Achieving & Evaluating Residential Compliance of Tight Envelopes

Southface
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U.S. Department of Energy
Building Energy Codes Program
Achieving & Evaluating Residential Compliance of Tight Envelopes
Mike Barcik
Steve Herzlieb
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Course Description

• In this session we will explore the relationship between home envelope tightness and energy performance and the policy implications of stronger energy code requirements.
• Focus will be given to the impact of envelope tightness on HVAC load calculations, the relationship between envelope tightness and intentional ventilation, and lessons learned from the Duct and Envelope Tightness (DET) verifier program.
• New technologies and approaches enter the marketplace every day. This session will help policy makers, builders, designers and code officials identify current code requirements, best practices and missteps to avoid when creating tighter envelopes and considering new code requirements.

Learning Objectives

At the end of the this course, participants will be able to:

• Understand the relationship between air infiltration, R-value and HVAC loads in homes
• Comprehend the requirements of the current Energy Code and Residential Building Codes related to envelope tightness and ventilation
• Discuss the opportunities of the DET verifier program and other testing certifications
• Identify new technologies and approved ventilation practices for creating energy savings and good IAQ in tight envelope homes
• Recognize the limitations of ACH50 and consider a new metric, ELR50
Who Is Participating?

- Name
- Organization/company
- How long have you been in the design, construction, or enforcement industry?
Status of Adopted Energy Codes

Brief History of Energy Codes

- **MEC 1992, ’93, 95** – “Early” energy codes, complicated, DP windows required
- **IECC 98, 2000, ’03** – “Strengthening”, SHGC of 0.4 required where < 3500 HDD
- **IECC 2004, ’06** – “Simplification”, Fewer CZ’s, eliminate % glazing, certificate required
- **IECC 2009** – Duct + envelope testing, efficient lighting – ARRA “mandated”
- **IECC 2012** – Higher envelope thresholds
- **IECC 2015** – Similar to 2012 but with “HERS” Index

- The code keeps raising the bar (typically 1-3%) until more recently!
  - ’09 Code is ~15% more stringent than ’06 version
  - ’12 Code is ~30% more stringent than ’06 version
  - ’15 Code target is ~2% > than ‘12 version
Brief History of Energy Codes

IECC 2009 vs. 2012 vs. 2015

Summary of Changes to IECC after ’09
- Major changes 2012
  - Much higher R-values
  - Mandatory whole-house pressure test and envelope air seal / insulation checklist
  - More stringent duct leakage test (4 %)
  - DHW distribution system requirements
  - IRC - requires whole house mech ventilation
  - 75% efficient lighting mandatory
  - Still no envelope-equipment trade-offs
- Major change in 2015
  - Compliance option based on Energy Rating Index
Building Thermal Envelope

The building thermal envelope is the barrier that separates the conditioned space from the outside or unconditioned spaces. The building envelope consists of two parts - an air barrier and a thermal barrier that must be both continuous and contiguous (touching each other). In a typical residence, the building envelope consists of the roof, walls, windows, doors, and foundation. Examples of unconditioned spaces include attics, vented crawlspaces, garages, and basements with ceiling insulation and no HVAC supply registers.

Example 1

Example 2

Example 3
Prescriptive Code: Insulation & Fenestration by Climate Zone

Table 402.1.1
Insulation and Fenestration Requirements by Component

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR</th>
<th>SKYLIGHT U-FACTOR</th>
<th>GLAZED FENESTRATION U-FACTOR</th>
<th>CEILING R-VALUE</th>
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<th>FLOOR R-VALUE</th>
<th>BASEMENT WALL R-VALUE</th>
<th>SLAB R-VALUE</th>
<th>CRAWL SPACE R-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.20</td>
<td>0.75</td>
<td>0.30</td>
<td>30</td>
<td>13</td>
<td>3 / 4</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.65</td>
<td>0.75</td>
<td>0.30</td>
<td>30</td>
<td>13</td>
<td>4 / 6</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>0.65</td>
<td>0.30</td>
<td>30</td>
<td>13</td>
<td>5 / 8</td>
<td>19</td>
<td>5 / 13</td>
<td>0</td>
<td>5 / 13</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>38</td>
<td>13</td>
<td>5 / 10</td>
<td>19</td>
<td>10 / 13</td>
<td>10, 2 ft</td>
<td>10 / 13</td>
</tr>
<tr>
<td>5 and Marine 4</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>38</td>
<td>20 or 13+5</td>
<td>13 / 17</td>
<td>30</td>
<td>10 / 13</td>
<td>10, 2 ft</td>
<td>10 / 13</td>
</tr>
<tr>
<td>6</td>
<td>0.35</td>
<td>0.60</td>
<td>NR</td>
<td>49</td>
<td>19 or 13+5</td>
<td>15 / 19</td>
<td>30</td>
<td>15 / 19</td>
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<td>7 and 8</td>
<td>0.35</td>
<td>0.60</td>
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<td>49</td>
<td>21</td>
<td>19 / 21</td>
<td>38</td>
<td>15 / 19</td>
<td>10, 4 ft</td>
<td>10 / 13</td>
</tr>
</tbody>
</table>

* R-values are minimums, U-factors and SHGC are maximums. R-19 batts compressed into a nominal 2 x 6 framing cavity such that the R-value is reduced by R-1 or more shall be marked with the compressed batt R-value in addition to the full thickness R-value.
* The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
* "15/19" means R-15 continuous insulated sheathing on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. "15/19" shall be permitted to be met with R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulated sheathing on the interior or exterior of the home. "10/13" means R-10 continuous insulated sheathing on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall.
* R-5 shall be added to the required slab edge R-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Zones 1 through 3 for heated slabs.
* There are no SHGC requirements in the Marine Zone.
* Insulation sufficient to fill the framing cavity, R-19 minimum.
* "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, structural sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.
* The second R-value applies when more than half the insulation is on the interior of the mass wall.
* For impact rated fenestration complying with Section R301.2.1.2 of the IRC or Section 1608.1.2 of the IBC, maximum U-factor shall be 0.75 in Zone 2 and 0.65 in Zone 3.
Prescriptive Code:
Insulation & Fenestration by Climate Zone

TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>.08</td>
<td>.75</td>
<td>.25</td>
<td>30</td>
<td>13</td>
<td>3/4</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>.35</td>
<td>.65</td>
<td>.25</td>
<td>38</td>
<td>13</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
<td>2 ft</td>
<td>10/13</td>
</tr>
<tr>
<td>3</td>
<td>.35</td>
<td>.55</td>
<td>.25</td>
<td>38</td>
<td>20 or 13+5</td>
<td>8/13</td>
<td>13</td>
<td>15/19</td>
<td>0</td>
<td>10/19</td>
</tr>
<tr>
<td>4 except Marine</td>
<td>.35</td>
<td>.55</td>
<td>.40</td>
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<td>13</td>
<td>10/13</td>
<td>0</td>
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<td>5 and Marine 4</td>
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<td>15/19</td>
</tr>
</tbody>
</table>

For SI: 1 foot = 304.8 mm.
a. R-values are minimums. U-factors and SHGC are maximums. When insulation is installed in a cavity which is less than the label or design thickness of the insulation, the installed R-value of the insulation shall not be less than the R-value specified in the table.
b. The fenestration U-factor column excludes skylights. The SHGC column applies to all glazed fenestration. Exception: Skylights may be excluded from glazed fenestration SHGC requirements in Climate Zones 1 through 3 where the SHGC for such skylights does not exceed 0.30.
c. “15/19” means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. “15/19” shall be permitted to be met with R-15 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home. “10/13” means R-10 continuous insulation on the interior or exterior of the home or R-13 cavity insulation at the interior of the basement wall.
d. R-5 shall be added to the required slab edge R-values for heated slabs. Insulation depth shall be the depth of the footing or 2 feet, whichever is less in Climate Zones 1 through 3 for heated slabs.
e. There are no SHGC requirements in the Marine Zone.
f. Basement wall insulation is not required in warm-humid locations as defined by Figure R301.1 and Table R301.1.
g. Or insulation sufficient to fill the framing cavity R-19 minimum.
h. First value is cavity insulation, second is continuous insulation or insulated siding, so “13+5” means R-13 cavity insulation plus R-5 continuous insulation or insulated siding. If structural sheathing covers 40 percent or less of the exterior, continuous insulation R-value shall be permitted to be reduced by no more than R-3 in the locations where structural sheathing is used – to maintain a consistent total sheathing thickness.
i. The second R-value applies when more than half the insulation is on the interior of the mass wall.

Structure of 2015 IECC

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>FENESTRATION U-FACTOR</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>NR</td>
<td>.75</td>
<td>.25</td>
<td>30</td>
<td>13</td>
<td>3/4</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>.35</td>
<td>.65</td>
<td>.25</td>
<td>38</td>
<td>13</td>
<td>4/6</td>
<td>13</td>
<td>0</td>
<td>2 ft</td>
<td>10/13</td>
</tr>
<tr>
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<td>13</td>
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<td>0</td>
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<td>.55</td>
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<td>20 or 13+5</td>
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<td>15/19</td>
<td>10.4 ft</td>
<td>15/19</td>
</tr>
</tbody>
</table>
Compliance Paths for Insulation & Windows

Mandatory Requirements

- The new ERI path gives the most design flexibility – such as credit for mechanical equipment efficiency
- It also credits items not covered by the code (e.g., appliance efficiencies)

Insulation & Window Requirements

- '09, '12, '15 IECC (prescriptive chart)
- UA Trade-off (RESCheck)
- Section 405 (annual simulation)
- 2015 IECC “HERS” Index

Explaining the Energy Rating Index

1. Simulate two homes
   - Rated Home – what will be built
   - Reference Home – same home but exactly meets ‘06 code

2. Compare Annual Energy
   - Space Heating & Cooling, Hot Water, Lighting and some Appliances
   - Multiply by 100 (lower w/ renewables)

\[ \text{Index} = 100 \times \frac{\text{Rated Home's Htg + Clg + WtrH + L.A.}}{\text{Refer. Home's Htg + Clg + WtrH + L.A.}} = 75 \]
HERS Index – What’s it Mean?

- **HERS Index**, now often referred to as HERS Index Score (lower is better)
- Rated home with Index of 100 = Reference home exactly meeting 2004/06 IECC
- 1% reduction in energy use = 1 point drop in Index
- Net Zero Energy Home = HERS Index of 0

\[
\text{Index} = \text{PE}_{\text{fraction}} \times 100 \times \frac{\text{Rated Home’s Htg + Clg + WtrH + L.A.}}{\text{Ref. Home’s Htg + Clg + WtrH + L.A.}} \quad = 75
\]

\[
\begin{array}{cccc}
40 & 30 & 30 & 50 \\
70 & 20 & 30 & 80 \\
\end{array}
\]

**PE\text{fraction}** is ratio of renewables to purchased energy
(For example, a home that produces 20% of its annual energy from renewables would have a \(\text{PE}_{\text{fraction}}\) of 0.8)
In this example, 0.8 x 75 = 60

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Explaining the Energy Rating Index

1. **2015 IECC targets**
   - Low 50’s

2. **Who Can Do This?**
   - 3rd party – HERS Rater
   - Approved software

3. **Benefits**
   - Greater design flexibility
   - High efficiency equipment and appliances credited

4. **Backstops**
   - Envelope cannot be traded to be worse than 2009 IECC
   - Must meet Mandatory Requirements (air sealing, duct insulation and sealing, duct and house testing, etc.)
Pros and Cons?

1. Concerns

- **Conflict of interest** because rater works for the builder
- **Size Bias** against small houses
  - **Code** – because it uses the antiquated ACH50 term for air tightness (which favors larger, high volume homes)
  - **ERI** – small homes have less envelope load and are hindered in a trade-offs
- **Credit for unregulated items** not in the Prescriptive code
  “Should the dishwasher be allowed to trade down insulation R-values?”

2. Benefits

- **Professional** (HERS Rater) who understands energy efficiency is now involved and energy code isn’t ignored
- **Marketing** – Builders can market their index and guarantee performance

HERS - Energy Label for Homes

- **Which home is energy efficient?**
Energy Code Compliance Pathways

Scope

Insulation & Window Requirements

- 2009/12/15 IECC (prescriptive chart)
- UA Trade-off Approach
- Section 405 (annual simulation)

Mandatory Requirements

2012 IECC - Section 401.3

Mandatory Requirement:
Certificate on panel box with:
- Major Component R-values
- U-factor, SHGC of Windows
- Equipment Efficiencies
- Duct & Envelope Testing Results
- GA Specific: Load Calculation Summary
GA Certificate

Visit southface.org to download fillable pdf of this form!

Blower Door Results go here:

Load Calc Results go here:

Duct testing Results go here:

**Test Results Form**

Version: 2012 IECC

Blower Door Results go here:

Air Seal / Insulation visual inspection checklist here:

Visit southface.org for free fillable pdf of this form!

Duct testing Results go here:
<table>
<thead>
<tr>
<th>NUMBER</th>
<th>COMPONENT</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Air barrier and thermal barrier</td>
<td>Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material. Air-permeable insulation is inside of an air barrier.</td>
</tr>
<tr>
<td>2</td>
<td>Ceiling/attic</td>
<td>Air barrier in any dropped ceiling/soffit is substantially aligned with insulation and any gaps are sealed. Attic access (except unvented attic), knee wall door, or drop down stair is sealed.</td>
</tr>
<tr>
<td>3</td>
<td>Walls</td>
<td>Corners and headers are insulated. Junction of foundation and sill plate is sealed.</td>
</tr>
<tr>
<td>4</td>
<td>Windows and doors</td>
<td>Space between window/door jambs and framing is sealed.</td>
</tr>
<tr>
<td>5</td>
<td>Rim joists</td>
<td>Rim joists are insulated and include an air barrier.</td>
</tr>
<tr>
<td>6</td>
<td>Floors (including above-garage and cantilevered floors)</td>
<td>Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of insulation.</td>
</tr>
<tr>
<td>7</td>
<td>Crawl space walls</td>
<td>Insulation is permanently attached to walls. Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped.</td>
</tr>
<tr>
<td>8</td>
<td>Shafts, penetrations</td>
<td>Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.</td>
</tr>
<tr>
<td>9</td>
<td>Narrow cavities</td>
<td>Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.</td>
</tr>
<tr>
<td>10</td>
<td>Garage separation</td>
<td>Air sealing is provided between the garage and conditioned spaces.</td>
</tr>
<tr>
<td>11</td>
<td>Recessed lighting</td>
<td>Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.</td>
</tr>
<tr>
<td>12</td>
<td>Plumbing and wiring</td>
<td>Insulation is placed between outside and pipes. Batt insulation is cut to fit around wiring and plumbing, or sprayed/blown insulation extends behind piping and wiring.</td>
</tr>
<tr>
<td>13</td>
<td>Shower/tub on exterior wall</td>
<td>Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.</td>
</tr>
<tr>
<td>14</td>
<td>Electrical/phone box on exterior walls</td>
<td>Air barrier extends behind boxes or air sealed-type boxes are installed.</td>
</tr>
<tr>
<td>15</td>
<td>Common wall</td>
<td>Air barrier is installed in common wall between dwelling units.</td>
</tr>
<tr>
<td>16</td>
<td>HVAC register boots</td>
<td>HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.</td>
</tr>
<tr>
<td>17</td>
<td>Fireplace</td>
<td>Fireplace walls include an air barrier.</td>
</tr>
</tbody>
</table>

Disclaimer: This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Air sealing key points

1. Insulate and install sheet material behind bathtub.
2. Seal wiring and plumbing penetrations.
3. Insulate corners.
4. Window sealed into rough opening using backer rod.
5. Insulate headers.
6. Fan vented through exterior wall sealed at penetration.
7. Seal lights and bath vent fans to ceiling drywall.
8. Seal plumbing penetrations (if ceiling is insulated).
9. Narrow stud cavity batts are cut to fit.
10. Seal gap between electrical box and drywall.
11. Seal airtight IC-rated recessed light fixtures to drywall.
12. Insulate corners.
13. Ladder T-wall.
14. Electrical panel box, recommend install on interior (non-insulated) wall. If installed on exterior wall, air barrier shall extend behind box or air-sealed box shall be installed.

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Air sealing key points continued

Chases and common by-passes

1. Seal top plate
2. Seal electrical boxes and fixtures to drywall
3. Seal bottom plate
4. Seal penetrations in common wall
5. Seal HVAC boot penetrations
6. Seal HVAC penetrations
7. Install insulation and sealed air barrier behind tub (required)
8. Seal tub penetrations
9. Cap top of chase with solid air barrier and insulate above dropped soffit
10. Install air barrier on interior of all insulated walls
11. Seal bottom plate

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Window rough opening

Use backer rod or spray foam (appropriate for windows) to fill gaps between window/door and rough opening.

Wall cross-section

1. Glue drywall to top plate (recommended)
2. Tape or caulk exterior sheathing seams
3. Caulk bottom plate to subfloor
4. Wind wash baffle and dam for air-permeable insulation
5. Underfloor insulation must be installed in permanent contact with subfloor (air barrier required at any exposed edge of insulation)
6. 3-inch inspection gap
7. Sealed CLASS I vapor retarder required in crawlspace

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This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Combustion chase penetrations

Seal around chimney flues with sheet metal cap

Rigid foam option (recommend covering with ignition barrier for fire protection)

Internal air barrier (recommended)

Blocking above supporting wall for cantilevered floor (required)

Insulation above top plate of supporting wall

Underfloor insulation must be installed in permanent contact with subfloor (air barrier required at any exposed edge of insulation)

Seal gas and plumbing penetrations through walls

Insulated walls (not required unless walls are part of building thermal envelope)

Insulated water heater (not required)

Combustion closet

Combustion air inlets as per mechanical and/or fuel gas code

Seal

Flue stack

Seal around flue

Bottom plate sealed

Solid (non-louvered) door with weatherstripping

Exterior penetrations

Caulk exterior wall penetrations for refrigeration lines, condensate line, etc.

Disclaimer:
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Air sealing key points continued

1. Cavity Insulation - fit in joist cavity, caulked or foamed

2. Attic knee-walls
   - Caulk and seal rough opening
   - Rigid insulation (recommended)
   - Minimum R-value equivalent to surrounding wall insulation
   - Weather-strip door opening and threshold

3. Sealed attic-side air barrier (required) — OSB, insulated sheathing, etc.

4. Install blocking and rafter baffle to prevent wind-washing if vented, insulated roofline (required)

5. Blocking - fit in joist cavity, caulked or foamed

6. Weather-strip door opening and threshold

7. Air barrier required, (rigid insulation board recommended)

8. Disclaimer: This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
**Attic scuttle**

- Insulation dams prevent loose-fill insulation from falling through access.
- Hatch lid pushes up and out of the way for access.
- Rigid insulation plus batt (recommended), minimum R-value equivalent to surrounding ceiling R-value.

**Attic pull-down stairs**

- Rigid insulation box forms lid for pull-down attic staircase (recommended).
- Insulation dams prevent loose-fill insulation from falling through access.
- Cover box pushes up and out of the way for access.
- Minimum R-value equivalent to surrounding ceiling R-value.
- Boxed enclosure for staircase has rigid hinged lid with insulation on top.

**Disclaimer:**

This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Air sealing key points continued

2009 IECC

Air barrier behind steps

Garage to house door

Garage (unconditioned)

Web trusses

Rigid foam (recommend covering with ignition barrier, if required)

Basement (conditioned)

Inset garage to house door

Garage (unconditioned)

Web truss

Air seal

Sheath and insulate

Rigid foam (recommend covering with ignition barrier, if required)

Basement (conditioned)

Disclaimer:
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Additional Multifamily Air-sealing Keypoints

1. Cap and seal all chases including chases for grouped utility lines and radon vents
2. Seal penetrations in mechanical closet including penetrations for the:
   a. supply plenum
   b. outside air ventilation
   c. refrigerant line
   d. plumbing
   e. electrical
   f. gas fuel
3. Seal band area at exterior sheathing side and all penetrations through band
4. Air seal at drywall finishing for any wall adjacent to stairwell or elevator. Air seal this gap at every change in floor level
5. Seal miscellaneous clustered penetrations through building envelope (e.g. refrigerant lines)

Rigid foam sheathing or water-resistant barrier on exterior sheathing
Air sealing key points continued

Mechanical Closet

- Seal plenum penetration through drywall
- Seal refrigerant penetration
- Seal plumbing penetration
- Seal perimeter of drain penetration
- Seal electrical and plumbing penetrations and perimeter of outside air ventilation duct
- Seal electrical and plumbing penetrations
- Seal perimeter of outside air ventilation duct

Disclaimer:
This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Seal gap between concrete wall and framed units at each level.

Recommend rigid foam between concrete masonry units and framed stud wall.

Seal penetrations through exterior sheathing.

Cavity insulation plus exterior sheathing.

Seal gap between levels.

Disclaimer: This document is intended solely to help graphically demonstrate the air leakage provisions of section 402.4 of the 2009 IECC. It does not cover all airsealing locations or techniques. Other code provisions may be applicable as well.
Building Thermal Envelope — The basement walls, exterior walls, floor, roof, and any other building element that enclose conditioned space. This boundary also includes the boundary between conditioned space and any exempt or unconditioned space. —2009 IECC

The building thermal envelope is the barrier that separates the conditioned space from the outside or unconditioned spaces. The building envelope consists of two parts - an air barrier and a thermal barrier that must be both continuous and contiguous (touching each other). In a typical residence, the building envelope consists of the roof, walls, windows, doors, and foundation. Examples of unconditioned spaces include attics, vented crawlspaces, garages, and basements with ceiling insulation and no HVAC supply registers.

**Example 1**
- Attic
- Conditioned space
- Garages
- Conditioned space
- Basements/vented crawlspace

This is a conventional approach that likely locates all ductwork in unconditioned spaces.

**Example R-values**
1. Flat ceiling: R-30
2. Exterior walls: R-13 + R-3 sheathing
3. Floor over garage and basement/crawl: R-19
4. Ductwork sealed with mastic and insulated to R-8 in attic, R-6 in basement/crawl
5. Garage, attic and basement/crawl are unconditioned spaces

**Example 2**
- Vaulted conditioned space
- Kneewall
- Attic
- Garage
- Conditioned space
- Basement (conditioned or indirectly-conditioned)

If supply registers deliver conditioned air to basement, it is considered conditioned. With no supply air, it is considered an indirectly-conditioned space.

**Example R-values**
1. Flat ceiling: R-38
2. Kneewalls: R-18 (required) (R-13+ R-5, R-15 + R-3, R-19 in 2x6)
3. Vaulted ceiling: R-19 air-permeable insulation plus R-5 rigid foam board
4. Exterior walls: R-13
5. Basement masonry walls: R-5
6. Basement slab: R-0
7. Ductwork sealed with mastic and insulated to R-8 in attic, R-6 in basement
8. Garage and attic are unconditioned spaces

**Example 3**
- Conditioned space
- Indirectly-conditioned space
- Garages, attics, basements, and crawlspaces

The top conditioned floor functions as a vaulted ceiling with interior walls although it appears to have kneewalls and a flat ceiling. An advantage of this approach is that all upstairs ductwork is located inside the building envelope.

The crawlspace walls are insulated and do not contain vents. The crawlspace ground is covered with 100% plastic and functions as a “mini-basement.”

**Example R-values**
1. Vaulted ceiling: R-19 air-impermeable foam insulation
2. Exterior walls: R-13 + R-3 sheathing
3. Crawlspace walls: R-5
4. Ductwork sealed with mastic and insulated to R-6
5. Garage is unconditioned space

---

1. R-values shown are examples and not code requirements. Refer to table 402.1.1 for specific prescriptive insulation requirements.
2. Although there is nothing to prevent the garage walls from being insulated, due to indoor air quality concerns, the garage should never be considered inside the building envelope.
Insulation Details for Ceilings with Attic spaces
Rafter and Truss

Standard Truss
with tapered insulation depth

Energy Truss
with full height insulation
(recommended)

Standard rafter and top plate
with tapered insulation depth

Rafter on raised top plate
with full height insulation
(recommended)

Note: Wind wash baffle and air-permeable insulation dam. For air permeable insulation in vented attics, baffles shall be installed adjacent to soffit and eave vents. A minimum of a 1-inch of space shall be provided between the insulation and the roof sheathing and at the location of the vent. The baffle shall extend over the top of the insulation inward until it is at least 4 inches vertically above the top of the insulation. Any solid material such as cardboard or thin insulating sheathing shall be permissible as the baffle.
Why is air sealing so important?

- Energy penalty associated with infiltration / exfiltration
- Comfort due to drafts
- Impact on Indoor Air Quality (IAQ)
- Ability to control building pressure
- Moisture transported by air flow

402.4 Air Leakage

- Mandatory Requirement: Air Sealing
  - Detailed list
  - Fireplaces
  - Fenestration
  - Recessed light fixtures: airtight, IC-rated
- Details on techniques for air sealing – in flip book format
402.4.1.1 Air Barrier & Insulation Inspection Checklist is mandatory

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 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>2. Ceiling/Attic</td>
<td>The air barrier in any dropped ceiling/wall shafts shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or linear wall doors to unconditioned attic spaces shall be sealed.</td>
</tr>
<tr>
<td>3. Walls</td>
<td>Corners and headers shall be insulated and the juncture of the foundation and stilt plate shall be sealed. The juncture 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>4. Windows, skylights and doors</td>
<td>The space between windows or doors and framing and framing and framing shall be sealed.</td>
</tr>
<tr>
<td>5. Bays</td>
<td>Bay joints shall be insulated and include the air barrier.</td>
</tr>
<tr>
<td>6. Floors (including above garage and crawl space floors)</td>
<td>Insulation shall be installed to maintain permanent contact with underside of outdoor decking. The air barrier shall be installed at any exposed edge of insulation.</td>
</tr>
<tr>
<td>7. Crawlspace walls</td>
<td>Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in vented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.</td>
</tr>
<tr>
<td>8.Shafts, penetrations</td>
<td>Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.</td>
</tr>
<tr>
<td>9. 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>10. Garage separation</td>
<td>Air sealing shall be provided between the garage and conditioned spaces.</td>
</tr>
<tr>
<td>11. 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>12. Plumbing and wiring</td>
<td>Insulation shall be cut so as 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>13. Showers on exterior wall</td>
<td>Exterior walls adjacent to showers and tubs shall be insulated and the air barrier insulated separating them from the showers and tubs.</td>
</tr>
<tr>
<td>14. Electrical 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>15. HVAC intake doors</td>
<td>HVAC register doors that penetrate building thermal envelope shall be sealed to the subfloor or drywall.</td>
</tr>
<tr>
<td>16. Fireplace</td>
<td>An air barrier shall be installed on firewall walls. Fireplaces shall have gasketed doors.</td>
</tr>
</tbody>
</table>

402.4.3 Wood Burning Fireplaces

- New *wood-burning fireplaces shall have gasketed doors tight fitting dampers and outdoor combustion air*

  *”site-built masonry” – unofficial letter*
402.4.1.1 Air Barrier & Insulation Inspection Checklist is mandatory.
Advanced Framing

Insulated headers

Double top plate

2" of foam sheathing or fiberglass bale

2x4 nailer added to outside and flush to the exterior of window opening to provide nailing surface for siding and window trim

Drywall clip to hold drywall in place

Two-stud corner

Ladder "T"-wall

Position clip support at gypsum backer, if it does not connect with trim nailing

Batten support for gypsum backer

Ladder T-wall uses less wood and allows for insulation cavities behind partition walls

Air Sealing Chases (p. 3)

Chases and common by-passes

Seal top plate

Caulk electrical boxes and fixtures to drywall

Install air barrier on interior of all insulating walls

Seal HVAC penetrations

Seal HVAC penetrations

Seal penetrations in common wall

Seal penetrations in common wall

Seal penetrations in common wall

Cap top of chase with solid air barrier and insulate above dropped soffit

Seal HVAC penetrations
Air Sealing Blocking & Sheathing (p. 3)

Solid sheet behind tubs & showers on insulated walls

Call back waiting to occur

Call back prevention
402.4.4 - Windows, skylights and doors ≤ 0.3 cfm/s.f., Swinging doors ≤ 0.5 cfm/s.f. Exception: site built

Air Sealing Exterior Walls
Air Sealing Exterior Walls

402.4.3- Site built masonry wood-burning fireplaces must have gasketed doors and outdoor combustion air.
Air Sealing Kneewalls (p. 6)

Kneewall – WX photo shows need for blocking
Kneewall – Pics shows need for blocking & sheathing

Kneewall – Sheathed and blocked as per GA Code
Air Sealing Attic Access (p. 7)

Attic scuttle
- Insulation stud present looses fill insulation from falling through access
- Hatch lid pushes up and out of the way for access
- Rigid insulation plus batt recommended, minimum R-value equivalent to surrounding ceiling R-value
- Air seal gasket

Attic pull-down stairs
- Rigid insulation box forms lid for pull-down attic staircase (recommended)
- Insulation stud present looses fill insulation from falling through access
- Closure box pushes up and out of the way for access
- Minimum R-value equivalent to surrounding ceiling R-value
- Insulated enclosure for storage has rigid hinged lid with insulation on top
- Weatherstripping
- Seal gap between frame and rough opening with caulks, backers, or foam

Air Sealing - Adjacent Garage

Images of attic and garage structures with insulation and weatherstripping.
Air Barrier at the Ceiling

Drywall is the only air barrier

- After drywall, but before ceiling insulation is added, interior wall plate leak paths are sealed with caulk, foam, or gaskets
- Exterior walls have glued drywall
- Light fixture boxes are caulked
- Bath vent fan rough openings sealed

402.4.2.1 Envelope Tightness

REQUIRED Blower Door test

- CZ 1-2 Test out at ≤ 5 ACH\(_{50}\)
- CZ 3-8 Test out at ≤ 3 ACH\(_{50}\)

For reference, the 2009 IECC requires ACH\(_{50}\) < 7

ACH\(_{50}\) = \(\frac{CFM_{50} \times 60}{Volume}\)

1st Floor: \(38\times50\times11 = 20,900\) c.f.
2nd Floor: \(38\times50\times9 = 17,100\) c.f.
Total Volume: \(38,000\) c.f.

Measured Blower Door result is 4,305 CFM @ 50 Pascals

ACH\(_{50}\) = \(\frac{4305 \times 60}{38,000}\) = 6.8
• Whole House Mechanical Ventilation is REQUIRED
  – Any home tighter than 5 ACH₅₀

• Between ‘12 IECC and ‘12 IRC, whole house mechanical ventilation is now mandated!

R303.4 Mechanical ventilation. Where the air infiltration rate of a dwelling unit is less than 5 air changes per hour when tested with a blower door at a pressure of 0.2 inch w.c. (50 Pa) in accordance with Section N1102.4.1.2, the dwelling unit shall be provided with whole-house mechanical ventilation in accordance with Section M1507.3.

R303.5 Opening location. Outdoor intake and exhaust openings shall be located in accordance with Sections R303.5.1 and R303.5.2.

R303.5.1 Intake openings. Mechanical and gravity outdoor air intake openings shall be located a minimum of 10 feet (3048 mm) from any hazardous or noxious contaminant, such as vents, chimneys, plumbing vents, streets, alleys, parking lots and loading docks, except as otherwise specified in this code. Where a source of contaminant is located within 10 feet (3048 mm) of an intake opening, such opening shall be located a minimum of 3 feet (914 mm) below the contaminant source.

For the purpose of this section, the exhaust from dwelling unit toilet rooms, bathrooms and kitchens shall not be considered as hazardous or noxious.

R303.5.2 Exhaust openings. Exhaust air shall not be directed onto walkways.

---

**IRC Ventilation (based on ASHRAE 62.2 table)**

**TABLE M1507.3.3(1) CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOW RATE REQUIREMENTS**

<table>
<thead>
<tr>
<th>DWELLING UNIT FLOOR AREA (square feet)</th>
<th>NUMBER OF BEDROOMS</th>
<th>Airflow in CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 1</td>
<td>2 - 3</td>
</tr>
<tr>
<td>&lt; 1,500</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>1,501 - 3,000</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>3,001 - 4,500</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>4,501 - 6,000</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>6,001 - 7,500</td>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>&gt; 7,500</td>
<td>105</td>
<td>120</td>
</tr>
</tbody>
</table>

**Note:**
IECC 2012 does **not** include ASHRAE 62.2 details & formula:

\[(\#BR+1) \times 7.5 \text{ cfm} + 1 \text{ cfm} / 100 \text{ s.f.}\]

(Suggest state amendment with 62.2 as alternative approach)

For SI: 1 square foot = 0.0929 m², 1 cubic foot per minute = 0.0004719 m³/s.

**TABLE M1507.3.3(2) INTERMITTENT WHOLE-HOUSE MECHANICAL VENTILATION RATE FACTORS**

<table>
<thead>
<tr>
<th>RUN-TIME PERCENTAGE IN EACH 4-HOUR SEGMENT</th>
<th>25%</th>
<th>33%</th>
<th>50%</th>
<th>66%</th>
<th>75%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor²</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

a. For ventilation system run time values between those given, the factors are permitted to be determined by interpolation.

b. Extrapolation beyond the table is prohibited.
2015 Energy Code Field Study in GA:

- Blower door test of ~90 random homes around the state
  - Average of 4.8 $\text{ACH}_{50}$
  - Median was 5 (~half were tighter)
  - 4 homes $> 7 \text{ACH}_{50}$ ($< 5\%$)
- Conclusion:
  Half of new homes tested would be required to have whole house mechanical ventilation system

$\text{ACH}_{50} = \frac{\text{CFM}_{50} \times 60}{\text{Volume}}$

403.5 Mechanical Ventilation

- Ventilation is REQUIRED
  - Any home tighter than $5 \text{ACH}_{50}$
- [Negative] Exhaust
  - (whole house exhaust systems)
- [Balanced] Air-in / Air-out
  - (HRV, ERV, multiple fans)
- [Positive] Pull/pump air into home
  - (ducted supply, return intake)
Balanced Ventilation

ERV - energy recovery ventilator

Positive Ventilation

Positive Ventilation Supplied via O.A. Ducted to Return
403.2.2. Duct Tightness Testing

- Duct Tightness Testing REQUIRED (by DET Verifier?)
  - When tested at rough-in
    - Maximum 4% Total Leakage with AHU installed (RIT)
    - Maximum 3% Total Leakage without AHU installed (RITnah)
  - When tested at final
    - Maximum 4% Total Leakage (PCT)

**Note:** Blower Door and Duct Leakage test results **MUST be displayed on Certificate!**
(but code provides no other detail on this)

---

403.2 - Ducts

Mandatory Requirement:

- **Insulation:**
  - R-8 Insulation in Attic
  - R-6 Insulation other unconditioned space
  - No Insulation required when inside envelope
- May not use building cavities as supply or return
- **Sealing with Mastic required** – “thick as a nickel” (GA specific)
403.6 Equipment Sizing

• Load Calcs & Sizing
  - Per Mechanical section of IRC
  - ACCA Manual J or approved equivalent, i.e., ASHRAE Fundamentals
  - MUST BE ACCURATE
  - Permits 72 and 75 as indoor design temps

M1401.3 Sizing. Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies.

403.6 Equipment Sizing

• Load Calcs - how to enter air leakage

Choices are:
- Tight
- Semi-tight
- Average
- Semi-loose
- Loose
403.6 Equipment Sizing

- Load Calcs – how to enter air leakage

Home Heating & Cooling Energy

Heating and cooling no longer majority of U.S. home energy use

- Shrink the pie!
- Usage shifts
Certified DET Verifier can either:

- Be previously certified
  - HERS Rater
  - BPI Building Analyst
  - BPI IDL certification
- Pass a DET Verifier Course
  - Discuss testing protocol (setup, safety, and accuracy)
  - Explain calculations for ACH50 and % duct leakage
  - Field exam on tools (use blower door and duct tester)
  - Pass Written Exam – 25 Questions (1 hour)
- Free 10-minute training videos – BD + DB
- CERTIFIED DUCT AND ENVELOPE TIGHTNESS (DET) VERIFIER. A certified DET verifier shall be a certified Home Energy Rating Systems (HERS) rater, or be a certified Home Performance with ENERGY STAR contractor, or be a Building Performance Institute (BPI) Analyst, or successfully complete a certified DET verifier course that is approved by the Georgia Department of Community Affairs.
  (Effective January 1, 2011)

DET Verifier Study

Buildings XII Conference – Lessons from DET Verifier program
(available from southface.org)

Results from first year of statewide testing and deployment of testing requirements
### DET Verifier Code Comparison

#### Table 1: Duct and Envelope Tightness Requirements

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope Testing – Single Family</td>
<td>Optional Blower door (BD) test or Visual Inspection checklist</td>
<td>Mandatory BD test with optional Visual Inspection checklist</td>
<td>Mandatory BD test and Visual Inspection checklist</td>
</tr>
<tr>
<td>Envelope Testing – Multifamily</td>
<td>Optional – BD test or Visual Inspection checklist</td>
<td>Optional – Visual Inspection or BD test. Sampling 1 in 4 units per floor permitted or RESNET protocol</td>
<td>Mandatory BD test (no mention of sampling)</td>
</tr>
<tr>
<td>Envelope passing criteria</td>
<td>&lt; 7 ACH₆₀ all Climate Zones (CZ)</td>
<td>&lt; 7 ACH₆₀ all CZ (2-4)</td>
<td>≤ 3 ACH₆₀ in CZ 3-8</td>
</tr>
<tr>
<td>Clarify if envelope test required on alteration or renovation</td>
<td>No guidance</td>
<td>&quot;When construction affects all aspects of building envelope (not renovation)&quot;</td>
<td>No guidance</td>
</tr>
<tr>
<td>Duct Testing criteria at Rough-in (RI) (Total)</td>
<td>4% - RI Total no Air Handler 6% - RI Total w/ Air Handler</td>
<td>6% - RI Total w/ Air Handler</td>
<td>3% - RI Total no Air Handler 4% - RI Total w/ Air Handler</td>
</tr>
<tr>
<td>Duct Testing criteria at Post Construction—Post Construction Total (PCT) or Post Construction to Outside (PCO)</td>
<td>12% - PCT 8% - PCO</td>
<td>12% - PCT 8% - PCO</td>
<td>4% - PC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(no incentive for testing at final or To Outside)</td>
</tr>
</tbody>
</table>

### DET Verifier - Code Comparison

#### Table 1: Duct and Envelope Tightness Requirements

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Record / Display Test Results</td>
<td>Not required</td>
<td>On Energy Code certificate – template provided</td>
<td>On Energy Code certificate – no specifics on what to provide</td>
</tr>
<tr>
<td>Exempt from Duct Testing</td>
<td>Ducts and Air Handler Unit (AHU) entirely inside building Thermal Envelope</td>
<td>Ducts and AHU entirely inside building Thermal Envelope</td>
<td>Ducts and AHU entirely inside building Thermal Envelope</td>
</tr>
<tr>
<td>Duct pressure test required when modifying an existing system</td>
<td>No guidance</td>
<td>When &gt; 50% of existing duct system is modified. When AHU is changed out, test is not required but duct sealing with mastic through plenum connections is required</td>
<td>No guidance</td>
</tr>
<tr>
<td>Building cavities allowed as ducts</td>
<td>Only for returns</td>
<td>Not allowed for supply or returns</td>
<td>Not allowed for supply or returns</td>
</tr>
<tr>
<td>Duct sealing material</td>
<td>UL tape, mastic, etc.</td>
<td>No UL tape, only mastic and mastic tape</td>
<td>UL tape, mastic, etc.</td>
</tr>
<tr>
<td>Qualified testers</td>
<td>No guidance</td>
<td>DET verifiers and RESNET and BPI certified professionals</td>
<td>No guidance</td>
</tr>
</tbody>
</table>
DET Verifier – Lessons Learned

Eight items for consideration:
1) Ventilation now “required”
2) Multi-day training – 2 days is needed
3) Central database of DET Verifiers
4) Quality Assurance and continuing education
5) Equipment loan program
6) Reciprocity
7) Issue of 3rd party testing
8) Consistent curriculum

DET Verifier Test Data Study

Four Companies Surveyed around Georgia:
• Company A – metro Atlanta -CZ3A (944 homes)
  – 595 minimum code / 349 beyond code single family
• Company B – southeast -CZ2A & 3A (77 dwellings)
  – 3 multifamily developments – all in beyond code program
• Company C – southern -CZ2A (22 homes)
  – 19 minimum code / 3 beyond code single family
• Company D – northern -CZ4A (55 homes)
  – All minimum code single family
Envelop Testing Results

Company A released data for 936 homes that were blower door tested (587 minimum code and 349 beyond code). The average building envelope leakage for code compliant homes was 4.42 ACH_{50} while the average for homes in beyond code programs was 3.41 ACH_{50}.

Company B showed that for 77 units in three different multifamily developments in three different cities under a beyond code program (EarthCraft), the overall average ACH_{50} was 4.26. The data shows that, in spite of an ACH_{50} bias that favors large volume homes and works against small volume homes, multifamily units can still successfully pass leakage criteria, particularly when participating in a beyond code program.

Company C provided blower door results for twenty homes with an average ACH_{50} of 3.76. Seventeen of the homes featured spray foam rooflines and easily passed the blower door test on the first attempt. The three remaining homes were conventional vented attic-style construction; two of these required retesting after not passing their initial envelope tightness test. These vented attic homes were also the only ones that required duct testing (since the spray foam houses created fully encapsulated ductwork).

Company D provided simple code compliance data for 55 single family homes in north Georgia (Climate Zone 4A). Of the 45 homes that passed, the average blower door test score was 4.7 ACH_{50}. For the 10 homes that did not pass the blower door test, the results ranged from 7.5 to 12 ACH_{50}. Only two homes chose to retest since the county code officials chose to grant the Certificate of Occupancy without enforcing energy code performance requirements.

Duct Leakage Testing Results

Company A performed a total of 1,617 duct leakage tests (1,022 systems to meet minimum code requirements and 595 systems for homes in beyond code programs). The ducts were tested either at rough-in stage (RIT) or at final stage measuring leakage to outside (PCO). The average duct leakage for minimum code compliance was 3.9% while the average beyond code program duct leakage was 2.9%.

Company B measured duct leakage in 77 multifamily beyond code units that averaged 2.7%.

Company C provided duct testing data for the five homes out of 22 that were conventionally vented attic-style construction. These vented attic homes were also the only ones that required duct testing (since the sprayed foam roofline houses created fully encapsulated ductwork). Five duct systems were tested but only three passed initially; the other two required minor sealing around the boot penetrations and some touch-up around the air handler but, after this, were able to pass while still on the initial visit.

Company D only leak tested 18 duct systems out of the 55 single family homes in the northern part of the state (Climate Zone 4A). About half of the remaining duct systems did not require testing since the ductwork was inside the thermal envelope. The other half ignored the required testing but the home still received a Certificate of Occupancy due to the jurisdiction’s lack of energy code enforcement. The average passing duct leakage test score was around 11% total leakage at final (PCT). This value is close to the non-compliant threshold of 12%. Five of 18 duct systems failed but only two chose to retest since code compliance was not being enforced.
Additional

Company A also performed air sealing and inspection services in many of their over 1,200 single-family homes. In all cases, the need to perform blower door or duct leakage retests was fairly small (less than 2%).

Company B also evaluated 32 single family homes that passed all envelope and duct leakage tests. Failure rate here was estimated at less than one percent.

Company C did not perform air sealing as part of their scope of work. They did bring air sealing materials along to help educate on how to seal top plates, penetrations and chases. Company C did not charge for this service but saw the value of fostering good business relationships in case the homes did not pass on the first blower door attempt.

Company D expressed frustration at the lack of or inconsistent code enforcement. Retests were rarely performed even if the envelope or duct system failed; only fear of liability was enough to spur some builders to pay for a retest. Other blatant lack of enforcement issues included walkout basements with no insulation on the concrete walls as required by code and that, “certain counties aren’t even doing insulation inspections.”

Key results and conclusions:

• 2009 energy code requirements can be met
  – Fairly modest effort and should pass

• Beyond Code programs work
  – Results consistently exceeded code minimum

• Companies that performed additional services achieved higher performance
  – Air sealing, duct touch-up

• Impact of poor energy code enforcement matters
  – Homes and ducts that did pass were only barely passing
  – Houses that did not pass were still granted C.O. and thus did not follow up on testing requirements

• Spray foam houses performed well
DET Implications in 2012/15 IECC

Key results and conclusions:
• 2012/15 energy code requirements are much more challenging (but can be met with suggested phase-in)
  – Serious attention to detail
  – Concern over adoption, enforcement, then compliance
  – Feet to the fire mentality by jurisdiction
  – Phase-in of tighter requirements?: < 5 $ACH_{50}$ to < 4 to < 3
• Beyond Code programs – can show how it can be done
  – Results consistently exceed '09 code minimum
  – Results do not always align with 2012 IECC but foster it
• Ventilation
  – Standard builders not necessarily accustomed to it
  – Not all strategies are equally valid but cheapest may win out
  – IECC chart vs. ASHRAE 62.2

DET Implications – going forward

Key results and conclusions:
• Quality Assurance issues
  – Spot checking results
  – Code official notification for observing
  – Continuing education
• Statewide / regional registry of DET Verifiers
  – Who can / will maintain this?
  – What information do you need to keep?
  – Violations - License revoked?
• Sampling Protocol for MF (test all SF homes)
• A better metric –
  – Prefer $ELR_{50}$ instead of $ACH_{50}$
  – Or, range of passing $ACH_{50}$ based on house size (MF is penalized)
    • Under 1000 s.f. – 4 $ACH_{50}$
    • 1000-3000 s.f. – 3 $ACH_{50}$
    • Over 3000 s.f. – 2 $ACH_{50}$

Possible future amendment
• Under 1,200 s.f. < 5 $ACH_{50}$
• 1,200-3,000 s.f. < 4 $ACH_{50}$
• Over 3,000 s.f. < 3 $ACH_{50}$
Envelope Leakage Ratio - ELR

\[ ELR_{50} = \frac{CFM_{50}}{\text{Shell Area}} \]

- Shell Area = SFBE
- Square Footage of Building Envelope
- Surface area of the building envelope

Example Calculation:
A 1,200 square foot building has an SFBE of 3,234 square feet and a measured fan flow of 1.40 at CFM_{50}. Determine the Envelope Leakage Ratio at 75 ~ by dividing the cubic feet per minute of air volume moved through the fan by the total square footage of the building thermal envelope.

\[ \text{SFBE} = 3,234^2 + 400^2 + 18647^2 = 3,234^2 \]

\[ \text{Fan Flow Measurement} = 1,403 \text{ CFM}_{50} \]

\[ ELR_{75} = \frac{CFM_{50}}{SFBE} \]

\[ ELR_{75} = 1.403 \text{ CFM}_{50} \]

\[ ELR_{75} = 0.46 \text{ Envelope Passes} \]

DET Testing – ELR vs. ACH

\[ ACH_{50} = \frac{CFM_{50} \times 60}{\text{Volume}} \]

\[ ELR_{50} = \frac{CFM_{50}}{\text{Shell Area}} \]
DET Testing – ELR vs. ACH

### Volume vs. Shell

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<th>CEA s.f.</th>
<th>per floor s.f.</th>
<th>width</th>
<th>length</th>
<th>cell. ht</th>
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<th>floor</th>
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$$\text{ACH}_{50} = \frac{\text{CFM50} \times 60}{\text{Volume}}$$  
$$\text{ELR}_{50} = \frac{\text{CFM50}}{\text{Shell Area}}$$

### Wrap up and Q&A

Thank you!

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BECP help desk