Enclosure Air Leakage Testing: What's New and What's Coming?

RESNET Annual Conference
Atlanta, GA
February 26, 2014

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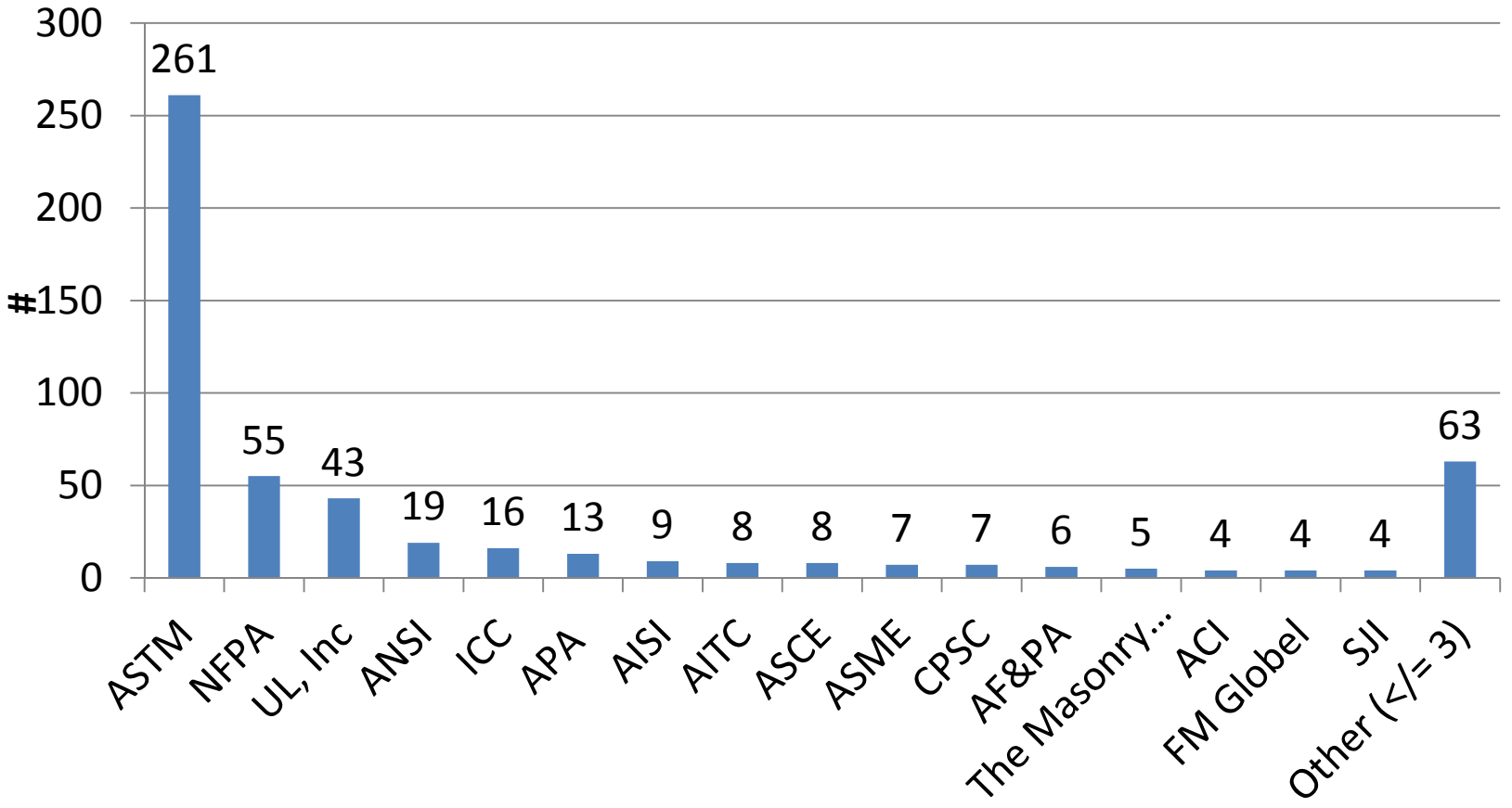
DuPont Building Knowledge Center

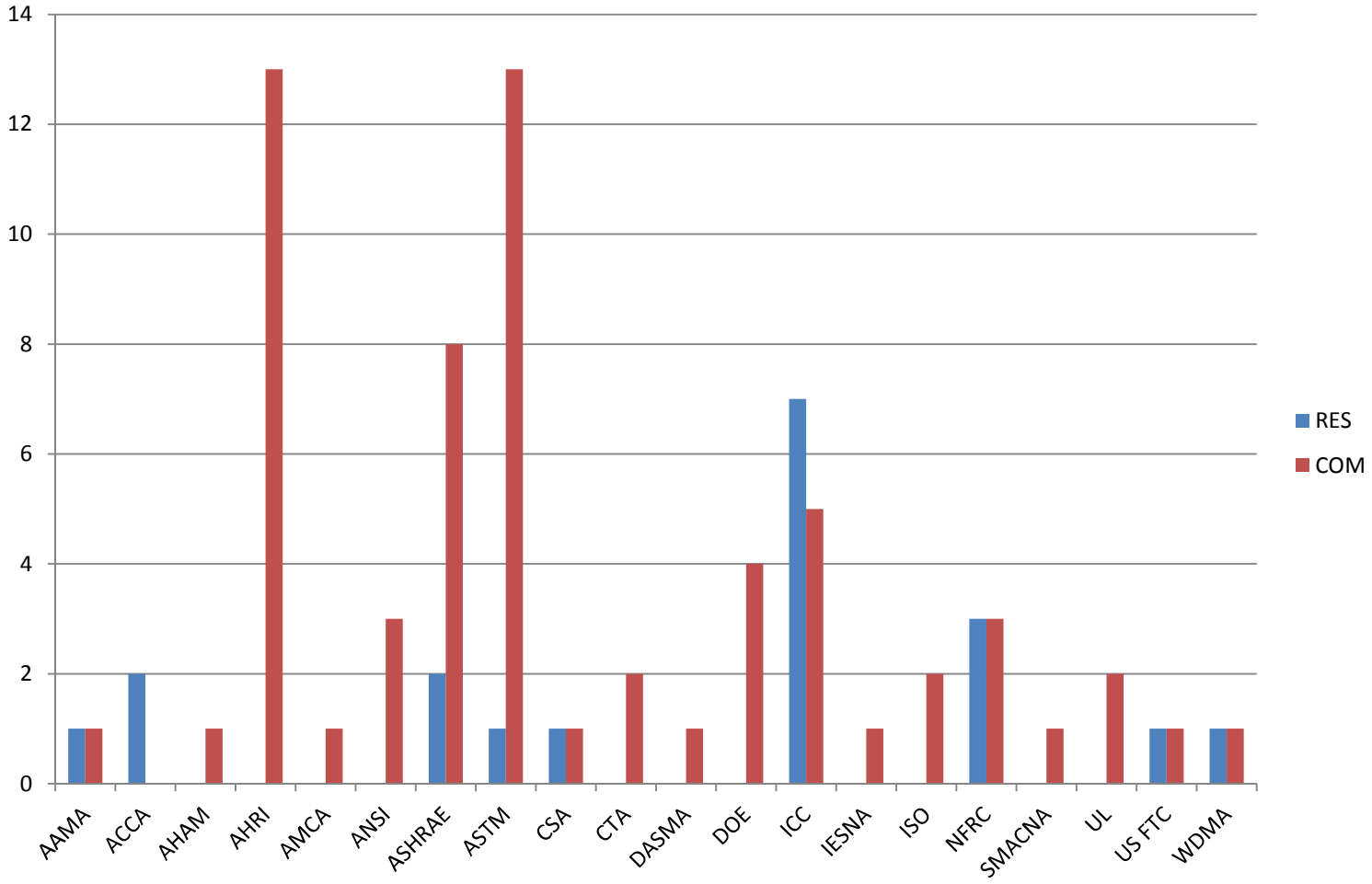
Learning Objectives:

- Understand Energy Code air barrier and building air leakage requirements
- Learn air leakage requirement changes coming in the 2015 IECC
- Understand the different air leakage test method standards
- Learn what developments in ASTM air leakage test methods are underway

Referenced Standards IBC-2012 (532 Total)



Reference Standards in the IECC-2012 (19 Residential, 64 Commercial)



Home For Sale by Owner
110 W. King Place, Nome, Alaska

This 2,009 square foot superinsulated energy-efficient and low maintenance home includes a 364 square foot heated garage with cement floor. It's one of Nome's finest houses, located on a 7,700 square foot lot (55 x 140), in an extremely convenient location. It's less than a five-minute walk from downtown, from Nome's Safeway store, and from nine of Nome's

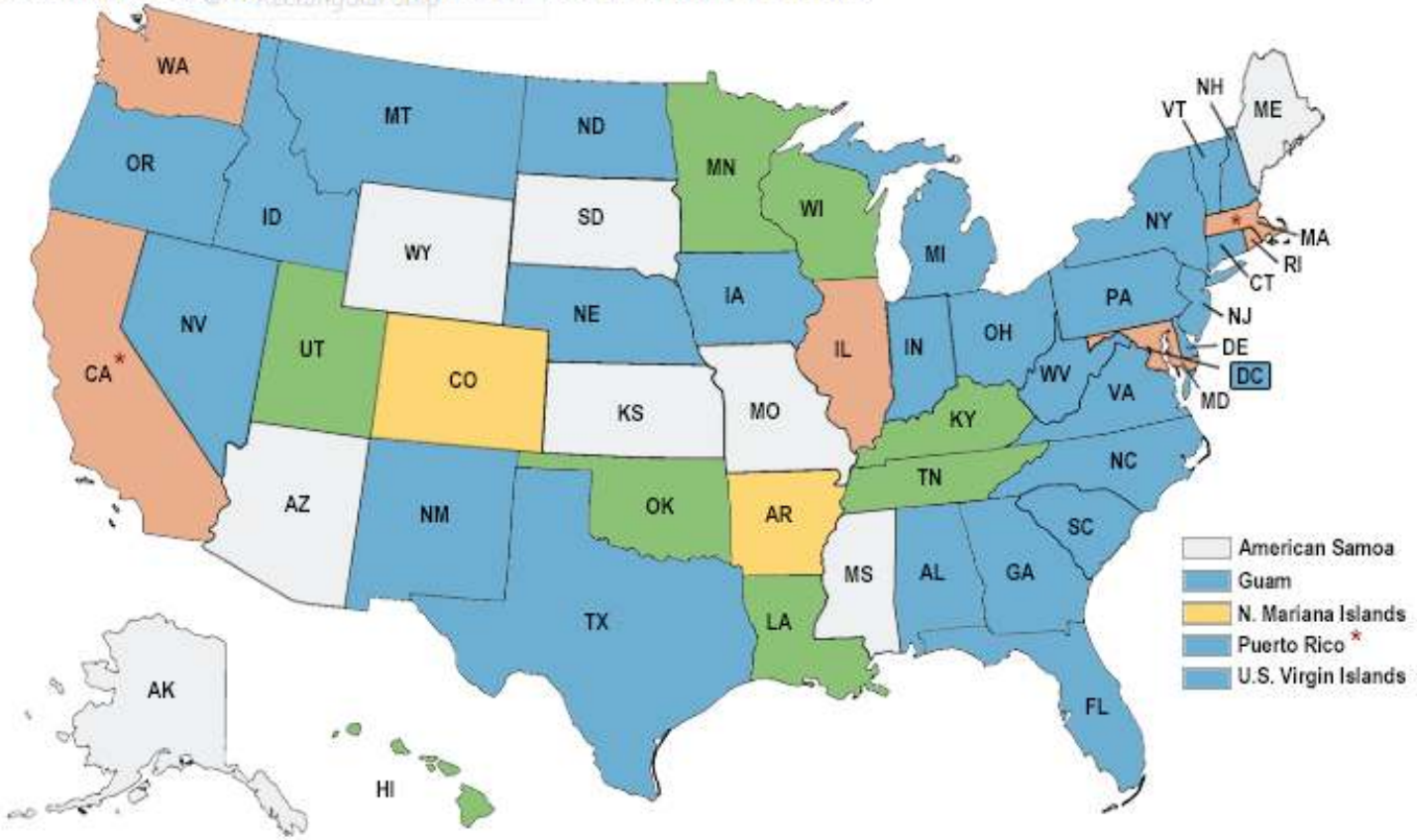
"In 1993, the home was re-sheathed in "a housewrap" with all joints carefully glued with acoustic sealant (thirty tubes of it!), providing extreme protection from wind. (Although the 1993 addition increased floor space by 30%, our heating bills actually dropped.)"

surrounds.

Performance Testing

Photos courtesy of Construction Instruction

Current Residential Building Energy Code Adoption Status



www.energycode.gov

IECC Residential – Compliance Paths

Prescriptive Path

Performance Path

Energy Rating Index Path (2015)

2015 IECC

Some jurisdictions, currently :

- ***New Mexico***
- ***Local Adoption in Arkansas, Colorado, Idaho, Kansas, Massachusetts, New York***

IECC Residential – Mandatory Provisions

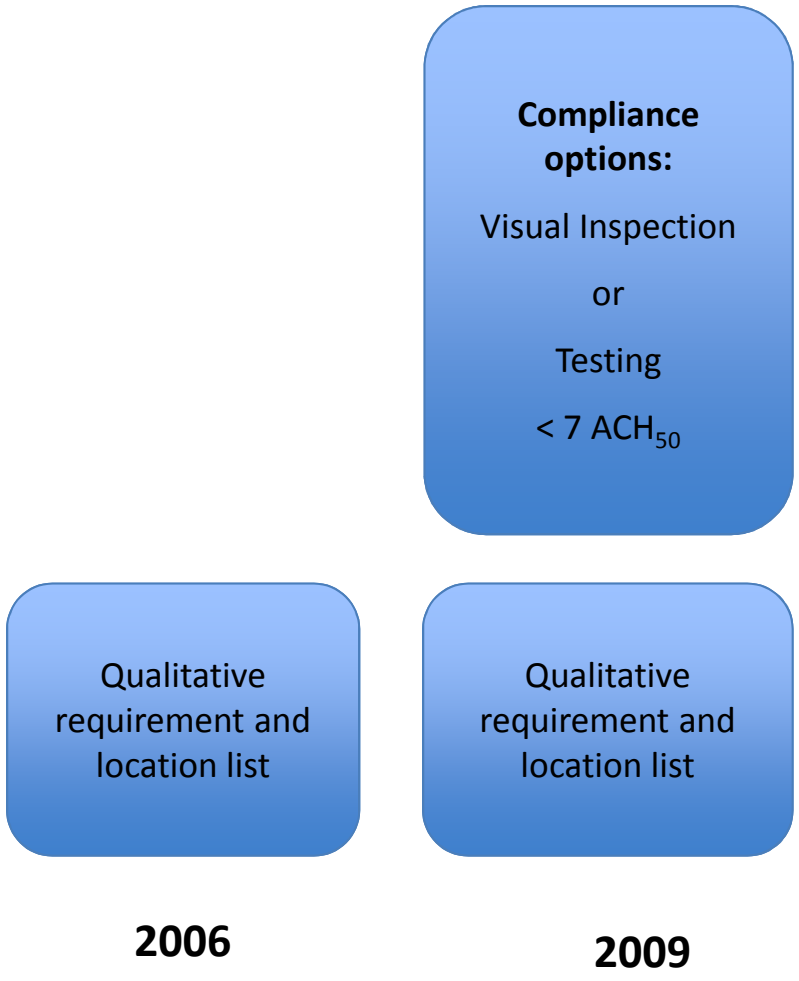
402.4.1 Building thermal envelope. The building thermal envelope shall be durably sealed to limit infiltration. The sealing methods between dissimilar materials shall allow for differential expansion and contraction. The following shall be caulked, gasketed, weatherstripped or otherwise sealed with an air barrier material, suitable film or solid material:

1. All joints, seams and penetrations.
2. Site-built windows, doors and skylights.
3. Openings between window and door assemblies and their respective jambs and framing.
4. Utility penetrations.
5. Dropped ceilings or chases adjacent to the thermal envelope.
6. Knee walls.
7. Walls and ceilings separating a garage from conditioned spaces.
8. Behind tubs and showers on exterior walls.
9. Common walls between dwelling units.
10. Other sources of infiltration

Qualitative requirement and location list

2006

IECC Residential – Mandatory Provisions



Residential: IECC-2009 R402.4

402.4.2 Air sealing and insulation. Building envelope air tightness and insulation installation shall be demonstrated to comply with one of the following options given by Section 402.4.2.1 or 402.4.2.2:

402.4.2.1 Testing option. Building envelope tightness and insulation installation shall be considered acceptable when tested air leakage is less than seven air changes per hour (ACH) when tested with a blower door at a pressure of 33.5 psf (50 Pa). Testing shall occur after rough in and after installation of penetrations of the building envelope, including penetrations for utilities, plumbing, electrical, ventilation and combustion appliances.

During testing:

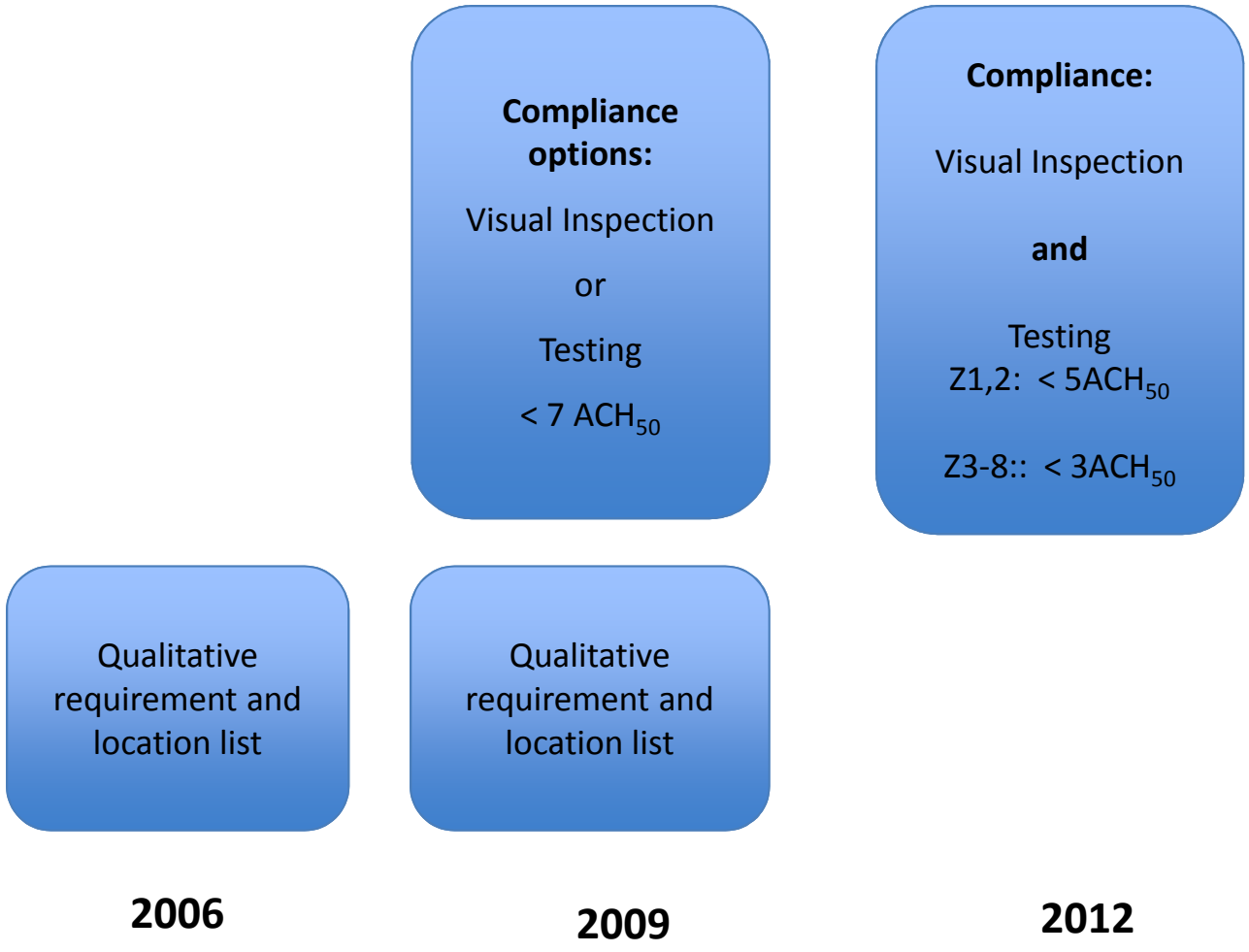
1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed;
2. Dampers shall be closed, but not sealed, including exhaust, intake, makeup air, backdraft and flue dampers;
3. Interior doors shall be open;
4. Exterior openings for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;
5. Heating and cooling system(s) shall be turned off;
6. HVAC ducts shall not be sealed; and
7. Supply and return registers shall not be sealed.

402.4.2.2 Visual inspection option. Building envelope tightness and insulation installation shall be considered acceptable when the items listed in Table 402.4.2, applicable to the method of construction, are field verified. Where required by the *code official*, an *approved* party independent from the installer of the insulation shall inspect the air barrier and insulation.

TABLE R402.4.1.1
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	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
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 crawlspace walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	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 sub-floor or drywall.
Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

IECC Residential – Mandatory Provisions



Residential: IECC-2012 R402.4

R402.4 Air leakage (Mandatory). The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.

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.

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.

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate of 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.

IECC Residential – Prescriptive Path

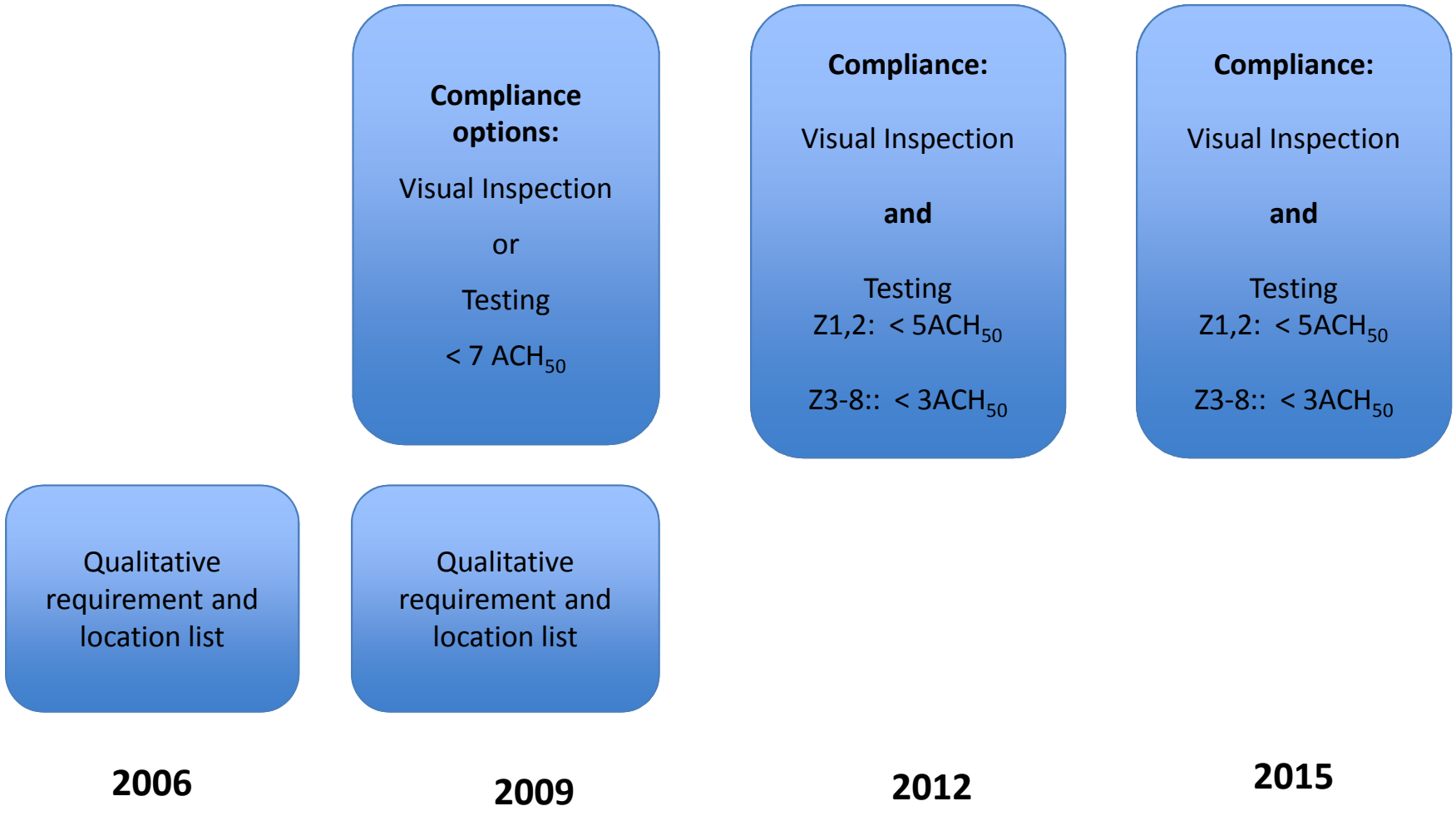


TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	CRITERIA[a]
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 [illegible] to unconditioned attic spaces shall be sealed.
Walls	Corners and headers [illegible] and the junction of the foundation and sill plate shall be sealed. The junction [illegible] and top of exterior walls shall be sealed. Exterior th[illegible] insulation for framed walls shall be installed in substantial contact [illegible] alignment with the air barrier. Knee [illegible] sealed.
Windows, skylights and doors	Th[illegible] window/door jambs and framing and skylights and framing shall be [illegible]
Rim joints	[illegible]ll be insulated and include the air barrier.
Floors (including above-garage and cantilevered floors)	[illegible]hall be installed to maintain permanent contact with underside of subfloor [illegible] [illegible]rrier shall be installed at any exposed edge of insulation.
Crawl space walls	[illegible]rovided in lieu of floor insulation, insulation shall be permanently attached to [illegible]hspace walls. [illegible] earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, an[illegible] space shall be sealed.
Narrow cavities	Batts in narrow cavities shall be cu[illegible] that on installation readily conform[illegible]
Garage separation	Air sealing shall be provided betwe[illegible]
Recessed lighting	Recessed light fixtures installed in[illegible] rated, and sealed to the drywall.
Plumbing and wiring	Batt insulation shall be cut neatly t[illegible] insulation that on installation readi[illegible] piping and wiring.
Shower/tub on exterior wall	Exterior walls adjacent to showers [illegible] separating them from the showers [illegible]
Electrical/phone box on exterior walls	The air barrier shall be installed be[illegible] boxes shall be installed.
HVAC register boots	HVAC register boots that penetrate[illegible] floor or drywall.
Fireplace	An air barrier shall be installed on [illegible]

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

TABLE 402.4.1.1 (N1102.4.1.1)
AIR BARRIER AND INSULATION INSTALLATION

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
General Requirements	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.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Knee walls shall be sealed.	Corners and headers shall be insulated. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.	
Rim joists	Rim joists shall include the air barrier.	Rim joists shall be insulated.

IECC (2015) – R402.4.1.2

R402.4.1.2 (N1102.4.1.2) Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate of 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 in **accordance with ASTM E 779 or ASTM E 1827 and reported** 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.

Performance Path – 2006 / 2009 IECC Residential

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Air exchange rate	Specific Leakage Area (SLA)d = 0.00036 assuming no energy recovery	For residences that are not tested, the same as the standard reference design. For residences without mechanical ventilation that are tested in accordance with ASHRAE 119, Section 5.1, the measured air exchange rate but not less than 0.35 ACH For residences with mechanical ventilation that are tested in accordance with ASHRAE 119, Section 5.1, the measured air exchange rate combined with the mechanical ventilation rate, *f* which shall not be less than $0.01 \times CFA + 7.5 \times (Nbr+1)$ where: *CFA* = conditioned floor area *Nbr* = number of bedrooms

Performance Path – 2012 IECC Residential

BUILDING COMPONENT	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Air exchange rate	Air leakage rate of 5 air changes per hour in Climate Zones 1 and 2, and 3 air changes per hour in Climate Zones 3 through 8 at a pressure of 0.2 inches w.g (50 Pa). The mechanical ventilation rate shall be in addition to the air leakage rate and the same as in the proposed design, but no greater than $0.01 \times CFA + 7.5 \times (Nbr + 1)$ where: *CFA* = conditioned floor area *Nbr* = number of bedrooms Energy recovery shall not be assumed for mechanical ventilation	For residences that are not tested, the same air leakage rate as the standard reference design. For tested residences, the measured air exchange rate. The mechanical ventilation rated shall be in addition to the air leakage rate and shall be as proposed.

Commercial: IECC-2006/2009 502.4 Air leakage. (Mandatory).

502.4.3 Sealing of the building envelope. Openings and penetrations in the building envelope shall be sealed with caulking materials or closed with gasketing systems compatible with the construction materials and location. Joints and seams shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials spanning joints between construction materials shall allow for expansion and contraction of the construction materials.

IECC(2012) Commercial (Mandatory)

C402.4.1 Air barriers. *A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.4.1.1 and C402.4.1.2.* ***Exception:*** *Air barriers are not required in buildings located in Climate Zones 1, 2 and 3.*	
Air barrier compliance options.	*C402.4.1.2.1* ***Materials.*** *Materials with an air permeability no greater than* ***0.004 cfm/ft² (0.02 L/s · m²)*** *under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with* ***ASTM E 2178*** *shall comply with this section..*
	C402.4.1.2.2 Assemblies. *Assemblies of materials and components with an average air leakage not to exceed* ***0.04 cfm/ft² (0.2 L/s · m²)*** *under a pressure differential of 0.3 inches of water gauge (w.g.)(75 Pa) when tested in accordance with* ***ASTM E 2357, ASTM E 1677 or ASTM E 283*** *shall comply with this section*
	C402.4.1.2.3 Building test. *The completed building shall be tested and the air leakage rate of the building envelope shall not exceed* ***0.40 cfm/ft2 at a pressure differential of 0.3 inches water gauge (2.0 L/s · m2 at 75 Pa)*** *in accordance with* ***ASTM E 779*** *or an equivalent method approved by the code official.*

ASHRAE 90.1 (2010) Envelope Air Leakage Requirements

5.4.3.1 *Continuous Air Barrier*. The entire *building envelope* shall be designed and constructed with a *continuous air barrier*.

Exceptions to 5.4.3.1:

a. *Semiheated spaces* in climate zones 1 thru 6.

b. Single wythe concrete masonry buildings in climate zone 2B

5.4.3.1.1 Air Barrier Design. The air barrier shall be designed and noted in the following manner:

a. All air barrier components of each *building envelope* assembly shall be clearly identified or otherwise noted on *construction documents*.

b. The joints, interconnections, and penetrations of the air barrier components including lighting *fixtures* shall be detailed or otherwise noted.

c. The *continuous air barrier* shall extend over all surfaces of the *building envelope* (at the lowest floor, exterior *walls*, and ceiling or *roof*).

d. The *continuous air barrier* shall be designed to resist positive and negative pressures from wind, stack effect, and mechanical *ventilation*.

5.4.3.1.2 Air Barrier Installation The following areas of the *continuous air barrier* in the *building envelope* shall be wrapped, sealed, caulked, gasketed, or taped in an approved manner to minimize air leakage:

Air barrier compliance options.	Materials that have an air permeance not exceeding 0.004 cfm/ft2 under a pressure differential of 0.3 in. w.g. (1.57psf) when tested in accordance with ASTM E 2178.
	Assemblies of materials and components (sealants, tapes, etc.) that have an average air leakage not to exceed 0.04 cfm/ft2 under a pressure differential of 0.3 in. w.g. (1.57psf) when tested in accordance with ASTM E 2357 ASTM E 1677, ASTM E 1680 or ASTM E283;

IECC(2015) Commercial (Mandatory)

C402.4 Air leakage (Mandatory). The thermal envelope of buildings shall comply with Sections C402.4.1 through C402.4.8. Alternatively the building thermal envelope shall be permitted to be tested in accordance with ASTM E779 at a pressure differential of 0.3 inches water gauge, or an equivalent method approved by the code official, and deemed to comply with the provisions of this section when the tested air leakage rate of the building thermal envelope does not exceed 0.40 cfm/ft^2. Where compliance is based on such testing the building shall also comply with Sections C402.4.5, 402.4.6 and 402.4.7.

C402.4.1 Air barriers. A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.4.1.1 and C402.4.1.2.

Exception: Air barriers are not required in buildings located in Climate Zone 2B

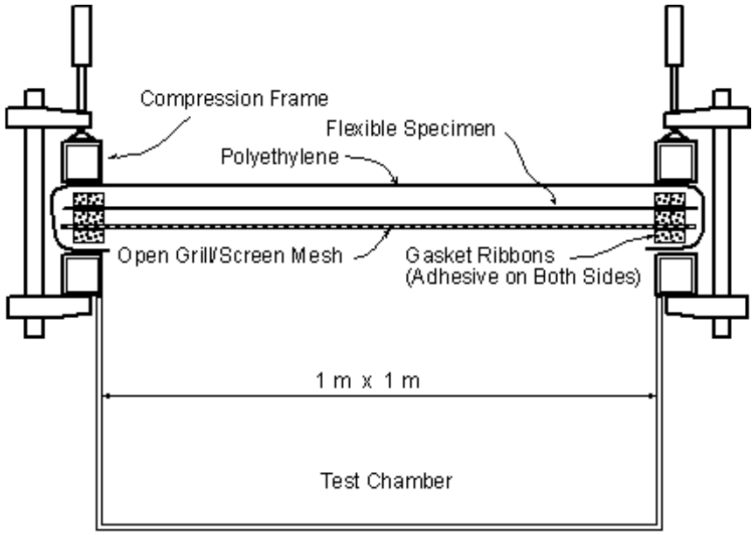
Referenced Test Standards

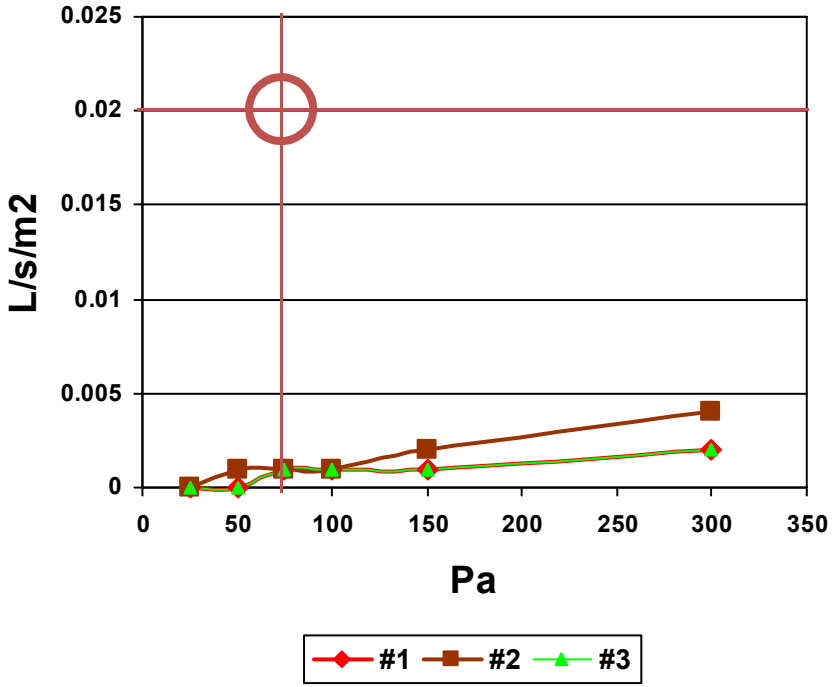
Material	Commercial	ASTM E2178
Assembly	Commercial	ASTM E283
Assembly	Commercial	ASTM E1677
Assembly	Commercial	ASTM E2357
Assembly	Commercial (ASHRAE 90.1)	ASTM E1680
Whole Building	Residential / Commercial	ASTM E779
Whole Building	Residential	ASTM E1827
Whole Building	Residential	ASHRAE 119, Section 5.1 → ASTM E779 or → CGSB 149

Materials Air Leakage Testing

- ASTM E2178 Standard Test Method for Air Permeance of Building Materials
- 0.004 cfm/sq.ft. @75 Pa
- Must be combined with installation

Air Barrier Materials – ASTM E2178





Current method is defined for flexible sheet and rigid boards. Standard specimen preparation for fluid applied materials still being developed.

Diagram from CCMC Technical Guide for Air Barrier Materials Testing

Code Evaluation Reports

ESR-2375
Issued September 1, 2008
This report is subject to re-examination in one year.

ICC Evaluation Service, Inc.
www.icc-es.org

Business/Regional Office ▪ 5360 Workman Mill Road, Whittier, California 90601 ▪ (562) 699-0543
Regional Office ▪ 900 Montclair Road, Suite A, Birmingham, Alabama 35213 ▪ (205) 599-9800
Regional Office ▪ 4051 West Flossmoor Road, Country Club Hills, Illinois 60478 ▪ (708) 799-2305

DIVISION: 07—THERMAL AND MOISTURE PROTECTION
Section: 07270—Air Barriers
Section: 07280—Water-resistive Barriers

REPORT HOLDER:

E.I. DuPONT DE NEMOURS & COMPANY, INC. (DuPONT™)
DuPONT BUILDING INNOVATIONS
WILMINGTON, DELAWARE 19880-0721
(800) 44-TYVEK
www.construction.tyvek.com
tyvekinf@usa.dupont.com

EVALUATION SUBJECT:

DUPONT™ TYVEK® HOMEWRAP®–STYLE 1056B; DUPONT™ TYVEK® STUCCOWRAP®–STYLE 1062X; DUPONT™ TYVEK® DRAINWRAP™–STYLE 1063X; DUPONT™ TYVEK® COMMERCIALWRAP®–STYLE 1162B; AND DUPONT™ TYVEK® HEADERWRAP

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2006 *International Building Code*® (IBC)
- 2006 *International Residential Code*® (IRC)
- 2006 *International Energy Conservation Code*® (IECC)
- Other Codes (see Section 8.0)

Properties evaluated:

- Water resistance
- Surface-burning characteristics
- Air leakage
- Wall draining characteristics (DuPont™ Tyvek® StuccoWrap®–Style 1062X and DuPont™ Tyvek® DrainWrap™–Style 1063X only) for EIFS and one-coat stucco

2.0 USES

DuPont™ Tyvek® HomeWrap®–Style 1056B; DuPont™ Tyvek® StuccoWrap®–Style 1062X; DuPont™ Tyvek® DrainWrap™–Style 1063X; DuPont™ Tyvek® CommercialWrap®–Style 1162B; and DuPont™ Tyvek® HeaderWrap® are used as water-resistive barriers on the exterior side of exterior walls of buildings of any construction type under the IBC and construction permitted under the IRC, except as noted in Section 4.4. They are equivalent to Grade D paper with a 60-minute water-resistance rating as described in IBC Section 2510.6 and IRC Section R703.6.3. All products may be used as air

sheets with variations as described in Sections 3.2 through 3.6.

All products have a flame spread index of less than 25 and a smoke-developed index of less than 450, when tested in accordance of ASTM E 84.

The sheet materials have an air leakage rate not exceeding 0.02 L/s/m² (0.004 cfm/ft²) when used as an air barrier material under IRC Section N1102.4.1 and IECC Section 402.4 or 502.4.

3.2 DuPont™ Tyvek® HomeWrap®–Style 1056B:

This product is a smooth sheet with a nominal basis weight of 1.8 ounces per square yard (61 grams per square meter) and is produced in rolls of varying sizes.

3.3 DuPont™ Tyvek® StuccoWrap®–Style 1062X:

The product has a surface texture that is intended to allow for drainage of water that may get behind the exterior wall finish material. This product has a nominal basis weight of 2.1 ounces per square yard (71 grams per square meter) and is produced in rolls of varying sizes.

3.4 DuPont™ Tyvek® DrainWrap™–Style 1063X:

The product has a surface texture that is intended to allow for drainage of water that may get behind the exterior wall finish material. This product has a nominal basis weight of 2.1 ounces per square yard (71 grams per square meter) and is produced in rolls of varying sizes.

3.6 DuPont™ Tyvek® CommercialWrap®–Style 1162B:

This product is a smooth sheet with a nominal basis weight of 2.7 ounces per square yard (92 grams per square meter) and is produced in rolls of varying sizes.

3.8 DuPont™ Tyvek® HeaderWrap®:

This product is the same as Tyvek® HomeWrap®, except that the rolls are narrower.

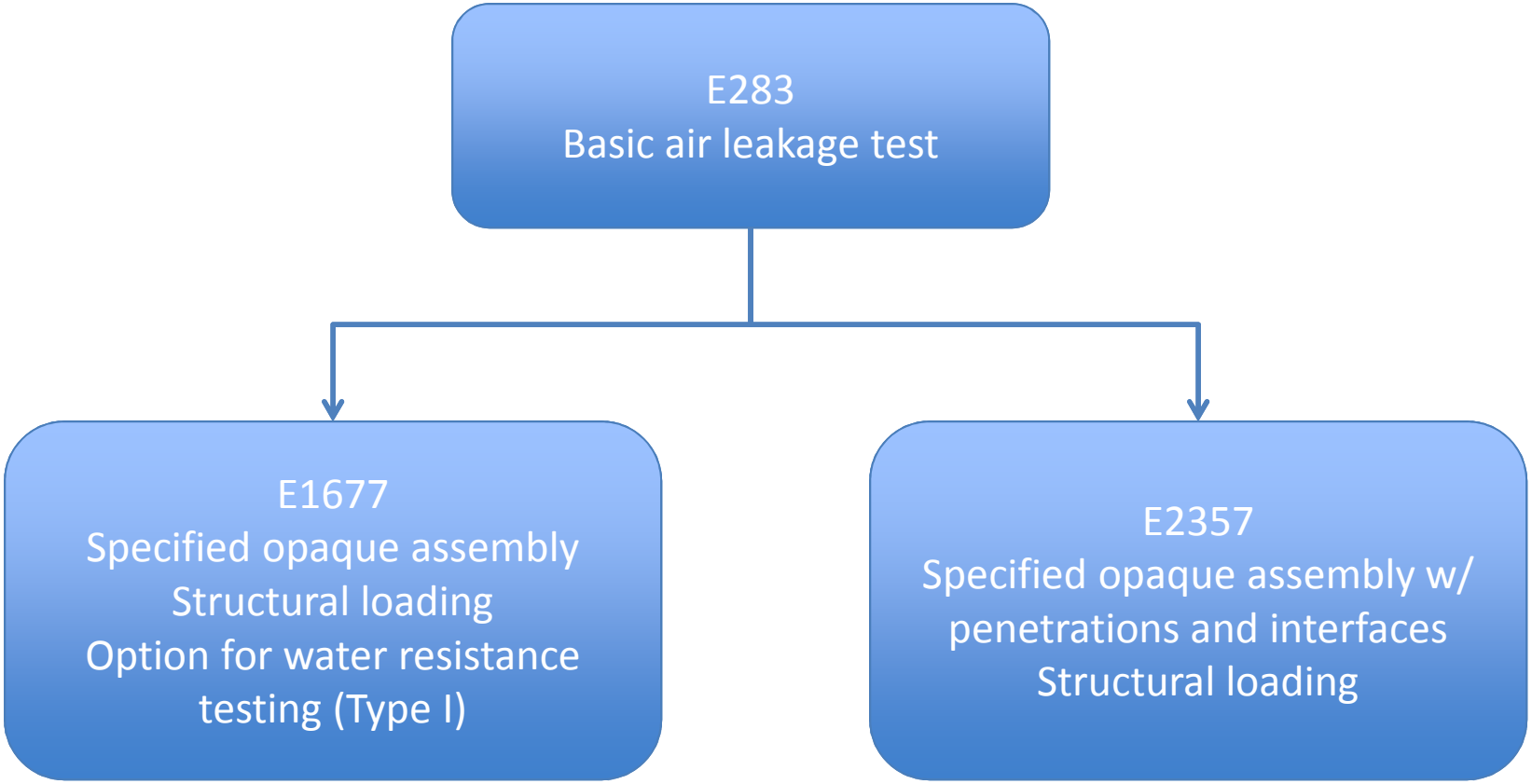
The sheet materials have an air leakage rate not exceeding 0.02 L/s-m^2 [0.004 cfm/ft^2 at 0.3 w.g. (1.57 psf)] when used as an air barrier material under IRC Section N1102.4.1 and IECC Section 402.4 or 502.4.

Assembly Air Leakage Testing

Testing of *air barrier assemblies* is an essential step to demonstrate performance of installed air barriers

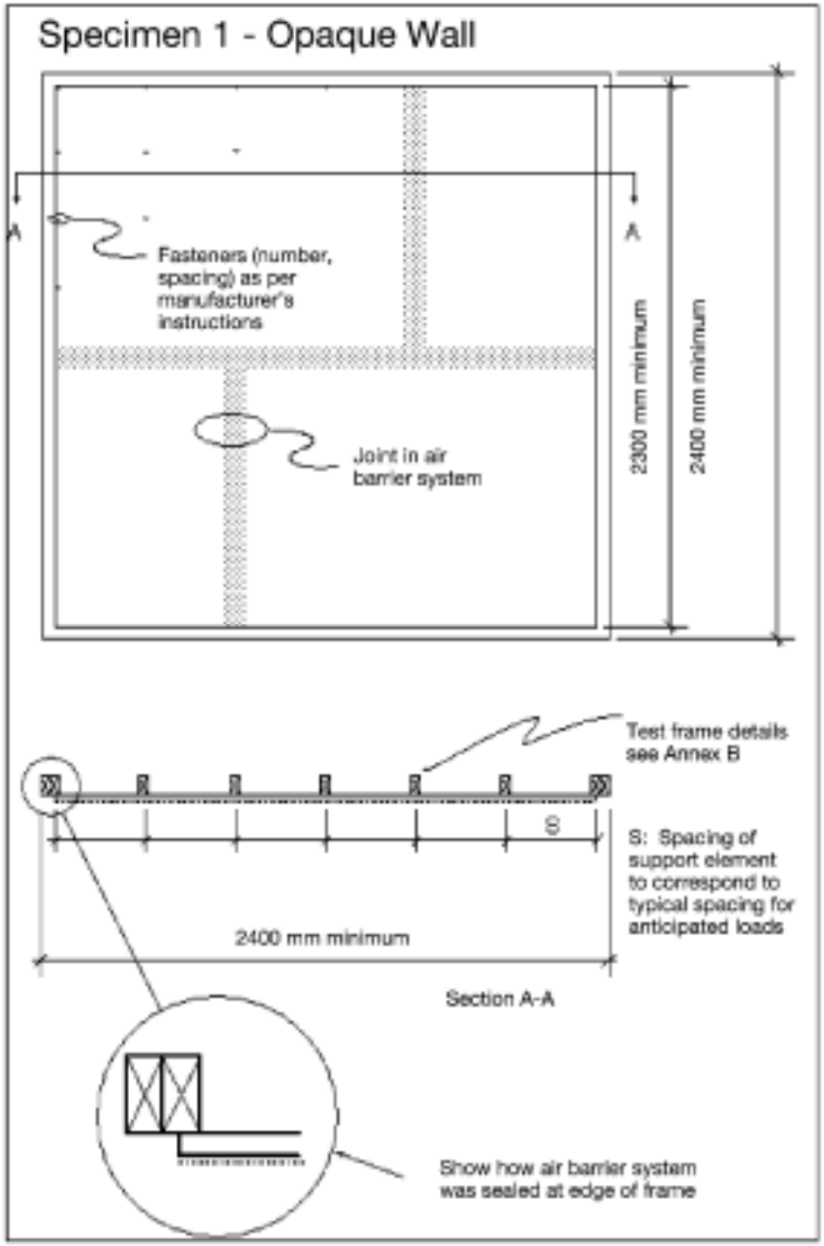
- ASTM E283 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
- ASTM E1677 Standard Specification for an Air Barrier (AB) Material or System for Low-Rise Framed Building Walls
- ASTM E2357 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies
- ASTM E1680 Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems

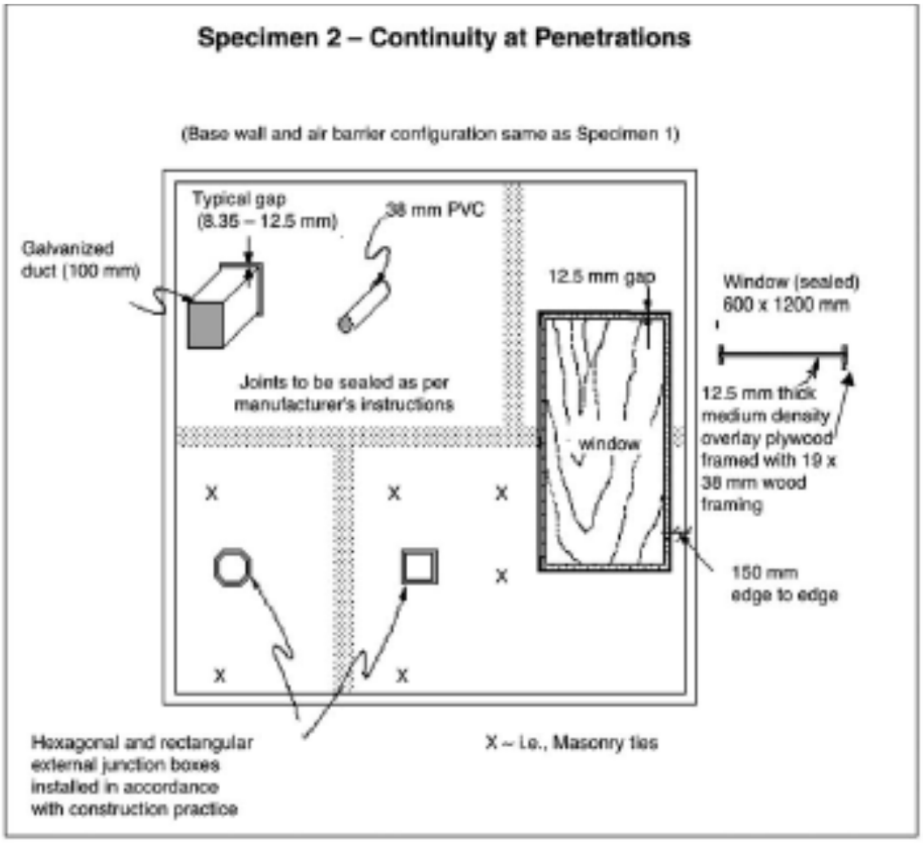
- 0.04 cfm/sq.ft. @75 Pa



ASTM E1677 / ASTM E2357

	ASTM E1677-05	ASTM E2357-05
Number of Test Specimen and configuration	One Specimen: Opaque Wall (8 x 8-ft walls) (fasteners to simulate wood siding or brick ties required)	Test two of the three Specimens (8 x 8 -ft walls): 1 – Opaque Wall 2 – Wall with penetrations 3 – Wall-Foundation Interface
Conditions for Air Leakage Testing	**Five Test Pressures:** • 75Pa (1.56 psf, 25 mph) • two pressures below 75 Pa • two pressures above 75 Pa Air leakage results are reported at 75Pa ***(Positive & negative pressures)***	**Seven Test Pressures:** +/- 25Pa (0.56 psf, 15 mph) +/- 50Pa (1.04 psf, 20 mph) +/- 75Pa (1.56 psf, 25 mph) +/- 100Pa (2.09 psf, 30 mph) +/- 150Pa (3.24 psf, 35 mph) +/- 250Pa (5.23 psf, 45 mph) +/- 300Pa (6.24 psf, 50 mph) ***(Positive & negative pressures)***
Pressure Loading Schedule	Sustained loads up to +/- 500 Pa (10.4 psf, 65 mph) ***(Positive & negative pressures)***	1 - Sustained, +/- 600Pa (12.5 psf, 71 mph) 2 - Cyclic, +/- 800 Pa (16.7 psf, 82 mph) 3 - Gust, +/- 1200 (25 psf, 100 mph) ***(Positive & negative pressures)***





Illustrations for ASTM E2357

ASTM E1677: Two Air Barrier Classifications

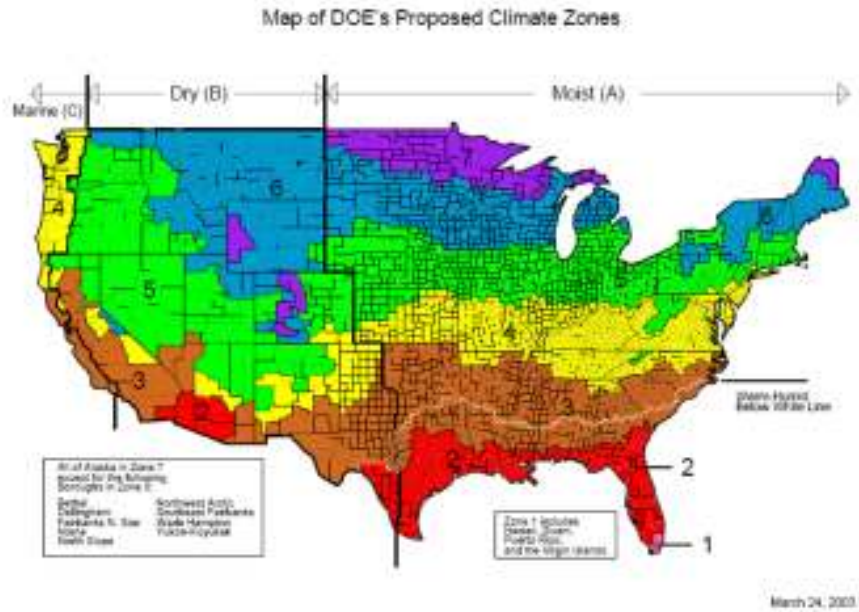
Performance Properties	AB Classifications	
	Type I	**Type II**
Air leakage As tested by E283	**< .06 cfm/ft² @ 75 Pa**	
Structural Integrity As tested by E330	**2 in. H_20 or 500 Pa (65 mph) for 1 hr in each direction**	
Water Resistance As tested by E331	**No penetration for 15 min of simulated wind driven rain @ 0.11 H_2O or 27 Pa (15 mph)**	**Not Required**
Water Vapor Permeance As tested by E96A	**Measured**	

Building Air Leakage Testing

Testing *whole building* at the end of the project may be too late and/or too expensive to fix mistakes

- ASTM E779 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
- ASTM E1827 Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
- CAN/CGSB-149.10-M86, Standard for Determination of Airtightness of Buildings by the Fan Depressurization Method

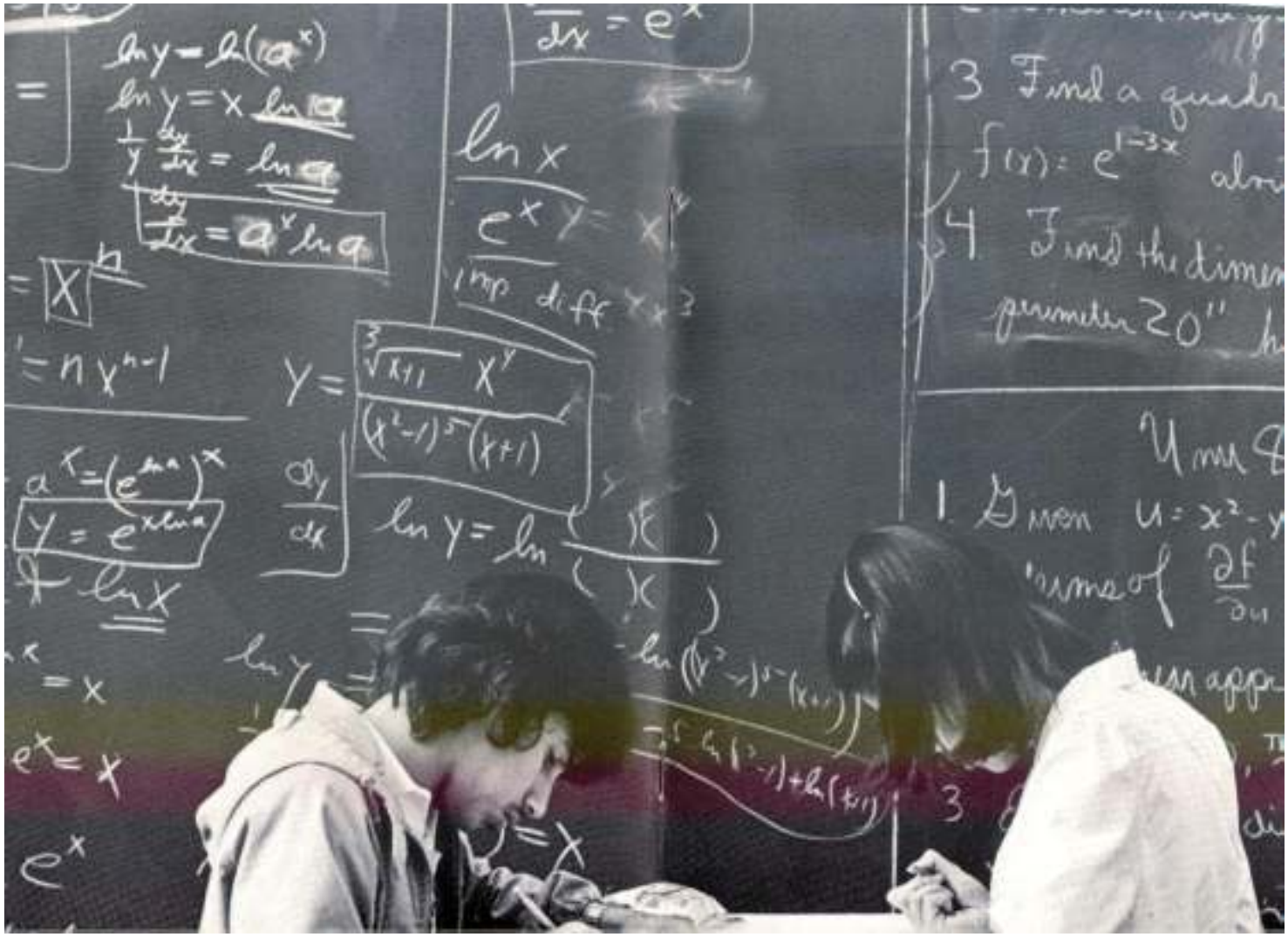
Air Leakage Requirements

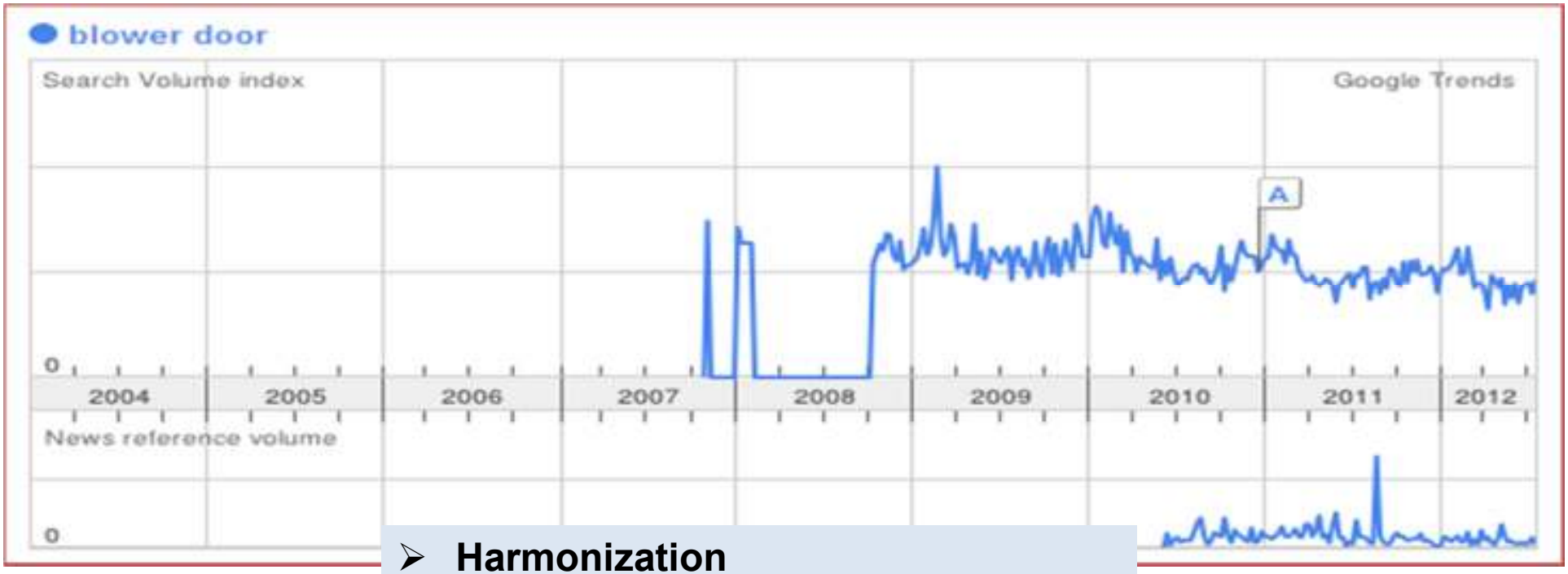


CLIMATE ZONE	2012 IECC RES	2012 IECC COM
1	5 ACH_{50}	Air barrier not required
2	5 ACH_{50}	Air barrier not required
3	3 ACH_{50}	Air barrier not required
4 X-MARINE	3 ACH_{50}	0.40 cfm/ft^2
4 MARINE	3 ACH_{50}	0.40 cfm/ft^2
5	3 ACH_{50}	0.40 cfm/ft^2
6	3 ACH_{50}	0.40 cfm/ft^2
7	3 ACH_{50}	0.40 cfm/ft^2
8	3 ACH_{50}	0.40 cfm/ft^2

Comparison of Building Air Leakage Test Standards

Standard	Test Conditions	Measurement Protocol	Metric	Reference Pressure	Building Type
ASTM E779	Pressurization & Depressurization	Multi-point Measurement	Equivalent Leakage Area	4 Pa	single zone
CGSB 149	Pressurization	Multi-point Measurement	Equivalent Leakage Area	none specified	small detached buildings
ASTM E1827	Pressurizaton, Depressurization or Both	Single-point and dual point methods	Air Leakage	50 Pa	single zone
RESNET Ch 8	Pressurization or Depressurization	Single-point, multi-point, repeated single-point	Air Leakage	50 Pa	low rise, three stories or less, residential and light commercial buildings





- **Harmonization**
- **Additional Applications**
- **Support Compliance**

Harmonization

Whole Building	Residential / Commercial	E779
Whole Building	Residential	E1827
Whole Building	Residential	ASHRAE 119, Section 5.1 → ASTM E779 or CGSB 149

IECC-Residential	ASTM E779	RESNET Chapter 8
Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weatherstripping or other infiltration control measures;		Doors and windows that are part of the conditioned space boundary shall be closed and latched.
		Operable window trickle-vents and through-the-wall vents: Shall be closed.
Interior doors, if installed at the time of the test, shall be open;	All interconnecting doors in the conditioned space shall be open such that a uniform pressure shall be maintained within the conditioned space to within 610 % of the measured inside/outside pressure difference.	Interior Doors: Shall be open within the Conditioned Space Boundary.
		Attached garages: All exterior garage doors and windows shall be closed and latched unless the blower door is installed between the house and the garage, in which case the garage shall be opened to outside by opening at least one exterior garage door.
		Crawlspaces: If a crawlspace is inside the conditioned space boundary, interior access doors and hatches between the house and the crawlspace shall be opened and exterior crawlspace access doors, vents and hatches shall be closed. If a crawlspace is outside the conditioned space boundary, interior access doors and hatches shall be closed. For compliance testing purposes, crawl-space vents shall be open.
		Attics: If an attic is inside the conditioned space boundary, interior access doors and hatches between the house and the conditioned attic shall be opened; and attic exterior access doors and windows shall be closed. If an attic is outside the conditioned space boundary, interior access doors and hatches shall be closed and exterior access doors, dampers or vents shall be left in their as found position and their position during testing shall be recorded on the test report.

IECC-Residential	ASTM E779	RESNET Chapter 8
Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but not sealed beyond intended infiltration control measures;	HVAC balancing dampers and registers shall not be adjusted. Fireplace and other operable dampers shall be closed unless they are used to pass air to pressurize or de-pressurize the building.	Chimney dampers and combustion-air inlets on solid fuel appliances: Dampers shall be closed.
Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;		
		Evaporative coolers: The opening to the exterior shall be placed in its off condition. If there is a seasonal cover, install it.
		Whole building fan louvers/shutters: Shall be closed. If there is a seasonal cover, install it.
		Non-motorized dampers which connect the conditioned space to the exterior or to unconditioned spaces: Dampers shall be left as found.
		Un-dampered or fixed-damper intentional openings between conditioned space and the exterior or unconditioned spaces: Shall be left open or fixed position, however, temporary blocking shall be removed. For example: fixed-damper ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) shall be left in their fixed-damper position. Exception: Un-dampered supply-air or exhaust-air openings of continuously operating mechanical ventilation systems shall be sealed (preferably seal at the exterior of enclosure) and ventilation fans shall be turned off as specified above.

IECC-Residential	ASTM E779	RESNET Chapter 8
Heating and cooling systems, if installed at the time of the test, shall be turned off; and		Combustion appliances: Shall remain off during the test.
		Combustion appliance flue gas vents: Shall be left in their normal appliance-off condition.
		Fans: Any fan or appliance capable of inducing airflow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawl space and attic ventilation fans. Continuously operating ventilation systems shall be turned off and the air openings sealed, preferably at the exterior terminations.
Supply and return registers, if installed at the time of the test, shall be fully open		Supply registers and return grilles: Shall be left open and uncovered.
		Plumbing drains with p-traps: Shall be sealed or filled with water, if empty

Expanded Applications

Materials: E2178 currently just covers flexible sheet and rigid board

→ Fluid applied applications being developed

- ❑ Free film method
- ❑ Substrate application method

Assemblies: E2357

→ Proposed inclusion of additional wall & roofing assemblies

Expand Applications

Building Enclosure Testing:

→ multi-zone

→ Larger building

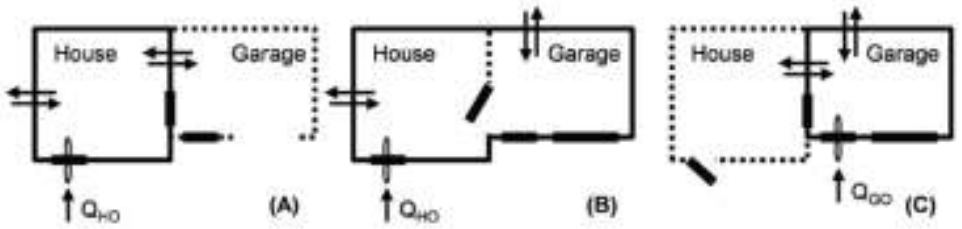
IECC Garage / House Interface Proposal RE93-13

R402.4.1.3 (N1102.4.1.3) Connection to Garage. The building or dwelling unit shall be tested and verified as being separate from an attached garage. While the blower door is being utilized to test the building or dwelling unit's leakage rate, the connection between the dwelling unit and the garage shall also be tested. The pressure in the garage with reference to dwelling unit shall not be less than 45 Pascals relative to the dwelling unit when the dwelling unit pressure is at 50 Pascals relative to the outside.

Research example:
Erin L. Hult, PhD, Max H. Sherman, PhD, and Iain Walker, PhD, "*Blower Door Techniques for Measuring Interzonal Leakage*", Thermal Performance of the Exterior Envelopes of Whole Buildings XII, Clearwater Beach, FL, December 2013.

Compared Different test configurations:
Sets of single blower
- Three single zones method
- Conventional two-test method
- Garage 0/1 method
- LBNL IzLT method

Methods that use two blower doors simultaneously :
- Pressure balancing method
- Herrlin and Modera (1988) method



gure 1 Three single zones method using test configurations A, B, and C.

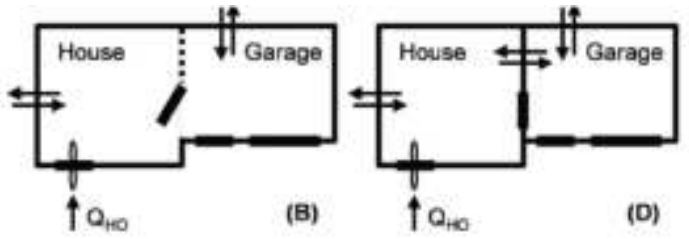


Figure 2 Conventional two-test method, using configurations B and D.

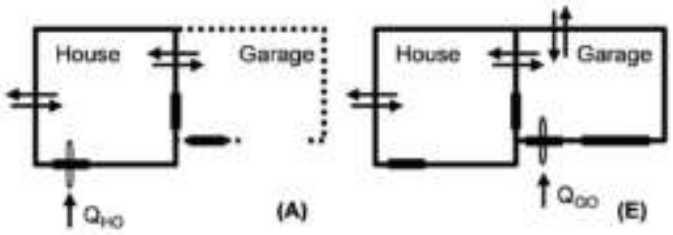
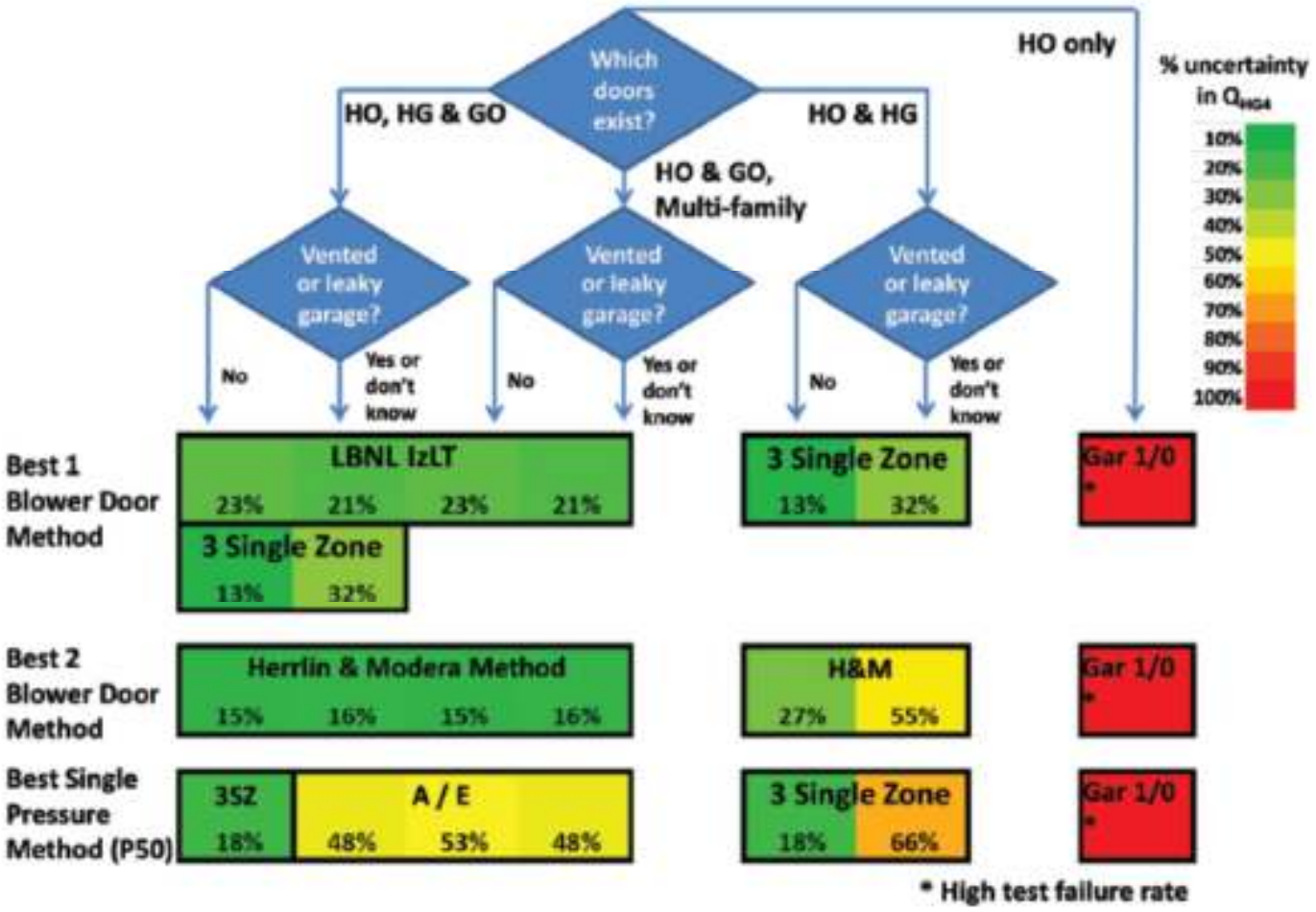


Figure 3 LBNL IzLT, using configurations A and E.

Decision Tree for Hult, et. al. "*Blower Door Techniques for Measuring Interzonal Leakage*", Thermal Performance of the Exterior Envelopes of Whole Buildings XII, Clearwater Beach, FL, December 2013.



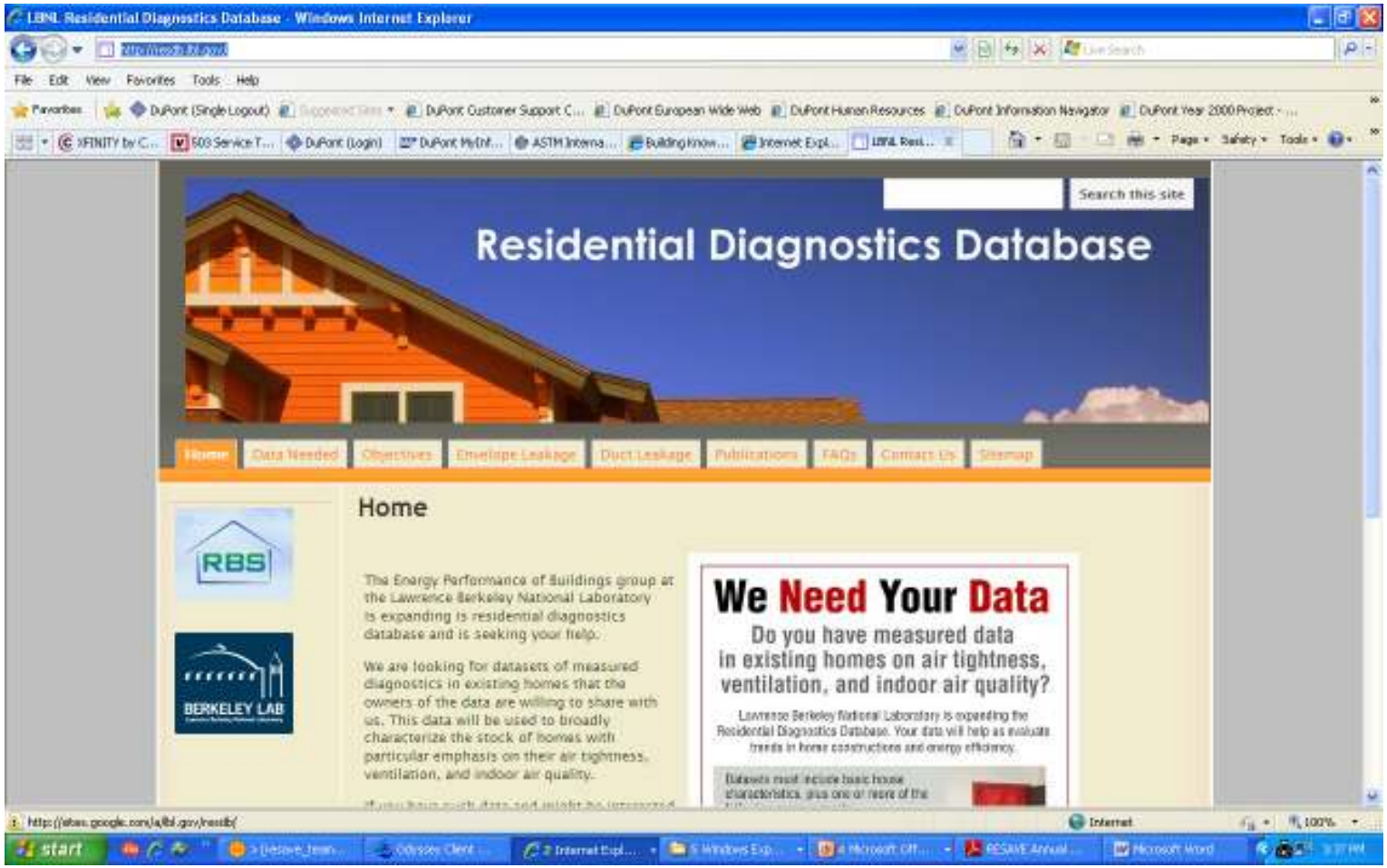
Research example:
Terry Brennan, Wagdy Anis, Gary Nelson, and Collin Olson, PhD , "*ASHRAE 1478: Measuring Airtightness of Mid- and High-Rise Non-Residential Buildings*" Thermal Performance of the Exterior Envelopes of Whole Buildings XII, Clearwater Beach, FL, December 2013.

- ASHRAE 1478 is a research project designed to measure enclosure airtightness of mid- and high-rise buildings in the United States.
- Data were collected from 16 non-residential buildings in climate zones 2–7 constructed since the year 2000.
- A fan pressure testing protocol based on ASTM E779 was developed by the project team.
- A number of issues in using E779 to test large building were identified, discussed, and addressed.

Support Compliance

- Build on industry experience & research
- New Standards Development
- “Interlaboratory” Studies to determine precision & bias

LBNL Data Base
http://resdb.lbl.gov/



Research example:
Wanyu R. Chan, PhD. And Max H. Sherman, PhD, "*Building Envelope and Duct Airtightness of New US Dwellings*", Thermal Performance of the Exterior Envelopes of Whole Buildings XII, Clearwater Beach, FL, December 2013.

- *Analyzed the building envelope and duct system airtightness of US single-family detached homes built since 2000 (Lawrence Berkeley National Laboratory Residential Diagnostics Database (ResDB)).*
  - *26,000 building envelope and 11,000 duct system air leakage data.*
- *The majority of US homes built in the past ten years meet IECC 2009.*
  - *About 80% met the IECC building envelope airtightness guideline of 7 ACH50.*
  - *Over 90% of the homes met the IECC 2009 duct system airtightness guideline of 12 cfm25.*
- *Fewer homes are meet the 2012 levels,*
  - *Only30%of the homes met IECC 2012 building envelope airtightness of 5ACH50 in climate zones 1 and 2, and 10% meeting 3 ACH50 in climate zones 3–8.*
  - *Slightly over half of the US homes in ResDB are meeting the IECC 2012 duct system airtightness guideline of 4 cfm25..*

Residential Air Leakage Sequential Testing: IBACOS Lab House

Stage	Tested Air Leakage	
Housewrap installed: Window and door openings andother penetrations integrated with air barrier and drainage plane	**3.0 ACH_{50}**	*"Housewrap as primary air barrier required great attention to detail…but it worked"*
After spray foam installed in attic, strategically sealing penetrations in 2nd floor ceiling plane	**0.88 ACH_{50}**	
After spray foam in the band joists	**0.77 ACH_{50}**	
After wall cavity insulation and drywall installed	**0.65 ACH_{50}**	
Complete	**0.54 ACH_{50}**	"*Ultimate target was Passivhaus level of airtightness, which is 0.6"*

*Source: Oberg, B, "**Energy Efficiency Lab Home: Case Study", EEBA Conference, September 2011.***


US Army Corps of Engineers Air Leakage Test Protocol

Measuring Air Leakage in Buildings for the US Army Corps of Engineers

Written by:
Collin Genge, Retrotec Inc

All new buildings must:

1. Achieve an air leakage rate not to exceed **0.25 cfm/ft²** *@ 75Pa*

2. Pass an air leakage test per ASTM E779

The Blower Door Testing – Basic Steps

The blower door test is performed by certified professionals, after the exterior envelope is completed. The test consists of the following basic steps:

1. Set up the building

- Close exterior doors and openings
- Open interior doors and openings
- Control occupants

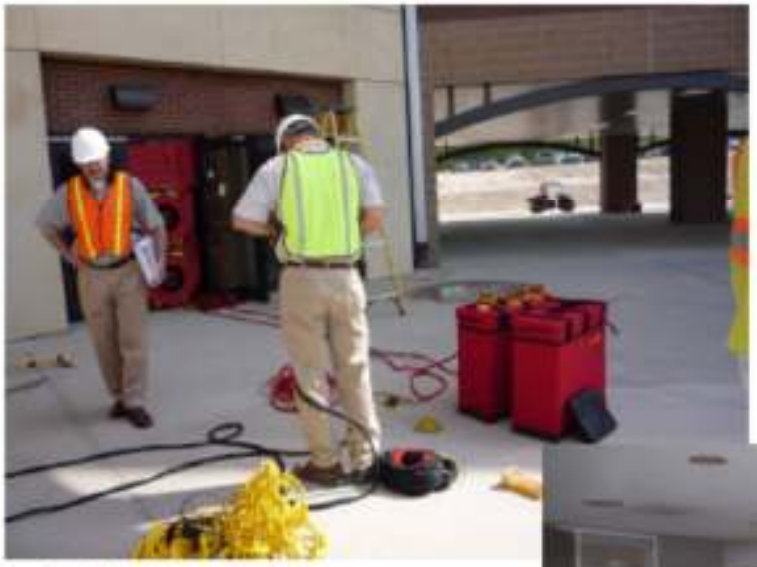
ASHRAE 1478-RP: Testing UCF Engineering 3 Building, Orlando, FL

Morrison Arboretum, U Penn

The Blower Door Testing, *Cont'd 1*

Source: ASHRAE Project 1478

2. Set up the door fans



Ft. Jackson, NC test

ASHRAE 1478-RP testing, Orlando, FL

Multiple fans can be mounted in one panel to increase capacity

Source: PIE Forensic Consulting

The Blower Door Testing, *Cont'd 2*

3. Run a preliminary test

Ft. Jackson, NC test

To make sure enough fans have been installed to pressurize the building, and to identify major air leakage sources that need to be addressed prior to the testing.

Ft. Jackson, NC test

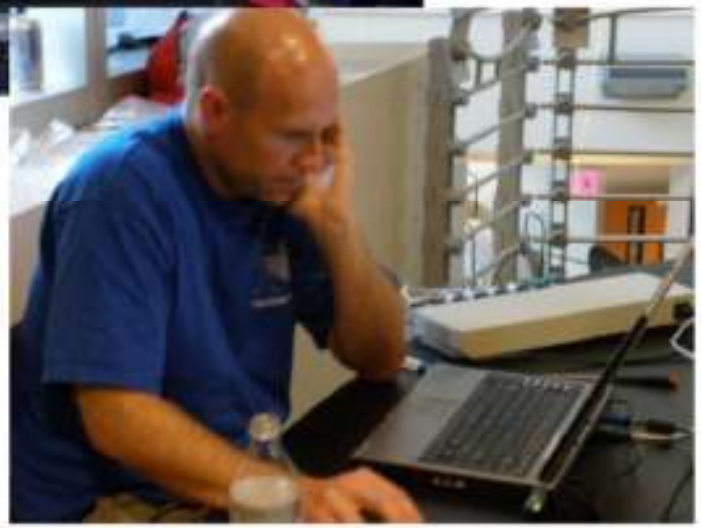
The Blower Door Testing, *Cont'd 3*

4. Conduct the final test

Pressurization & depressurization to minimize errors

Ft. Jackson, NC test

Ft. Jackson, NC test



ASHRAE 1478-RP testing, Orlando, FL

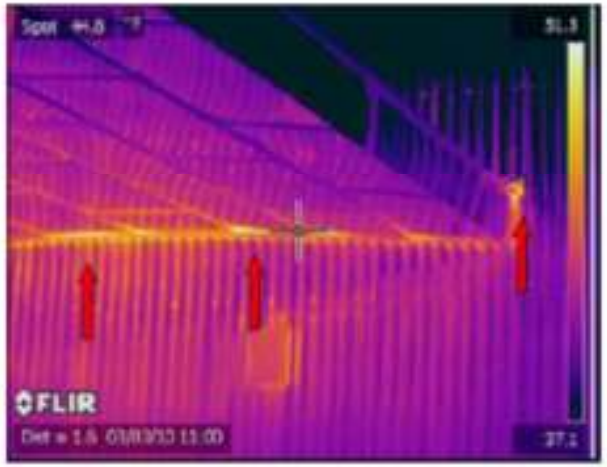
The Blower Door Testing, *Cont'd 4*

5. Identify sources of air leakage:

Ft. Sam Houston, Texas – Pie Forensic Consulting

Ft. Jackson, NC test

Smoke test

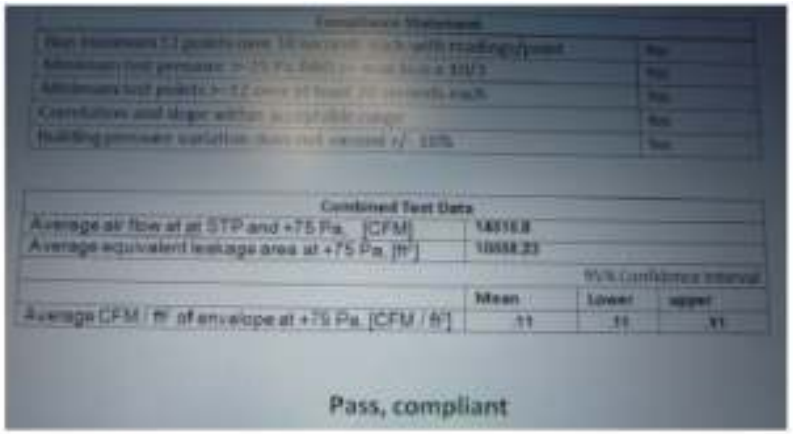


Pictures: Morrison Arboretum Project, U Penn, PA

Thermal Infrared

The Blower Door Testing, *Cont'd 5*

6. ***Pack up and return*** building to normal
7. ***Issue*** a formal test report



Ft. Jackson, NC

Implementing USACE Air tightness Requirements:
A General Contractor's Perspective

Follow the details – ***know what items are part of the continuous air barrier; attention to detail is critical in design and construction***

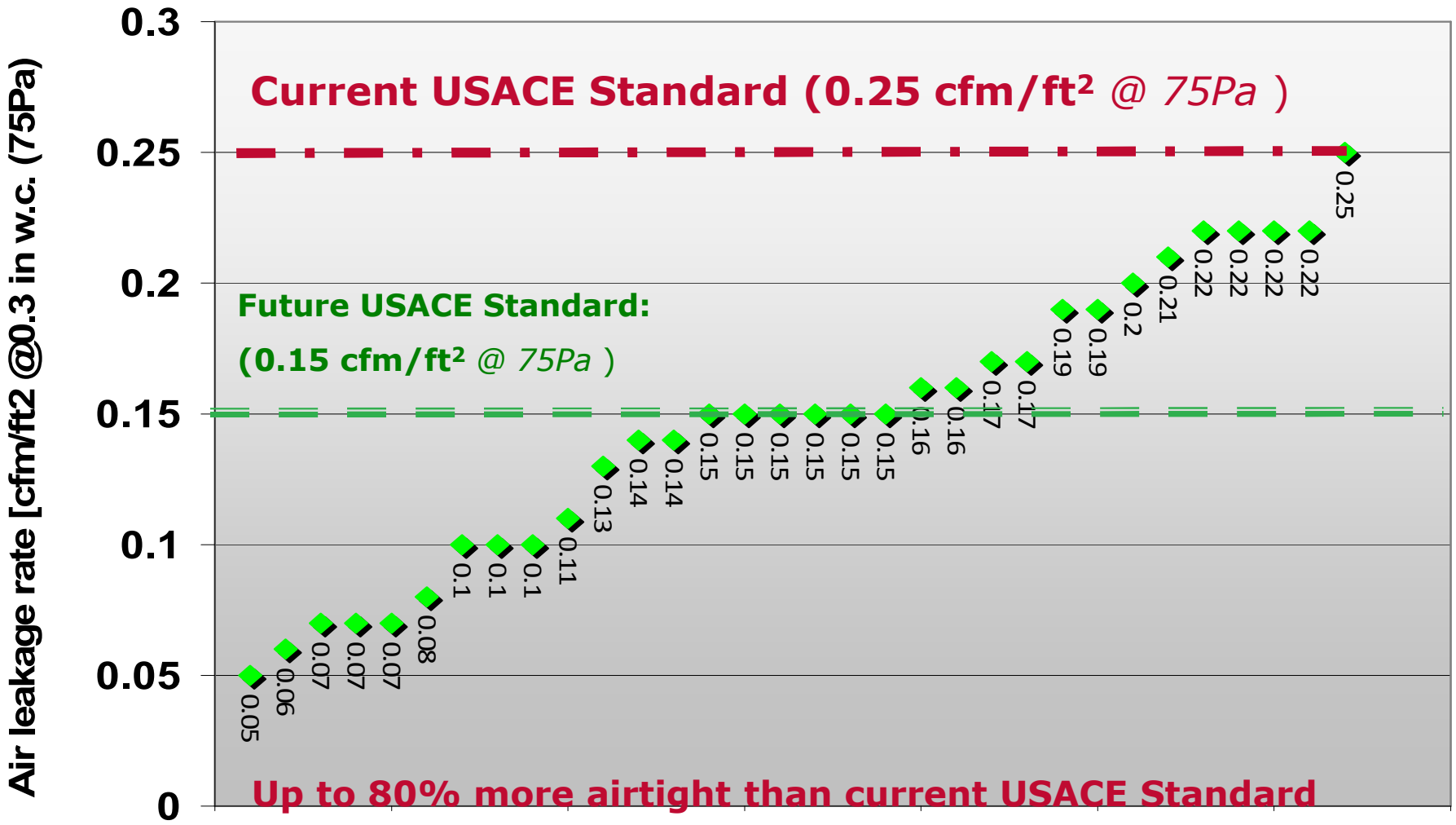
Materials compatibility – ***make sure the materials specified are compatible***

Manufacturers' installation instruction – ***engage manufacturers' representatives for training, site visits, inspections***

Verify & document – ***make sure that the details are being followed. Sealing the envelope is cheap during construction but more expensive afterwards (cost 10 to 1000X more afterwards).***

Source: Hensel Phelps Construction Co.

USACE Standard Experience



Source: Dr. Alexander Zhivov, USACE ERDC, Champaign, USA: AIVC Workshop, June 14, 2010, Brussels, Belgium

Enabling Compliance

E1186 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems

New Standard Test Method by ABAA & ASTM E06.41: Standard Method for Building Enclosure Air Tightness Compliance Testing

Draft Scope

- *This standard test method provides a quantitative field-test procedure and calculation method for assessing compliance of a building enclosure with an air tightness specification using fan- induced pressure differences.*
- *Building setup conditions appropriate for testing the enclosure's air tightness are defined in this standard.*
- *Guidelines to identify the air barrier boundaries of the building enclosure to be tested are provided in this standard.*
- *This test method applies to all building types and portions thereof.*
- *This test method is applicable to typical indoor-outdoor temperature differentials and low to moderate wind pressure conditions.*
- *This standard defines two test procedures: multipoint regression and repeated single point pressure testing.*
- *This standard allows for testing compliance with pressurization only, depressurization only or a combination.*

ASTM Workshop on Whole-Building Airtightness Testing, October 2012, Atlanta GA.

- Terry Brennan / Collin Olson: *Building Airtightness Testing Overview*
- Phil Emory: *Case Studies Using ASTM E1827 to Pressure-Test Whole Buildings*
- Colin Genge: *Case studies of air leakage tests on large, complex buildings.*
- Max Sherman: *Variations in Residential Air Leakage Measurements*
- Steven Emmerich: *Update on U.S. Commercial Building Airtightness – Data and Standards Issues*
- Wagdy Anis: *Reality Check: Actual Air Leakage Rates in Buildings*
- Kevin Knight : *Building Enclosure Commissioning*

ASTM Inter-laboratory studies (Jan 10, 2012 email)

Dear Theresa,

ASTM's Interlaboratory Study Program would like to lend you a hand! According to our records, we see that ASTM WK35913…needs Repeatability and Reproducibility cited in the precision and bias section.

ASTM's Form and Style Manual requires test methods contain a statement (1) regarding within-laboratory precision of the test results (repeatability) when approved, and (2) regarding the precision of test results obtained in different laboratories (reproducibility) within 5 years. …

Precision and bias statements validate the methodology of your standard, and greatly benefit the user. The ILS Program is designed to support the committees in their efforts to produce precision statements for their test methods and is available to assist in the following areas:

- *Designing an interlaboratory study*
- *Identifying potential samples*
- *Soliciting volunteer laboratories*
- *Finding available suppliers*
- *Contracting with distributors*
- *Reviewing laboratory instructions*
- *Collecting and analyzing data*
- *Producing a draft precision statement*
- *Compiling information for the research report*
- *Giving recognition to participating laboratories*

		Type of Test	Test Result	P&B Statement
E283	**Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen**	Lab Assembly	Curve of air leakage vs. pressure	The precision and bias of this test method has not been determined.
E2178	**Standard Test Method for Air Permeance of Building Materials**	Product Performance	Air Leakage @75 Pa Curve of air leakage vs. pressure	The precision and bias of the test method have not been determined
E2357	**Standard Test Method for Determining Air Leakage of Air Barrier Assemblies**	Specified lab assembly subjected to specified proconditioning.	Air Leakage @75 Pa Curve of air leakage vs. pressure	The precision and bias of this practice has not been determined. The precision and bias of the individual test procedures required are given in those methods.
E330	**Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference**	Lab Assembly	pass/fail at specified or max pressure	No statement is made either on the precision or bias of this test method for measuring structural performance, since this method merely states whether or not the test specimen sustained the loads applied and otherwise conformed to the criteria specified for success.
E331	**Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference**	Lab Assembly	pass/fail at specified or max pressure	No statement is made either on the precision or bias of this test method for measuring water penetration since the result merely states whether there is conformance to the criteria specified for success.
E779	**Standard Test Method for Determining Air Leakage Rate by Fan Pressurization1**	Whole Building	Multi-point Air Leakage under infiltration and exfiltration conditions	The confidence limits calculated in 9.7 give an estimate of the precision uncertainty of the test results. The specific precision and bias of this test method is dependent largely on the instrumentation and apparatus used and on the ambient conditions under which the data are taken.
E1827	**Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door1**	Whole Building	Air Leakage under infiltration and exfiltration conditions	11.1 Measurement Uncertainty—The precision and bias of this standard depend on the instrumentation and apparatus used, the test zone envelope, and the ambient conditions under which the data are taken.6 Refer to recommended maximum values for precision and bias in Tables X1.1 and X1.2. These recommendations achieve the following uncertainties when calculated in accordance with Annex A3. 11.2 Single-Point Method—The uncertainty of measured flow at 50 Pa is 10 % using the single-point measurement assumptions for precision and bias and 5 % using the two-point assumptions. 11.3 Two-Point Method—Assuming an exponent of n = 0.65, P1 = 50 Pa (0.2 in. H2O), and P2 = 12.5 Pa (0.05 in. H2O), the uncertainty of extrapolating to measured flow at 4 Pa (0.016 in. H2O) would be 13 % using the two-point assumptions for precision and bias. Estimates of C and n have uncertainties of 10 % and 0.05, respectively, for the two-point assumptions.

Many enclosure air leakage test method standards date back to the mid 1980's

With the recent code evolution is creating the need to update the standards with a focus on compliance.

Change will not be made by a single person – we need to work together.

Opportunities:

- Communication with and training of building officials
- Participate in Codes and Standard development
- Participation in Interlaboratory studies, and other research to understand repeatability and reproduceability of test methods

Thank You

The miracles of science™