Successful Vapor Control

Vapor drive isn't as obvious as air or water leaks, but the potential for mold and rot is just as real

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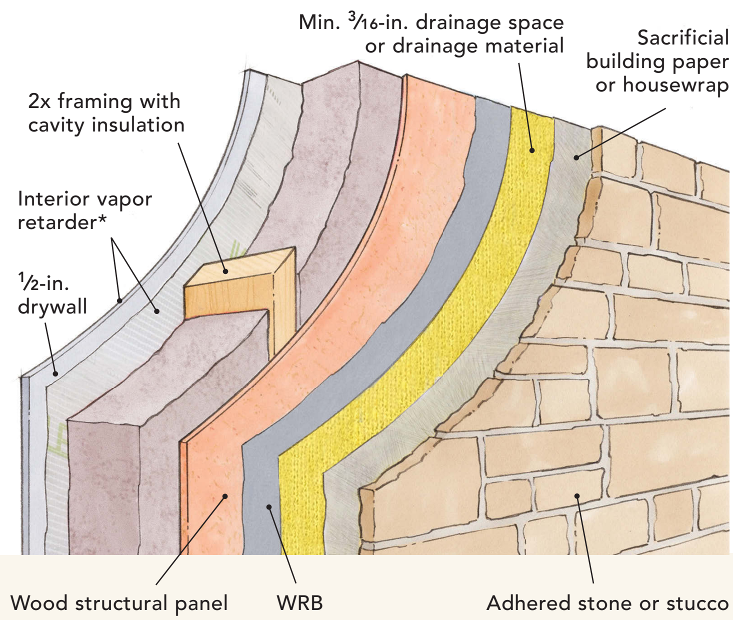
Building materials and wall assemblies have evolved significantly over the last century. Where walls were once sheathed with lumber boards, most homes now are sheathed with plywood and OSB. We replaced interior lath-and-plaster with gypsum wallboard. Insulation became the norm, and energy codes have continued to add even more and different types of insulation. These changes affect the moisture behavior of walls and, when not thought out or tested, can cause problems. For example, starting in the 1990s, we discovered that improved flashing and water-resistive barrier (WRB) requirements were needed to better protect water-sensitive materials in walls such as plywood, OSB, and drywall.

We also realized that as insulation levels increase and heat flow through wall assemblies decreases, air leakage becomes more of a problem. Air leaks allow airborne moisture (vapor) inside walls, where it can condense on cool surfaces and lead to mold



WALLS THAT WORK

A durable assembly considers inside and outside sources of water vapor and allows drying to exceed wetting over the long haul. Managing water vapor depends on climate, the insulation strategy, and the vapor-permeance characteristics of every building component from interior paint to exterior cladding. Vapor control is more than an interior vapor retarder. These three drawings show conventional walls with cavity insulation only and three different cladding types. Exterior continuous insulation is addressed later.

***Some interior vapor-retarder options for each assembly**

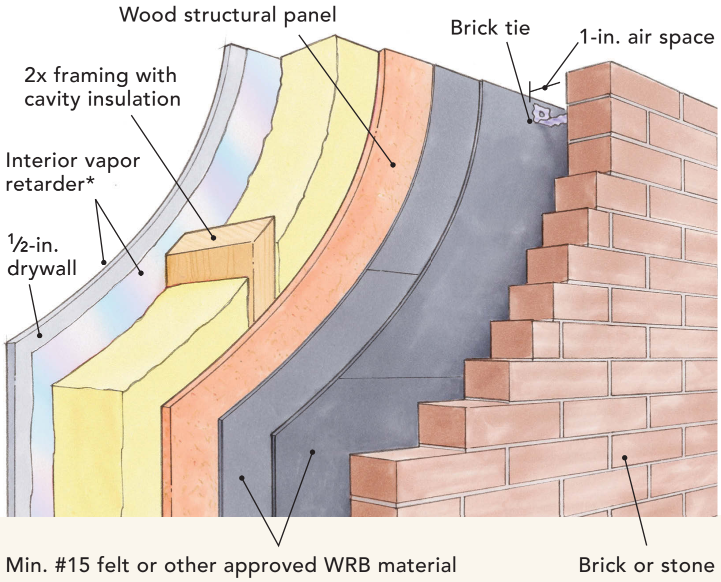
STUCCO AND ADHERED MASONRY

Stucco and adhered masonry need a drainage space behind the first layer of WRB. Traditional stucco uses two layers of building paper, relying on "wrinkling" of the paper layers to provide drainage. This method is now limited to the "dry" climate region (see map, p. 52). In "moist" and marine climates, positive drainage is required and preferred in any climate.

*** Climate zone 1: No interior vapor retarder**
Climate zones 2 to 4, excluding marine: Class III vapor retarder
Climate zones 4 to 6: Class II smart vapor retarder
Climate zones 5 to 8: Class I smart vapor retarder

Photo: courtesy of Everett Kramer. Drawings: Dan Thornton.

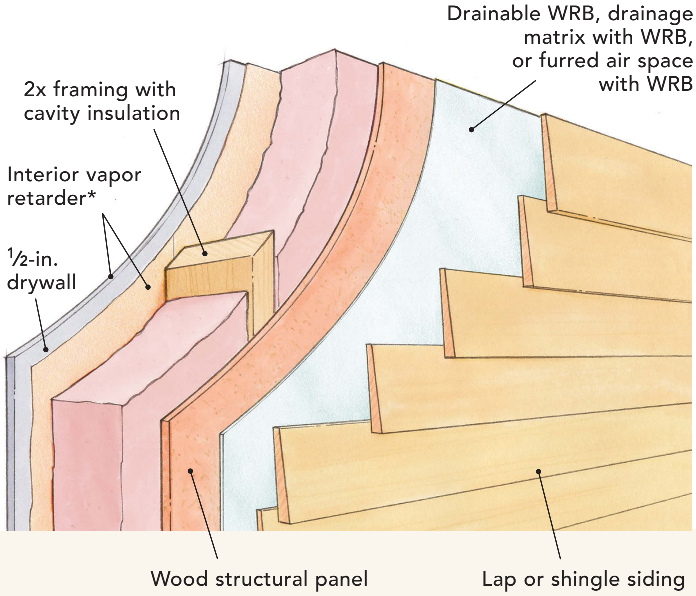
Slow the flow. *A properly installed vapor retarder slows seasonal water-vapor movement to prevent wet walls. The most sophisticated (smart) vapor retarders also become more vapor open when assemblies need to dry, creating a more forgiving wall assembly.*



MASONRY VENEER

Brick- and stone-veneer walls, like other reservoir claddings, benefit from a larger vented air space that helps remove inwardly driven vapor from the brick so less diffuses into the wall. The air space also speeds drying when conditions are right, and allows bulk water to drain.

* Climate zone 1: No interior vapor retarder
Climate zones 2 to 5: Class III vapor retarder
Climate zones 4 to 6: Class II smart vapor retarder
Climate zones 5 to 8: Class I smart vapor retarder



WOOD, COMPOSITE, OR VINYL

Wood, vinyl, and composite siding aren’t reservoir claddings, making inward vapor drive less important, but a drainage space or material prevents moisture accumulation behind the siding and helps protect the wall, even if not required by code. Note that some sidings may not qualify as a vented cladding without a back-vented air space.

* Climate zone 1: No interior vapor retarder
Climate zones 4 to 6: Class II smart vapor retarder
Climate zones 5 to 8: Class I smart vapor retarder
(Use of a Class III vapor retarder is dependent on both climate zone and whether the siding is vented.)

3 CLASSES OF VAPOR RETARDER

Vapor permeance, measured in “perms,” represents a standard measure of water-vapor movement through a material under laboratory conditions. A membrane with a high perm rating allows water vapor to pass through easily. In contrast, one with a low perm rating throttles the passage of water vapor. Vapor retarders are the building component most-often described with a vapor-permeance rating, but all materials, even those not expressly designed to affect the flow of water vapor, have a perm rating. The IRC groups vapor retarders into three classes.

CLASS I VAPOR BARRIER

0.1 perms or less (sheet polyethylene)

CLASS II VAPOR RETARDER

0.1 perm or greater up to 1 perm (kraft-faced fiberglass batts)

CLASS III VAPOR RETARDER

1 perm up to 10 perms (painted drywall often applies; check permeance of paint)

Grouping vapor retarders into three classes creates overly broad ranges and some confusing contradictions. For example, a ten-fold difference exists between a Class II barrier of 0.1 and 1. And in the starkest contradiction, the IRC defines a vapor-permeable material as any with a perm rating greater than 5. This means a Class III vapor retarder with a perm rating of 5 could be considered both a vapor retarder and a vapor-permeable material. While these classification oddities remain in the code, engineers considered the “worst-case” scenario when establishing the newest IRC provisions.

and rot. It also wastes a lot of energy. The solution in the energy code was to tighten up building envelopes to limit air leakage. Unfortunately, we have paid less attention to improving vapor control in step with the changes to wall assemblies over the course of several decades.

Water vapor is simply water in its gaseous state. We experience its effects on our own comfort: When humidity spikes on a hot day, it feels much warmer than the temperature alone would indicate. Many building components—especially wood— are affected by water vapor as well. If you have a door that sticks in the summer but not in the winter, it’s likely that water vapor is the culprit. But this is a minor nuisance compared to the damage water vapor can wreak inside a wall.

The problems associated with poor vapor control are not as immediately obvious as those from bulk water or air leaks, and their solution even less so. Vapor diffusion through materials, or vapor drive, is a much more subtle form of moisture intrusion. While rain leaking through an improperly installed window may be obvious straightaway, water vapor is diffuse and invisible, and capable of causing damage slowly and often imperceptibly. And while the damage from a poorly flashed window tends to be localized to the portion of the wall where the leak occurs, insufficient vapor control can have destructive impacts that, over time, affect a much larger area than a water or air leak.

The extent of this problem and the need for improved code provisions was realized in a review published in 2015 by the Applied Building Technology Group, which can be found online at appliedbuildingtech.com/rr/141003. It assessed data from both good- and poor-performing walls in various climates and provided a rational basis to begin to fill gaps in the code.

New code rules help

The International Code Council responded to poor water-vapor control with improved provisions in the 2021 International Residential Code (IRC). Even if your jurisdiction is using an older version of the IRC, you may want to implement the 2021 version’s vapor-management prescriptions right away, because older versions may allow for some risky wall assemblies.

In heating climates, the effects of excessive vapor diffusion into wall cavities typically

Photos: top, Patrick McCombe; bottom left, courtesy of CertainTeed; bottom right, Matthew Millham manifests as repeatedly wetted sheathing (cycling above 20% moisture content each winter), with or without condensation or rot. In cooling climates or anywhere air conditioning is used in the summer, vapor problems can show up as mold or condensation on the back side of drywall.

There are hundreds, if not thousands, of possible wall configurations and material combinations that affect water-vapor behavior. The 2021 IRC does a good job tackling the complexities of the vapor-control issue. Code writers had to balance the variations in water vapor's behavior across the nine U.S. climate zones with the various properties of the wall's interior layers, exterior layers, and insulation, as well as the insulation strategy (e.g., cavity insulation only or cavity plus continuous exterior insulation).

Blocking water vapor is imperfect

In most climates, the traditional method of reducing moisture accumulation inside a wall is to use a suitable interior vapor retarder. The 2021 IRC follows this conventional approach for wall assemblies without exterior continuous insulation. What's still missing from this approach, however, is specifications for minimum permeance requirements for materials on the assembly's exterior side when a Class I or II interior vapor retarder is used in colder climates as specified in the code.

Unfortunately, most exterior materials (except WRBs) do not have any product-specific perm-rating information or requirements, or the information we have about them is too generic to be very useful (for more on perm ratings, see facing page, left). For example, research data indicates that OSB's permeance may vary from less than 2 perms to as much as 5 perms. Depending on the climate and the vapor retarder used inside, this difference in exterior sheathing permeance can have a significant impact on its moisture content during the winter. Fortunately, this is rather easy to remedy by going beyond code minimum and using a Class I variable-permeance (smart) vapor retarder in colder climates.

When Class III interior vapor retarder is used without exterior insulation, it becomes important in climate zones 4 and higher to use vented claddings, such as vinyl siding, to aid drying and prevent excessive wetting of the sheathing during winter. The sheathing permeance is important too. A

Dos and Don'ts of Vapor Control

Do For walls with exterior continuous insulation: Do match the R-value of the exterior insulation with the R-value of the vapor-permeable cavity insulation. Use Table R702.7(2), Table R702.7(3), or Table R702.7(4) (see pp. 52-53), considering the climate and interior vapor retarder selected (e.g., Class II or Class III). You also need to consider the wall thickness (2x4 or 2x6 cavity) to determine the minimum continuous insulation R-value needed to control water vapor and maintain inward drying.

Do For walls without exterior insulation: Do put a vapor retarder on the interior side and see Table R702.7(2) and Table R702.7(3) for specific code requirements. In climate zones 6 to 8, use a Class I smart vapor retarder.

Do Do provide drying potential in at least one direction. In other words, don't build a double-vapor-barrier assembly unless properly using smart vapor retarders.

Do Do provide a means to monitor and, if needed, control indoor relative humidity (RH). Ideally, for human health and building health, relative humidity should be 30% to 40% maximum in the coldest periods of winter and 60% to 65% maximum in the summer. Don't over- or underhumidify or ignore control of indoor RH altogether. Doing so makes the durability of the assembly too dependent on occupant behavior.

Do Do be particular about quality of WRB and flashing installations. Even the most thought-out vapor-control strategy will not save a building with major water leaks, although it can help reduce the impacts of minor leaks.

Do Do install air barriers carefully and seal all air leaks. Air leaks allow moist air into an assembly, especially when "blocking" vapor with a Class I retarder. Continuous exterior insulation makes assemblies more forgiving of air leakage by keeping the cavities warm.

Don't Don't think that by putting a vapor-open or vapor-permeable material layer (like a high-perm WRB) on a poorly designed assembly that the assembly automatically has drying potential that will save it from vapor diffusion problems—it doesn't. You have to consider the whole design.

Don't Don't use a Class I interior vapor barrier in climate zones 1 to 4. In climate zones 1 to 3 a vapor retarder is not required, which allows maximum inward drying, but Class I or II smart and Class III retarders are permitted.

ANSWER THESE QUESTIONS FOR

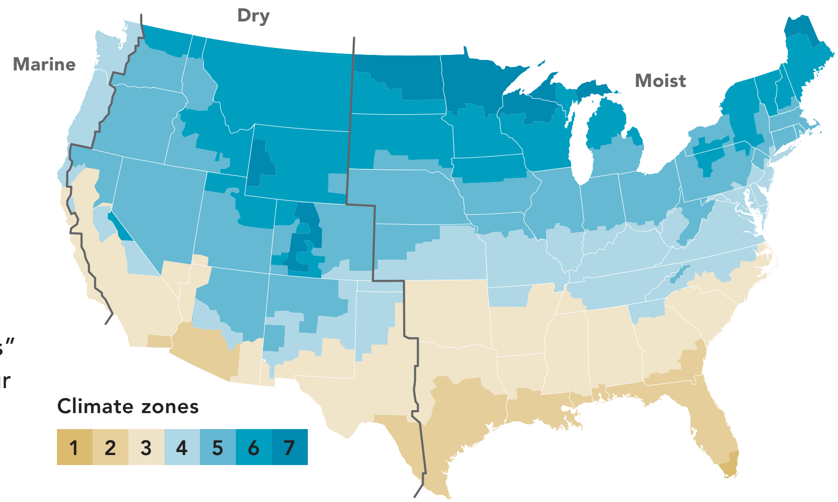
Are you using exterior insulation?

Continuous exterior insulation affects the vapor-retarder requirements, because it controls water vapor by temperature and permeance. Whether or not you are using exterior insulation, your design starts with Table R702.7(2). From there, other tables or footnotes are accessed to address specific design conditions or options. Also see Table R702.7(1), which defines vapor-retarder classes. This table is the same in prior code cycles, except when it comes to using paint as vapor retarder. The coating must now be identified as a vapor retarder and applied in accordance with manufacturer instructions.

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 greater than 1.0 and less than or equal to 10.0

What's your climate zone?

You will need to know your climate zone to choose a compliant vapor-retarder solution matching your insulation strategy (which must also satisfy the energy code). Refer to climate map N1101.7 to find your climate zone. The 2021 IRC version shows that climate boundaries have moved slightly northward in recent decades.



Which retarder is right?

Next, refer to Table R702.7(2): "Vapor Retarder Options" to determine what vapor retarders are permitted in your climate with your cladding. Study the footnotes.

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). (NOTE: This requires that the Class II vapor retarder is also a smart vapor retarder, like coated kraft-paper facing on fiberglass batts; use of a Class I smart vapor retarder would provide equal or better performance.)

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)

Class III vapor retarder provides more inward drying potential, but increases outward vapor flow toward the sheathing in winter, which is why highly vapor-permeable exterior sheathings (e.g., gypsum sheathing and fiberboard) are required above climate zone 5 when exterior insulation isn't included. The same sheathing-permeance concern arises with use of a Class II vapor retarder in climate zones 6 and higher, but addressing this nuance remains a gap in the code. More details can be found in the IRC tables, above.

Exterior insulation helps

If we keep the temperature inside the wall cavities closer to the temperatures inside the home with exterior insulation and use a vapor retarder that maintains inward drying, we keep the vapor from condensing inside the wall and the relative humidity low enough to prevent mold and reduce moisture uptake by wood materials.

But success requires the right ratio of continuous exterior insulation to interior cavity insulation, which depends both on climate and the vapor retarder selected. Even if the outer layers have low permeance and prevent the wall from drying outward, the wall will be protected against diffusion-based

Will Class III work with your wall?

Refer to Table R702.7(3) to see if a Class III retarder will work with your wall assembly. Table R702.7(3) includes both permeance-controlled wall designs (those without continuous exterior insulation) and temperature-controlled wall designs (those with continuous exterior insulation). The exterior insulation assemblies work in all climates by changing the insulation ratio (or R-value) accordingly. For walls without continuous insulation, a Class III vapor retarder does not work in colder climate zones. Walls without exterior insulation also require an appropriate sheathing material (based on its permeance). You will need to install a vented cladding (like vinyl) to help remove moisture that accumulates in and passes through cold sheathing in the winter.

TABLE R702.7(3) CLASS III VAPOR RETARDERS

Climate zone	Class III vapor retarders permitted for A,B
Marine 4 (2021 IBC includes all of zone 4)	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

A Vented cladding shall include vinyl, polypropylene, or horizontal aluminum siding, or brick veneer with a clear air space as specified in Table R703.8.4(1), or other approved vented claddings.

B The requirements of 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 Chapter 11 [Energy Efficiency].

Can I install less exterior insulation?

Table R702.7(4) is a new table. It specifies a Class II vapor retarder, and the code requires it to be a smart vapor retarder (like conventional coated kraft-paper-faced batts) and allows you to use less exterior continuous insulation than the specifications published in Table R702.7(3). You can use less exterior insulation because of the additional interior vapor control with a Class II compared to a Class III vapor retarder. The overall wall insulation design will still need to meet the energy code, but this option makes it possible to not "overshoot" the energy code while maintaining good water-vapor performance.

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, 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[Energy Efficiency].

moisture accumulation because the air in the cavity will be warmer, lowering the risk of reaching the dewpoint inside the wall.

Interior drying is maintained with a Class III vapor retarder or Class I or II smart vapor retarder. Tables R702.7(3) and R702.7(4) provide different minimum continuous-insulation R-value requirements based on fibrous-cavity R-values for 2x4 and 2x6 walls, and these vary by climate.

Why use the 2021 code today?

Most of us do not want to hire an engineer to calculate hygrothermal designs for walls we build. The 2021 IRC provides guidance that builders can use today. With Section R702.7: Vapor Retarders as a guide, you can have reasonable assurance that the walls you build will perform well, and the vapor-retarder and vented-cladding options offer flexibility for the presence or absence of exterior insulation. It doesn't contradict existing regulation, and does fill some gaps in earlier code cycles, to prescribe more-resilient wall assemblies. □

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