2012 Energy Codes: Performance Standards for Air Sealing and Duct Leakage

Presented by:
Peter Harding
Home Energy Technologies

Outline

- Energy Codes
  - 2009, 2012 & 2015 IECC codes
  - Mandatory requirements
  - Prescriptive compliance options
  - Performance compliance options
- Ventilation Requirements
- Envelope Sealing Requirements
- Duct Sealing Requirements
Compliance Options for 2009 & 2012 IECC/IRC

**Mandatory Provisions**
- Labeling
- Air sealing
- Duct leakage
- Programmable thermostats
- Building cavities
- Equipment sizing
- Lighting
- Ventilation (2012)
- Pipe insulation (2012)

**Prescriptive Path Option**
- Prescriptive Envelope Specs
  - Or
  - Total UA Alternative (REScheck)
  - Plus
  - Specific Insulation, Fenestration and Lighting Provisions

**Performance Path Option**
- Simulated Cost Performance Alternative

Compliance Options for 2015 IECC

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- Simulated Cost Performance Alternative

**Energy Rating Index Alternative**
- (ERI ≤ 55 in CZ5, ≤ 54 in CZ6)
Performance-based Alternatives

  - Compares projected heating and cooling energy use of proposed design to same home configured to prescriptive requirements
  - Allows credit for better than code air leakage or duct leakage

- Energy Rating Index Compliance Alternative (2015 IECC)
  - Compares projected energy use of rated home to same home configured to 2006 code requirements
  - Includes all energy uses
    - Heating & cooling
    - Water heating
    - Lighting, appliances, miscellaneous loads

ERI Scale

The ER Index is identical to the HERS Index

- ERI expressed on a 0-100 scale of relative energy usage
- 2015 IECC Standard for CZ5
  - ERI ≤ 55
- Mandatory requirements
  - Thermal envelope ≥ 2009 IECC requirement
  - Air leakage
  - Pipe insulation
Labeling - Mandatory

- 2009 IECC requires
  - A permanent certificate posted on or in the electrical distribution panel
  - Completed by the builder or registered design professional
  - List predominant R-values, fenestration U and SHGC values, and types and efficiencies of heating, cooling and water heating equipment
- 2012 IECC additional requirements
  - Air leakage test results
  - Duct leakage test results

Prescriptive Insulation for CZ5

<table>
<thead>
<tr>
<th>Component</th>
<th>2009 IECC</th>
<th>2012/2015 IECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fenestration U-factor</td>
<td>0.35</td>
<td>0.32</td>
</tr>
<tr>
<td>Ceiling</td>
<td>38</td>
<td>49</td>
</tr>
<tr>
<td>Framed wall</td>
<td>20 or 13+5</td>
<td>20 or 13+5</td>
</tr>
<tr>
<td>Basement/crawl wall</td>
<td>10/13</td>
<td>15/19</td>
</tr>
<tr>
<td>Frame floor</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Slab R &amp; depth</td>
<td>10, 2’</td>
<td>10, 2’</td>
</tr>
</tbody>
</table>
Prescriptive Total UA Alternative

- REScheck allows builders to trade-off envelope insulation values
  - e.g. better windows for lower R-values in other assemblies
- Only applies to insulation requirements
  - No mechanical equipment trade-offs

<table>
<thead>
<tr>
<th></th>
<th>2009 IECC</th>
<th>2012/2015 IECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load &amp; sizing calculations</td>
<td>Manuals J &amp; S (by reference to Section M of the 2009 IRC)</td>
<td>Manuals J &amp; S</td>
</tr>
<tr>
<td>Mechanical ventilation</td>
<td>Not required</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Duct insulation</td>
<td>R8 for supply ducts in unconditioned attics. R6 in other unconditioned spaces</td>
<td>R8 for supply &amp; return ducts in unconditioned attics (2015 IECC). R6 in other unconditioned spaces</td>
</tr>
<tr>
<td>Building cavities</td>
<td>Building framing cavities shall not be used as supply ducts</td>
<td>Building framing cavities shall not be used as supply or return ducts</td>
</tr>
<tr>
<td>Programmable thermostats</td>
<td>Required for all forced-air systems</td>
<td></td>
</tr>
<tr>
<td>Duct leakage</td>
<td>Testing required unless system is located completely inside the conditioned space</td>
<td></td>
</tr>
</tbody>
</table>
Pipe Insulation - Mandatory

Recirculating Systems
• Automatic control or readily-accessible switch
• R3 insulation

R3 Hot water pipe insulation
• Piping >3/4” diameter
• From water heater to
  • Distribution manifold
  • Kitchen outlets
• Buried or under-slab piping
• Piping outside the conditioned space
• Pipe runs exceeding prescribed length
  • E.g. ½” pipe over 20’

Lighting (except low-voltage lighting)

A minimum of 75% of the lamps in permanently installed fixtures shall be high-efficacy lamps
(50% in 2009 IECC)

Or

A minimum of 75% of the permanently installed lighting fixtures shall contain only high-efficacy lamps
Ventilation - Mandatory

The building shall be provided with a mechanical ventilation system per the IRC. For example, a 4-bedroom, 2,500 square foot home must have 75 cfm of continuous mechanical ventilation. Interchangeable systems providing the equivalent ventilation rate over a four-hour period are acceptable.

### Ventilation System Types

- **Exhaust only**
  - Often combined with local exhaust
- **Supply only**
  - Often combined with ducted heating/cooling systems
- **Balanced systems**
  - Standalone or combined with ducted heating/cooling systems

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**TABLE M1507.2.3(1)**

<table>
<thead>
<tr>
<th>DWELLING UNIT FLOOR AREA (square feet)</th>
<th>0 - 1</th>
<th>2 - 3</th>
<th>4 - 5</th>
<th>6 - 7</th>
<th>&gt; 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1,500</td>
<td>30</td>
<td>45</td>
<td>50</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>1,501 - 3,000</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>3,001 - 4,500</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>120</td>
</tr>
<tr>
<td>4,501 - 6,000</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>135</td>
</tr>
<tr>
<td>6,001 - 7,500</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>135</td>
<td>150</td>
</tr>
<tr>
<td>&gt; 7,500</td>
<td>105</td>
<td>120</td>
<td>135</td>
<td>150</td>
<td>165</td>
</tr>
</tbody>
</table>
Exhaust-only ventilation

Two commonly installed options:
1. Controller in unit
2. Separate controller

Advantages
• Lowest cost
• Uses local exhaust equipment

Disadvantages
• No control over makeup air sources
• No heat recovery

Supply-only ventilation

Two system components
• Fresh air intake duct with mechanical damper
• Ventilation controller
  • Opens damper for set minutes per hour
  • Cycles air handler if insufficient heating/cooling run time

Advantages
• Known air source
• Filtered, conditioned air

Disadvantages
• High energy use in fan-only mode
  • IECC mandates ECM blower motors in supply-only systems
Balanced ventilation

Balanced supply and exhaust airflows
• HRV - Heat transfer only
• ERV – Heat & moisture transfer

Advantages
• Neutral pressure effect on home
• Controlled source
• Heat/moisture recovery

Disadvantages
• Highest initial cost

HRV/ERV Installation

Three installation options
• Standalone – dedicated exhaust and supply ducts
  • Best ventilation, most expensive installation
• Hybrid – dedicated exhaust, supply through heating/cooling ducts
  • Reasonably effective
• Integrated system – exhaust & supply from heating/cooling ducts
  • Lowest cost installation, requires air handler fan operation
Other Ventilation Requirements

- Exhaust openings must terminate >3’ from operable and inoperable openings and >10’ from mechanical air intakes
- Whole house ventilation systems must be provided with controls that enable manual override
- Kitchen range hoods >400 cfm capacity must have automatically-controlled makeup air with a means of closure (2009 IRC)

Air Sealing - Mandatory

<table>
<thead>
<tr>
<th>2009 IECC</th>
<th>2012/2015 IECC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air sealing mandatory</td>
<td>Air sealing mandatory</td>
</tr>
<tr>
<td>Verification by</td>
<td>Verification by</td>
</tr>
<tr>
<td>Tested Leakage ≤ 7 ACH50</td>
<td>Tested Leakage ≤ 3 ACH50</td>
</tr>
<tr>
<td>OR</td>
<td>AND</td>
</tr>
<tr>
<td>Completed Inspection Checklist (Table 402.4.2)</td>
<td>Completed Inspection Checklist (Table 402.4.1.1)</td>
</tr>
</tbody>
</table>
Benefits of Envelope Sealing

- **Energy efficiency**
  - Low cost/high impact measures
  - Principal improvement measures used in existing home weatherization programs

- **Comfort**
  - Reduced thermal stratification, drafts, hot/cold spots

- **Air quality**
  - Reduced infiltration from garages, basements, crawl spaces, etc.

- **Initial cost**
  - Smaller, simpler mechanical systems

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**Table R402.4.1.1**

- A great builders guide!
  - If Table 402.4.1.1 is followed builders should not have difficulty in meeting the < 3 ACH50 requirement
Table R402.4.1.1

<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.</td>
</tr>
<tr>
<td></td>
<td>Exterior thermal envelope contains a continuous air barrier.</td>
</tr>
<tr>
<td></td>
<td>Breaks or joints in the air barrier shall be sealed.</td>
</tr>
<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>insulation and any gaps in the air barrier sealed.</td>
</tr>
<tr>
<td></td>
<td>Access openings, drop down stair or knee wall doors to unconditioned</td>
</tr>
<tr>
<td></td>
<td>attic spaces shall be sealed.</td>
</tr>
<tr>
<td>Walls</td>
<td>Corners and headers shall be insulated and the junction of the foundation</td>
</tr>
<tr>
<td></td>
<td>and sill plate shall be sealed.</td>
</tr>
<tr>
<td></td>
<td>The junction of the top plate and top of exterior walls shall be sealed.</td>
</tr>
<tr>
<td></td>
<td>Exterior thermal envelope insulation for framed walls shall be installed</td>
</tr>
<tr>
<td></td>
<td>in substantial contact and continuous alignment with the air barrier.</td>
</tr>
<tr>
<td></td>
<td>Knee walls shall be sealed.</td>
</tr>
<tr>
<td>Windows, skylights, and doors</td>
<td>The space between window, door, jams and framing and skylights and</td>
</tr>
<tr>
<td></td>
<td>framing shall be sealed.</td>
</tr>
</tbody>
</table>

Red-Line Drawing

A continuous air barrier shall be installed in the building envelope.

Breaks or joints in the air barrier shall be sealed:
- Connections are always the weak point.
Table R402.4.1.1

<table>
<thead>
<tr>
<th>Rim joints</th>
<th>Rim joints shall be insulated and include the air barrier.</th>
</tr>
</thead>
<tbody>
<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>Crawl space walls</td>
<td>Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawl space walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.</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>
</tbody>
</table>

Table R402.4.1.1

<table>
<thead>
<tr>
<th>Recessed lighting</th>
<th>Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.</th>
</tr>
</thead>
<tbody>
<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>
Critical Air Leakage Points

<table>
<thead>
<tr>
<th>Joint</th>
<th>ACH50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top plate to attic</td>
<td>0.29 to 1.60</td>
</tr>
<tr>
<td>Duct boots</td>
<td>0.13 to 0.26</td>
</tr>
<tr>
<td>Recessed lights</td>
<td>0.15 to 0.31</td>
</tr>
<tr>
<td>Band joists</td>
<td>0.37 to 0.42</td>
</tr>
<tr>
<td>Garage-house common wall</td>
<td>0.14 to 0.26</td>
</tr>
<tr>
<td>Sheathing to plate</td>
<td>0.04 to 0.38</td>
</tr>
<tr>
<td>Window/door framing to sheathing</td>
<td>0.02 to 0.10</td>
</tr>
<tr>
<td>Bottom plate to subfloor</td>
<td>0 to 0.11</td>
</tr>
</tbody>
</table>

Source: Owens Corning Just How Airtight are Your Homes?

Knee wall sealing
Eave vents

Attic rooms
Floor/ceiling blocking & sealing

Floor/ceiling truss blocking
Duct boots

Duct chases
Soffits

- Insulation over soffit capping
- Flexible sealant to create air barrier on all four sides
- Air barrier, such as continuation of ceiling sheetrock or rigid material installed over open cavity
- Soffit
- Cabinet

Showers & tubs

- Exterior wall
- Shower
- Rigid material or air barrier enclosing cavity insulation behind shower

- Exterior wall
- Tub
- Rigid material or air barrier enclosing cavity insulation behind tub
Gas fireplaces

Rings are installed as necessary to ensure adequate air flow for accurate flow readings.

Blower Door Testing - Equipment
Manometer

Manometer measures pressure differences

• Left channel: Between inside house and the outside
• Right channel: Measures fan pressure
  – Automatically converted to CFM of air flow based on ring size used

Blower Door Testing - Timing

• Code states:
  – “Testing shall occur after rough-in and after installation of penetrations in the building envelope, including penetrations for utilities, plumbing, electrical, ventilation and combustion appliances”

• In practice
  – Test immediately before final CO
    • Duct boots sealed to air barrier
    • Attic hatch gasketed
    • Door & window seals in place
Test preparation

2009 IECC Section 402.4.2.1 requires that
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 systems shall be closed and sealed
5. Heating, cooling and ventilation system(s) shall be turned off
6. HVAC ducts shall not be sealed; and
7. Supply and return registers shall not be sealed

Test protocol

RESNET Standard Section 802.5 Procedure for Conducting a One-Point Depressurization Air Tightness Test
1. With fan sealed, measure baseline inside/outside pressure differential and set in manometer
2. Unseal fan, turn on and increase exhaust flow until inside/outside pressure differential equals 50 Pascals
3. Record fan flow in CFM from manometer (minimum 10 second average), inside & outside temperatures, fan and manometer model and serial numbers
4. Calculate corrected CFM50 value if inside/outside $\Delta T > 30$ degrees

While fan is running it is good practice to show builder any notable sources of air infiltration
Interpretation

\[
\text{ACH50} = \frac{\text{CFM50} \times 60}{\text{Volume of Enclosure}}
\]

- ACH50 is the number of complete air exchanges the home would experience in one hour with a 50 Pascal inside/outside pressure differential.
- Volume may be calculated from (conditioned floor area) x (average ceiling height).
  - Includes all volume within the thermal envelope, e.g. insulated basements and crawlspaces, sealed attics.

Benchmarks

<table>
<thead>
<tr>
<th>ACH50</th>
<th>CFM/sf*</th>
<th>ELA (sq. in.)</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>15+</td>
<td>2.0+</td>
<td>150</td>
<td>Older homes, balloon framed</td>
</tr>
<tr>
<td>10</td>
<td>1.3</td>
<td>100</td>
<td>Recent code-built homes</td>
</tr>
<tr>
<td>7</td>
<td>0.93</td>
<td>70</td>
<td>2009 IECC standard</td>
</tr>
<tr>
<td>4</td>
<td>0.53</td>
<td>40</td>
<td>ENERGY STAR v3 prescriptive standard</td>
</tr>
<tr>
<td>3</td>
<td>0.4</td>
<td>30</td>
<td>2012 &amp;2015 IECC standard</td>
</tr>
<tr>
<td>0.6</td>
<td>0.08</td>
<td>6</td>
<td>Passive House standard</td>
</tr>
<tr>
<td>0.05</td>
<td>0.007</td>
<td>0.5</td>
<td>Claimed record (Dillingham, Alaska)</td>
</tr>
</tbody>
</table>

* 8’ ceiling height
ACH50 and ACHn

The natural rate of air exchange (ACHn) can be estimated from the ACH50 results:

\[
ACH_n = \frac{ACH_{50}}{n}
\]

In Connecticut, for a normally exposed, 2-story building \(n=14.8\) so

\[
7 \text{ ACH50} = \left(\frac{7}{14.8}\right) \text{ ACHn} = 0.47 \text{ ACHn}
\]

and

\[
3 \text{ ACH50} = \left(\frac{3}{14.8}\right) \text{ ACHn} = 0.20 \text{ ACHn}
\]

Testing challenges

- Additions
  - Generally impossible to isolate old and new construction in one building
- Multi-family units
  - Most infiltration is from adjacent units and common spaces
  - Compartmentalization is critical. Demising building assemblies must be airsealed to exterior wall standards
What if I fail?
Blower door may identify specific problem areas

Treat drywall as the air barrier
• Seal duct boots and recessed lights
• Seal baseboard and trim
• Seal electrical outlets & plumbing penetrations
• Seal top plate-attic joints

Insulate the basement to bring it inside the conditioned volume

Duct Leakage - Mandatory

<table>
<thead>
<tr>
<th>2009 IECC</th>
<th>2012 IECC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post Construction</strong></td>
<td><strong>Post Construction</strong></td>
</tr>
<tr>
<td>DLO ≤ 8 CFM/25/100SF or TDL ≤ 12 CFM/25/100 SF</td>
<td>TDL ≤ 4 CFM/100SF</td>
</tr>
<tr>
<td>Or <strong>Rough In</strong></td>
<td>Or <strong>Rough In</strong></td>
</tr>
<tr>
<td>TDL ≤ 6 CFM/25/100 SF including air handler or TDL ≤ 4 CFM/25/100SF excluding air handler</td>
<td>TDL ≤ 4 CFM/100 SF including air handler or TDL ≤ 3 CFM/25/100SF excluding air handler</td>
</tr>
</tbody>
</table>

Duct leakage testing not required if air handler and all ductwork are inside the conditioned space
Leakage Test Types

• Duct testing is done at 25 Pascals (0.1” wc), similar to normal operating pressure
• Total Duct Leakage
  – All leakage from the duct system regardless of whether the loss is to conditioned or unconditioned space
• Leakage to Outside
  – That part of total duct leakage that is outside the conditioned space

Duct Leakage Testing - Equipment
Test Preparation

- Turn off HVAC systems
- Turn off fans, ventilation systems
- Remove filters
- Open windows, doors, access panels to outside of unconditioned spaces where ducts are run
- Seal supply registers and return grills
  - Rough-in: Seal boots with duct sealing tape
  - Post-Construction: Seal registers with register sealing tape
- Connect Duct Blaster to
  - Major return closest to air handler, or
  - Air handler cabinet, or
  - Duct plenum (Rough-in test if air handler not installed)
- Insert test probe to measure duct system pressure
  - Largest supply register close to air handler
  - Main supply trunk line

Test Protocol – Total Duct Leakage Test

- Open at least one door or window between building and outside
- Turn on fan. Increase speed until pressure in duct system is +25 Pascals with respect to the building
- Record fan flow CFM reading, fan and manometer model and serial numbers
Test Protocol – Leakage to Outside Test

• Ensure all doors and windows to outside are closed
• Reverse direction of blower door fan (installed as for blower door test) so that building will be pressurized rather than depressurized
• Turn on blower door fan. Increase speed to make building pressure +25 Pascals with respect to outside
  – Pressure in duct system will be negative with respect to the building if there is any leakage outside the conditioned space
• Turn on and increase Duct Blaster fan speed to blow air into duct system until the pressure in the duct system is equal to the building pressure (zero pressure differential)
• Record fan flow CFM, fan and manometer model and serial numbers

Interpretation

Duct leakage test result is normalized for building size by dividing by the Conditioned Floor Area:

\[
\text{Leakage/100 sf CFA} = \frac{\text{CFM25 Leakage Test Result}}{\text{Conditioned Floor Area}}
\]
Failures

The vast majority of failures are due to the contractor’s failure to seal the duct boots to the building thermal/pressure envelope allowing leakage into unconditioned spaces. Fortunately this is (usually) easy to correct.

Less common problems are due to:
- Toe kick ducts not connected
- Buried ducts
- Disconnected fittings
- Unsealed connections

Recommendations

- Keep all ducts and air handlers in conditioned space
- Test ducts at rough-in
  - Problems easier to find and fix
  - Sealing boots during installation keeps duct systems clean
  - OK for code compliance, ENERGY STAR still requires post construction testing
- Use mastic!
- Ensure boots are sealed to floor or drywall
  - Ensure cabinet installer aware of proper toe kick duct installation requirements
Recap

• Duct and Envelope Tightness standards account for the majority of the energy efficiency gains in the 2009 and 2012 IECC
  – 2009 Standards: A learning opportunity
  – 2012 Standards: The bar is raised
• Reducing Duct and Envelope Leakage is the most cost effective energy efficiency improvement in most homes
  – Success requires paying attention to details, not expensive upgrades

Incentives for Duct & Envelope Tightness Testing

The CT Energy Efficiency Fund offers a $300 incentive for homes that meet the 2009 IECC Duct & Envelope tightness standards. Testing must be performed by a qualified verifier. Applications and information may be obtained at www.EnergizeCT.com.
Questions?

Peter Harding
peter@homeenergytechnologies.com

Home Energy Technologies LLC
(877) 800-6440
www.homeenergytechnologies.com