Residential Air Sealing: The Importance of Air Barriers and Evolving Code Requirements

Theresa A. Weston, PhD.
DuPont Building Innovations

EEBA Conference, September 27, 2012
Learning Objectives

- Understand the physics of air and moisture movement through the building envelope and the role of air, water and vapor barriers
- Describe the air barrier functions, benefits, and performance requirements for effective air leakage control in residential structures.
- Understand how to manage the balance between wetting and drying (prevent wetting/ promote drying) for effective moisture management
- Explain recent trends in air barrier codes
Agenda

Air Leakage – Why is it important?

Fundamentals of air leakage

Water Management: Air Barriers vs. Water-resistive barriers vs. Vapor Barriers

Air Sealing Code requirements

Industry Status & Trends
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 churches.

“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.)”
What is Air Leakage?

Unplanned/Unpredictable/Unintentional Airflow

Air Leakage needs BOTH:

1. A Driving Force (Δ Pressure)
2. A Pathway (Unintended Opening)
Air Leakage Impact

Transport of:
- Heat
- Moisture
- Contaminants

Impact on Buildings:
- Energy Efficiency
- Energy & Durability
- IEQ & Comfort
Direct Air Leakage Impact on the HVAC Energy Use


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Direct Air Leakage Impact on HVAC Energy Use:
Percent energy savings due to reduced infiltration/exfiltration

Source: NISTIR 7238, "Investigation of the impact of Commercial Building Envelope Airtightness on HVAC Energy Use", S. J. Emmerich, Tim McDowell, W. Anis

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6.6% to 16.3% H/AC energy reduction results from an 18.6% reduction in air leakage, dependent on climate.
Indirect Air Leakage Impact on Energy Use:
Wind Degradation of Thermal Insulation Performance

Measured Effective R-value under Simulated Wind-Load (R-19 Walls).
Data from Jones, 1995

Source: Impact of Airflow on the Thermal Performance of Various Residential Wall Systems utilizing a calibrated hot box, Thermal Envelopes VI/ Heat Transfer in Walls -- Principles

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**Air Leakage Impact**

Transport of:
- Heat
- Moisture
- Contaminants

Impact on Buildings:
- Energy Efficiency
- Energy & Durability
- IEQ & Comfort

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Water Carried by Air Leakage

Air Currents...
- ...account for 90x more moisture vapor entering a wall cavity than diffusion.
- ...reduce the effectiveness of the insulation.
- ...reduce overall comfort
- ...can place unnecessary stress on HVAC System
Wintertime Condensation

**Air leakage condensation potential** can be estimated by determining the hourly dew point of the interior air, and the temperature of the potential condensation plane:

» When the temperature of the condensation plane is below the dew point of the interior air, condensation would occur if air exfiltration reaches the condensation plane.

Interior, moisture-laden air **Ex**filtration could lead to condensation on cooler exterior surfaces, *e.g.* if the temperature of the sheathing is below the dew point of the interior air.
Air Leakage Condensation Potential:
Chicago Example -- Heating Season, Air Exfiltration

- Traditional Wall: Sheathing Temperature
- Hybrid Wall: Sheathing Temperature
- Exulation Wall: Sheathing Temperature
- Dew Point Temperature, Interior Air

Temperature, °F

Hours

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Summer Time Air Leakage Condensation Potential

Exterior, moisture-laden air **In**filtration could lead to condensation on cooler interior surfaces, *e.g.* if the temperature on the back of interior Vapor Retarder is below the dew point of the exterior air.
Typical Problem Causes in Hot, Humid Climates

Shortly after construction was completed, a seven-story, four-star hotel in Charleston, South Carolina, developed severe moisture and mildew problems. The investigators attributed the problems to rainwater intrusion through the hotel’s exterior brick veneer (Figure 1-6). Following that diagnosis, the hotel owner spent over $10 million on renovations, including a completely redesigned and reconstructed building envelope.

The summer after the renovations were completed, the moisture and mildew problems returned. They returned because the investigators had focused on the envelope leaks and overlooked the significant secondary source of interior moisture (outside air infiltration).

In areas like Charleston, where hot, humid conditions persist, IAQ problems are largely due to a combination of the following factors:

From “Preventing Moisture and Mildew Problems in Hospitality Industry Buildings” - CH2M HILL

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Indirect Air Leakage Impact on Energy Use:
Moisture Impact on Thermal Insulation Performance

* The insulation thickness has only a small effect on the % R-value reduction
(measured at 20 degree C temperature difference)

Source: Controlling the Transfer of Heat, Air & Moisture through the Building Envelope  M.C. Swinton, W.C. Brown, G.A. Chown

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Air Leakage Impact

Transport of: Heat → Energy Efficiency
Moisture → Energy & Durability
Contaminants → IEQ & Comfort

Impact on Buildings
1. “Based on the airtightness testing completed on an additional 42 homes with attached garages, it was found that, on average, interface leakage accounts for approximately 10 per cent to 13 per cent of the total house leakage area. At these levels of garage-to-house transfer, carbon monoxide (CO) concentrations remain within acceptable exposure limits recommended by Health Canada.

2. If more than 25 per cent of the house air leakage occurs through the garage, our simulations show that garage based emissions could cause significant house indoor air quality problems.

3. Three remediation strategies were tested. All three strategies were found to reduce peak concentration of pollutants in both the garages and the houses where they were tested. Air sealing during construction is recommended to avoid pollutant entry. If a garage air infiltration problem is noticed in an existing house, airsealing should be the first line of defense.”

Source: CMHC Research Highlight 04-108, April 2004
Summary, Air Leakage Impact

Energy Efficiency: Direct & Indirect

Building Envelope Durability: Moisture Damage

Comfort & Safety: IAQ, Thermal Comfort

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What is Air Leakage

Unplanned/Unpredictable/Unintentional Airflow

Air Leakage needs BOTH:
1. A Driving Force (Δ Pressure)
2. A Pathway (Unintended Opening)

No pathway: No Flow

No Δ Air Pressure: No Flow

Pathway (Unintended Opening)
Sources of Air Pressure Difference (∆P)

- Wind Pressure
- Stack Pressure
- Mechanical Pressure
Wind Pressure

Wind Driven Pressure Differences

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Stack Pressure

\[ \Delta p_s = 0.00598 (\rho_o - \rho_i) g (H_{\text{NPL}} - H) \]

\[ = 0.00598 \rho_o \left( \frac{T_I - T_o}{T_I} \right) g (H_{\text{NPL}} - H) \]

where
- \( T_o \) = outdoor temperature, °R
- \( T_I \) = indoor temperature, °R
- \( \rho_o \) = outdoor air density, lb/ft³
- \( \rho_I \) = indoor air density, lb/ft³
- \( H_{\text{NPL}} \) = height of neutral pressure level above reference plane without any other driving forces, ft


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What is Air Leakage
Unplanned/Unpredictable/Unintentional Airflow

Air Leakage needs BOTH:
1. A Driving Force (Δ Pressure)
2. A Pathway (Unintended Opening)

No pathway: No Flow

No Δ Air Pressure: No Flow

Pathway (Unintended Opening)
Common Types of Air Barriers

Mechanically- Fastened Membranes

Self-Adhered Membranes

Fluid Applied Membranes

Spray Foam

Photo Source: ASHRAE Journal Nov. 2010 “Exterior Spray Foam”  
By Joseph W. Lstiburek, Ph.D., P.Eng., Fellow ASHRAE
Good enclosure water management design and detailing will minimize the risk of wetting, but drying potential must ALWAYS be considered.
“Liquid water and water vapor migrate by a variety of moisture transport mechanisms. The following are some of the most important mechanisms:

- Liquid flow by gravity or air pressure differences
- Capillary suction of liquid water in porous building materials
- Movement of water vapor by air movement
- Water vapor diffusion by vapor pressure differences

Although in the past many moisture control strategies focused on control of vapor diffusion through the installation of vapor (diffusion) retarders, the other mechanisms, when present, can move far greater amounts of moisture. Thus, liquid flow, capillary suction, and air movement should be controlled first”
Rating of Moisture Sources in Buildings

**Rain & Snow:**
(above grade envelope)

- Bulk Water: 
  - Transported by air currents
  - Diffusion

- Water Vapor:
  - 98% transport
  - 2% diffusion

>>1,000X

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Air Barriers, Water-resistive Barriers and Vapor Barriers

Air barriers can be placed anywhere in the wall.
Water-Resistive Barriers

A material behind an exterior wall covering that is intended to resist liquid water that has penetrated behind the exterior covering from further intruding (IBC, IRC)
Water-Resistive Barriers

Building Papers / Felts

Building Wraps

- Perforated Wraps
- Non-Perforated Wraps
- Specialty Wraps
- Self-Adhesive Wraps

Fluid Applied

Sheathing

- Foam Sheathing
- WRB Laminated Wood-Based Sheathing
- Laminated Fibrous Sheathing

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Air Barrier Materials – ASTM E2178

Diagram from CCMC Technical Guide for Air Barrier Materials Testing
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Housewrap Material Air Leakage Properties

Air Leakage (L/s-m²) vs. Pressure Difference

- Non-Perforated ASTM E2556 Type II
- Perforated ASTM E2556 Type I

Air Barriers
The sheet materials have an air leakage rate not exceeding 0.02 L/s-m² [0.004 cfm/ft² 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.

This is the same as Tyvek® Homewrap®, except that the lists are removed.
# Air Barrier Materials

## Products with ICC-ES Air Barrier Evaluation

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>PRODUCT NAME</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>JX Nippon ANCI, Inc.</td>
<td>Exaire® Plus Housewrap, Exaire® Plus Commercial Housewrap and Exaire® Plus Low Perm Housewrap</td>
<td>Wrap</td>
</tr>
<tr>
<td>Fiberweb</td>
<td>Typar® HouseWrap, Surround™ Housewrap B, W and G Weather-Resistant Barriers; Typar® StormWrap Weather-Resistant Barriers; Ty par® HouseWrap Weather-Resistant Barriers; Ty par® MetroWrap Weather Resistant Barriers; and Ty par® CertaWrap Weather-Resistant Barriers</td>
<td>Wrap</td>
</tr>
<tr>
<td>Huber Engineered Woods, LLC</td>
<td>ZIP System® Wall Sheathing</td>
<td>OSB Wood Structural Panel</td>
</tr>
<tr>
<td>Alpha ProTech Engineered Products, Inc.</td>
<td>REX Wrap Plus Protective House Wrap and Rex Wrap Homewrap Water-Resistive Barriers and Air Barriers</td>
<td>Wrap</td>
</tr>
<tr>
<td>The Dow Chemical Company</td>
<td>Styrofoam™ Brand Insulation Boards and Dow Fan-Fold Products, FROTH-PAK™ Polyurethane Foam Insulation, WEATHERMATE Plus™</td>
<td>Boards/ Foam Insulation/Wrap</td>
</tr>
<tr>
<td>Pactiv Building Products</td>
<td>GreenGuard® Ultra Wrap Building Wrap, GreenGuard® RainDrop Building Wrap, GreenGuard® MAX Building Wrap, GreenGuard® C500 Building Wrap and GreenGuard® C2000 Building Wrap</td>
<td>Wrap</td>
</tr>
<tr>
<td>Cosella-Dorken Products Inc</td>
<td>DELTA®-MAXX, DELTA®-MAXX PLUS, DELTA®-VENT S, DELTA®-VENT S PLUS,</td>
<td></td>
</tr>
</tbody>
</table>
Air Barriers, Water-resistive Barriers and Vapor Barriers

Air barriers can be placed anywhere in the wall.
Where are interior vapor retarders required?

- 2003: Above White Line
- 2006: Above Blue Line
1405.3.3 Minimum clear air spaces and vented openings for vented cladding. For the purposes of this section vented cladding shall include the following minimum clear air spaces.

1. Vinyl lap or horizontal aluminum siding applied over a weather resistive barrier as specified in this Chapter.
2. Brick veneer with a clear airspace as specified in this code.
3. Other approved vented claddings.
Air Transported Moisture must not be confused with Vapor Diffusion

Air Transported Moisture

\[ P_o > P_i \]

98% of all water vapor migration

Water Vapor Diffusion

\[ VP*o > VP*i \]

~ 2% of all water vapor migration

* Vapor pressure is proportional to Water Vapor Concentration
Good enclosure water management design and detailing will minimize the risk of wetting, but drying potential must ALWAYS be considered.
Total Moisture Content of Wall System Simulated 3 months starting July 1.

Data originally submitted to Texas Residential Construction Council Task-Group on Mold and Moisture
Gypsum Board RH
Simulated 3 months starting July 1.

Data originally submitted to Texas Residential Construction Council Task-Group on Mold and Moisture

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Air Barrier Performance

Material Properties
- Air Infiltration Resistance
- Vapor Permeability
- Durability

Installation
- Continuity
- Structural Integrity
- Durability
Continuity: Air Barrier System

The building envelope must be designed and constructed with a continuous air barrier:

- **Primary** Air Barrier Membranes
- **Installation & Continuity Accessories:** fasteners, adhesives & primers, tapes, flashing, transition membranes, caulks & sealants, etc…
Traditional Shingling: Tyvek® HomeWrap® with Lap
Traditional Shingling: Tyvek® HomeWrap® with Lap

Taped Traditional Shingling: Tyvek® HomeWrap® with Taped Lap

Taped Sheathing Joints: Taped XPS, EPS, or Polyiso
Sealing at Bottom of Wall
Sealing at the top of the Wall

Top of Wall Detail
Tested Systems

Window and Wall usually tested separately, should be tested as installed unit.
Air barriers must be able to withstand pressure loads (from wind, stack effect and mechanical system) or be able to transfer the loads to other elements of the building enclosure without rupture or displacement.
Assembly Testing: ASTM E 2357, ASTM E1677 or ASTM E 283
# ASTM E1677 vs. ASTM E2357

<table>
<thead>
<tr>
<th><strong>Number of Test Specimen and configuration</strong></th>
<th><strong>ASTM E1677-05</strong></th>
<th><strong>ASTM E2357-05</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>One Specimen: Opaque Wall (8 x 8-ft walls)</td>
<td>Test two of the three Specimens (8 x 8-ft walls): 1 – Opaque Wall 2 – Wall with penetrations 3 – Wall-Foundation Interface</td>
<td></td>
</tr>
<tr>
<td>(fasteners to simulate wood siding or brick ties required)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Conditions for Air Leakage Testing</strong></th>
<th><strong>Five Test Pressures:</strong></th>
<th><strong>Seven Test Pressures:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• 75Pa (1.56 psf, 25 mph)</td>
<td>+/− 25Pa (0.56 psf, 15 mph)</td>
<td>+/− 25Pa (0.56 psf, 15 mph)</td>
</tr>
<tr>
<td>• two pressures below 75 Pa</td>
<td>+/− 50Pa (1.04 psf, 20 mph)</td>
<td>+/− 50Pa (1.04 psf, 20 mph)</td>
</tr>
<tr>
<td>• two pressures above 75 Pa</td>
<td>+/− 75Pa (1.56 psf, 25 mph)</td>
<td>+/− 75Pa (1.56 psf, 25 mph)</td>
</tr>
<tr>
<td>Air leakage results are reported at 75Pa</td>
<td>+/− 100Pa (2.09 psf, 30 mph)</td>
<td>+/− 100Pa (2.09 psf, 30 mph)</td>
</tr>
<tr>
<td></td>
<td>+/− 150Pa (3.24 psf, 35 mph)</td>
<td>+/− 150Pa (3.24 psf, 35 mph)</td>
</tr>
<tr>
<td></td>
<td>+/− 250Pa (5.23 psf, 45 mph)</td>
<td>+/− 250Pa (5.23 psf, 45 mph)</td>
</tr>
<tr>
<td></td>
<td>+/− 300Pa (6.24 psf, 50 mph)</td>
<td>+/− 300Pa (6.24 psf, 50 mph)</td>
</tr>
<tr>
<td><em>(Positive &amp; negative pressures)</em></td>
<td><em>(Positive &amp; negative pressures)</em></td>
<td><em>(Positive &amp; negative pressures)</em></td>
</tr>
</tbody>
</table>

| **Pressure Loading Schedule** | **Sustained loads up to +/- 500 Pa (10.4 psf, 65 mph)** | **1 - Sustained, +/- 600Pa (12.5 psf, 71 mph)** |
| | *(Positive & negative pressures)* | **2 - Cyclic, +/- 800 Pa (16.7 psf, 82 mph)** |
| | *(Positive & negative pressures)* | **3 - Gust, +/- 1200 (25 psf, 100 mph) (Positive & negative pressures)** |
# ASTM E1677: Two Air Barrier Classifications

<table>
<thead>
<tr>
<th>Performance Properties</th>
<th>AB Classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I</strong></td>
<td><strong>Type II</strong></td>
</tr>
<tr>
<td><strong>Air leakage</strong>&lt;br&gt;As tested by E283</td>
<td>$&lt; .06 \text{ cfm/ft}^2 @ 75 \text{ Pa}$</td>
</tr>
<tr>
<td><strong>Structural Integrity</strong>&lt;br&gt;As tested by E330</td>
<td>2 in. $\text{H}_2\text{O}$ or 500 Pa (65 mph) for 1 hr in each direction</td>
</tr>
<tr>
<td><strong>Water Resistance</strong>&lt;br&gt;As tested by E331</td>
<td>No penetration for 15 min of simulated wind driven rain @ 0.11 $\text{H}_2\text{O}$ or 27 Pa (15 mph)</td>
</tr>
<tr>
<td><strong>Water Vapor Permeance</strong>&lt;br&gt;As tested by E96A</td>
<td>Measured</td>
</tr>
</tbody>
</table>
Durability

Air Barriers must withstand environmental exposures:

- **UV*** (NOT to exceed manufacturer’s recommendation for UV exposure)
- Thermal exposure & thermal cycling
- Repeated exposure to water
- Abrasion
- Mechanical stresses

* Most air barrier membranes are not designed for continuous UV exposure
“Durability and cost were seen as the key factors in choosing green products by respondents to the BD&C White Paper Survey.”

Green-product attributes
(rated by importance to user)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to last the life of the building</td>
<td>4.38</td>
</tr>
<tr>
<td>Cost vs. equivalent conventional product</td>
<td>4.27</td>
</tr>
<tr>
<td>Availability of product to job site</td>
<td>4.16</td>
</tr>
<tr>
<td>Use of renewable resources</td>
<td>4.01</td>
</tr>
</tbody>
</table>

From Building Design & Construction White Paper on Sustainability, November 2003
Factors to be considered in determining level of exposure:

Ø Building Location
  v Macro
  v Micro
Ø Construction Schedule and Duration
Ø Wall Type
  v Air space
  v Sheathed/Open Stud
  v Wood/Metal Stud
Ø Type of Cladding
Ø ...

Time

Exposure Intensity

During Construction

During Service
Material deterioration mechanism examples

Volatilization

Polymer degradation (embrittlement & micro-cracking)

As received | 44 MJ | 66 MJ

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Delamanation – material mis-match
Laminate Stretched to 50% Break Elongation
Adhesion Loss - adhesive vs. cohesive failure

Adhesion to OSB

Peel Strength (N/cm)

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Material Compatibility

“Certain asphalt-based peel-and-stick membranes used to seal sheathing membranes to vinyl doors and windows may react with the vinyl. The reaction results in the asphaltic membrane running and staining exterior surfaces. The asphaltic material is a first generation peel-and-stick product (4-in.-100-mm and 6-in.-150-mm rolls). In addition to staining the vinyl, it is likely the reaction also damages the window or door frame. Staining shows itself within one year of installation. It is not known if or when failure of the joint will occur.”

-- Incompatible Building Materials, A report documenting premature failure in residential construction resulting from material incompatibility, Canada Mortgage and Housing Corporation, June 2003. prepared by J.F. Burrows Consulting
Material deformation and loss of adhesion

Joints open
“Taped rigid insulation is not allowed as an air barrier in Wisconsin. When some types of insulation boards get colder by 70°F, they can shrink ¼” on all sides. The tape cannot adequately perform under such circumstances.”

ASTM E283 Air Leakage Measurements of Wall Assemblies

- Taped XPS Tyvek / OSB Infiltration
- Taped XPS Tyvek / OSB After Thermal

Data from ATI RPT #A3678.01-109-44
IECC Residential Building Envelope Air Leakage Requirements

Compliance options:
Checklist
or
Testing
< 7 ACH$_{50}$

Qualitative requirement and location list

2006

Qualitative requirement and location list

2009

Qualitative requirement and location list

2012
<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air barrier and thermal barrier</td>
<td>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.</td>
</tr>
<tr>
<td>Ceiling/attic</td>
<td>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.</td>
</tr>
<tr>
<td>Walls</td>
<td>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.</td>
</tr>
<tr>
<td>Windows, skylights and doors</td>
<td>The space between window/door jamb and framing and skylights and framing shall be sealed.</td>
</tr>
<tr>
<td>Rim joists</td>
<td>Rim joists shall be insulated and include the air barrier.</td>
</tr>
<tr>
<td>Floors (including above-garage and cantilevered floors)</td>
<td>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.</td>
</tr>
<tr>
<td>Crawlspace walls</td>
<td>Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in unvented crawlspace shall be covered with a Class I vapor retarder with overlapping joints taped.</td>
</tr>
<tr>
<td>Shafts, penetrations</td>
<td>Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.</td>
</tr>
<tr>
<td>Narrow cavities</td>
<td>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.</td>
</tr>
<tr>
<td>Garage separation</td>
<td>Air sealing shall be provided between the garage and conditioned spaces.</td>
</tr>
<tr>
<td>Recessed lighting</td>
<td>Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.</td>
</tr>
<tr>
<td>Plumbing and wiring</td>
<td>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.</td>
</tr>
<tr>
<td>Shower/tub on exterior wall</td>
<td>Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.</td>
</tr>
<tr>
<td>Electrical/phone box on exterior walls</td>
<td>The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.</td>
</tr>
<tr>
<td>HVAC register boots</td>
<td>HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.</td>
</tr>
<tr>
<td>Fireplace</td>
<td>An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.</td>
</tr>
</tbody>
</table>
IECC Residential Building Envelope Air Leakage Requirements

Compliance options:
- Checklist
- Testing

Z1,2: \( < 5 \text{ACH}_{50} \)
Z3-8:: \( < 3 \text{ACH}_{50} \)

Qualitative requirement and location list

2006

2009

2012

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## Air Barrier Test Methods and Usage

<table>
<thead>
<tr>
<th></th>
<th>Product Testing</th>
<th>Assembly Testing</th>
<th>As-built Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABAA Certification</strong></td>
<td>≤ .004 cfm/ft² at .3 in. H₂O (≤ .02 L/(s•m²) @75 Pa)</td>
<td>≤ .04 cfm/ft² at .3 in. H₂O (≤ .2 L/(s•m²) @75 Pa)</td>
<td>≤ .25 cfm/ft² at .3 in. H₂O (modified by USACE protocol)</td>
</tr>
<tr>
<td><strong>IECC (2012) Residential</strong></td>
<td>≤ .004 cfm/ft² at .3 in. H₂O (≤ .02 L/(s•m²) @75 Pa)</td>
<td>≤ .04 cfm/ft² at .3 in. H₂O (≤ .2 L/(s•m²) @75 Pa)</td>
<td>≤ .4 cfm/ft² at .3 in. H₂O</td>
</tr>
<tr>
<td><strong>IECC (2012) Commercial</strong></td>
<td>≤ .004 cfm/ft² at .3 in. H₂O (≤ .02 L/(s•m²) @75 Pa)</td>
<td>≤ .04 cfm/ft² at .3 in. H₂O (≤ .2 L/(s•m²) @75 Pa)</td>
<td>≤ .4 cfm/ft² at .3 in. H₂O</td>
</tr>
<tr>
<td><strong>USACE Specification</strong></td>
<td>≤ .004 cfm/ft² at .3 in. H₂O (≤ .02 L/(s•m²) @75 Pa)</td>
<td>≤ .04 cfm/ft² at .3 in. H₂O (≤ .2 L/(s•m²) @75 Pa)</td>
<td>≤ .25 cfm/ft² at .3 in. H₂O (modified by USACE protocol)</td>
</tr>
</tbody>
</table>
USACE Standard Experience

Current USACE Standard (0.25 cfm/ft² @ 75Pa)

Future USACE Standard:
(0.15 cfm/ft² @ 75Pa)

Up to 80% more airtight than current USACE Standard

Source: Dr. Alexander Zhivov, USACE ERDC, Champaign, USA: AIVC Workshop, June 14, 2010, Brussels, Belgium
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.
Ft. Sam Houston, San Antonio, TX  
Pie Forensic Consultants

### BRAC - FSH METC Student Dormitory 1

<table>
<thead>
<tr>
<th>Description</th>
<th>Air Leakage (cfm/ft² @75Pa)</th>
<th>Percent above Max Allowable (0.25 cfm/ft² @75Pa) OR PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurization</td>
<td>0.067</td>
<td>PASS</td>
</tr>
<tr>
<td>Depressurization</td>
<td>0.078</td>
<td>PASS</td>
</tr>
<tr>
<td>Average</td>
<td>0.073</td>
<td>PASS</td>
</tr>
</tbody>
</table>

### BRAC - FSH METC Student Dormitory 2

<table>
<thead>
<tr>
<th>Description</th>
<th>Air Leakage (cfm/ft² @75Pa)</th>
<th>Percent above Max Allowable (0.25 cfm/ft² @75Pa) OR PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurization</td>
<td>0.073</td>
<td>PASS</td>
</tr>
<tr>
<td>Depressurization</td>
<td>0.067</td>
<td>PASS</td>
</tr>
<tr>
<td>Average</td>
<td>0.070</td>
<td>PASS</td>
</tr>
</tbody>
</table>

72% better than the USACE max. allowable rate of 0.25 cfm/ft² @75Pa
**Fort Jackson, SC - Basic Training Complex**
Commissioning Consultants, LLP

### Basic Training Complex II- Building 1

<table>
<thead>
<tr>
<th>Description</th>
<th>Air Leakage (cfm/ft² @75Pa)</th>
<th>Percent above Max Allowable (0.25 cfm/ft² @75Pa) OR PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurization</td>
<td>0.11</td>
<td>PASS</td>
</tr>
<tr>
<td>Depressurization</td>
<td>0.10</td>
<td>PASS</td>
</tr>
<tr>
<td>Average</td>
<td>0.11</td>
<td>PASS</td>
</tr>
</tbody>
</table>

### Basic Training Complex II- Building 2

<table>
<thead>
<tr>
<th>Description</th>
<th>Air Leakage (cfm/ft² @75Pa)</th>
<th>Percent above Max Allowable (0.25 cfm/ft² @75Pa) OR PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressurization</td>
<td>0.09</td>
<td>PASS</td>
</tr>
<tr>
<td>Depressurization</td>
<td>0.07</td>
<td>PASS</td>
</tr>
<tr>
<td>Average</td>
<td>0.08</td>
<td>PASS</td>
</tr>
</tbody>
</table>

>60% better than the USACE max allowable rate of **0.25 cfm/ft² @75Pa**
## Residential Air Leakage Sequential Testing: IBACOS Lab House

<table>
<thead>
<tr>
<th>Stage</th>
<th>Tested Air Leakage</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housewrap installed: Window and door openings and other penetrations integrated with air barrier and drainage plane</td>
<td>3.0 ACH&lt;sub&gt;50&lt;/sub&gt;</td>
<td>“Housewrap as primary air barrier required great attention to detail…but it worked”</td>
</tr>
<tr>
<td>After spray foam installed in attic, strategically sealing penetrations in 2&lt;sup&gt;nd&lt;/sup&gt; floor ceiling plane</td>
<td>0.88 ACH&lt;sub&gt;50&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>After spray foam in the band joists</td>
<td>0.77 ACH&lt;sub&gt;50&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>After wall cavity insulation and drywall installed</td>
<td>0.65 ACH&lt;sub&gt;50&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>Complete</td>
<td>0.54 ACH&lt;sub&gt;50&lt;/sub&gt;</td>
<td>“Ultimate target was Passivhaus level of airtightness, which is 0.6”</td>
</tr>
</tbody>
</table>

US Home Airtightness

Source: 2009 ASHRAE Handbook of Fundamentals
LBNL Data Base
http://resdb.lbl.gov/
Final Thoughts

Build tight, ventilate right

Build to last