Photo: Ted Cushman

Avoiding Wet Walls

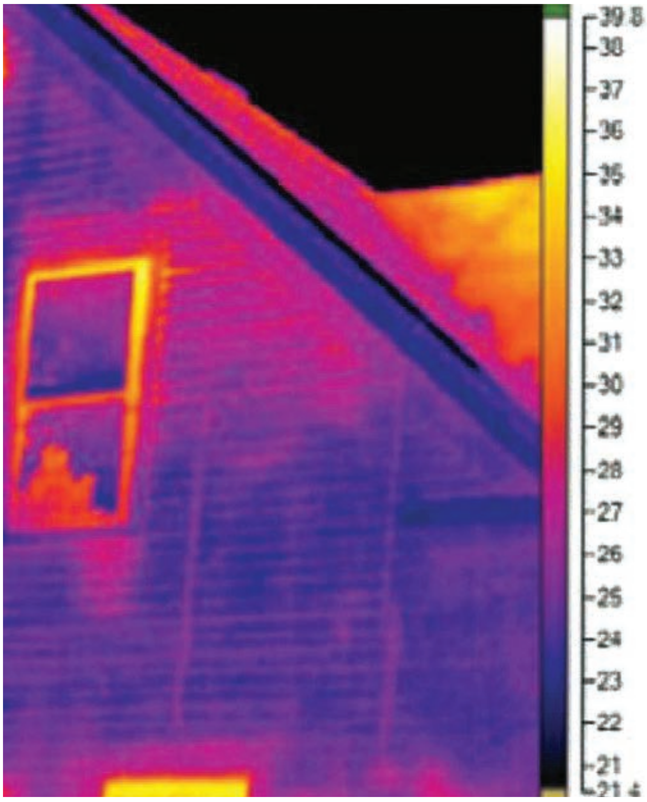
The energy code provides guidance on limiting the risk of condensation, if you know where to look

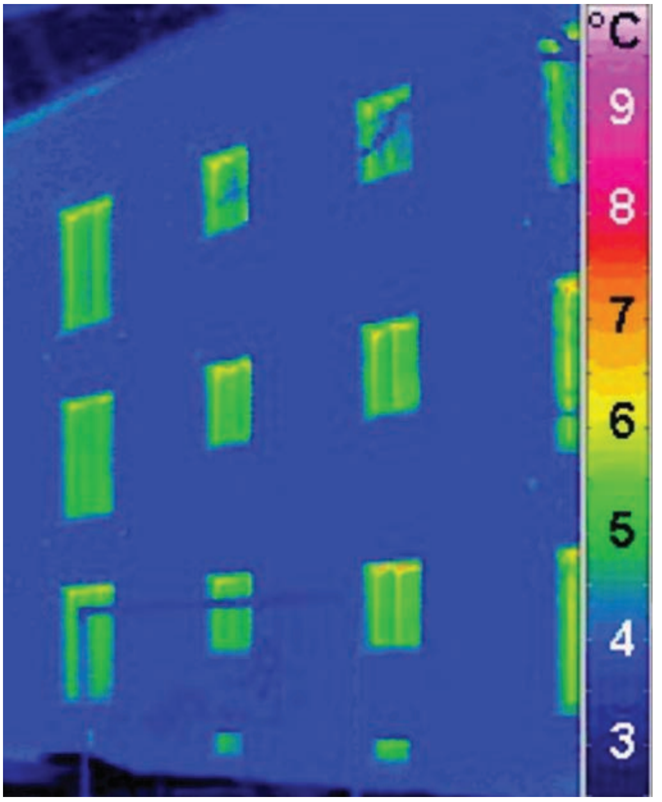
BY CLAYTON DEKORNE

Continuous exterior insulation—commonly provided by wrapping a building with rigid foam—is nothing new to residential construction. But as it has found its way into energy codes in northern communities, it has advanced to become a mainstream wall system, even though a lot of builders are still unfamiliar with it and don't always understand the role it plays in the thermal and moisture performance of walls.

Continuous insulation (CI) was first introduced to the 2006 International Energy Conservation Code (IECC) as an option in climate zones 5 and 6. (In the code, it is indicated with an equation, such as "13+5," which stands for R-13 in the wall cavity and R-5 continuous exterior insulation.) With the introduction of the 2012 IECC (and continued under the 2015 edition), continuous insulation became a requirement for climate zones 6, 7, and 8. In these zones, you have two choices and both require continuous insulation: 20+5 (for example, a high-density, R-20 batt in a 2x6 cavity with 1 inch of XPS foam on the exterior) or 13+10 (for example, a 3 5/8-inch fiberglass batt in a 2x4 wall with 2 inches of XPS on the exterior).

Perhaps leery of taking the CI plunge exclusively, some states have amended this requirement. New York is a notable example. By the time the state adopted the 2015 IECC (skipping over 2012), the NYS 2016 energy supplement allowed two options for climate zone 6. "Option 1" is equivalent to the chapter and verse of the current IECC wall insulation requirement. "Option 2" allows R-25 cavity insulation only, without continuous exterior insulation. (Note: if builders follow Option 2, they have to opt in for the full gamut of fenestration and insulation requirements, including slightly more energy-efficient windows and slightly better interior basement insulation). Option 2 is largely seen as a hat-tip to spray-foam insulation, which has gained a strong foothold in the New York market, though you





Thermal bridging at a glance. The effect of thermal bridging can be seen immediately in the infrared image of the house on the left. Without continuous exterior insulation, heat conducting through the framing is visible (also visible are air leaks and conductive losses at windows and through spotty patches of insulation). The thermal envelope on the house on the right has been built specifically to reduce thermal bridging and shows no heat loss through the framing.

Images: John Snell (left); Passivhaus Institut (right)

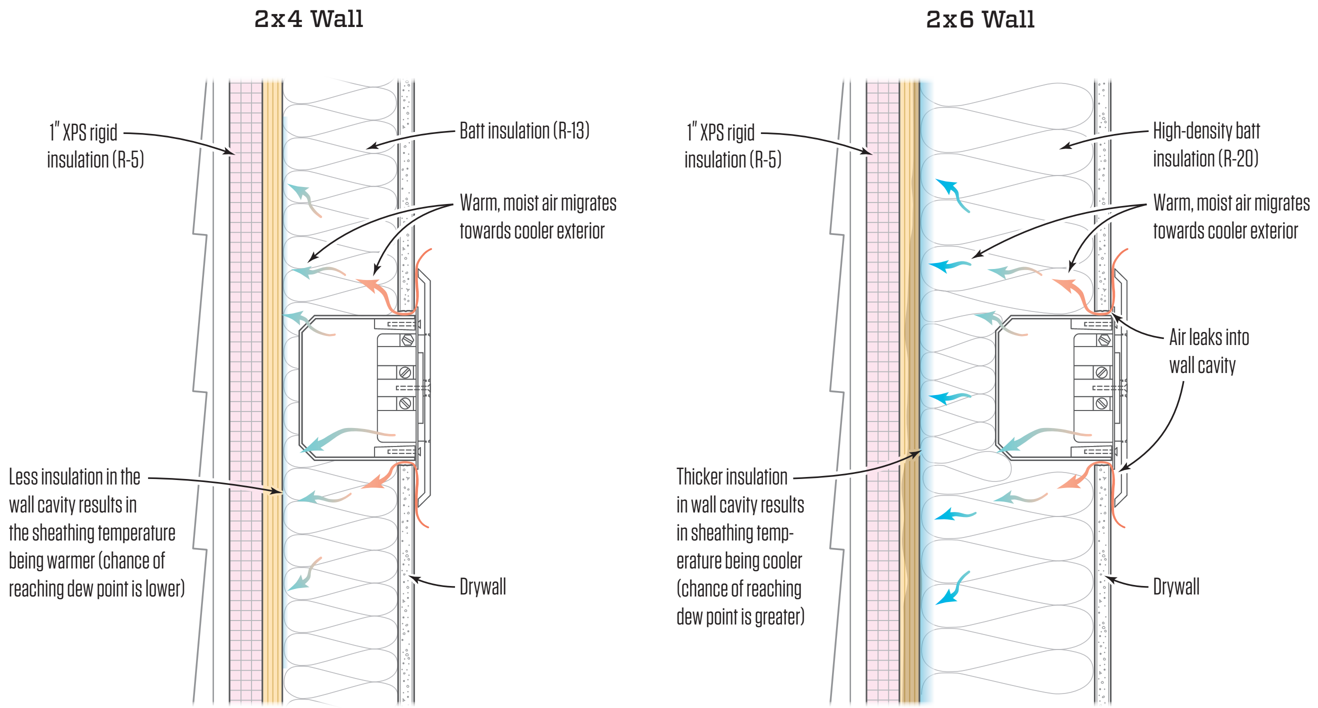
can comply with Option 2 using any wall system that provides R-25; an 8-inch fiberglass batt in a 2x8 wall, for example, would comply. What Option 2 doesn't provide is relief from thermal bridging or condensation control.

WHY CONTINUOUS INSULATION?

In a wall, cavity insulation only slows down the flow of heat through the stud bays, while every stud, trimmer, header, cripple, and wall plate acts as a thermal bridge, bypassing the cavities and siphoning heat from the building **(1)**. Peter Baker and Joe Lstiburek, in the must-have Building America resource "Measure Guideline: Incorporating Thick Layers of Exterior Rigid Insulation on Walls," estimate that thermal bridging reduces a conventionally framed wall's nominal insulation value by at least 20%. In a typical framed wall without continuous insulation, R-20 batts really perform at about R-16, and R-13 insulation at about R-10.5—well below nominal insulation values. Adding foam to the exterior brings the total wall value near the nominal values for the cavity fill: A "20+5" wall (for example, R-20 batts and 1 inch of XPS rigid foam) has a total wall value of R-19.4; a "13+5" wall (for example, R-13 batts and 1-inch XPS) has a total wall value of about 14.3.

Thermal performance is only part of the equation. The energy code is about much more than saving energy. As the code evolves, it is aligning more with building science and getting better at addressing the impacts on buildings that follow energy performance, namely building durability and indoor air quality. Of course, client comfort is another clear impact, but no code official is likely to say his job is to make occupants more comfortable. Nor is he likely to say it's about saving occupants money on their utility bills. For code officials, it's all about safety, and that's exactly

Condensation Potential in Wood-Framed Walls



More cavity fill requires more continuous insulation. In a wall with continuous exterior insulation, the risk of condensation depends on the proportion of cavity fill to continuous insulation. As you add insulation to the cavity, you need to increase the thickness of continuous exterior insulation. If you don't, the increased cavity insulation will result in the sheathing being cooler. This increases the chance that the sheathing temperature will reach dew point and wet the sheathing with condensation.

Illustration: Tim Healey

where the energy code is beginning to make sense.

Continuous insulation reduces the condensation potential of walls by keeping the exterior sheathing warmer. In theory, when the sheathing is warm enough to stay above the dew point, it doesn't matter from a vapor-control perspective if warm, moist air leaks into building cavities. The moisture stays in the air, doesn't condense, and doesn't risk mold growth or rot.

But here's the subtlety that this article is really about: While the insulation requirements in the latest versions of the energy code embrace the concept of condensation control more than they ever have, they don't go far enough to stave off the condensation risk completely. The current insulation requirements may even increase the risk in climate zones 6, 7, and 8.

To understand this risk, we need to examine exactly how the building code addresses the condensation risk.

CODE'S ELUSIVE CONDENSATION STRATEGY

Condensation happens all the time in most buildings. In winter when moist, indoor air leaks into building cavities, water is likely to condense on the inside of the sheathing in many homes. In the summer, it is likely to condense on the back of the drywall. If this happens occasionally on the coldest or hottest days of the year, the water usually dries eventually without mishap. Condensation only creates problems (peels paint, grows mold, rots the structure) when it occurs frequently enough that walls stay wet for longer periods than they stay dry.

Building codes have traditionally addressed condensation by trying to limit the amount of water vapor that gets inside building assemblies. Chapter 7 on Wall Coverings in the IRC is where you need to look to find guidance on reducing the condensation risk with continuous insulation. It's couched in the vapor-retarder requirement,

TABLE R402.1.2 WALL INSULATION REQUIREMENTS	
Climate zone	Wood frame wall R-value
1	13
2	13
3	20 or 13+5
4 except Marine	20 or 13+5
5 and Marine 4	20 or 13+5
6	20+ 5 or 13+10
7 and 8	20+ 5 or 13+10

The excerpt of Table R402.1.2 (left) shows IECC Chapter 4 wall insulation requirements. Continuous insulation is an option in climate zones 3 to 5 and is required in zones 6 to 8 under the IECC. For controlling condensation, the guidance in Table R702.7.1 (below) provides a safer wall system, regardless of which class vapor retarder you install.

TABLE R702.7.1 CLASS III VAPOR RETARDERS		
Climate zone	Class III vapor retarders permitted for:	Compliant wall example
Marine 4	Continuous insulation with R-value ≥ 2.5 over 2 × 4 wall.	½-inch XPS over 2x4 with R-13 batt
	Continuous insulation with R-value ≥ 3.75 over 2 × 6 wall.	¾-inch XPS over 2x6 with R-19 batt
5	Continuous insulation with R-value ≥ 5 over 2 × 4 wall.	1-inch XPS over 2x6 with R-13 batt
	Continuous insulation with R-value ≥ 7.5 over 2 × 6 wall.	1 ½-inch XPS over 2x6 with R-19 batt
6	Continuous insulation with R-value ≥ 7.5 over 2 × 4 wall.	1 ½-inch XPS over 2x4 with R-19 batt
	Continuous insulation with R-value ≥ 11.25 over 2 × 6 wall.	layered 1 ½-inch and ¾-inch XPS over 2x6 with R-19 batt
7 and 8	Continuous insulation with R-value ≥ 10 over 2 × 4 wall.	2-inch XPS over 2x4 with R-13 batt
	Continuous insulation with R-value ≥ 15 over 2 × 6 wall.	3-inch XPS over 2x6 with R-19 batt

Note: As a "base case," the IRC requires a Class I (e.g. poly) or a Class II (e.g. Kraft paper) vapor retarder on the interior side of walls in these five climate zones. You can use a Class III vapor retarder (e.g. latex paint), but only when the wall includes vented cladding (not included here) or continuous insulation. The example walls are for reference only and not mandated by code.

and is a little veiled. Section R702.7 states that you need a Class I (poly) or a Class II (Kraft-paper) vapor retarder on the interior face of walls in climate zones 5, 6, 7, 8, and Marine 4. You can use a Class III retarder (latex paint on the drywall), but only when you either install a vented cladding on the outside of those walls or install enough continuous exterior insulation to cool the sheathing.

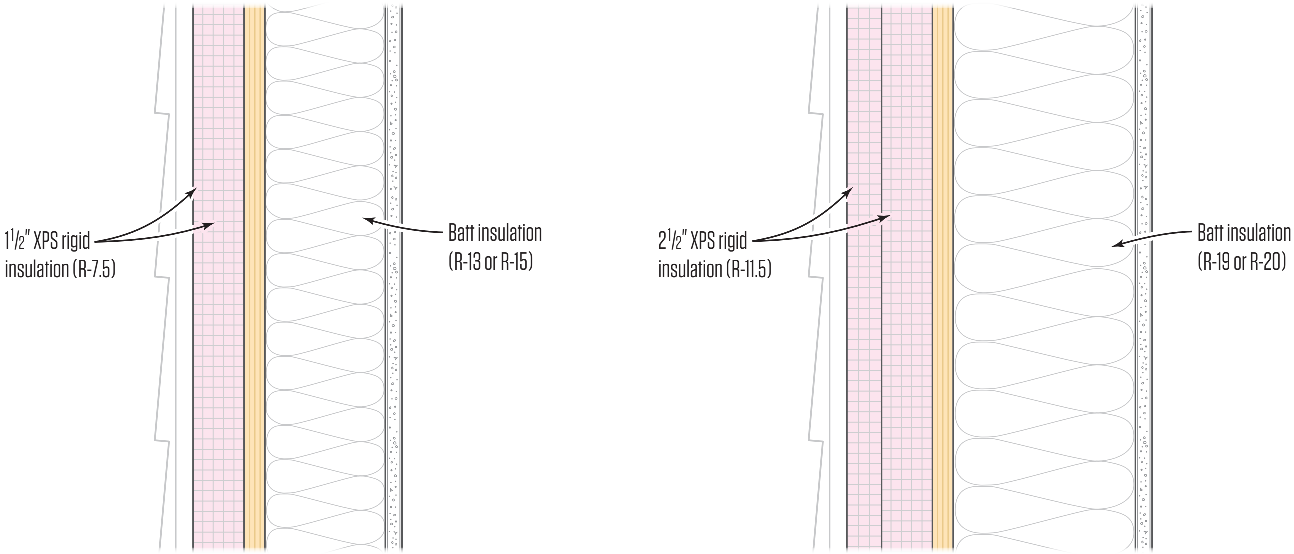
How much is enough? The minimum R-values for continuous insulation are provided in Table 702.7.1 (see excerpt, above). Note that when continuous insulation is installed over a 2x6 wall in climate zones 6, 7, and 8, the amount of continuous insulation needed to control condensation is more than the amount of insulation required to meet the building thermal envelope requirements (Table R402.1.2; see excerpt at top of page). In other words, if you follow only the insulation requirements in Chapter 4 of the IECC (which are the same as Chapter 11 of the IRC), you may be building a risky assembly (see "Condensation Potential in Exterior Walls," previous page). If you are only seeking code compliance, the safe bet for any wall *regardless of the type of vapor retarder you install* is to follow the recommendations for continuous insulation provided in Table R702.7.1.

The risk of not adding enough continuous insulation—or, more precisely, of unbalancing the wall with too much cavity insulation relative to the amount of continuous insulation—is even more critical to understand if you want to go *beyond* code. For example, what if you add only an inch of rigid foam to the exterior of an R-20 wall in climate zone 5 or Marine 4? If R-5 is allowed for the 2x4 wall, wouldn't adding R-5 to a 2x6 wall be even better? No, because compared with the 2x4 (13+5) wall allowed in these climate zones, the interior of the sheathing would be cooler in the 2x6 wall because there is more cavity insulation. As a result, the sheathing is still likely to reach dew point.

The simplest way to build better walls is to use Table R702.7.1 as

Safe Continuous Insulation Thickness for Cold Climates

Insulated Sheathing With R-Value ≥ 7.5 Over 2x4 Wall | **Insulated Sheathing With R-Value ≥ 11.25 Over 2x6 Wall**



In climate zones 6, 7, and 8, where the risk of condensation in walls is highest, the IRC requirements for using a Class III vapor retarder specify a thickness for continuous insulation that is greater than the insulation requirements in Chapter 4. This thickness provides a safe wall system, regardless of the type of vapor retarder you install. Note: Chapter 7 guidance does not differentiate between a high-density and a more conventional batt. In a 2x6 wall, a higher-density, R-20 batt may bring the temperature of the exterior sheathing close to dew point. This suggests that an R-19 batt is a safer option when using the minimum thickness for continuous insulation.

Illustration: Tim Healey

a baseline and add more continuous insulation outboard of the wall cavity. But if you are serious about going beyond code and avoiding wet walls, calculate the thickness for the given climate conditions and cavity insulation using the method described in John Straube's seminal article "Controlling Cold-Weather Condensation Using Insulation" (BSD-163; buildingscience.com). Ted Cushman's article "Robust Walls" (Nov/06) explains the calculation using specific examples for Boston conditions (climate zone 5).

WHY VAPOR RETARDERS?

According to John Straube, "cold-weather condensation is primarily the result of outward air leakage. Diffusion usually does not move sufficient quantities of water vapor fast enough to generate a problem." Why then does the code still require a Class I or Class II vapor retarder as a "base case" in wet walls? It's likely a symptom of the approach building codes have of assuming absolute compliance. Code assumes that if you comply with the air-sealing requirements, you won't have warm, moist air migrating through walls, leaving a very small potential for vapor diffusion, against which you mount a barrier defense. Code is not good at letting go of its barrier defense strategies. It needs to get better at writing in belt-and-suspenders approaches to moisture control and creating safeguards to address problems that arise from incomplete compliance.

Rather than mandating a vapor-control strategy based on blocking moisture diffusion, the energy code might serve us by upping the continuous insulation requirements for climate zones 6, 7, and 8 to align with its vapor-control recommendations. Then it might consider killing the vapor-retarder requirement altogether.

Clayton DeKorne is the editor of JLC.