TechNote

Building Air Tightness: Code Compliance & Air Sealing Overview

What is building air tightness?

Building air tightness describes the degree of air leakage into and out of the building's thermal enclosure which separates conditioned space from the outdoors. Air leakage is the uncontrolled flow through the thermal enclosure due to pressure imbalances caused by wind, stack effect, and mechanical equipment. Air leakage in a building should be minimized; this goal can be effectively and consistently achieved using an air sealing strategy (page 4).

Tighter buildings are intended to increase energy efficiency, durability, occupant comfort and indoor air quality. Houses have become considerably tighter over the past couple decades; however, the most recent energy codes mandate even more stringent air sealing and tightness testing requirements.

The building's air leakage rate is quantified by testing. The most common air tightness test is typically referred to as a "blower door" test (page 2). The test equipment consists of a calibrated fan, a panel to seal off the door, and a flow and pressure meter. For residential applications, the fan typically depressurizes the house to 50 Pascals at which point the air flow through the fan is recorded.

Potential Concerns with Tighter Houses

- Poor air quality due to "stale" air and indoor contaminants (such as formaldehyde, cleaning agents, and odors) that take longer to dissipate in a tighter house.
- Elevated indoor humidity that could lead to moisture accumulation and damage in the building.
- Increased risk for back-drafting of combustion appliances (caused by exhaust fans creating negative house pressures) that could lead to unsafe levels of carbon monoxide.

Benefits of Tight Houses (Reduced Air Leakage)

- Heating & cooling energy savings
- Reduced potential for moisture movement through the building thermal enclosure
- Improved insulation effectiveness and reduced risk of ice dams
- Reduced peak heating and cooling loads resulting in smaller HVAC equipment
- Improved comfort (reduces drafts and noise)
- Improved indoor air quality (limits contaminants from garages, crawl spaces, attics, and adjacent units)

Blower Door Test

Photo Provided by TEC

Testing

Blower Door Testing

Building tightness is measured by performing a blower door test [1, 2]. The most common method is a single-point depressurization test:

- Exterior windows and doors are closed, HVAC systems are off, and vents are generally left in a normal position.
- The house is depressurized to 50 Pascals (Pa) with respect to outdoors using a fan set up in a doorway.
- The fan air flow is measured in cubic feet per minute at 50 Pa (CFM50) using a pressure and flow meter.
- The air exchange rate is calculated in air changes per hour at 50 Pa (ACH50); ACH50 = CFM50x60/house volume.
- NOTE: For multifamily or attached housing, the leakage to outdoors will typically be less than total leakage. The adjacent unit(s) can be depressuraized concurrently to measure leakage to outdoors. The difference represents leakage between units.

Alternate methods include multi-point tests (measured air flows at multiple pressures used to create a curve) or tests that include pressurization measurements. Building tightness can also be presented as leakage area normalized to the building surface area. Testing standards include RESNET, ASTM E-779 and ASTM E-1827 [7].

Certified Testing Professionals

The most recent energy codes require building tightness testing. The codes do not require specific qualifications for the individual performing the blower door test. The building code official may require testing to be conducted by an approved third party. Builders may consider hiring trained and certified individuals to perform the building tightness testing. Organizations such as: RESNET (HERS raters) [2]; BPI (Building Analysts) [3]; ENERGY STAR (contractors/ raters) [4]; and State or local agency energy programs provide training and certifications to help ensure accurate results.

Understanding Air Barriers

- Air barriers control the movement of air, including entrained moisture and heat, through the building enclosure.
- Effective air barriers must be durable, continuous, air impermeable, and sealed to resist air flow and air pressure [5].
- Air barriers are required to restrict air flow through air permeable insulation (e.g., fiberglass) to maximize the installed R-value and minimize heat transfer.
- Because air carries water vapor, air barriers help reduce moisture flow and consequently moisture accumulation within walls and other building cavities; air leakage can be a greater source of moisture than vapor diffusion through building materials.
- The air barrier function can be performed by a single material or an assembly. Materials used as air barriers can perform other functions such as vapor barrier, bulk moisture barrier, wall sheathing, etc. Common construction materials such as exterior sheathing or drywall can function as an air barrier provided proper sealing of seams and penetrations.

2012 International Code Requirements

The 2012 International Residential Code (IRC) energy efficiency provisions (Chapter 11) are now identical to the residential energy efficiency requirements in the 2012 International Energy Conservation Code (IECC). The 2012 IRC mandates specific air sealing requirements, stricter building air leakage rates, and compliance inspection and testing in Section N1102.4 (IECC Section R402.4).

Section N1102.4.1.1 (R402.4.1.1) requires that components of the building thermal envelope listed in Table N1102.4.1.1 are installed in accordance with the manufacturer's instructions and the criteria listed in the table. The building code official may require that the compliance inspection be performed by an approved third party.

Table N1102.4.1.1 (R402.4.1.1) provides a comprehensive list of 16 components (such as air barriers, ceilings, walls, floors, framed cavities, and penetrations) and corresponding criteria with specific requirements (such as air barrier sealing and alignment with insulation, and the requirement for a continuous air barrier in the building envelope).

Section N1102.4.1.2 (R402.4.1.2) mandates testing and a verified maximum air leakage rate of 5 ACH50 in Climate Zones 1-2 and 3 ACH50 in Climate Zones 3-8. Testing must be conducted using a blower door at a pressure of 50 Pa (does not specify pressurization or depressurization). Basic steps to prepare the building are included. A written, and signed, report of the results must be provided to the building official. The building code official may require that testing be conducted by an approved third party.

NOTE: building tightness of 3 ACH50 or less represents less than 10% of existing buildings and will require special attention to meet the requirement, especially in attached dwelling units.

Other code considerations (2012 IRC/IECC): air leakage requirements are specified for fireplaces **(N1102.4.2/R402.4.2)**, fenestration (**N1102.4.3/R402.4.3)**, and recessed lighting **(N1102.4.4/ R402.4.4)**. Whole-house mechanical ventilation is generally required **(R303.4 & N1103.5/R403.5)**. Leaky heating and cooling ducts outside the building thermal envelope also contribute to whole building leakage rates. Duct tightness testing is not required where ducts and air handlers are located entirely within the building thermal enclosure **(N1103.2.2/R403.2.2)**.

The **2009 IRC Section N1102.4.2 (**and **2009 IECC Section 402.4.2)** included a detailed mandatory air sealing checklist, but the builder had two compliance options: a testing option to verify an air leakage rate of less than 7 ACH50 (all climate zones) or a visual inspection option to verify installation based on the checklist **(Table N1102.4.2/402.4.2**).

Critical Areas for Air Sealing

Prioritize the air sealing locations – some are more critical than others. Building science research shows that the highest priority locations are at the ceiling plane, penetrations, and rim joist areas. Walls are also a priority, particularly at top and bottom plates and at attached garages. Some areas (such as wall sheathing vertical joints) require a lot of sealant but may result in a relatively modest reduction in leakage [6].

Example Critical Areas for Air Sealing

The red dashed line represents an example continuous air boundary.

Ceiling Plane (vented attics)

- Top plates
- Access panel
- Penetrations – bath fans, duct boots, electrical
- Framed cavities – above kitchen cabinets, soffits, & chases

Walls

- Bottom plate at deck/slab
- Penetrations
- Sheathing
- Windows & doors
- Garage-side drywall
- Knee-wall air barriers
- Behind tubs & stairs
- Framed cavities – within chases & bulkheads

Fireplaces

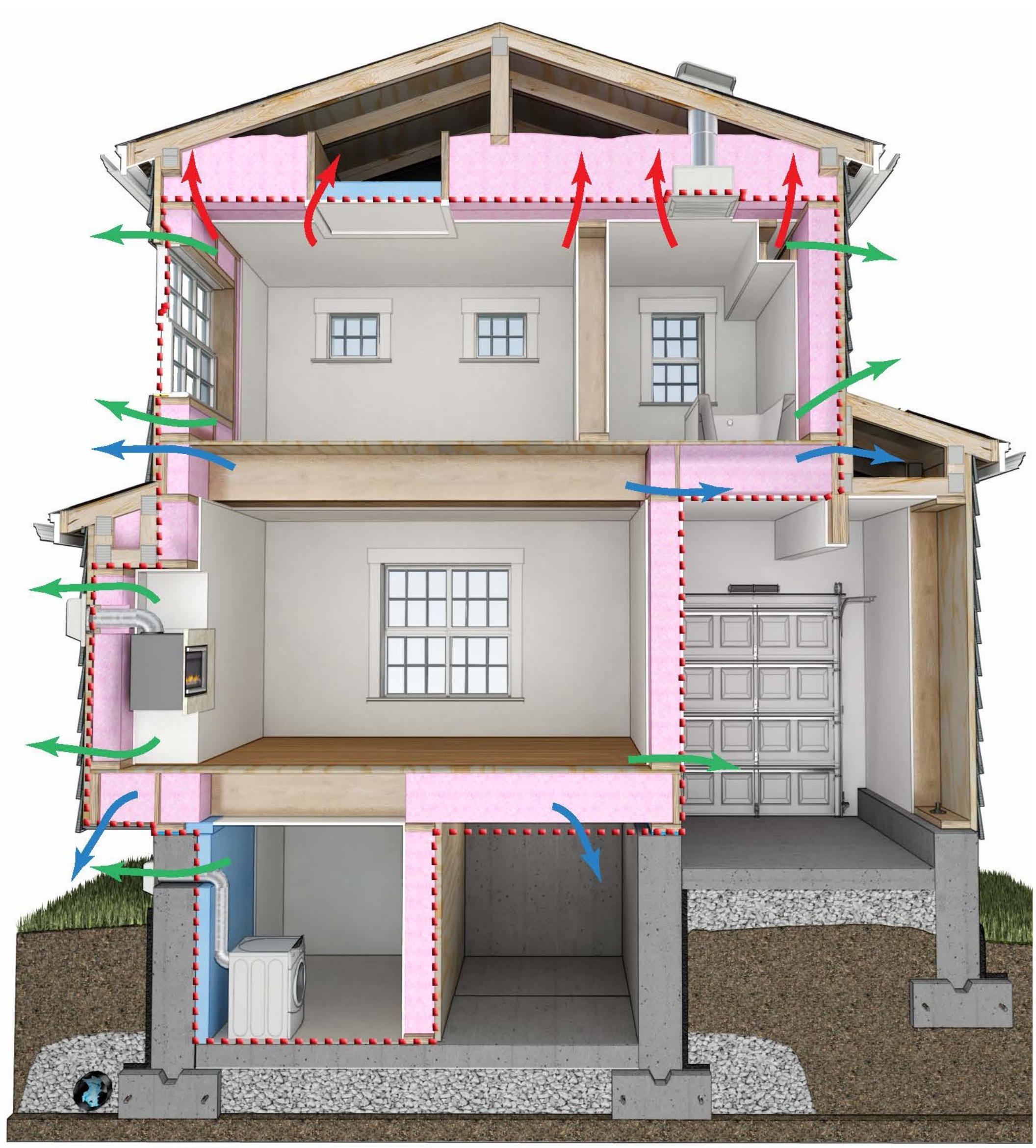
- Behind pre-fabricated fireplaces
- Around dampers & vents

Rim Joist Areas

- Rim board – joist cavity
- Sill plate at foundation
- Draft stops at garage & knee walls

Floors

- Cantilevered
- Above garages, vented crawl spaces, & unconditioned basements



Air Sealing Strategy

Develop a whole-house air sealing plan

1. Establish a specific house leakage goal to meet or exceed code (e.g., 2.5 ACH50).
2. Establish the continuous air boundary for the entire house. Avoid installing systems through the air boundary (e.g., HVAC systems not in conditioned space).
3. Prioritize the air sealing locations and efforts. Include all code requirements (See also ENERGY STAR air sealing resources [4].)
4. Conduct design review meetings with all affected trades and vendors. Include the testing partner if applicable (some may also be air sealing professionals). Evaluate available products, and select methods that are practical to install, cost-effective, and easily inspected for quality assurance. Establish trade partner scopes of work based on mutually agreed upon responsibilities and expectations.
5. Implement the plan – a thorough air sealing effort is critical for success. Quality inspections should allow for additional "touch-up" air sealing as required. Seal all large holes and focus on high priority areas.
6. Refine the plan as needed for optimum performance and cost.

Suggested techniques to achieve code compliance

- ✓ It is easier to air seal while the house is under construction rather than trying to seal after failing a tightness test. Testing prior to completion may identify leakage points that can be easily fixed.
- ✓ Perform blower door test prior to insulating the ceiling - this will allow easier access to air leakage points in the attic if the building does not meet the tightness requirement.
- ✓ When designing the house, avoid complex architectural designs that may be difficult to seal.
- ✓ Reduce the number of penetrations to the air barrier (e.g., recessed lights, speakers)
- ✓ Maintain continuity between air barrier materials

Consider combustion safety, humidity control, and air quality

- ✓ When measures are taken to tighten a house (new or existing), ensure that combustion appliances vent properly. Install direct vent (outdoor air for combustion) or power vent appliances. If you install or leave natural draft or fan-assisted draft appliances, perform combustion safety testing and install make-up air as required in accordance with industry standards and manufacturer instructions. See Reference [1] for charts that show appliance depressurization limits (p. 54) and the inter-relationship between house tightness, exhaust fan operation, and house depressurization (p. 51).
- ✓ Effective mechanical ventilation is more important installing tight buildings to control humidity and maintain indoor air quality. The HVAC trade partner is responsible for (1) designing layouts and (2) installing ducts so that measured air flows meet design expectations for source-exhaust (kitchen, bath, and garage exhaust fans) and whole-house (fresh air) ventilation systems.

What if the house fails to meet the house leakage target?

- ✓ Search for leaks at the most likely and easily accessible areas, such as the ceiling plane from the attic, with the blower door operating as a diagnostic tool.
- ✓ Multifamily/townhouse – depressurize the adjacent unit(s), or an entire building, to isolate leakage to outdoors. Air sealing common walls is still important to minimize leakage between units to control sound and odor transfer.

References

[1] The Energy Conservatory (TEC) Minneapolis Blower Door Operation Manual. August 2012. www.energyconservatory.com

[2] Residential Energy Services Network (RESNET) Chapter Eight RESNET Standard for Performance Testing and Work Scope. http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf

[3] Building Performance Institute (BPI) Technical Standards for the Building Analyst Professional, v1/4/12. http://www.bpi.org/Standards/

[4] ENERGY STAR Certified Homes: National Program Requirements, Version 3 (Rev. 07); Thermal Enclosure Checklist, Version 3 (Rev. 07); Thermal Bypass Checklist Guide, Version 2.1 updated June 2008. www.energystar.gov

[5] Lstiburek, J. (2006). BSD-104: Understanding Air Barriers. Somerville, MA: Building Science Corporation. www.buildingscience.com

[6] Characterization of Air Leakage in Residential Structures, ICAA Convention & Trade Show, 4 October 2012, Dave Wolf, Ph.D., Owens Corning, Science & Technology. http://www.insulate.org/2012ICAAConvention/airleakage.pdf

[7] ASTM E779: Standard Test Method for Determining Air Leakage Rate by Fan Pressurization; and ASTM E1827: Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door. ASTM International.