 perm in accordance with ASTM E96, Procedure A (dry cup) shall be placed on the exterior side of the wall and to the interior side of the exterior *continuous insulation*. The exterior *continuous insulation* shall be permitted to serve as the vapor control layer where, at its installed thickness or with a facer on its interior face, the exterior *continuous insulation* is a Class I or II vapor retarder.

c. The requirements in this table apply only to insulation used to control moisture in order to allow walls without a Class I, II, or III interior vapor retarder. The insulation materials used to satisfy this option also contribute to but do not supersede the thermal envelope requirements of the *International Energy Conservation Code*.

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SIMPLIFIED CODE-COMPLIANCE GUIDE

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

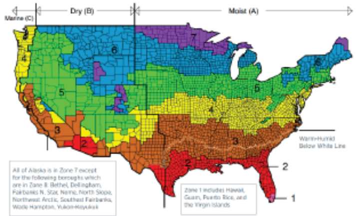
Use the following definitions for water vapor retarder classes when specifying interior vapor retarders in accordance with Steps 2 and 3:

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.

Content originally produced for continuousinsulation.org with support from ACC's Foam Sheathing Committee

https://www.continuousinsulation.org/resources/quick-guides

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WALL CALCULATOR

"Easy Button" to IECC/90.1 and IBC/IRC Coordinated Compliance

- Implements R-value and U-factor checks per IECC & 90.1 and also a moisture control check (including insulation and permeance ratio checks)
- Flexible, More Solutions than Code, More Precise
- Wood and steel framing

https://www.continuousinsulation.org

Wall Assembly Inputs

1. Building / Energy Code & Year

Energy code & year

IBC 2015 + IECC-C 2015 (Excluding group R)

2. Climate Zone and Heating Degree Days

Climate zone

5

Enter Heating Degree Days (HDD) if you want the minimum Insulation Ratio (Re/Ri) to be based on heating degree days, rather than strictly on the climate zone minimums. Values outside the range shown will be ignored. The heating degree days option is only available for some climate zones. HDD values are on a 65°F basis.

Optional Heating degree days (Valid range: 5401 - 7200)

3. Cladding

Cladding type and R-value

Stucco (0.08)

4. Exterior Continuous Insulation

Manufacturer's rated R-value at installed thickness

7.5

5. Exterior Sheathing

Output

Energy Code Thermal Check

U-Factor Method

Factor	Proposed Wall	Code Requirement	Compliance Check
U-factor of opaque wall assembly	0.060	0.064	✓ Passed

R-Value Method

Factor	Proposed Wall	Code Requirement	Compliance Check
*R-value of opaque wall assembly	R13+7.5ci	R13+7.5ci	✓ Passed

Building Code Water Vapor Control Check

	Insulation Ratio (Re/Ri) Method		
Interior Vapor Retarder Class[1]	Proposed Ratio	Minimium Ratio Required (Zone 5)	Pass/Fail
Class I[2]	0.58	0.30	✓ Passed
Class II[3]	0.58	0.30	✓ Passed
Class III[4]	0.58	0.45	✓ Passed
No Interior Vapor Retarder	0.58	1.40	✗

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2024 IBC SECTION 1403.2 – WATER-RESISTIVE BARRIER

1403.2 Water-resistive barrier. Not fewer than one layer of *water-resistive barrier* material shall be attached to the studs or sheathing, with flashing as described in Section 1404.4, in such a manner as to provide a continuous *water-resistive barrier* behind the exterior wall veneer. <u>The *water-resistive barrier* material shall be continuous to the top of walls and terminated at penetrations and building appendages in a manner to meet the requirements of the exterior wall envelope as described in Section 1402.2.</u> *Water-resistive barriers* 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. <u>Foam plastic insulating sheathing WRB systems complying with Section 1402.2 and installed in accordance with manufacturer's installation instructions.</u>
4. ASTM E331 in accordance with Section 1402.2, or
5. other approved materials installed in accordance with the manufacturer's installation instructions.

2024 IBC SECTION 1404.1 – FLASHING

- New provisions for fenestration flashing:

1404.4.1 Fenestration flashing. Flashing of the fenestration to wall assembly interface shall comply with the fenestration manufacturer's instructions or, for conditions not addressed by the fenestration manufacturer's instructions, shall comply with one of the following:

1. The water-resistive barrier manufacturer's flashing instructions;
2. The flashing manufacturer's flashing instructions;
3. A flashing design or method of a registered design professional; or
4. Other *approved* methods.

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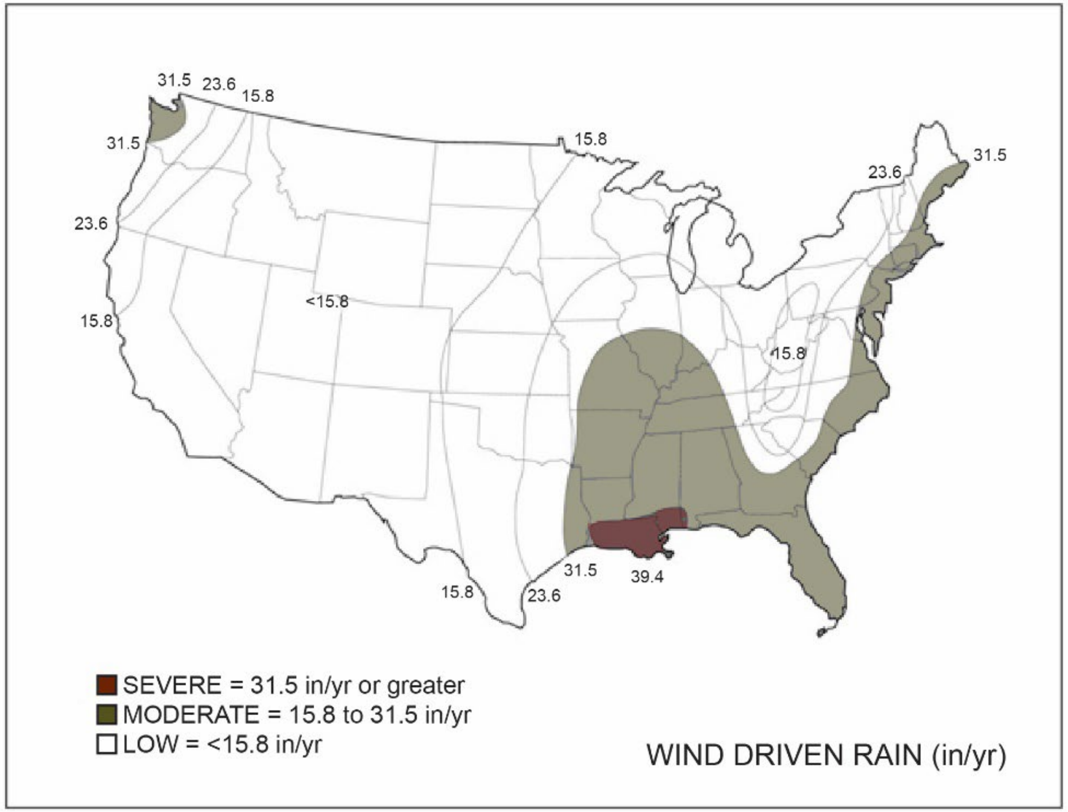
RAIN WATER CONTROL

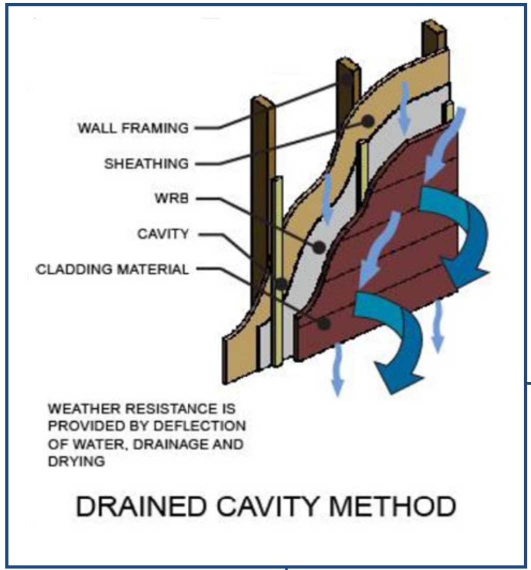
- Rain water control is often the primary factor associated with observed failure or success of moisture control.
- If rain water is not adequately controlled, other building science measures can be rendered ineffective.
- Concept is simple:
  Keep water out!

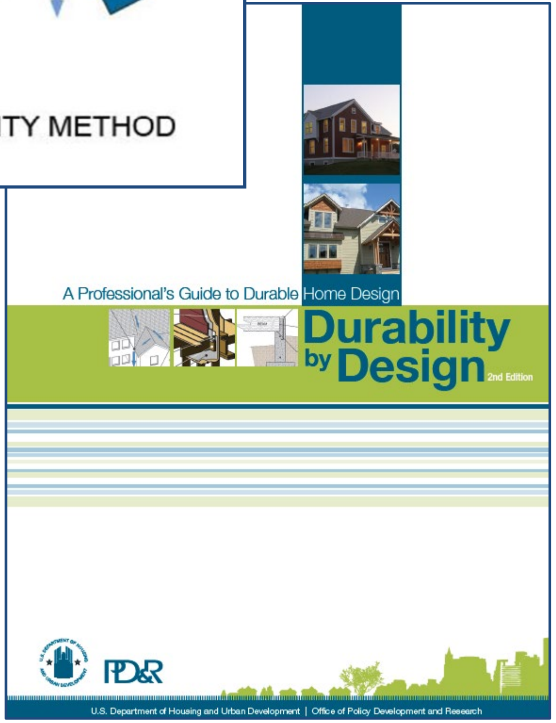


Wind driven rain is the primary hazard
(map based on UofGA research)

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 (http://www.huduser.gov/portal/publications/reports/Guide-Durability-by-Design.html)
- Variation in cladding material/method performance and variation in wind-driven rain hazard are not differentiated in the code.





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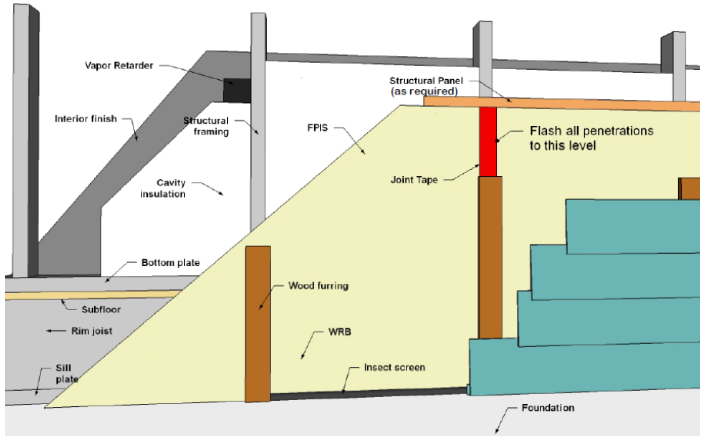
RAIN WATER CONTROL

- 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 additional information on code-compliant ci WRBs, refer to: https://www.continuousinsulation.org/applications/WRB
- Window flashing with pan flashing recommended (but not required by code)
  - WHY? Many windows/doors leak or will leak.
  - Refer to window manufacturer, WRB, and flashing manufacturer instructions
- Window flashing addressed more completely next…



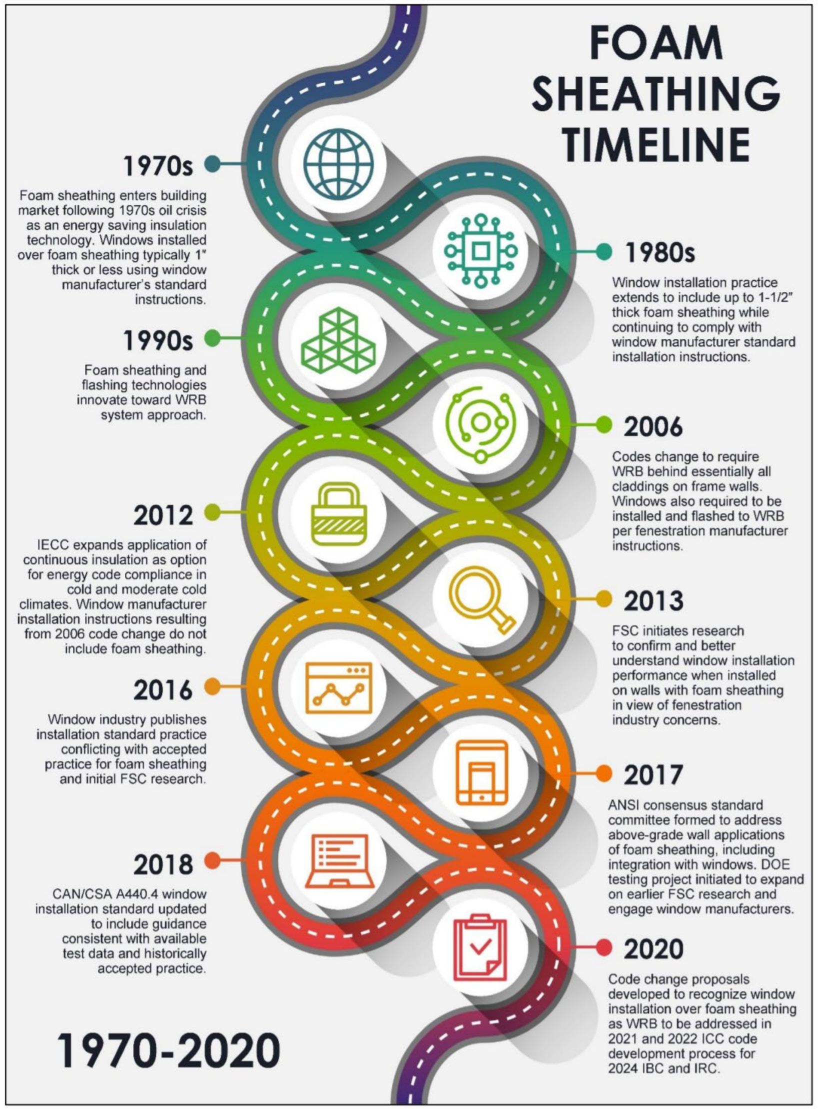
FENETRATION INSTALLATION & PERFORMANCE

- FPIS ci Timeline
- Field Installation Experience
- Installed Performance Testing Experience
- Recommended installation instructions

FPIS CI TIMELINE

- 1970s – FPIS ci introduced to market as energy conservation technology following 1970s oil crisis
- 1980s – installation over flanged fenestration progresses from 1” to 1-1/2” (window buck used for thicker foam)
- 1990s –FPIS ci WRB systems evolve
- 2006 – IRC & IBC codes change to require WRBs and require use of fenestration manufacturer instructions for flashing
- 2012 – IECC expands prescriptive R-value use of ci; few window installation instructions address foam sheathing (if any)
- 2013 – Present – Increased use of FPIS ci, but differing opinions and experience with how to integrate windows with FPIS ci, conflicting requirements, conflicting instructions, conflicting standards, etc.

➔ Research and testing conducted to resolve confusion
➔ Code changes initiated for appropriate requirements



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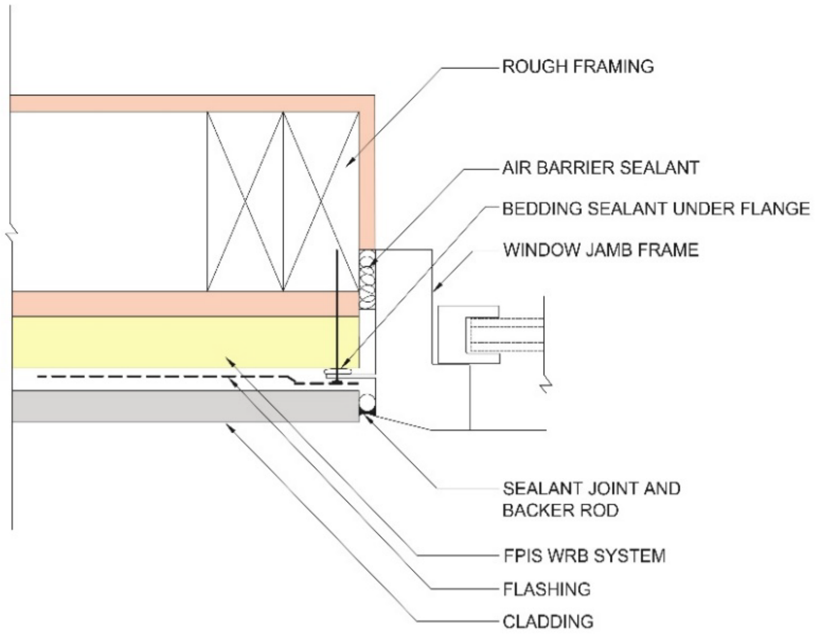
FIELD INSTALLATION EXPERIENCE

- Historically accepted practice (survey actual experience)
- Typical builder experienced with FPIS ci:

  "We have been installing vinyl double pane windows over 1-1/2" XPS foam with no OSB for over six years and before that over 1" foam for almost 30 years and have seen no issues with window movement."
- Other sources indicate similar experience
- Experience from Canada also imported to U.S.

MODERN EXAMPLES OF HISTORICALLY ACCEPTED PRACTICE

(≤ 1.5” FPIS ci)



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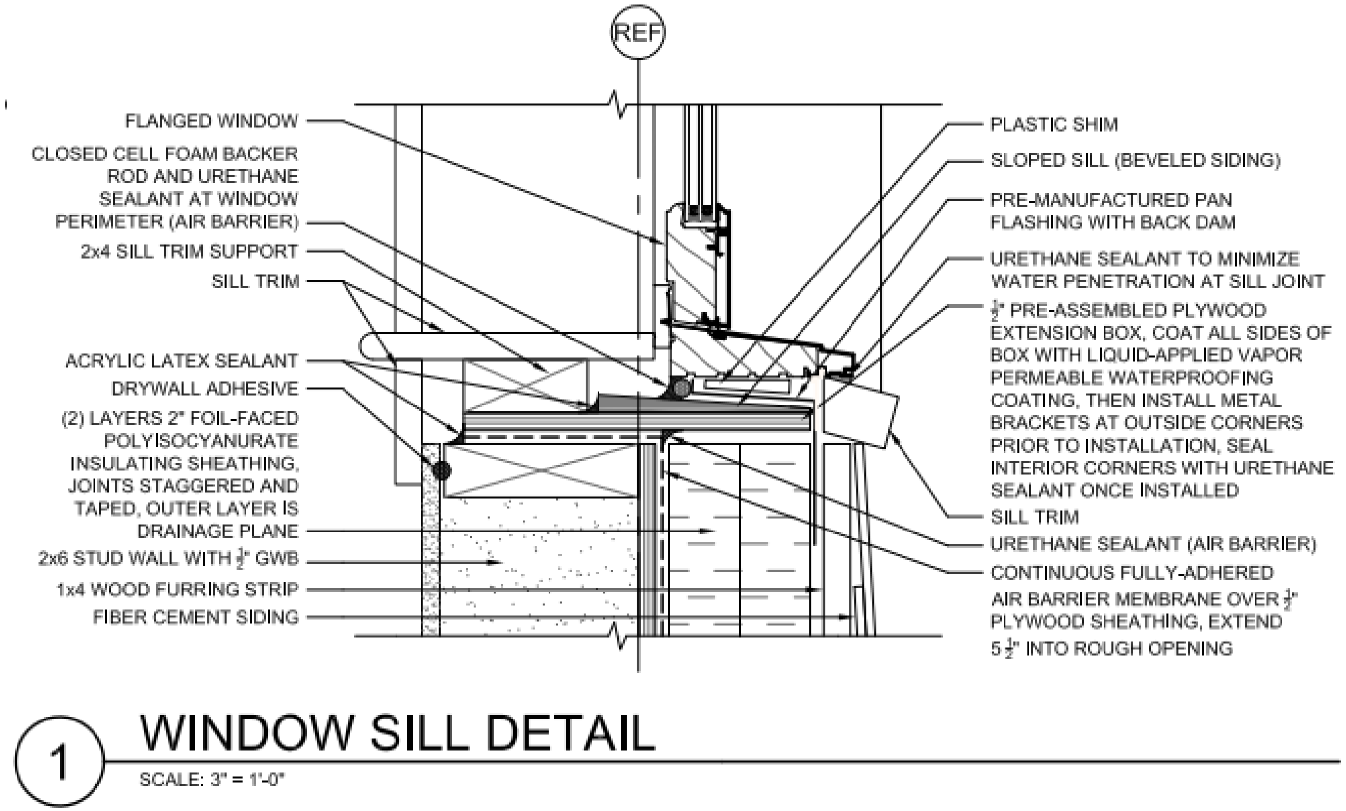
MODERN EXAMPLES OF HISTORICALLY ACCEPTED PRACTICE
(> 1.5" FPIS ci)

- Plywood window buck with 4"-thick FPIS ci



Source: www.nist.gov/system/files/nzertf-architectural-plans3-june2011.pdf

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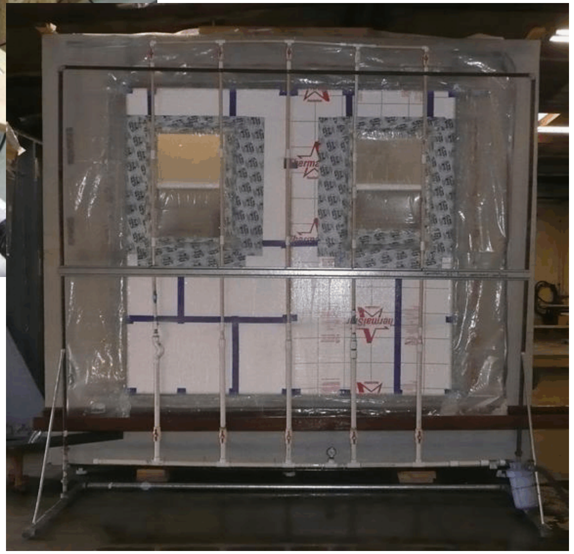
INSTALLED PERFORMANCE TESTING EXPERIENCE

- ~150 tests on ~30 wall assembly specimens by independent sources
- Four integrally-flanged window types (SH, DH, C, and HS)
- Two frame material types (vinyl and wood)
- Two installation configurations (single 1-wide, mulled 2-wide)
- Range of fenestration unit weights (~30 lbs to ~400 lbs)
- Rough opening sizes up to 6-feet
- Wall configurations with and without FPIS ci of three material types (XPS, EPS, and PIR), up to 2” thick, and 15 or 25 psi compressive resistance per ASTM C578 or ASTM C1289
- FPIS detailed to serve as WRB system and flashed per WRB manufacturer specifications

INSTALLED PERFORMANCE TESTING EXPERIENCE

- Test method generally followed AAMA TIR-504-2020:
  1. Initial air leakage resistance per ASTM E283
  2. Initial water resistance per ASTM E331
  3. Thermal cycling per ASTM E2264 Method A (level 1)
  4. Repeat air and water resistance testing (steps 1 and 2)
  5. Design pressure (DP) load test per ASTM E330
  6. Repeat water penetration test (step 2)
  7. Structural test pressure (STP) = 1.5 x DP load test per ASTM E330



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INSTALLED PERFORMANCE TESTING EXPERIENCE

- Performance criteria:
  - Report air leakage (Steps 1 and 4)
  - No water penetration (Steps 1, 4, and 6)
  - Design pressure (DP) – no damage that prevents normal operation
  - Structural test pressure (STP) – no damage that results in failure to sustain load; any operability impact reported.
- Several later tests were focused only on DP and STP testing as allowed by AAMA TIR-504-2020 to address specific questions regarding structural support and anchorage.
- Other tests to evaluate special loading conditions also conducted (shear load tests and long term creep/movement tests)

INSTALLED PERFORMANCE TESTING EXPERIENCE

- Water Penetration Resistance Tests
  - Tested per ASTM E331 using a 5.4psf pressure differential (just above 15% of the max 35 psf DP rated window unit used in testing).
  - Window units "masked" because not re-testing window unit rating itself
  - All used joint tapes and adhered flashing specified per the WRB manufacturer's instructions
  - None of the flanges used bedding sealant to the WRB surface (removed redundancy)
  - Sill pan flashing used (but without air sealing)
  - RESULTS: No water-penetration of assemblies with and without FPIS ci
    - As expected, some water movement onto sill pan behind unsealed bottom flange
    - Consequence of E331 testing without air sealing rough opening gap and flange providing only 1" lap down from surface of pan flashing

INSTALLED PERFORMANCE TESTING EXPERIENCE

- Uniform Pressure (Wind Load) Resistance
  - Tested per ASTM E330 at DP and STP = 1.5 x DP loading
    - Most tested to 1.58 x DP (conservatively above STP target)
  - Positive pressure then negative pressure tested
  - Two specimens ramped to failure (>> STP load)
  - Many window installation included weakening variances:
    - Flange bedding sealant omitted in all cases
    - Some flange fastener groups omitted
    - Air sealing of rough opening omitted
    - Some shims omitted (e.g., at head of HS window)
  - Tests also repeated without weakening variances

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INSTALLED PERFORMANCE TESTING EXPERIENCE

- Uniform Pressure (Wind Load) Resistance
  - **RESULTS:** No structural failures related to installation over foam sheathing when adhering to window manufacturer anchorage and support instructions (1” and 2” FPIS thickness, 15psi and 25 psi)
    - Some operability impacts observed with missing fastener groups (e.g., sash pin dislodge from brake/balance mechanism discovered after STP test level)
    - One structural failure related to missing shims (resulting in premature dislodging of sash from frame)
    - One structural failure caused by wood sash cross rail split out at end notch for sash bracket
    - As with any window installation with or without FPIS, following manufacturer shimming and flange fastener patterns (i.e., fastener groups) is important
    - Casement windows appeared most robust, double hung and horizontal slider appeared most sensitive to installation variances

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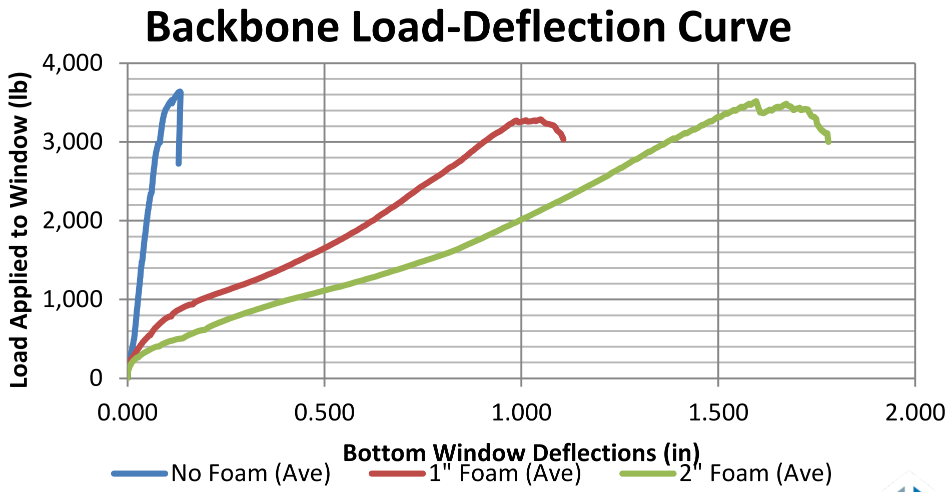
INSTALLED PERFORMANCE TESTING EXPERIENCE

- Sustained Dead Load & Creep Resistance
  - Evaluated movement of fenestration under sustained dead load (weight of fenestration unit)
  - Monitoring periods of 1 month to 6 months
  - Up to 2” thick foam (15 psi minimum)
  - Fenestration weights from 27lbs to 384 lbs
  - Included same installation weakening variances mentioned previously
  - RESULTS: Recorded movement of 0.000” to -0.032” (~1/32nd inch). Periods of upward movement also observed. No relationship to installation conditions discerned. All movement considered negligible or typical due to environmental changes (not creep).

PERFORMANCE TESTING EXPERIENCE

- Flange Fastener Shear Resistance
  - Test shear capacity and stiffness of flange fasteners through 1” and 2” thick FPIS (15 psi)
  - Windows installed with no shims and no bedding sealant so flange fasteners resist all shear load
  - RESULTS: Ultimate shear capacity changed little (~3,300 t0 3,600 lbs); stiffness was affected very predictably; foam sheathing added ductility while providing adequate stiffness for support of fenestration weight.



ABTG

PERFORMANCE TESTING EXPERIENCE

- Fenestration Size Effect on Installed Performance
  - Window size effect on DP rating permitted by code to be evaluated per AAMA 2502, Comparative Analysis Procedure
  - Comparative analysis by ASTM E330 testing of SH integral flange vinyl window as installed (positive pressure only):

Size	STP	DP	Safety Factor	Adjusted DP (min 1.5 safety factor)	Installation Notes*
42x66 (gateway)	37.5 psf	**25 psf**	1.5	n/a	Wood substrate + shims + ¼” r.o. gap
30x42	151 psf	25 psf	6.0	**80 psf**	Wood or up to 2” foam (15 psi) substrate, no shims, and 3/8” r.0. gap
30x42	118 psf	25 psf	4.7		

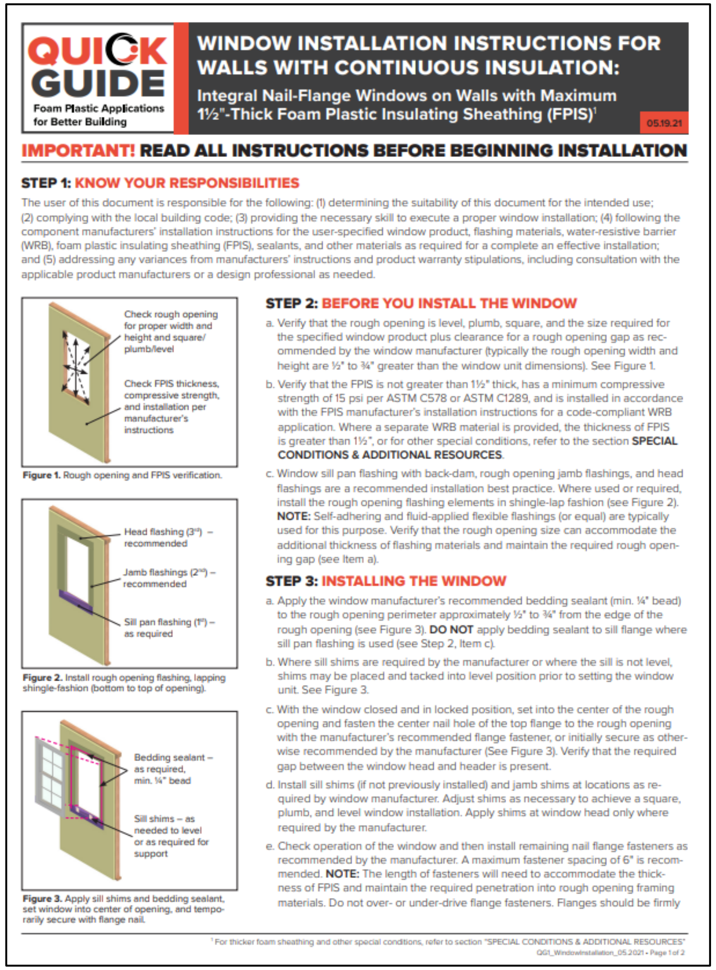
* Fasteners installed in every flange hole for all cases per manufacturer instructions

ABTG

RECOMMENDED INSTALLATION INSTRUCTIONS

- For FPIS of minimum 15 psi compression resistance and maximum 1.5” thickness:
  - Use fenestration manufacturer’s shim and fastener schedule
    - Adjust fastener length to maintain embedment in framing
  - Use WRB or window manufacturer flashing instructions
- For FPIS > 1.5” thick:
  - Use window buck or similar support method
    - Some manufacturer’s offer specialty support brackets
  - Otherwise, same as above for remaining installation details
- If window manufacturer’s instructions address the specific application with FPIS, use those instructions.

See Appendix B. For additional information, refer to:
https://www.continuousinsulation.org/applications/window-installation



QUICK GUIDE
Foam Plastic Applications for Better Building

WINDOW INSTALLATION INSTRUCTIONS FOR WALLS WITH CONTINUOUS INSULATION:

Integral Nail-Flange Windows on Walls with Maximum 1½"-Thick Foam Plastic Insulating Sheathing (FPIS)[1]

05.19.21

IMPORTANT! READ ALL INSTRUCTIONS BEFORE BEGINNING INSTALLATION

STEP 1: KNOW YOUR RESPONSIBILITIES

The user of this document is responsible for the following: (1) determining the suitability of this document for the intended use; (2) complying with the local building code; (3) providing the necessary skill to execute a proper window installation; (4) following the component manufacturers' installation instructions for the user-specified window product, flashing materials, water-resistive barrier (WRB), foam plastic insulating sheathing (FPIS), sealants, and other materials as required for a complete an effective installation; and (5) addressing any variances from manufacturers' instructions and product warranty stipulations, including consultation with the applicable product manufacturers or a design professional as needed.

Figure 1. Rough opening and FPIS verification.

Figure 2. Install rough opening flashing, lapping shingle-fashion (bottom to top of opening).

Figure 3. Apply sill shims and bedding sealant, set window into center of opening, and temporarily secure with flange nail.

STEP 2: BEFORE YOU INSTALL THE WINDOW

a. Verify that the rough opening is level, plumb, square, and the size required for the specified window product plus clearance for a rough opening gap as recommended by the window manufacturer (typically the rough opening width and height are ½" to ¾" greater than the window unit dimensions). See Figure 1.

b. Verify that the FPIS is not greater than 1½" thick, has a minimum compressive strength of 15 psi per ASTM C578 or ASTM C1289, and is installed in accordance with the FPIS manufacturer's installation instructions for a code-compliant WRB application. Where a separate WRB material is provided, the thickness of FPIS is greater than 1½", or for other special conditions, refer to the section **SPECIAL CONDITIONS & ADDITIONAL RESOURCES**.

c. Window sill pan flashing with back-dam, rough opening jamb flashings, and head flashings are a recommended installation best practice. Where used or required, install the rough opening flashing elements in shingle-lap fashion (see Figure 2). **NOTE:** Self-adhering and fluid-applied flexible flashings (or equal) are typically used for this purpose. Verify that the rough opening size can accommodate the additional thickness of flashing materials and maintain the required rough opening gap (see Item a).

STEP 3: INSTALLING THE WINDOW

a. Apply the window manufacturer's recommended bedding sealant (min. ¼" bead) to the rough opening perimeter approximately ½" to ¾" from the edge of the rough opening (see Figure 3). **DO NOT** apply bedding sealant to sill flange where sill pan flashing is used (see Step 2, Item c).

b. Where sill shims are required by the manufacturer or where the sill is not level, shims may be placed and tacked into level position prior to setting the window unit. See Figure 3.

c. With the window closed and in locked position, set into the center of the rough opening and fasten the center nail hole of the top flange to the rough opening with the manufacturer's recommended flange fastener, or initially secure as otherwise recommended by the manufacturer (See Figure 3). Verify that the required gap between the window head and header is present.

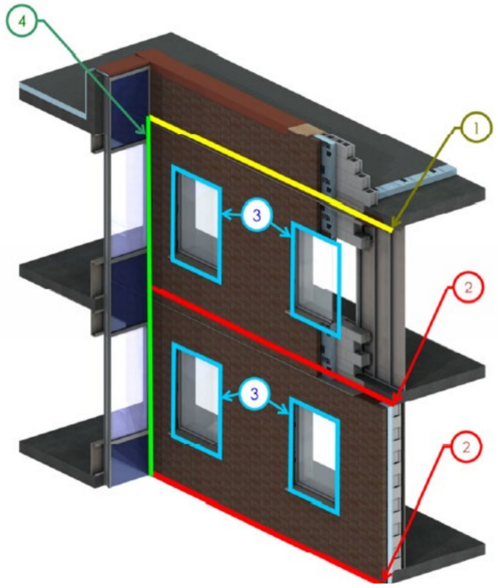
d. Install sill shims (if not previously installed) and jamb shims at locations as required by window manufacturer. Adjust shims as necessary to achieve a square, plumb, and level window installation. Apply shims at window head only where required by the manufacturer.

e. Check operation of the window and then install remaining nail flange fasteners as recommended by the manufacturer. A maximum fastener spacing of 6" is recommended. **NOTE:** The length of fasteners will need to accommodate the thickness of FPIS and maintain the required penetration into rough opening framing materials. Do not over- or under-drive flange fasteners. Flanges should be firmly

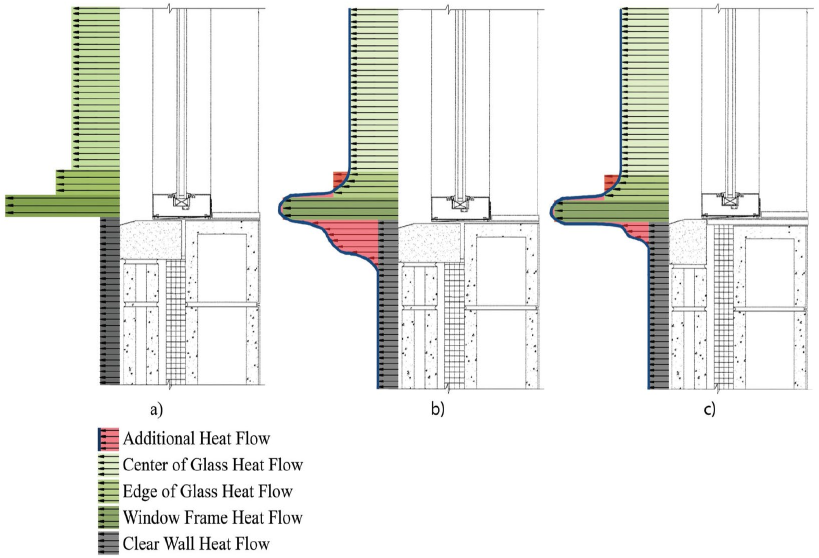
[1] For thicker foam sheathing and other special conditions, refer to section "SPECIAL CONDITIONS & ADDITIONAL RESOURCES"

THERMAL BRIDGING IMPACTS OF FENESTRATION INSTALLATION

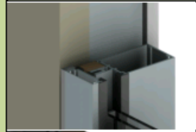
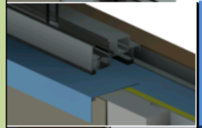
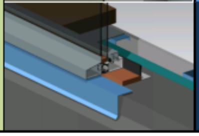
- Linear thermal bridge around window opening
  - Not accounted for in window component U-factor
  - Not accounted for in wall clear-field assembly U-factor



Source: Morrison-Hershfield (2020)



Source: Barnes et al. (2013)

GLAZING TRANSITIONS	Performance Category	Description and Examples	Linear Transmittance Btu/hr ft F	Linear Transmittance W/m K
	 Efficient	**Well aligned glazing without conductive bypasses** Examples: wall insulation is aligned with the glazing thermal break. Flashing does not bypass the thermal break.	0.12	0.2
	 Regular	**Misaligned glazing and minor conductive bypasses** Examples: wall insulation is not continuous to thermal break and framing bypasses the thermal insulation at glazing interface.	0.20	0.35
	 Poor	**Un-insulated and conductive bypasses** Examples: metal closures connected to structural framing. Un-insulated concrete opening (wall insulation ends at edge of opening).	0.29	0.5

Source: Morrison-Hershfield (2020)

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THERMAL BRIDGING IMPACTS OF FENESTRATION INSTALLATION

- CFS frame office building with 2o% WWR (punched openings) or 33% WWR (ribbon openings) results in 3,200 lnft of linear thermal bridge at window to wall interface
- Poor details can reduce overall wall effective R-value by half.
- Ignoring thermal bridges can overstate opaque wall performance by as much as 100%
- Using efficient thermal bridge mitigation details minimizes the impact.

TABLE 4
Comparison of "Poor" and "Efficient" Thermal Bridging Details at the Window-to-Wall Interface[1]

Thermal Bridge Condition		Clear-field Wall Thermal Performance (R13+7.5ci steel frame)[2]		Adjusted Wall Thermal Performance including Window-Wall Interface		Reduction in Wall Thermal Performance
Detailing Practice (Fig. 13)	Linear Thermal Transmittance (Psi-factor, Btu/hr-ft-F)	U-factor (Btu/hr-ft^2-F)	Effective R-value (1/U)	U-factor (Btu/hr-ft^2-F)	Effective R-value (1/U)	
"Poor"	0.3	0.064	R-15.6	0.134	R-7.5	52%
"Efficient"	0.1	0.064	R-15.6	0.088	R-11.4	27%

TABLE NOTES:
1. Table is based on a typical 3-story office building (168'x109') with 21,400 sf of gross above-grade wall area of cold-formed steel frame construction having R13 cavity insulation and R-7.5 continuous insulation on the exterior (i.e., R13+7.5ci wall per code as typical for moderate climate zones). The window-to-wall area ratio is assumed to be 33% for ribbon windows or 20% for punched window openings resulting in a total of about 3,200 ft of window perimeter interface with the wall assembly.
2. As a point of reference, a similar wall without the R7.5ci and having only R13 cavity insulation would have a U-factor of 0.125 Btu/hr-ft^2-F (effective R-value of 8) because in that case the steel frame thermal bridging in the clear-field of the assembly and at the fenestration perimeter would not be mitigated.

WIND-DRIVEN RAIN RESEARCH

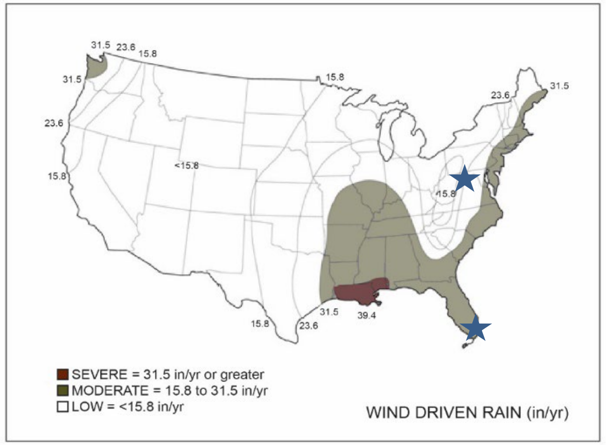
- U.S. does not have a wind-driven rain hazard map to establish performance criteria for building enclosures
- Wind-driven rain hazard must correlate annual extreme wind speed at a given coincidental rainfall rate considered as a threshold for concern with generating a leak
- Wind-driven rain resistance test criteria must then correlate static or cyclic (non-spatially dynamic) test methods like ASTM E331 to observed performance in real wind flow and rain conditions
- A wind-driven rain hazard map is the first critical step

WIND-DRIVEN RAIN RESEARCH

- The implications vary by climate based on coincidental wind speed and rainfall rate, frequency/duration, site exposure, and consequences of water leakage or intrusion.
- Ultimately, the selected hazard level and performance criteria for design and product evaluation must align with past successful practice, discriminate against unacceptable practice, and consider consequence of different types of leaks.

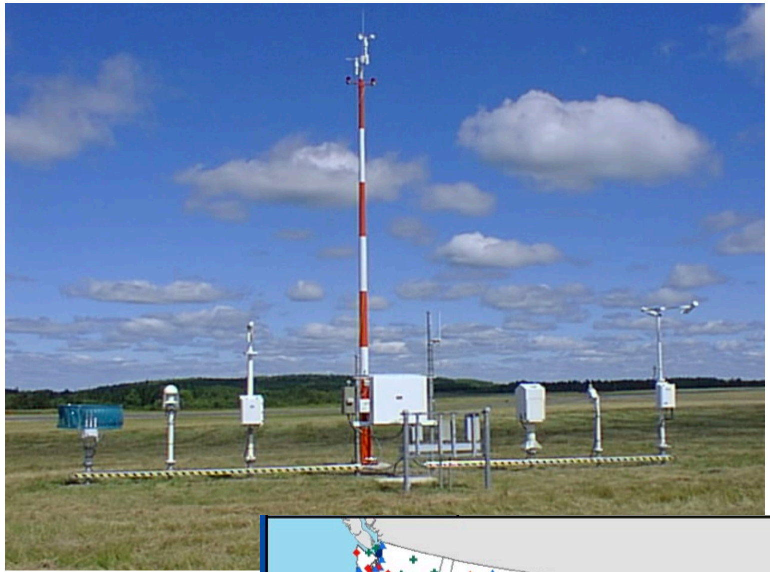
Extreme Wind-Driven Rain Hazard (Tropical) – Hurricane Andrew, 1992 (~600 yr MRI wind event); Contents Damage in South Florida

South Florida vs. Virginia



Typical Wind-Driven Rain Hazard Exposure (non-tropical, t-storms, etc.); 35-year old building; only minor water staining below window with no WRB, flashing, or bedding sealant

WIND-DRIVEN RAIN RESEARCH



Every 5 minutes

- 2- minute average wind
- Max 5-sec gust
- 5-minute rainfall accumulation

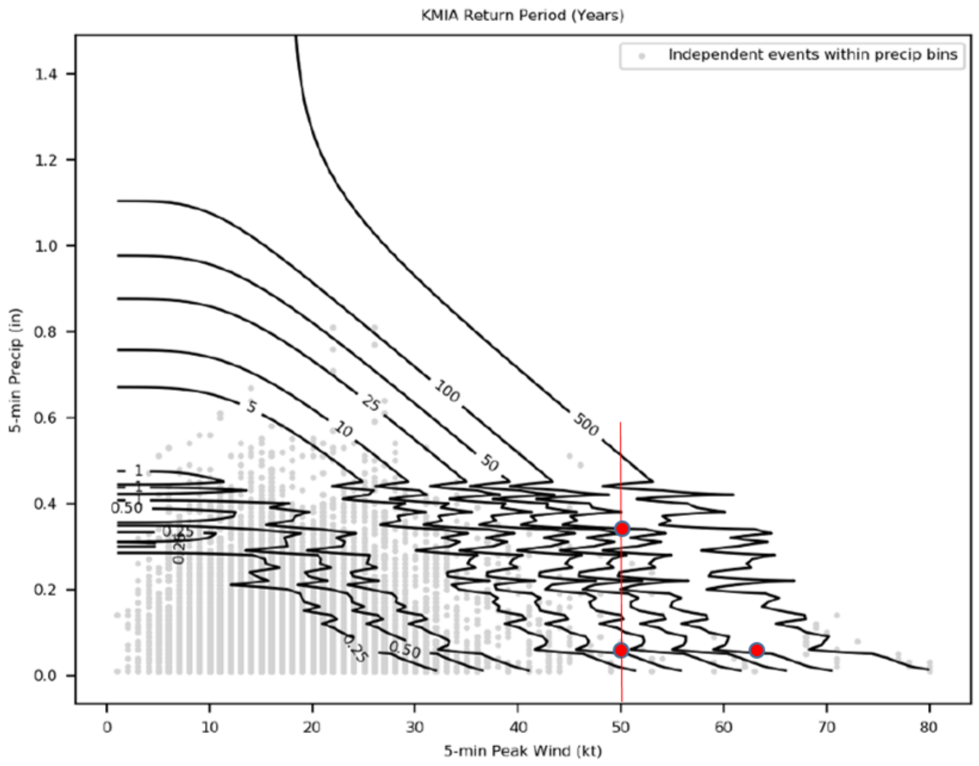
Every 1-minute

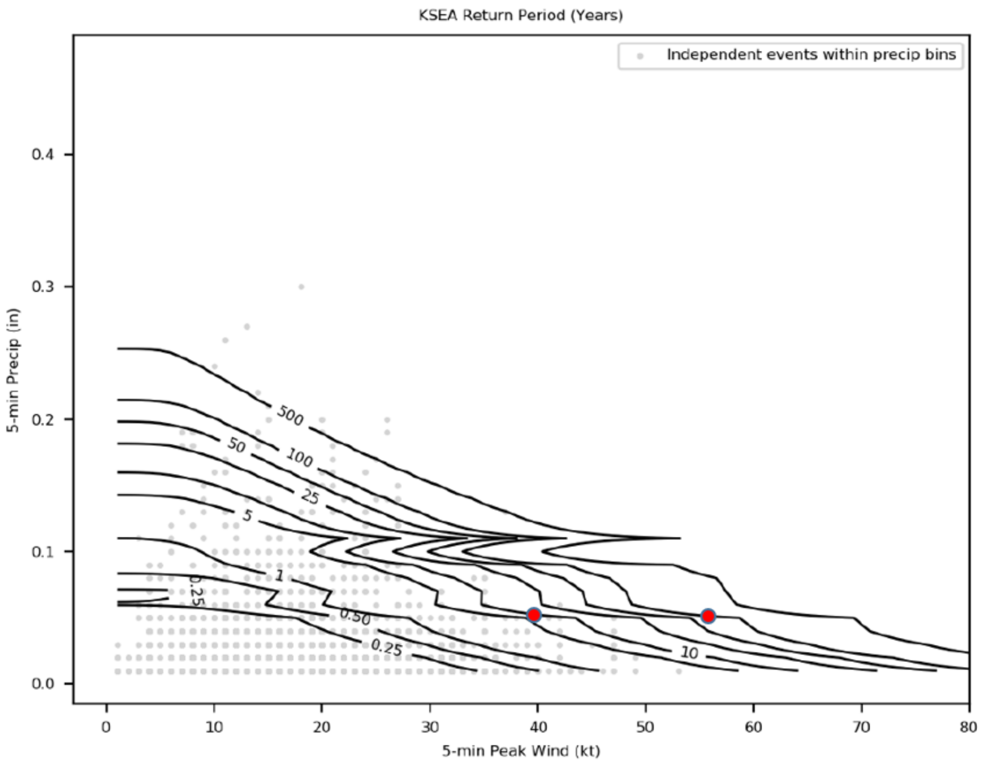
- 2- minute average wind
- max 5-sec wind
- 1- minute rainfall accumulation

11 MILLION observations/ station for 20 year record!

WIND-DRIVEN RAIN RESEARCH

- Preliminary Findings (Pilot Study funded by IBHS at Cornell U. / NOAA Northeast Region Climate Data Center):





Miami, FL vs. Seattle, WA

CONCLUSION

- Insulation requirements continue to advance
- Building codes continue to improve moisture control
- Energy code and building code better coordinated
- Fenestration installation practices evaluated & confirmed for use with FPIS ci (with appropriate limitations)
- Minimizing thermal bridging at window-wall interface is increasingly important
- New wind-driven rain research holds promise to better coordinate risk-consistent enclosure design and product evaluation for variation in U.S. climate hazard.

QUESTIONS?

Jay Crandell

www.aresconsulting.biz

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