



PLANNING: Air Sealing Measures and Checklists

The 2012 IECC provides a comprehensive list of components that must be sealed and inspected. However, unless the components are installed properly, passing the inspection and meeting the tested air leakage rate requirements may not be achievable without rebuilding some construction assemblies (such as gypsum board) that were previously installed. A good example is the air barrier between the ceiling (unconditioned attic) and conditioned space (living area). Since air leakage paths are driven by the fact that warm air rises, the attic is the largest area (square footage) of potential heat loss. Areas in the ceiling that might not have been sealed properly could include recessed cans, wires, pipes, attic access panels, drop down stair or knee wall doors and more. Figure 3 is a picture taken with an infrared camera illustrating where the temperature difference is and potential heat loss. The reds and purples indicate higher heat loss areas.

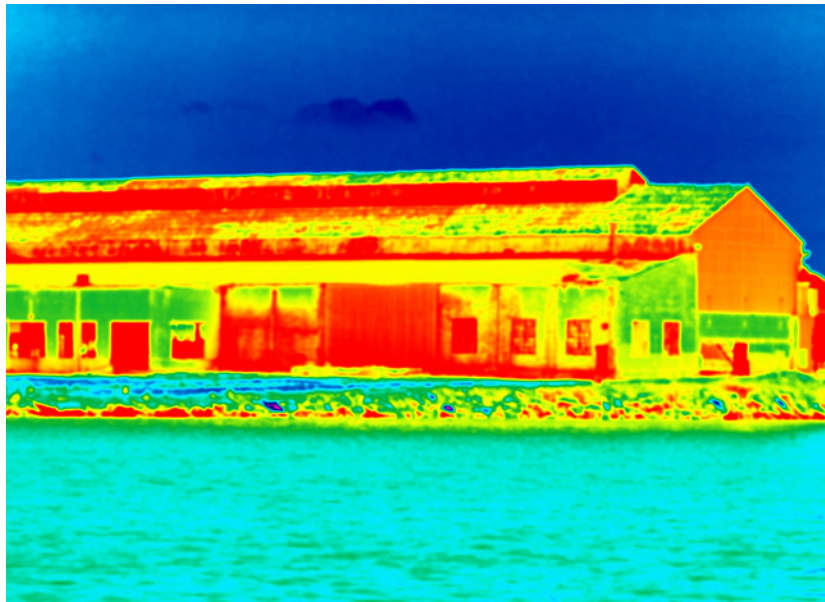
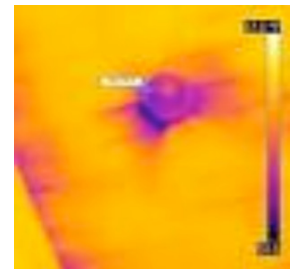
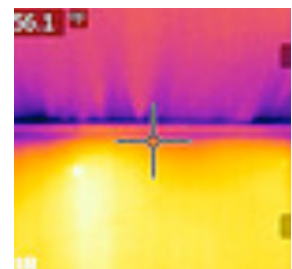


Figure 3: Air Leakage Test Results



Recessed Can



Ceiling Plane

DEFINITIONS

As defined according to 2012 IECC:

AIR BARRIER

Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or combination of materials.

CONTINUOUS AIR BARRIER

A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

R402.4.1.1 Installation

The components of the building thermal envelope as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction. Where required by the code official an approved third party shall inspect all components and verify compliance.

The IECC's checklist covers not only air barriers but proper installation of insulation and other elements. **In Table 402.4.1.1, items that are directly related to air leakage and proper air barriers are highlighted in yellow.**

Even though the IECC checklist lists 14 specific components that are directly related to air barriers, more attention must be focused on all areas that have potential for air leakage. A good understanding of building science can facilitate proper air sealing. For example, Building America research identifies 19 key areas where air sealing can improve a home's energy efficiency, comfort, and building durability.

Common air sealing trouble spots are shown in Figure 4 on page 8 and listed in the following table. Several of these trouble spots are described in more detail as highlighted in the Building America Air Sealing Checklist.



Additional information on other trouble spots and other building science information can be found in the Building America Best Practices guides and Air Leakage guide available for free download at www.buildingamerica.gov.

Builders, contractors, and/or designers should develop an air sealing strategy beginning with reviewing the building plans and identifying potential areas of air leakage. These checklists can be used to help identify the areas. The strategy also needs to include the types of materials that will be used to create an air barrier and seal the building envelope. The IECC does not identify specific products that must be used to create air barriers and seal the building envelope, but does require that the materials allow for expansion and contraction.

Table R402.4.1.1 (2012 IECC). Air Barrier and Insulation Installation*

COMPONENT	CRITERIA*
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
Walls	<p>Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed.</p> <p>The junction of the top plate and top of exterior walls shall be sealed.</p> <p>Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.</p> <p>Knee walls shall be sealed.</p>
Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.
Rim joists	Rim joists shall be insulated and include the air barrier.
Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawl space walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetration	Duct shafts, utility penetrations and flue shafts opening to exterior or unconditioned space shall be sealed.
Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.
Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

*In addition, inspection of log walls shall be in accordance with the provisions of ICC-400.

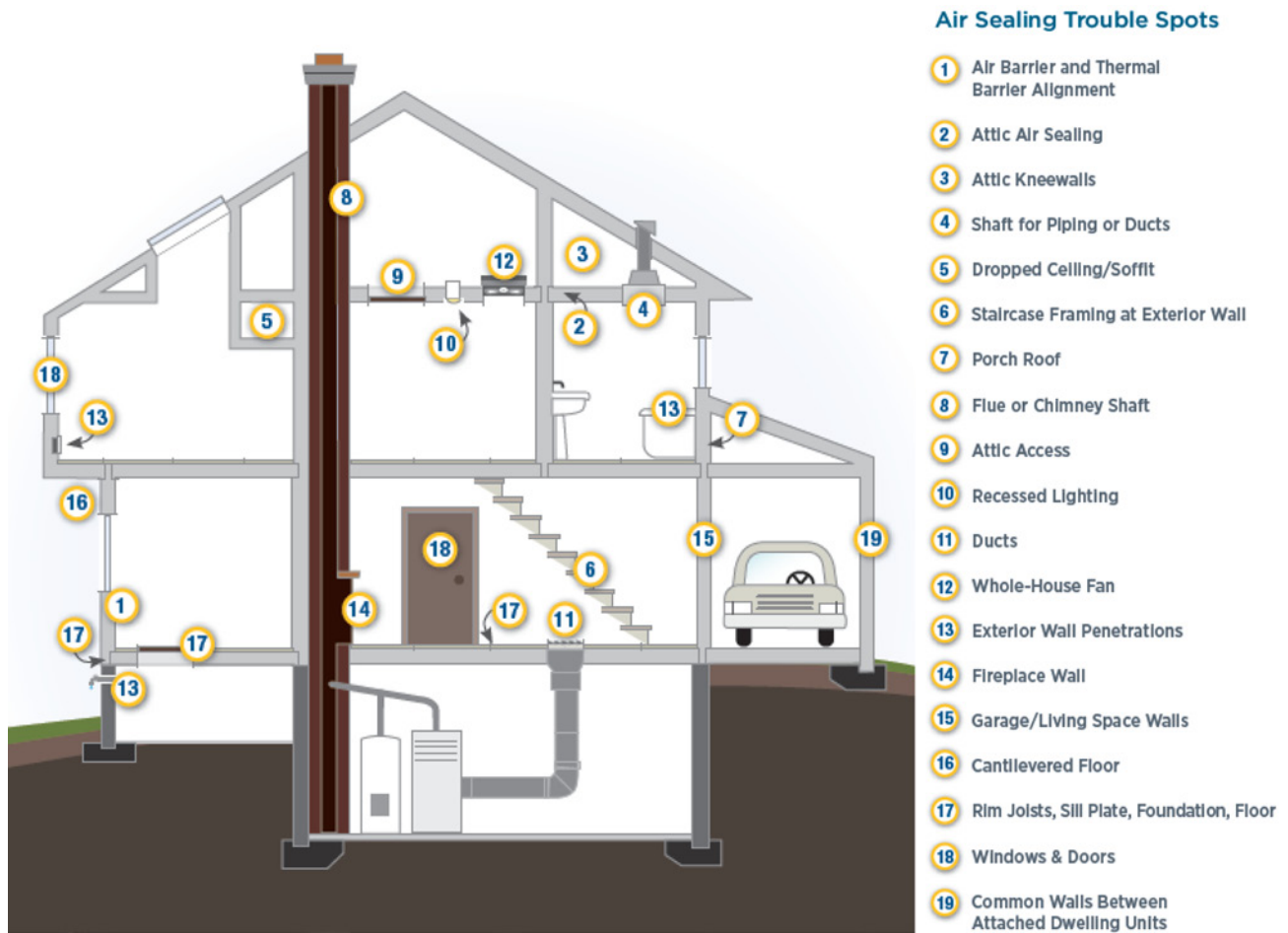


Figure 4: Building America—air sealing trouble spots

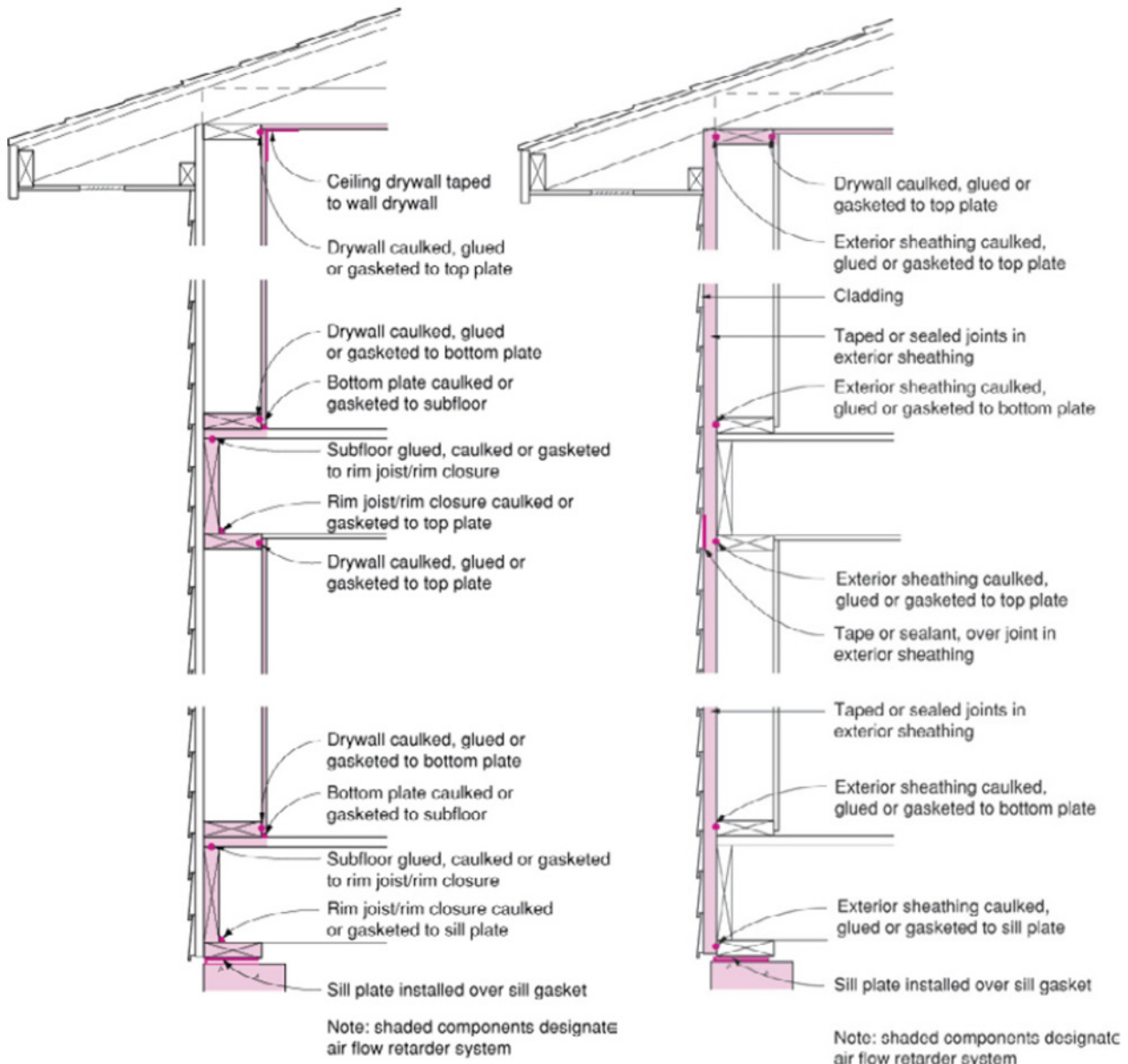
Table 2. Building America Air Sealing Checklist

Air Barrier	Completion Guidelines
1. Air Barrier and Thermal Barrier Alignment	Air Barrier is in alignment with the thermal barrier (insulation).
2. Attic Air Sealing	Top plates and wall-to-ceiling connections are sealed.
3. Attic Kneewalls	Air barrier is installed at the insulated boundary (kneewall transition or roof, as appropriate).
4. Duct Shaft/Piping Shaft and Penetrations	Openings from attic to conditioned space are sealed.
5. Dropped Ceiling/Soffit	Air barrier is fully aligned with insulation; all gaps are fully sealed.
6. Staircase Framing at Exterior Wall/Attic	Air barrier is fully aligned with insulation; all gaps are fully sealed.
7. Porch Roof	Air barrier is installed at the intersection of the porch roof and exterior wall.
8. Flue or Chimney Shaft	Opening around flue is closed with flashing, and any remaining gaps are sealed with fire-rated caulk or sealant.
9. Attic Access/Pull-Down Stair	Attic access panel or drop-down stair is fully gasketed for an air-tight fit.
10. Recessed Lighting	Fixtures are provided with air-tight assembly or covering.
11. Ducts	All ducts should be sealed, especially in attics, vented crawlspaces, and rim areas.
12. Whole-House Fan Penetration at Attic	An insulated cover is provided that is gasketed or sealed to the opening from either the attic side or ceiling side of the fan.
13. Exterior Walls	Service penetrations are sealed and air sealing is in place behind or around shower/tub enclosures, electrical boxes, switches, and outlets on exterior walls.
14. Fireplace Wall	Air sealing is completed in framed shaft behind the fireplace or at fireplace surround.
15. Garage/Living Space Walls	Air sealing is completed between garage and living space. Pass-through door is weather stripped.
16. Cantilevered Floor	Cantilevered floors are air sealed and insulated at perimeter or joist transition.
17. Rim Joists, Seal Plate, Foundation, and Floor	Rim joists are insulated and include an air barrier. Junction of foundation and sill plate is sealed. Penetrations through the bottom plate are sealed. All leaks at foundations, floor joists, and floor penetrations are sealed. Exposed earth in crawlspace is covered with Class I vapor retarder overlapped and taped at seams.
18. Windows and Doors	Space between window/door jambs and framing is sealed.
19. Common Walls Between Attached Dwelling Units	The gap between a gypsum shaft wall (i.e., common wall) and the structural framing between units is sealed.

Items highlighted in yellow will be discussed in more detail.

Air Barrier and Thermal Barrier Alignment

Envelope Air Sealing



Source: Building Science Corporation

Attic Kneewalls

Air barrier is installed at the insulated boundary (kneewall transition or roof, as appropriate)

Kneewalls, the sidewalls of finished rooms in attics, are often leaky and uninsulated. A contractor can insulate and air seal these walls in one step by covering them from the attic side with sealed rigid foam insulation. A contractor can plug the open cavities between joists beneath the kneewall with plastic bags filled with insulation or with pieces of rigid foam. Another option is to apply rigid foam to the underside of the rafters along the sloped roof line and air seal at the top of the kneewall and the top of the sidewall, which provides the benefit of both insulating the kneewall and providing insulated attic storage space.

Doors cut into kneewalls should also be insulated and air sealed by attaching rigid foam to the attic side of the door, and using a latch that pulls the door tightly to a weather-stripped frame.

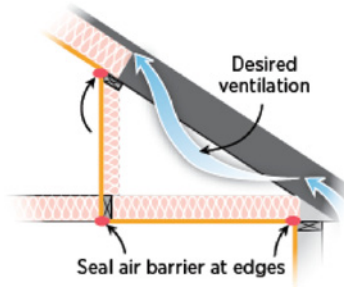


Figure 5. Insulate and air seal the kneewall itself, as shown, or along the roof line (Source: DOE 2000a).



Figure 6. Air seal floor joist cavities under kneewalls by filling cavities with fiberglass batts that are rolled and stuffed in plastic bags (as shown here) or use rigid foam, Oriented Strand Board (OSB), or other air barrier board cut to fit and sealed at the edges with caulk.

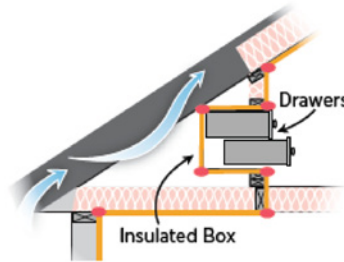


Figure 7. Build an airtight insulated box around any drawers or closets built into attic kneewalls that extend into uninsulated attic space. Insulate along air barrier (shown in yellow on drawing) or along roof line with rigid foam (Source: Iowa Energy Center 2008).

Dropped Ceiling/Soffit

Air barrier is fully aligned with insulation; all gaps are fully sealed

Soffits (dropped ceilings) found over kitchen cabinets or sometimes running along hallways or room ceilings as duct or piping chases are often culprits for air leakage. A contractor will push aside the attic insulation to see if an air barrier is in place over the dropped area. If none exists, the contractor will cover the area with a piece of rigid foam board, sheet goods, or reflective foil insulation that is glued in place and sealed along all edges with caulk or spray foam, then covered with attic insulation. If the soffit is on an exterior wall, sheet goods or rigid foam board should be sealed along the exterior wall as well. If the soffit contains recessed can lights, they should be rated for insulation contact and airtight or a dam should be built around them to prevent insulation contact.

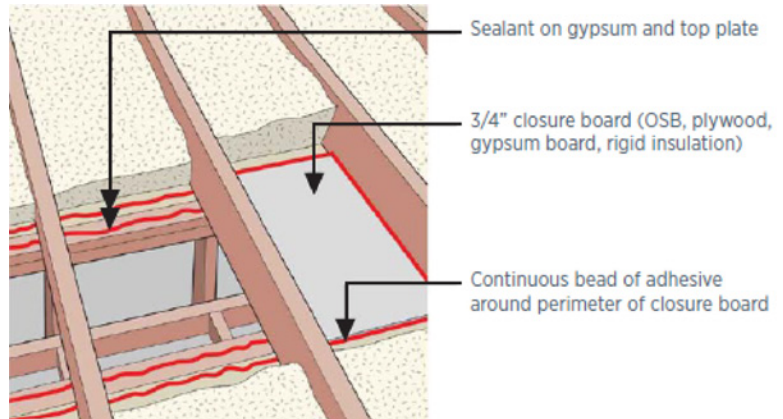
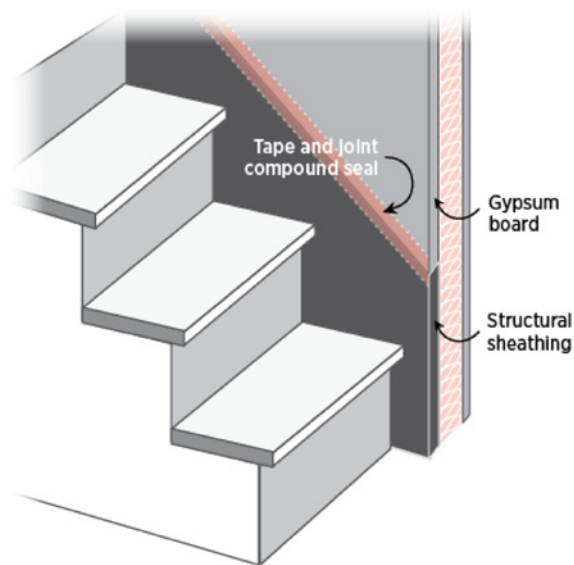


Figure 8. Place a solid air barrier over soffits as follows: pull back existing insulation; cover area with air barrier material (gypsum, plywood, OSB, rigid foam, etc.); seal edges with caulk; cover with insulation (Lstiburek 2010).



Staircase Framing at Exterior Wall/Attic

Air barrier is fully aligned with insulation; all gaps are fully sealed

If the area under the stairs is accessible, look to see if the inside wall is finished. If not, have your contractor insulate it, if needed, and cover it with a solid sheet product like drywall, plywood, OSB, or rigid foam insulation. Then, your contractor can caulk the edges and tape the seams to form an air-tight barrier. Stairs should be caulked where they meet the wall.

Figure 9. Install an air barrier and air sealing on exterior walls behind stairs. If the area behind the stairs is inaccessible, caulk stairs where they meet the wall. Use caulk if the area is already painted; use tape and joint compound if area will be painted.

Porch Roof

Air barrier is installed at the intersection of the porch roof and exterior wall

If a test-in inspection identifies air leakage at the wall separating the porch from the living space, the contractor will investigate to see if the wall board is missing or unsealed. If this is the case, the contractor will install some type of wall sheathing (oriented strand board, plywood, rigid foam board) cut to fit and sealed at the edges with spray foam. A contractor will also make sure this wall separating the attic from the porch is fully insulated.

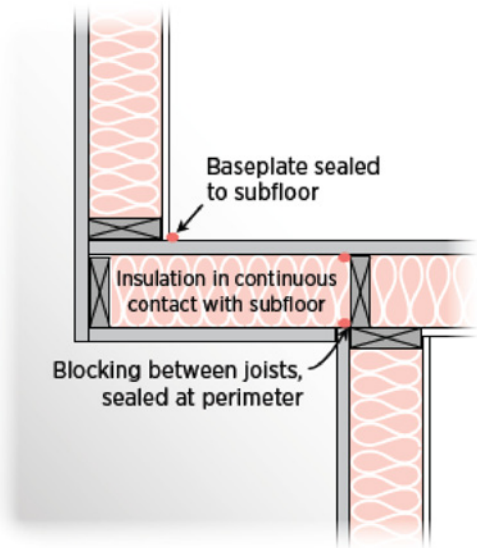


Figure 10. When researchers pulled back the porch ceiling, they found the wall board was missing so nothing was covering the insulation on this exterior wall. An air barrier of rigid foam board was put in place with spray foam (Image: Moriarta 2008).

Studies Show

Steven Winter Associates, a Building America research team lead, used a blower door test and infrared cameras to investigate high-energy bill complaints at a 360-unit affordable housing development and found nearly twice the expected air leakage. Infrared scanning revealed an air leakage path on an exterior second-story wall above a front porch. Steven Winter Associates found that, while the wall between the porch and the attic had been insulated with unfaced fiberglass batts, wall board had never been installed. The insulation was dirty from years of windwashing as wind carried dust up through the perforated porch ceiling, through the insulation, into the attic and into the wall above. Crews used rigid foam cut to fit and glued in place with expandable spray foam to seal each area. Blower door tests showed the change reduced overall envelope leakage by 200 CFM₅₀. At a cost of \$267 per unit, this fix resulted in savings of \$200 per year per unit, for a payback of less than two years.

Cantilevered Floor



Cantilevered floors are air sealed and insulated at perimeter or joist transitions

Cantilevered floors, second-story bump-outs, and bay windows are another area in the home that often lacks proper air sealing. The floor cavity must be filled with insulation with good alignment (i.e., that is completely touching) the underside of the floor. The interior and exterior sheathing needs to be sealed at the framing edges. Blocking between floor joists should form a consistent air barrier between the cantilever and the rest of the house. Continuous sheathing, such as insulating foam sheathing, should cover the underside of the cantilever and be air sealed at the edges with caulk.

Figure 11. Block and air seal both the floor-to-upper wall junction and the floor-to-lower wall junction.

R402.4.1 Building thermal envelope

The building thermal envelope shall comply with Sections R402.4.1.1 and R402.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

The most common products for creating an airtight barrier are tapes, gaskets, caulks, and spray foam materials.

Tapes

To limit air leakage, builders use tapes to seal the seams of a variety of membranes and buildings products, including housewrap, polyethylene, OSB, and plywood. Tapes are also used to seal duct seams; seal leaks around penetrations through air barriers, for example, around plumbing vents, and sheet goods to a variety of materials, including concrete. No single tape works well in all of these applications, so builders, general contractors and trades need to familiarize themselves with the range of products and what will work best (time tested) and include these materials in the overall air barrier strategy.



Image: GreenBuildingAdvisor.com

Gaskets can be Better than Caulk

When builders first learn about air sealing, they often depend heavily on caulk. After inspecting a home for leaks during a blower-door test, however, they learn that caulk has a few downsides. That's when they usually graduate to gaskets.

Typical locations for gaskets include between the:

- Top of the foundation and the mudsill;
- Subfloor and the bottom plate;
- Window frame and the rough opening;
- Bottom plate and the drywall; and
- Top plate and the drywall.

Spray Foams

Spray foams are available in a variety of different forms, from small cans to larger industrial gallon sizes. Special care needs to be taken when using these products, as some expand more than others and some can exert significant pressure on the surrounding structure during expansion.



Image: Sprayfoam.com

Who is Responsible for Air Sealing?

The IECC does not specify who is responsible for air sealing; it states that the building envelope shall be sealed in accordance with manufacturers' instructions and the provisions (checklist) of the IECC. The construction documents for permitting to begin construction are typically submitted by the person in charge of the project and responsible for making sure all measures are installed properly and meet the provisions of the code. The inspector is responsible for making sure those measures meet code by verifying through on-site inspections.

Since so many different areas of the building envelope must be sealed, the responsibility will not always be on one person, installer, or trade. For example, the mechanical contractor who installs the heating and cooling equipment most likely will not be installing an air barrier between the attic and conditioned space, as that is usually the responsibility of the insulation contractor.

However, general contractors typically assume that the insulation and air sealing contractors seal and fill the holes, including filling any unintended holes that other subs leave behind. An air sealing strategy

can include identifying who is responsible for sealing which building components, including unintended cracks or holes in the building thermal envelope.

The following table is an example of building components to be sealed and who might be responsible for sealing those components.

Table 3. Building components to be sealed and who might be responsible for sealing those components

Building Components	Contractor/Trade
Ceiling/attic, kneewalls, attic access, recessed lighting, walls, floors, garage separation, electrical and service penetrations in ceiling, floors, and walls	<ul style="list-style-type: none"> • Insulation/air sealing installers • Gypsum board contractors • Foundation contractors • Electricians • Roofers • Framers • General contractors
Service water piping, penetrations for water supply and demand	<ul style="list-style-type: none"> • Plumbers • Electricians
Rim joists, sill plates, windows, skylights, doors, porch roof, shower/tub on exterior wall, electrical box on exterior wall, fireplace	<ul style="list-style-type: none"> • Framers • Roofers • Plumbers • Electricians • Insulation/air sealing installers • Window and door installers • General contractors
Ducts, piping, shafts, penetrations, register boots	<ul style="list-style-type: none"> • HVAC installers
All of the above	<ul style="list-style-type: none"> • Inspectors • General contractors



TESTING: Requirements

The specific test requirements are based on the flow rate of air produced by a blower door at a specified pressure (50 pascals or 0.2 inches of water) when exterior doors are closed, dampers are closed but not otherwise sealed, exterior openings for continuous ventilation systems and heat recovery ventilators are closed but not sealed, HVAC systems are turned off, and duct supply and return registers are not covered or sealed.

The infiltration rate is the volumetric flow rate of outside air into a building, typically in cubic feet per minute (CFM) or liters per second (LPS). The air exchange rate, (I), is the number of interior volume air changes that occur per hour, and has units of 1/h. The air exchange rate is also known as air changes per hour (ACH).

ACH can be calculated by multiplying the building's CFM by 60, then dividing by the building volume in cubic feet. $(CFM \times 60)/\text{volume}$. The requirement is expressed in ACH, which takes account of the overall size (volume) of the home:

Total air leakage < 3-5 ACH (air changes per hour)

What is a blower door? It is a powerful fan that attaches and seals to a door (typically the entrance door to the home) and blows air into or out of the house to pressurize or depressurize the home. The inside-outside pressure difference will cause air to force its way through any cracks in the building thermal envelope. Measuring the flow rate at the specified test pressure indicates the leakiness of the envelope.



Figure 12. Blower door

Who Performs the Test and is Certification Required?

The IECC does not specifically address who should perform the test. Builders, contractors, tradesmen, or code officials can perform the test. Code officials can also request the test be performed by an independent third party. The IECC does not require the person performing the test to be certified. However, it is recommended that the person be knowledgeable and have experience in using the equipment.



RESNET and BPI provide certifications for whole-house testing. For more information go to www.resnet.org or www.bpi.org.



R402.4.1.2 Testing

The building or dwelling unit shall be tested and verified as having an air leakage rate not exceeding 5 air changes per hour in Climate Zones 1 and 2, and 3 air changes per hour in Climate Zones 3 through 8. Testing shall be conducted with a blower door at a pressure of 0.2 inches w.g. (50 pascals). Where required by the code official, testing shall be conducted by an approved third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. Testing shall be performed at any time after creation of all penetrations of the building thermal envelope.

During testing:

1. *Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures;*
2. *Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures;*
3. *Interior doors, if installed at the time of the test, shall be open;*
4. *Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;*
5. *Heating and cooling systems, if installed at the time of the test, shall be turned off; and*
6. *Supply and return registers, if installed at the time of the test, shall be fully open.*



TESTING: Presenting Results

A permanently affixed certificate posted on or near the electrical panel is not a new requirement in the IECC. However, the information required on the certificate **NOW** includes results of duct and whole-house pressure tests in addition to the predominant R-values of insulation installed in or on ceiling/roof, walls, foundations, and ducts outside conditioned spaces; fenestration U-factors and solar heat gain coefficients (SHGCs); and efficiencies of heating, cooling, and service water heating equipment.

As a recommendation for verification of testing, whomever performs the testing should also submit the test results to the building official and/or general contractor, confirming the air leakage levels have been met.

R401.2 Certificate (Mandatory)

A permanent certificate shall be completed and posted on or in the electrical distribution panel by the builder or registered design professional. The certificate shall list the results from any required duct system and building envelope air leakage testing done on the building.

2012 IECC Energy Efficiency Certificate

Insulation Rating		R-Value	
Ceiling / Roof		_____	
Wall		_____	
Floor / Foundation		_____	
Ductwork (unconditioned spaces):		_____	
Glass & Door Rating		U-Factor	SHGC
Window		_____	_____
Door		_____	_____
Heating & Cooling Equipment		Efficiency	
Heating System:	_____	_____	
Cooling System:	_____	_____	
Water Heater:	_____	_____	
Testing Results			
Ducts (unconditioned spaces):	_____	CFM/100 ft ² of conditioned floor area	
Whole House	_____	ACH @ 50 Pascals	
Name:	_____	Date:	_____
Comments:			

The illustration is an Energy Efficiency Certificate that can be created and printed using DOE's Building Energy Codes Program software called REScheck™.

www.energycodes.gov