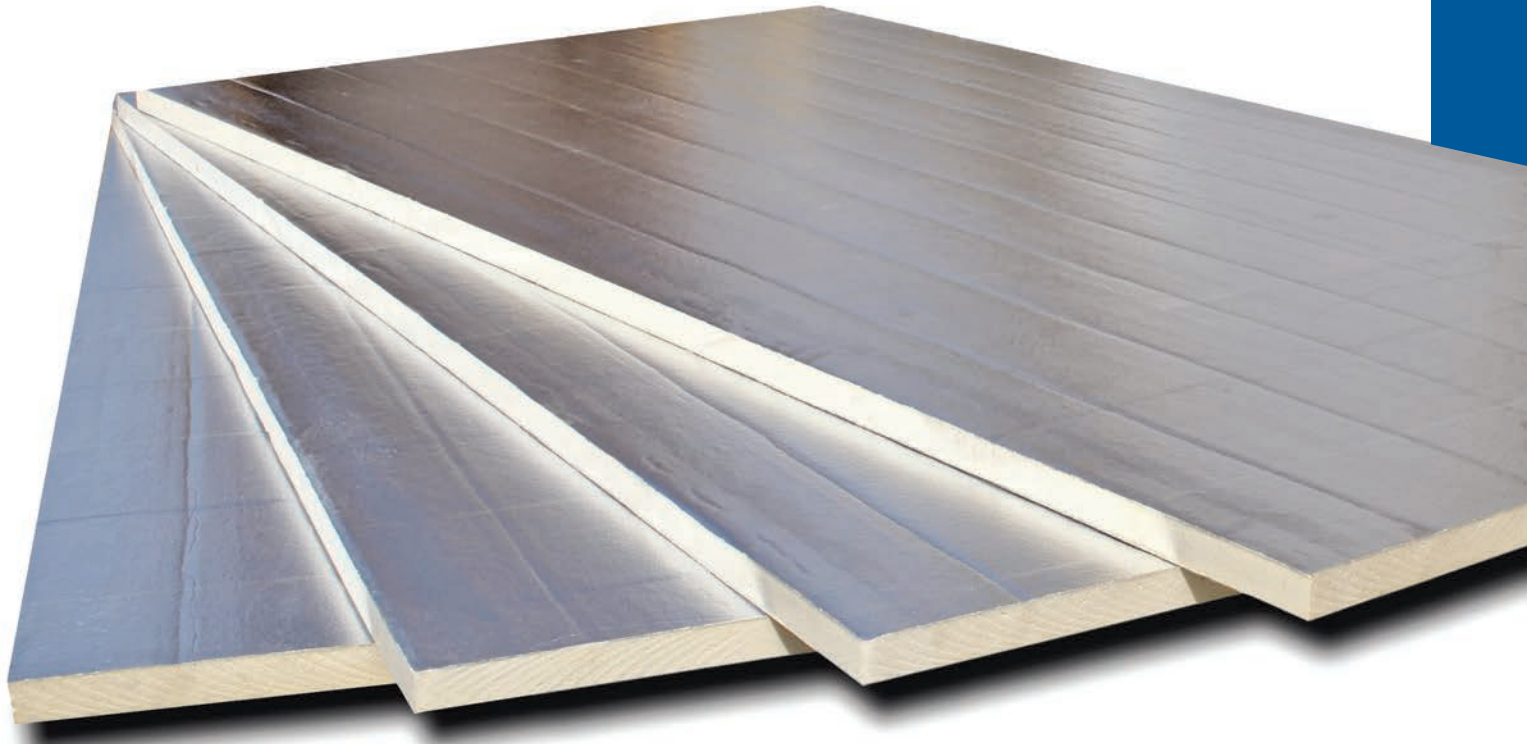


# THE “PERFECT WALL” IN COLD CLIMATES:

## *Solutions with Polyiso CI*

By Timothy Ahrenholz



*Figure 1 – Polyiso insulation with foil facer.*

### **ABSTRACT**

Have you ever viewed certain building code provisions as impediments to an optimum design solution? You likely answered “yes” if you’ve tried to address moisture control for walls in cold climates.

One solution to this difficulty is implementing the so-called “perfect wall” approach as described by Joseph Lstiburek.<sup>1</sup> A recent study<sup>2</sup> from the Applied Building Technology Group (ABTG) confirmed that the “perfect wall” for both energy and moisture vapor performance uses foam insulation on the exterior of the wall studs with no vapor retarder on the interior of the studs. Currently, neither the U.S. code nor the Canadian code completely allows the “perfect wall” approach.

This article will explain the “perfect wall” concept and how the U.S. and Canadian code requirements together put this solution within reach.

### **THE “PERFECT WALL”**

Before jumping straight to the perfect wall, let’s talk about walls in general. What do walls do? Primarily, along with floors and roofs, they are there to keep us comfortable when it isn’t that pleasant outside by separating the interior from the exterior environment. In this role, they: 1) keep out water, 2) restrict air from moving through the assembly, 3) control the movement of water vapor, and 4) restrict the conductance of energy or heat through the building envelope. Today, there are many types of

building materials designed for one or more of these tasks. And with so many choices, there are an even larger number of possible ways to assemble them into a wall. Many of these configurations don’t work very well. We’re going to discuss one that does: the so-called perfect wall.

In the perfect wall, all the control layers (thermal insulation, air barrier, water-resistive barrier, and vapor barrier) are located on the exterior side of the framing, just inside of the cladding. With all these layers in the same place, it would be nice if they could be combined. They can. Polyisocyanurate (or simply “polyiso”) is a type of rigid foam insulation that, when properly installed, can fulfill the role of thermal barrier, air barrier, vapor retarder, and

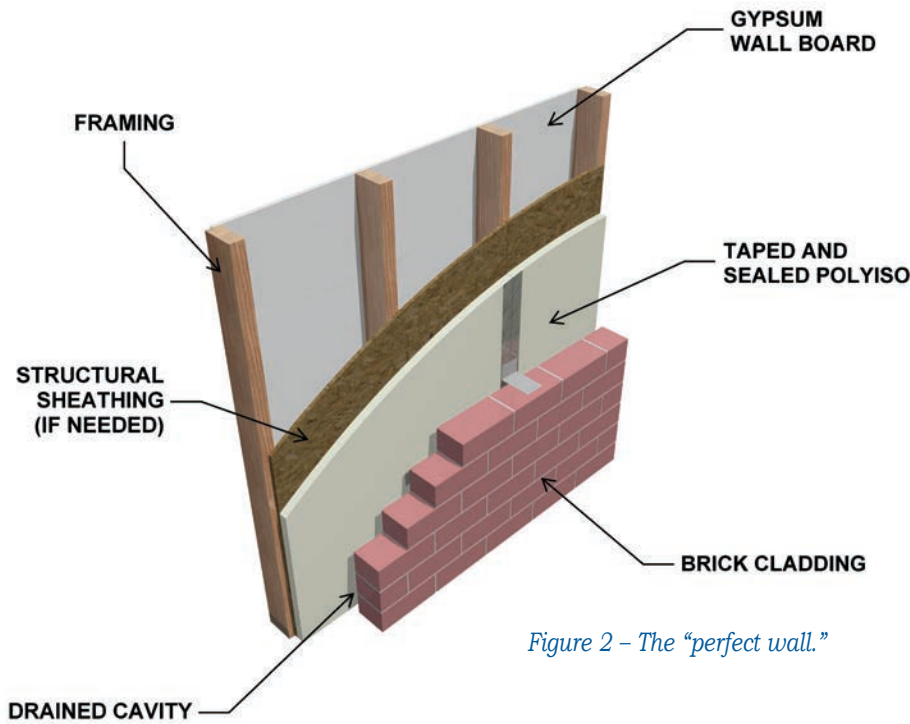


Figure 2 - The "perfect wall."

water-resistive barrier. Proper installation in this case requires that all joints between adjacent polyiso boards are sealed with an approved joint tape, and that the polyiso is integrated into window flashing (refer to the manufacturer's approved installation details for water-resistive barrier applications). Polyiso is sold as boards of thicknesses at half-inch intervals. Most polyiso used in wall applications has a foil facer on it (Figure 1), which helps it perform well in the air, vapor, and water-resistive barrier

roles. Polyiso without a foil facer needs to be augmented with a dedicated vapor barrier to ensure a low permeability, and this control layer should be placed on the interior side of the polyiso in cold climates or the exterior side in hot/humid climates.

Figure 2 shows a representation of the perfect wall constructed with foil-faced polyiso that combines each of the control layers in one product. Additionally, multiple cladding options are available (in addition to the brick pictured) if the cladding is properly drained.

## HOW IT WORKS

Let's take a closer look at the "perfect wall" and how it behaves in different climates and seasons.

The first thing that might look different about this wall is the lack of cavity insulation. Traditionally, the thermal insulation for a wall is installed in the cavities between framing members. But that approach allows heat to flow through the "thermal bridge" caused by the framing members, and leaves those framing members exposed to exterior temperature changes, sometimes referred to as thermal cycling. It is a much better idea to use a layer of continuous insulation (CI) on the exterior side of the studs, reducing thermal bridging and keeping the structure close to the same temperature as the interior all year long. It is common to see both CI and cavity insulation used on the same assembly. Adding CI to cavity insulation (Figure 3) can increase the temperature within the wall, leading to a lessened risk of condensation. When enough CI is used independent of any other insulation, the materials on the interior of the CI can be maintained at the same temperature as the interior environment.

In general, there are two approaches to moisture control in a wall: the permeance focus and the temperature focus. The permeance-focused approach aims to make sure the wall can dry to the exterior in cold climates, with a low-permeability vapor retarder on the warm (interior) side of the wall to prevent too much water vapor flow

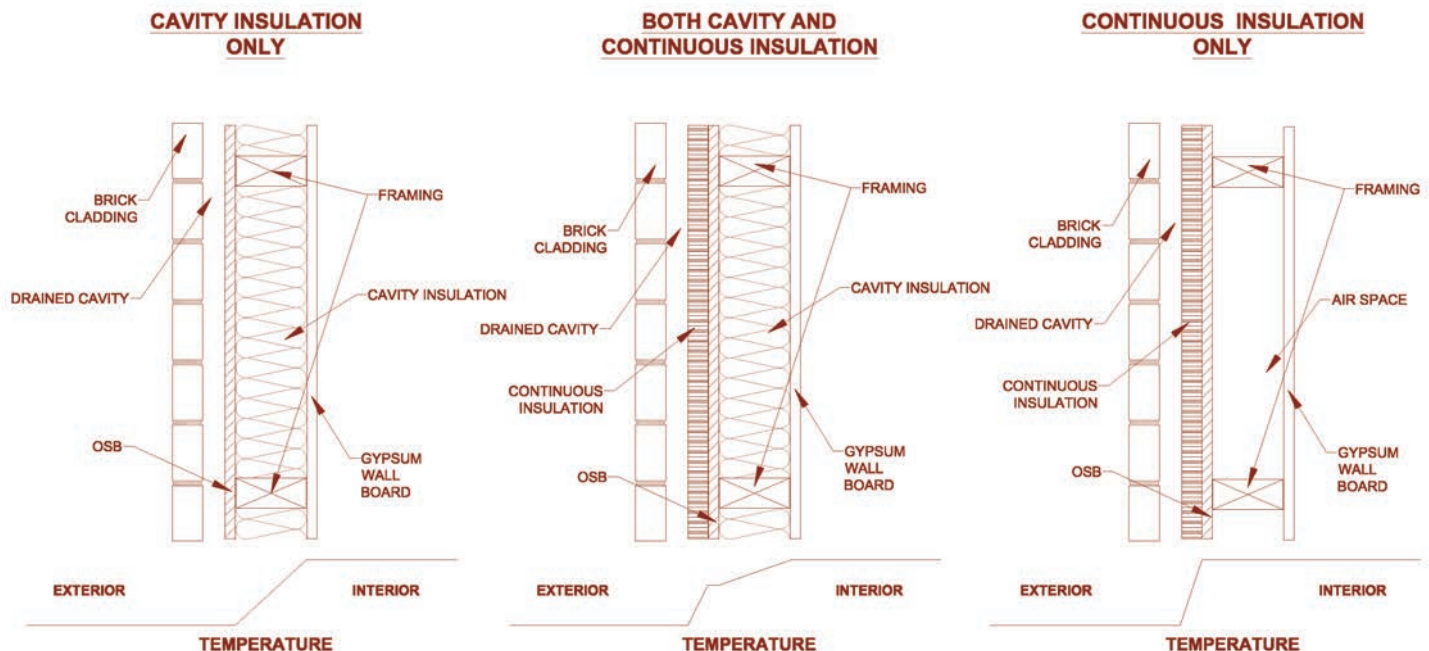


Figure 3 - Temperature gradients for three walls.

and moisture buildup during the winter. However, this approach to drying during the winter can cause increased moisture buildup in the summer. Conversely, in a hot and humid climate, the vapor retarder (if any) is better located on the outside of the wall. While this system does work, it is complicated to implement and somewhat unreliable because it requires that vapor permeance be known (reported and controlled) for all materials in the assembly, not just the vapor retarder. Different strategies apply to different climate zones, and a workable solution can be difficult in marine climates or climates with a lot of variation between the summer and winter temperatures. Sometimes, the permeance focus may require use of a rainscreen or back-ventilated cladding installations to help the wall system work, which adds another complication and cost. The left side of *Figure 4* demonstrates the logic of this approach.

The second approach is focused on temperature control and in many ways is more elegant and easier to implement. The wall is provided with enough exterior insulation to keep the structural elements warm and prevent moisture accumulation in materials or condensation on cold surfaces within an assembly. A moderate vapor retarder (or “smart” vapor retarder like Kraft paper) on the interior of the wall allows drying to the inside. However, an interior vapor retarder is not even necessary in the “perfect wall,” and eliminating the vapor barrier further increases drying potential to the interior, while also reducing the need for drying potential (*Figure 4*, right side).

## DESIGN

When designing a perfect wall with polyiso, the first step is to determine how much polyiso insulation is required for the location. This can be done by consulting the local energy code or using the wall calculator that the Applied Building Technology Group (ABTG) has developed.<sup>3</sup> After finding the required CI R-value, convert this to the thickness of polyiso needed. The R-value per inch of polyiso increases with the thickness of the foam, so three inches of foil-faced polyiso has a higher R-value per inch than two inches. The R-value per inch of foil-faced polyiso ranges from 6.0 to 6.8 (long-term thermal resistance varies from 5.7 to 5.9 per inch). Thicker exterior insulation (or more exterior insulation relative to any amount of CI used) also provides great-

er moisture control. The rest of the design stays the same for every climate zone.

In warm climates or during hot summers, foil-faced polyiso on the exterior acts as a water, air, and vapor retarder, preventing moisture from getting inside and condensing on the cool interior surface of the foam or behind interior finishes. In cold climates, during the winter, the polyiso keeps the interior of the wall warm, preventing condensation or high humidity conditions within the assembly that can support mold growth. With a high-perm vapor retarder or no vapor

retarder on the interior side of the wall, any incidental water that may enter the assembly is able to readily dry to the interior.

Controlling indoor relative humidity (RH) to acceptable levels is important for any wall assembly, especially those without exterior insulation. With exterior insulation, additional amounts can be added to address elevated levels of indoor RH that may be typical with sauna rooms or pool rooms. However, even in this case, a vapor control layer is needed and, as discussed earlier, this can be provided by the polyiso (foil-

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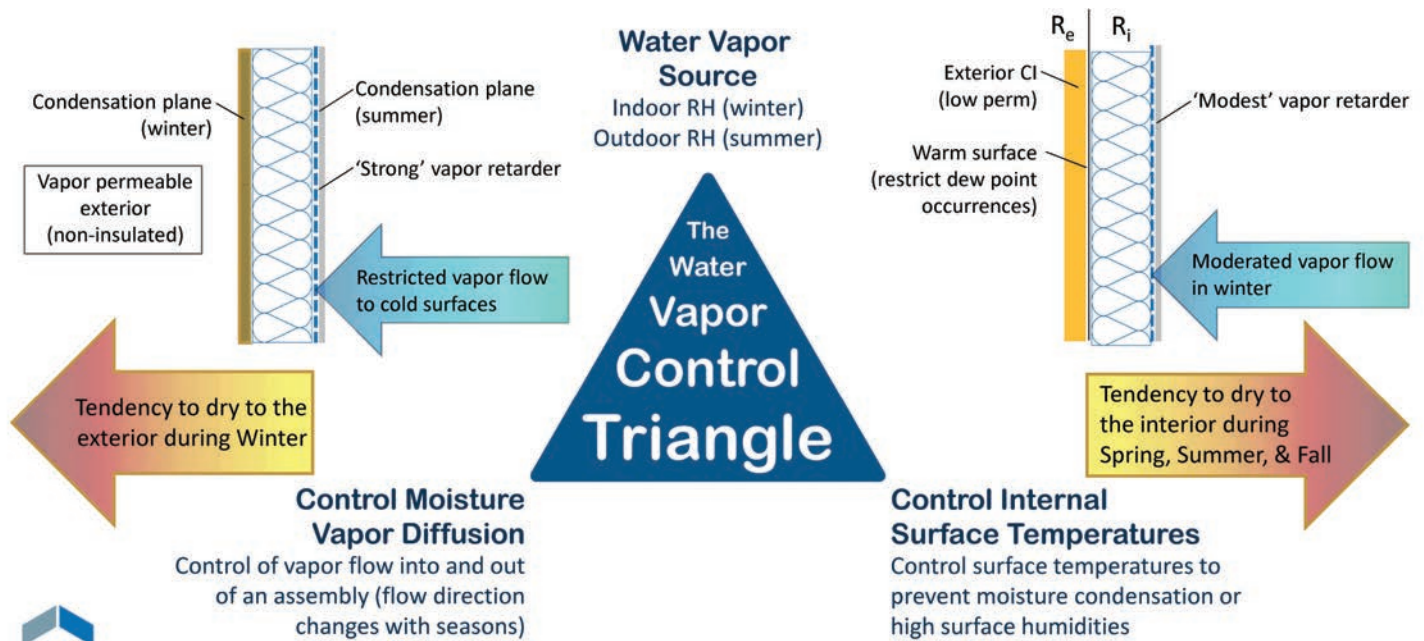


Figure 4 – Two water vapor control strategies.

faced) or a separate vapor control layer on the exterior of the assembly.

**CODE COMPLIANCE**

As mentioned earlier, the applicable building or energy code must be consulted to determine how much insulation is required. None of the I-codes list any prescriptive solutions that rely on CI alone.

Instead, the codes provide various equation- and table-based methods for determining the assembly U-factor of a specific wall.

The 2015 International Residential Code (IRC) specifies a maximum assembly U-factor for wood frame walls in each climate zone. This U-factor can be hand-calculated using the parallel-path method detailed in ASHRAE 90.1. The 2015

International Building Code (IBC) references the International Energy Conservation Code (IECC), which specifies maximum assembly U-factors for both steel-framed walls and wood-framed walls.

Alternatively, the ABTG has developed the previously mentioned online calculator tool that can be used to determine the code compliance of thermal insulation and moisture control for wood-framed walls, with a steel version to be added within the next year.

Regarding moisture control, the IRC requires class I or class II vapor retarders on the inside wall surface in colder climate zones, except for walls that have a certain amount of CI (Figure 5).

Because a “perfect wall” uses CI exclusively, using a class III vapor retarder on the interior of the wall is permissible and allows for the best drying potential. Class I and class II vapor retarders can also be

IRC Interior Vapor Retarder Provisions						
Climate Zone	1, 2, 3, 4	Marine 4	5	6	7	8
Class I		Y	Y	Y	Y	Y
Class II		Y	Y	Y	Y	Y
Class III (2x4 wall)		ci ≥ 2.5	ci ≥ 5	ci ≥ 7.5	ci ≥ 10	ci ≥ 10
Class III (2x6 wall)		ci ≥ 3.75	ci ≥ 7.5	ci ≥ 11.25	ci ≥ 15	ci ≥ 15

Figure 5 – IRC guidance on vapor retarders.

**CONTINUOUS INSULATION REQUIREMENTS FOR INTERIOR VAPOR RETARDER CLASSES**

CLIMATE ZONE	Interior Vapor Retarder Class			
	Class I	Class II	Class III	No interior VR
1-2	Not Permitted	Not Permitted	Continuous insulation with R-value ≥2	Continuous insulation with R-value ≥2
3	Not Permitted	Continuous insulation with R-value ≥2	Continuous insulation with R-value ≥2	Continuous insulation with R-value ≥2
4	Not Permitted	Continuous insulation with R-value ≥2	Continuous insulation with R-value ≥2.5 (2x4) Continuous insulation with R-value ≥3.75 (2x6)	Continuous insulation with R-value ≥4.5
5	Continuous insulation with R-value ≥3 (2x4) Continuous insulation with R-value ≥5 (2x6)		Continuous insulation with R-value ≥5 (2x4)	Continuous insulation with R-value ≥6.5
6			Continuous insulation with R-value ≥7.5 (2x6)	Continuous insulation with R-value ≥8.5
7	Continuous insulation with R-value ≥5 (2x4) Continuous insulation with R-value ≥7.5 (2x6)		Continuous insulation with R-value ≥7.5 (2x4)	Continuous insulation with R-value ≥11.5
8			Continuous insulation with R-value ≥11.25 (2x6)	Continuous insulation with R-value ≥11.5
	Continuous insulation with R-value ≥7.5 (2x4) Continuous insulation with R-value ≥10 (2x6)		Continuous insulation with R-value ≥10 (2x4)	Continuous insulation with R-value ≥11.5
			Continuous insulation with R-value ≥15 (2x6)	Continuous insulation with R-value ≥11.5
	Continuous insulation with R-value ≥7.5 (2x4) Continuous insulation with R-value ≥10 (2x6)		Continuous insulation with R-value ≥12.5 (2x4)	Continuous insulation with R-value ≥14
			Continuous insulation with R-value ≥20 (2x6)	Continuous insulation with R-value ≥14

Figure 6 – Guidelines for using vapor retarders with continuous insulation.

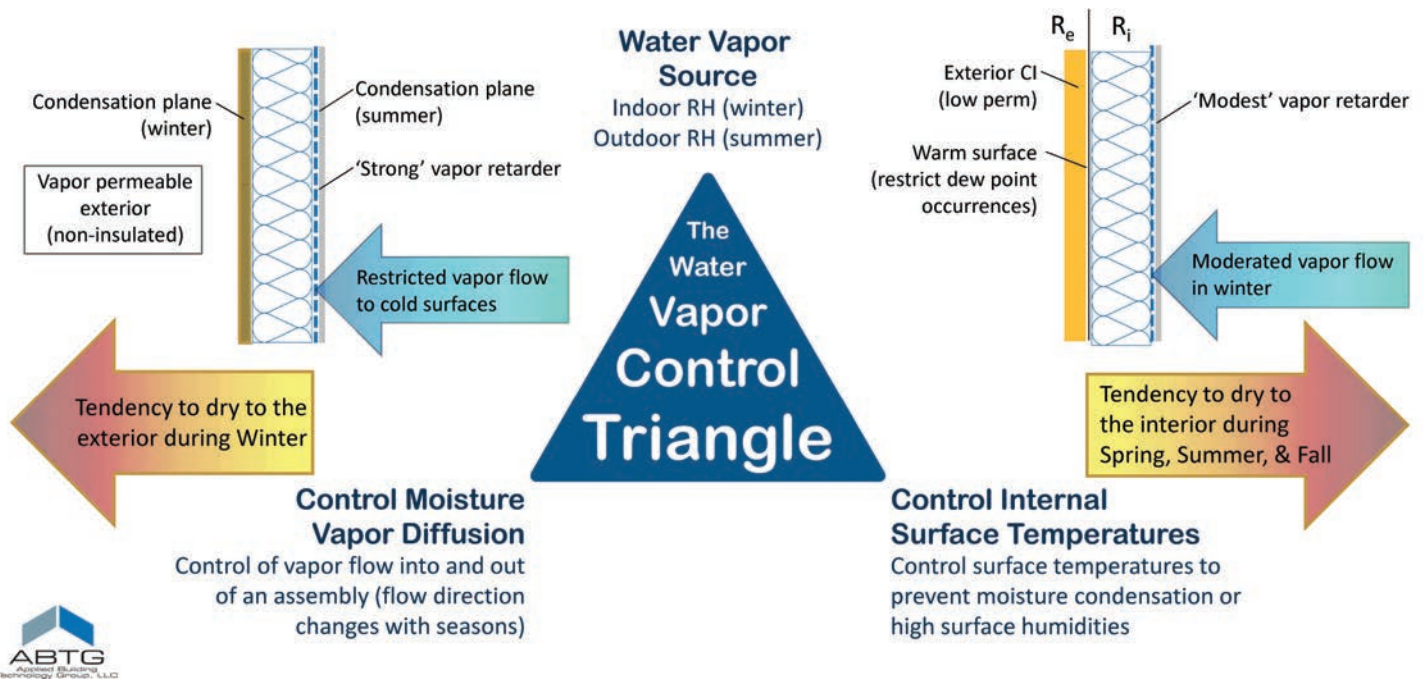


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Figure 6 – Guidelines for using vapor retarders with continuous insulation.

### Wall Assembly Inputs

1. Building / Energy Code & Year  
 Building code & year: International Residential Code / IECC-R (2015)

2. Climate Zone and Heating Degree Days  
 Climate zone: 6

3. Exterior Continuous Insulation  
 Manufacturer's rated R-value at installed thickness: 18

4. Cavity Insulation  
 Manufacturer's rated R-value at installed thickness: 1

5. Cladding  
 Manufacturer's rated R-value: 0.5

6. Exterior Sheathing  
 Exterior Structural Sheathing: OSB 5/8" (0.45)

7. Stud & Framing Factor  
 Stud Size: Wood 2x4  
 Framing Factor: 16" studs: 25%

8. Interior Finish  
 Interior Finish: Gypsum 1/2" (0.45)

### Output

#### Energy Code Thermal Check

Factor	Proposed Wall	Code Requirement	Compliance Check
Effective R-value <sup>1</sup> for the opaque assembly	22.222	22.222	✓ Passed
U-factor of opaque wall assembly	0.045	0.045	✓ Passed

#### R-Value Method

Factor	Proposed Wall	Code Requirement	Compliance Check
R-value for wall assembly <sup>2</sup>	R1+18.0	R20+5.0 or R13+10.0	✗

<sup>1</sup> Based on U-Factor Method  
<sup>2</sup> Based on R-Value Method

#### Building Code Water Vapor Control Check

Interior Vapor Retarder Class <sup>1</sup>	Option One Insulation Ratio (R <sub>e</sub> /R <sub>i</sub> ) Method		Pass/Fail
	Proposed	Minimum Required (Zone 4)	
Class I <sup>2</sup>	18.00	0.2	✓ Passed
Class II <sup>3</sup>	18.00	0.2	✓ Passed
Class III <sup>4</sup>	18.00	0.5	✓ Passed

Figure 7 – Applied Building Technology Group wall calculator sample input and output.

used with success when care is taken to avoid trapping moisture on the interior side of the wall. More guidance in this regard can be found in the ABTG research report referenced earlier in the article. In the warmer climate zones (zones 1-3), no vapor retarder is required on the interior.

### SUMMARY

The “perfect wall” is a simple wall that performs well in all climate zones. It consists of a taped, flashed, and sealed layer of polyiso foam installed on the exterior of wall framing behind drained cladding. No cavity insulation or interior vapor retarder is required. The taped insulation serves as the

retarder in each climate zone. The last column represents the “perfect wall” with no interior vapor retarder installed. The other columns explain the proper ways that class I, II, and III vapor retarders can be used on the interior of a wall assembly with CI.

In addition, ABTG has developed the online calculator tool mentioned earlier, which can be used to check whether a certain wall is code-compliant in a specific climate zone for thermal performance and moisture control requirements. This calculator can be used to design the “perfect wall” in any climate zone without the need to look up specific thermal requirements in the code. Currently, the calculator only

water-resistive barrier (where approved for this application), the air barrier, and the vapor barrier, when care is taken to ensure that these barriers are properly taped and sealed—especially around penetrations. The only design decision involves determining the minimum thickness of polyiso needed.

Alternatives to the “perfect wall” design that is described in this article are possible and may present advantages for a specific project. Figure 6 presents guidance for integrating CI with an interior vapor

accepts wood framing as an input, but a steel framing option will be added within the next year. Supported building codes include both the 2015 IRC and 2015 IBC (group R buildings and others). Figure 7 presents a sample calculator input and output for a “perfect wall” in climate zone 6.

### REFERENCES

1. “BSI-001: The Perfect Wall.” Available at: <https://buildingscience.com/documents/insights/bsi-001-the-perfect-wall>.
2. “Assessment of Water Vapor Control Methods for Modern Insulated Light-Frame Wall Assemblies.” Available at: <http://www.appliedbuildingtech.com/rr/1410-03>.
3. Wall Calculator for R-values and U-factors Including Checks for Moisture Control. Available at: <http://www.appliedbuildingtech.com/fsc/calculator>.



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Timothy Ahrenholz is a special projects engineer with the Applied Building Technology Group. In this role, he works to develop design solutions for foam sheathing products, and has been involved with standards development and code change proposals for the I-codes and the National Building Code of Canada. He holds a master’s degree in civil engineering with a structural focus from the University of Illinois, and bachelor’s degrees in physics and mathematics from Covenant College.

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