Achieving & Evaluating Residential Compliance of Tight Envelopes

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Mike Barcik Steve Herzlieb

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U.S. Department of Energy
Building Energy Codes Program

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Mike Barcik
Steve Herzlieb

March 10, 2016

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Course Description

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- 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

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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?

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- Name
- Organization/company
- How long have you been in the design, construction, or enforcement industry?

Status of Adopted Energy Codes

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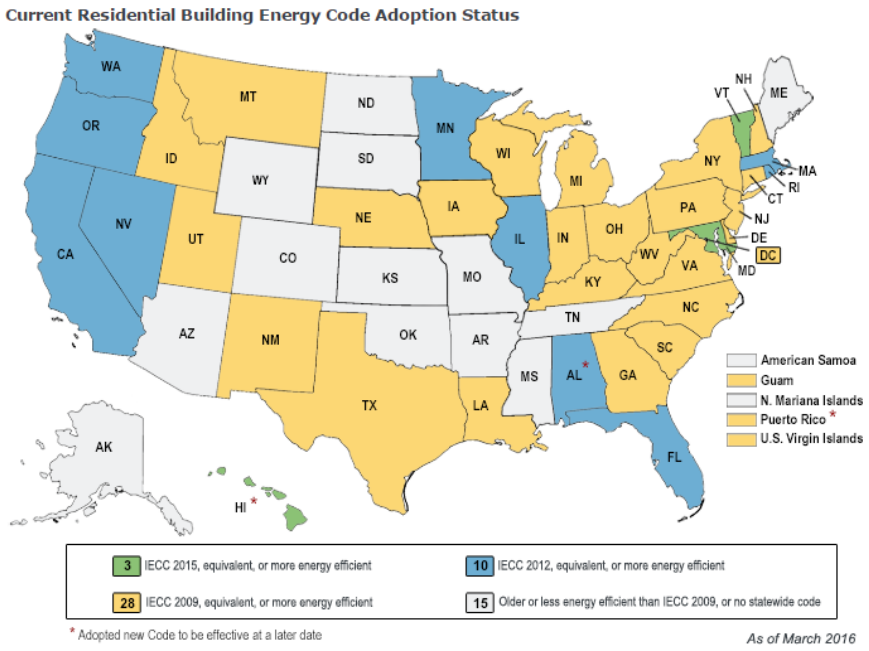

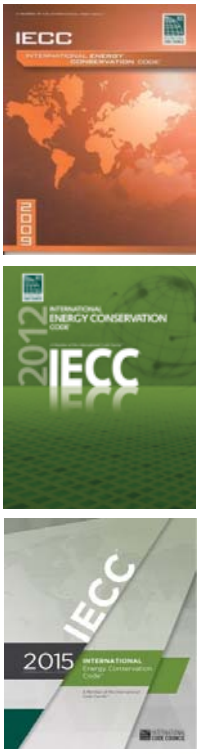

Brief History of Energy Codes

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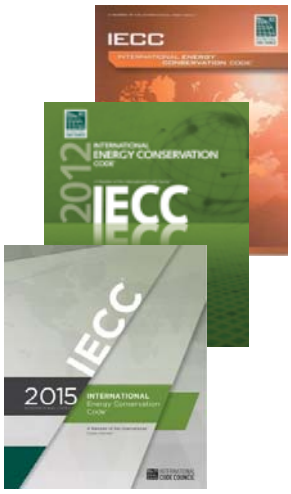
- MEC 1992, '93, 95 – "Early" energy codes, complicated, DP windows required
- IECC 98, 2000, '03 – "Strengthening", SHGC of 0.4 required where < 3500 HDD
- IECC 2004, '06 – "Simplification", Fewer CZ's, eliminate % glazing, certificate required
- IECC 2009 – Duct + envelope testing, efficient lighting – 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

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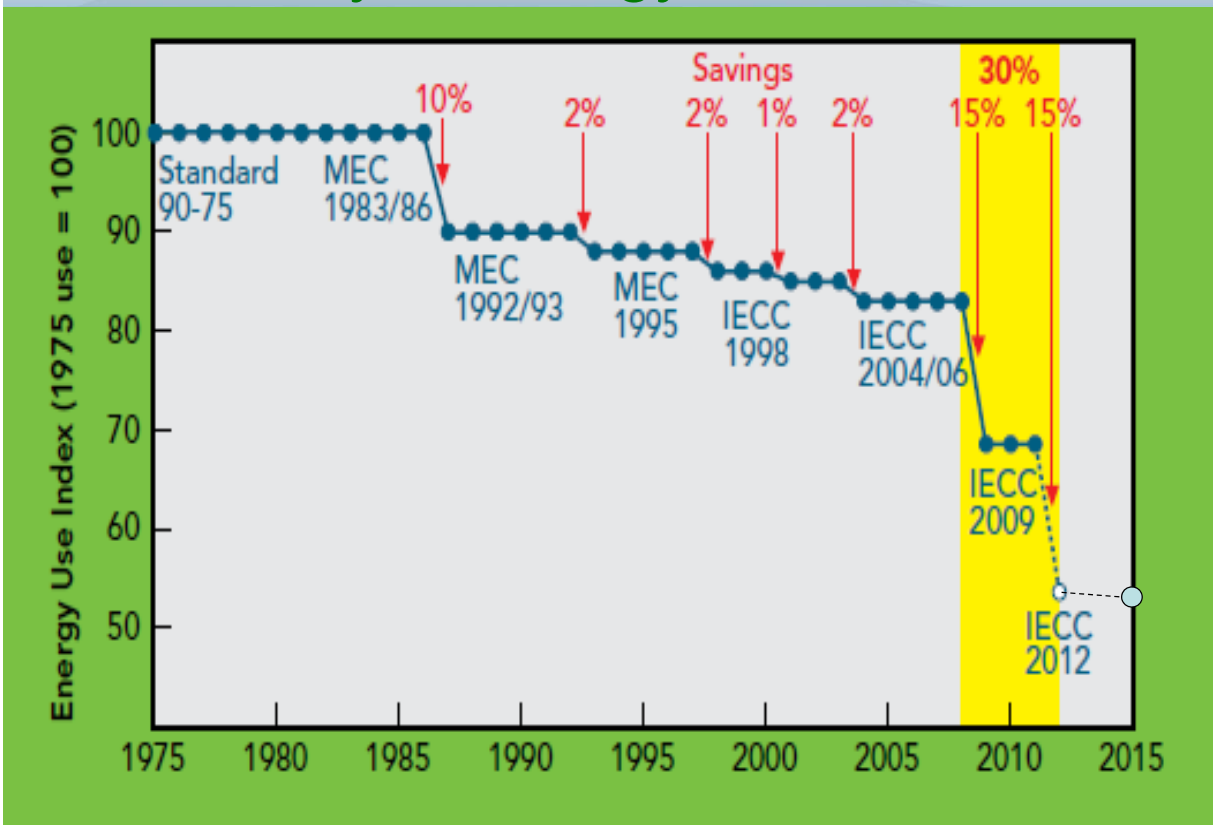

IECC 2009 vs. 2012 vs. 2015

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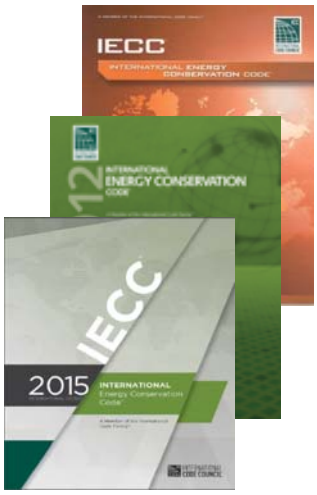
Summary of Changes to IECC after '09



- 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

Structure of 2012/15 IECC

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Commercial Section

- Ch. 1 Scope, Application, Administrative and Enforcement
- Ch. 2 Definitions
- Ch. 3 General Requirements
- Ch. 4 Commercial Energy Efficiency
- Ch. 5 Referenced Standards
- Index

Residential Section

- Ch. 1 Scope and Application / Administrative and Enforcement
- Ch. 2 Definitions
- Ch. 3 General Requirements
- Ch. 4 Residential Energy Efficiency
- Ch. 5 Referenced Standards
- Index

Building Thermal Envelope

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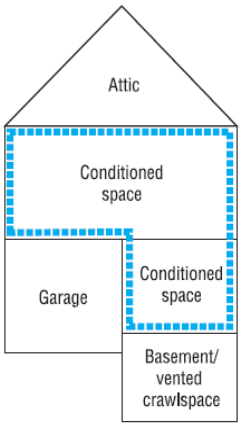
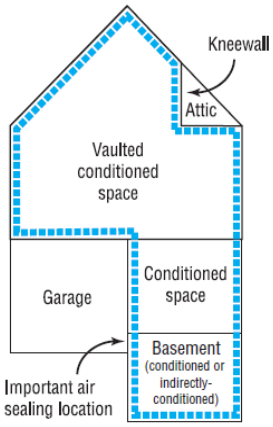
The *building thermal envelope* is the barrier that separates the conditioned space from the outside or unconditioned spaces. The building envelope consists of two parts - an air barrier and a thermal barrier that must be both continuous and contiguous (touching each other). In a typical residence, the 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.

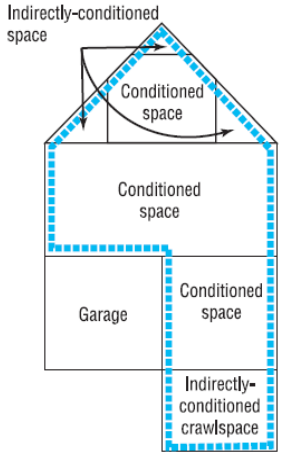
Example 1



Example 2



Example 3



Energy Code Compliance Pathways

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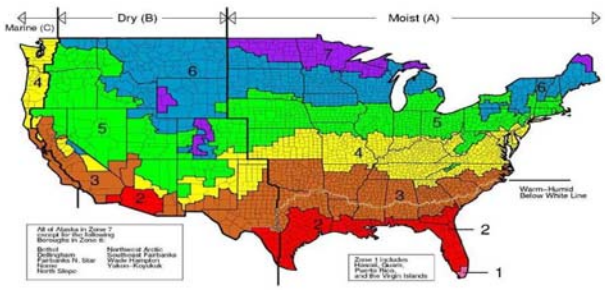
Scope

Insulation & Window Requirements

Prescriptive Pathway | **UA Trade-off Approach** | **Section 405 (IECC) (annual simulation)**

Mandatory Requirements



Prescriptive Code:

Insulation & Fenestration by Climate Zone

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Table 402.1.1
Insulation and Fenestration Requirements by Component[a]

CLIMATE ZONE	FENESTRATION U-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION[b,e] SHGC	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	1.20	0.75	0.30	30	13	3 / 4	13	0	0	0
2	0.65[j]	0.75	0.30	30	13	4 / 6	13	0	0	0
3	0.50[j]	0.65	0.30	30	13	5 / 8	19	5 / 13[f]	0	5 / 13
4 except Marine	0.35	0.60	NR	38	13	5 / 10	19	10 / 13	10, 2ft	10 / 13
5 and Marine 4	0.35	0.60	NR	38	20 or 13+5[h]	13 / 17	30[g]	10 / 13	10, 2 ft	10 / 13
6	0.35	0.60	NR	49	19 or 13+5[h]	15 / 19	30[g]	15 / 19	10, 4 ft	10 / 13
7 and 8	0.35	0.60	NR	49	21	19 / 21	38[g]	15 / 19	10, 4 ft	10 / 13

[a] *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.
[b] The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
[c] "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.
[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 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 301.1 and Table 301.1.
[g] Or insulation sufficient to fill the framing cavity, R-19 minimum.
[h] "13+5" means R-13 cavity insulation plus R-5 insulated sheathing. If structural sheathing covers 25 percent or less of the exterior, insulating 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.
[i] The second *R*-value applies when more than half the insulation is on the interior of the mass wall.
[j] 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

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TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

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-13 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

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TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

Compliance Paths for Insulation & Windows

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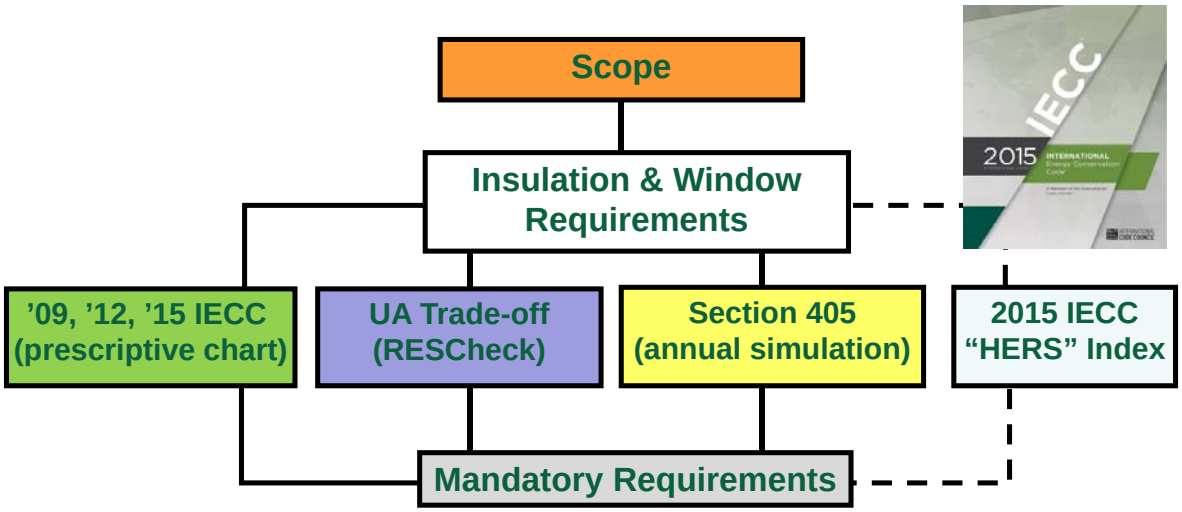
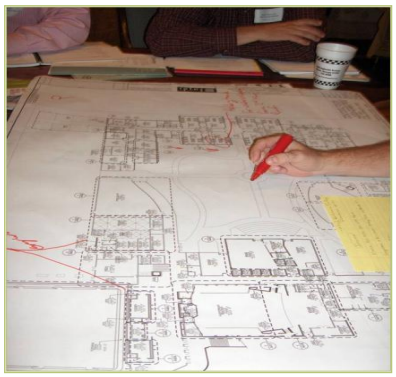


- The new ERI path gives the most design flexibility – such as credit for mechanical equipment efficiency
- It also credits items not covered by the code (e.g., appliance efficiencies)

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)

$$\text{Index} = 100 \times \frac{[\textbf{Rated}\text{ Home's Htg (40) + Clg (30) + WtrH (30) + L.A. (50)}]}{[\textbf{Refer}\text{. Home's Htg (70) + Clg (20) + WtrH (30) + L.A. (80)}]} = 75$$

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HERS Index – What's it Mean?

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- 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

$$\textbf{Index} = PE_{fraction} \times 100 \times \frac{[\text{Rated Home's Htg (40) + Clg (30) + WtrH (30) + L.A. (50)}]}{[\text{Ref. Home's Htg (70) + Clg (20) + WtrH (30) + L.A. (80)}]} = 75$$

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

Explaining the Energy Rating Index

1. 2015 IECC targets

- **Low 50's**

TABLE R406.4
MAXIMUM ENERGY RATING INDEX

CLIMATE ZONE	ENERGY RATING INDEX
1	52
2	52
3	51
4	54
5	55
6	54
7	53
8	53

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.)

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Pros and Cons?

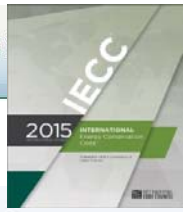
1. Concerns

- **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?"

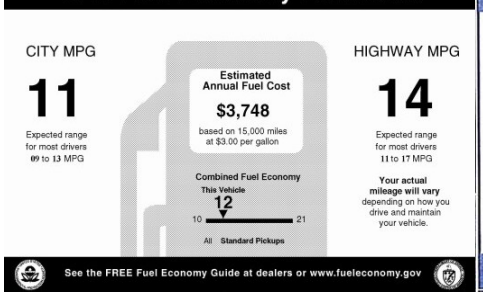
2. Benefits

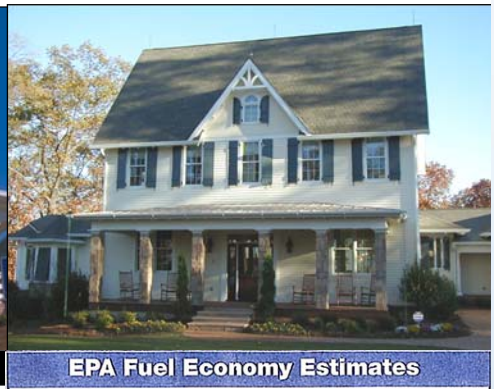
- **Professional** (HERS Rater) who understands energy efficiency is now involved and energy code isn't ignored
- **Marketing** – Builders can market their index and guarantee performance

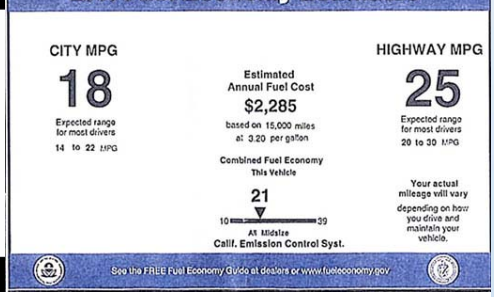
HERS - Energy Label for Homes

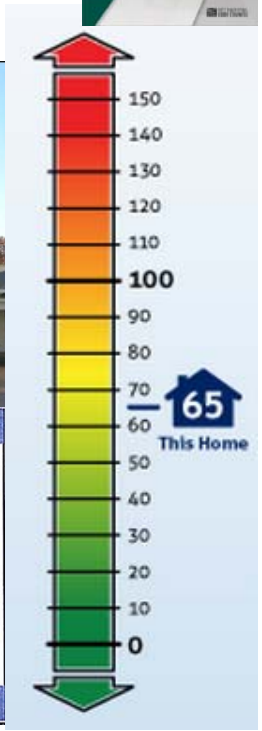


- Which home is energy efficient?









Energy Code Compliance Pathways

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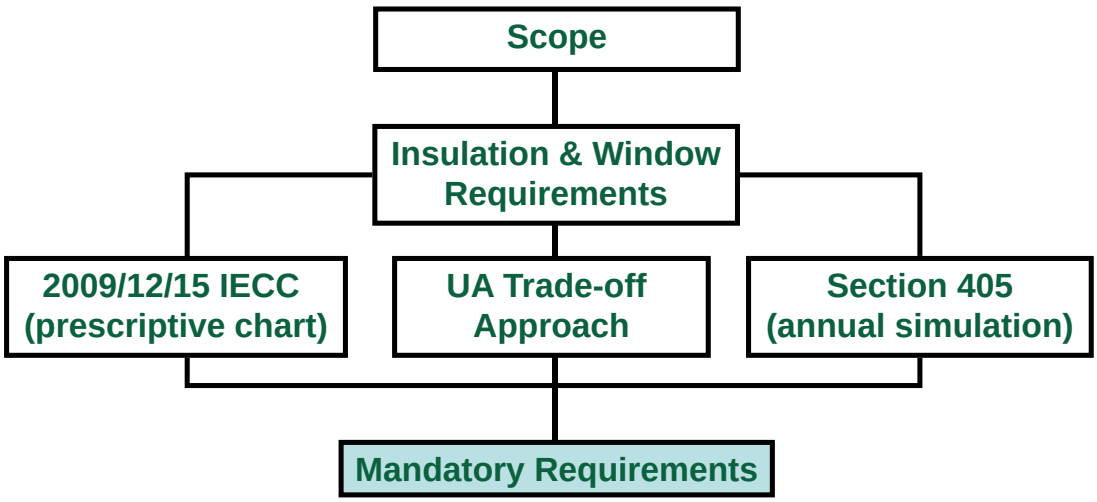

2012 IECC- Section 401.3

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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:

Georgia Residential Energy Code Compliance Certificate*

Builder/Design Professional: ABC Builder Phone: 404-123-4567

Envelope Summary:

- List the R-Value for the following components:

Flat ceiling/roof:	R-30	Sloped/vault ceiling:	n/a
Exterior wall:	R-13	Above grade mass wall:	n/a
Attic kneewall:	n/a	Attic kneewall sheathing:	R18
Basement stud wall:	n/a	Basement continuous:	n/a
Crawlspace stud wall:	n/a	Crawlspace continuous:	n/a
Foundation slab:	R-0	Floors over unconditioned space:	R19
Cantilevered Floor:	n/a	Other insulation:	n/a

- Fenestration Components:

Window U-factor:	0.32	Window SHGC:	0.29
Skylight U-factor:	n/a	Skylight SHGC:	n/a
Glazed Door U-factor:	n/a	Opaque Door U-factor: (<50% glazed)	0.35

- Building Envelope Tightness (BET):

BET test conducted by: Home Performance Smith Phone: 404-123-6547

Fan Flow at 50 Pascals= 2,000 CFM_{50} Total Conditioned Volume = 20,000 ft^3

ACH_{50} = CFM_{50} x 60 / Volume= 6 ACH_{50} (must be less than 7 ACH_{50})

Low Rise Multifamily Visual Inspection Option

(The visual inspection option may be conducted by a third-party instead of the BET test for R-2 buildings only.)

Visual inspection conducted by: n/a Phone: n/a

Mechanical Summary:

Water Heater Energy Factor: 0.61 EF Fuel type: ☑ Gas ☐ Electric ☐ Other

Number of Heating and Cooling Systems: 1

Heating System Type (choose one):

☑ Gas: 90% AFUE ☐ Air-Source Heat Pump: HSPF

☐ Other: Efficiency:

Cooling System Type (Standard DX, Heat Pump, Geothermal, etc.): Standard DX

Cooling System Efficiency: 13 ☑ SEER ☐ EER ☐ Other

Heating/Cooling Load Calculations Performed by: HVAC Smith Phone: 770-123-4567

Total Heating Load (Based on ACCA Man. J or other approved methodology): 39,800 Btu/h

Total Cooling Load (Based on ACCA Man. J or other approved methodology): 28,800 Btu/h

Cooling Sensible Load: 20,800 Btu/h Cooling Latent Load : 8,000 Btu/h

Total Air Handler CFM (based on design calculations): 1600 CFM

Duct Tightness Test Conducted by: HVAC Smith Phone: 404-123-4567

CFM_{25} per 100 ft^2 of conditioned floor area = CFM_{25} x 100 / Conditioned floor area served

If all ducts are not located within conditioned space, builder must verify that either the post-construction duct leakage to outdoors (**PCO**) is ≤ 8 cfm/100 ft^2, the post construction total duct leakage (**PCT**) is ≤ 12 cfm/100 ft^2, or the rough-in test (**RIT**) with air handler installed is ≤ 6 cfm/100 ft^2. State which method was used to conduct the duct tightness test: duct blower (**DB**), modified blower door subtraction method (**MBDS**), or automated multipoint blower door (**AMBD**).

	System	Method (DB, MBDS, AMBD)	Test (PCO, PCT, RIT)	CFM_{25}	Area served (ft^2)	Test Result
1	Home	DB	PCT	100	2,000	5
2						
3						

*Note: This permanent certificate shall be posted on or in the electrical distribution panel. Certificate shall be completed by the builder or registered design professional. Where there is more than one value for each component, certificate shall list the value covering the largest area.

Test Results Form

Version: 2012 IECC

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

Blower Door Results go here:

Air Seal / Insulation visual inspection checklist here:

Duct testing Results go here:

2012 IECC Residential Energy Code Duct & Envelope Testing Results*

Address: 1234 Sample House Lane

Builder/Designer: Bill D. Home Phone: 222-333-4444

Envelope Summary: Building Envelope Tightness (BET)

BET test conducted by: Joe Tester Phone: 222-555-6666

Fan Flow at 50 Pascals= 1,044 CFM_{50} Total Conditioned Volume = 22,600 ft^3

ACH_{50} = CFM_{50} x 60 / Volume= 2.8 ACH_{50} (must be ≤3 ACH_{50})

Visual Inspection Checklist (to be conducted by an approved entity or other third-party)

Visual Inspection Conducted by: I.M. Looking Phone: 444-333-2222

AIR BARRIER AND INSULATION INSTALLATION

	COMPONENT	CRITERIA*
√	Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
√	Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
√	Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
√	Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.
√	Rim joists	Rim joists shall be insulated and include the air barrier.
√	Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
n/a	Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
√	Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.
√	Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
√	Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
√	Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
√	Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
n/a	Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
√	Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
√	HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.
n/a	Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

Mechanical Summary: Duct Tightness Verification (DTV)

DTV Test Conducted by: Jane Tester Phone: 777-888-9999

Unless all ducts are located within conditioned space, must verify one of the following:

- Post-construction total duct leakage (**PCT**) is ≤ 4%
- Rough-in total duct leakage (**RIT**) with air handler installed is ≤ 4%
- Rough-in total duct leakage without air handler installed (**RITnah**) is ≤ 3%

% Duct Leakage Result = CFM_{25} x 100 / Conditioned floor area served

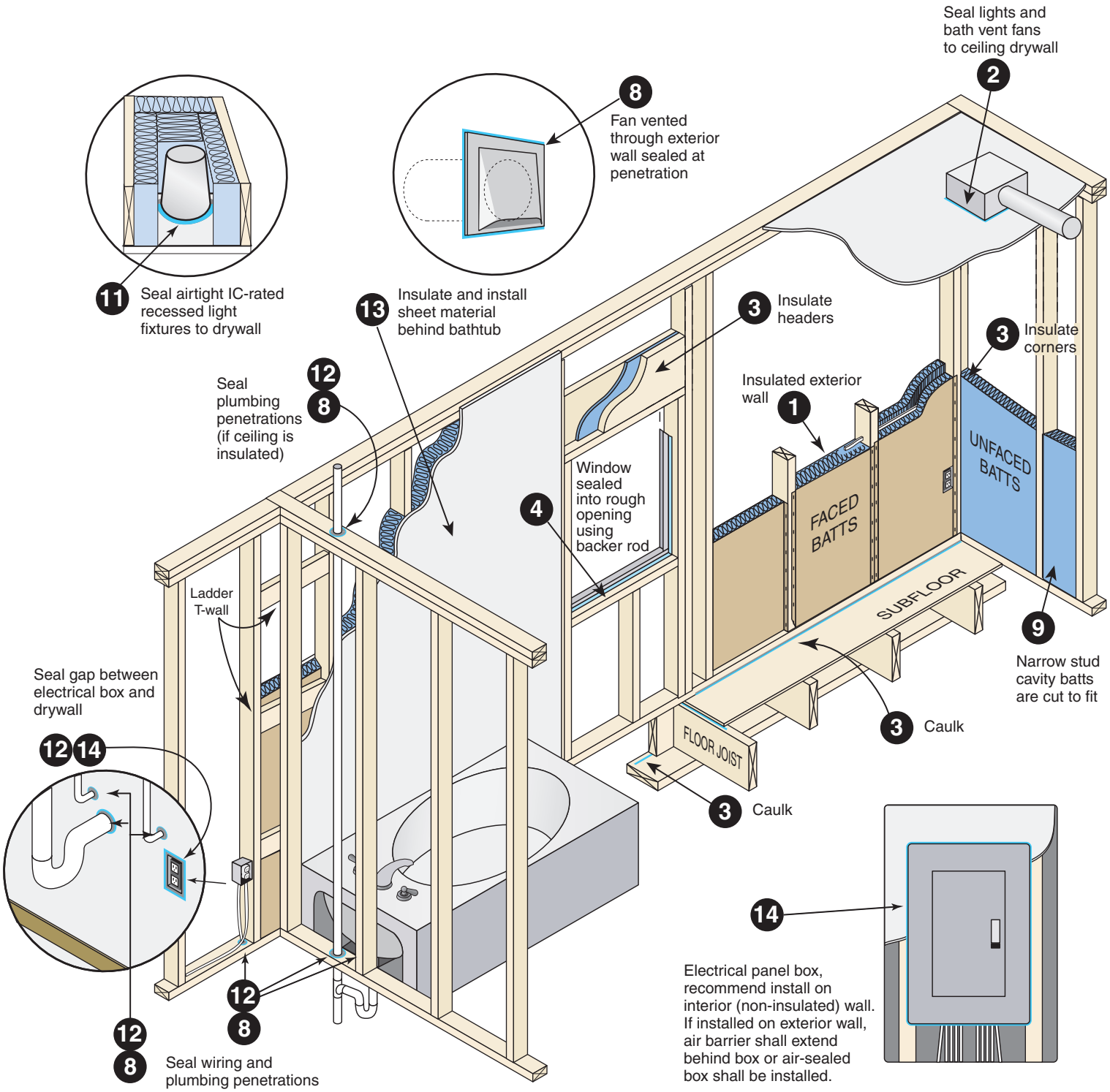
	System	Test (PCT, RIT, RITnah)	CFM_{25}	Area served (ft^2)	Result (%)	Comments
1	Main	PCT	83	2,300	3.6%	n/a
2						
3						

*Note: This document to be posted on or in the electrical distribution panel

Air Barrier and Insulation Inspection Component Guide

NUMBER	COMPONENT	CRITERIA
1	Air barrier and thermal barrier	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.
2	Ceiling/attic	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.
3	Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
4	Windows and doors	Space between window/door jambs and framing is sealed.
5	Rim joists	Rim joists are insulated and include an air barrier.
6	Floors (including above-garage and cantilevered floors)	Insulation is installed to maintain permanent contact with underside of subfloor decking. Air barrier is installed at any exposed edge of insulation.
7	Crawl space walls	Insulation is permanently attached to walls. Exposed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped.
8	Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
9	Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
10	Garage separation	Air sealing is provided between the garage and conditioned spaces.
11	Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.
12	Plumbing and wiring	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.
13	Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
14	Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed.
15	Common wall	Air barrier is installed in common wall between dwelling units.
16	HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
17	Fireplace	Fireplace walls include an air barrier.

Air sealing key points



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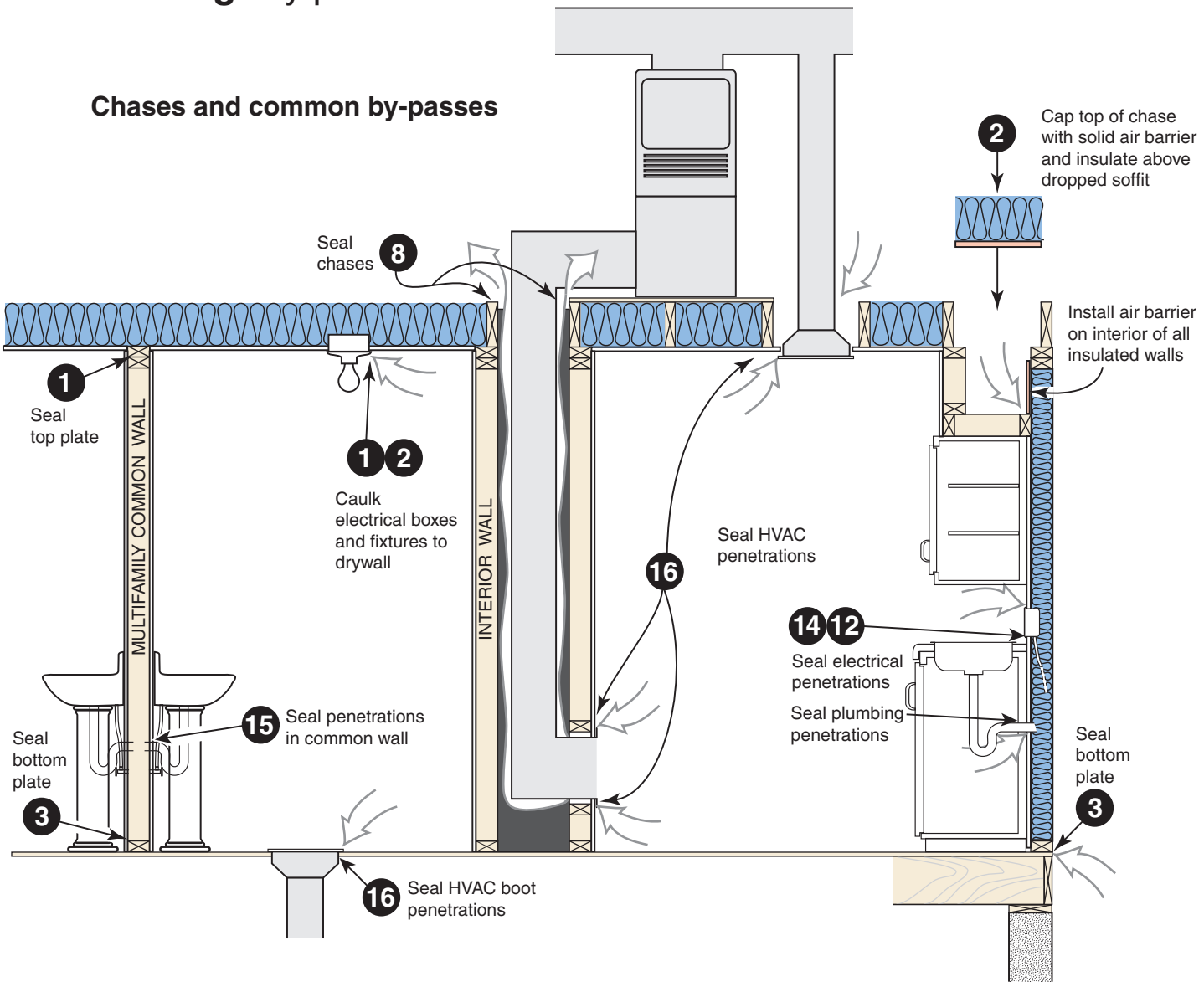
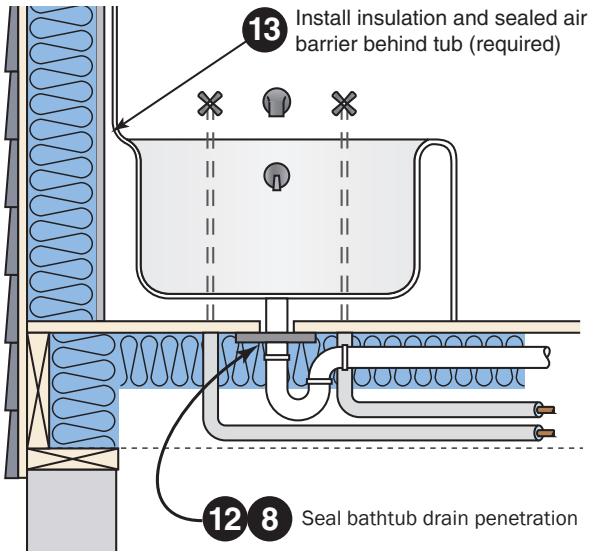
Air sealing key points *continued*

Chases and common by-passes



Shower/tub drain rough opening



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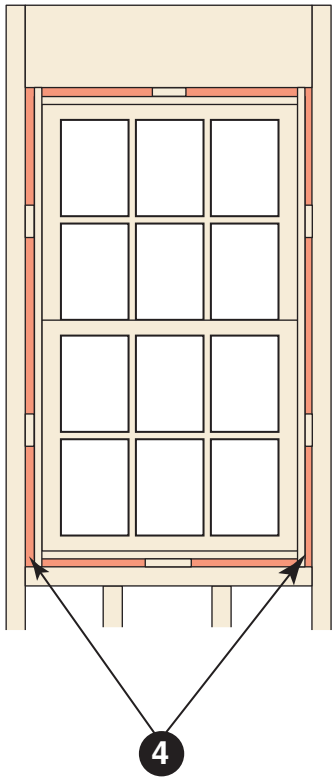
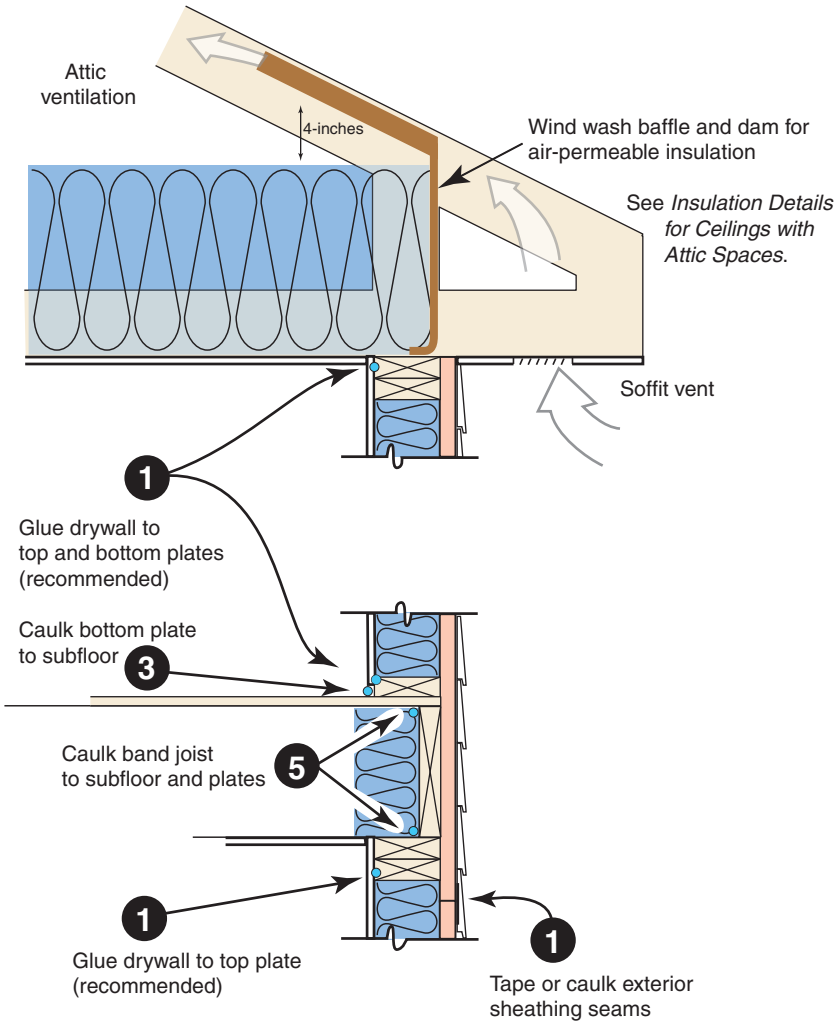
Air sealing key points *continued*

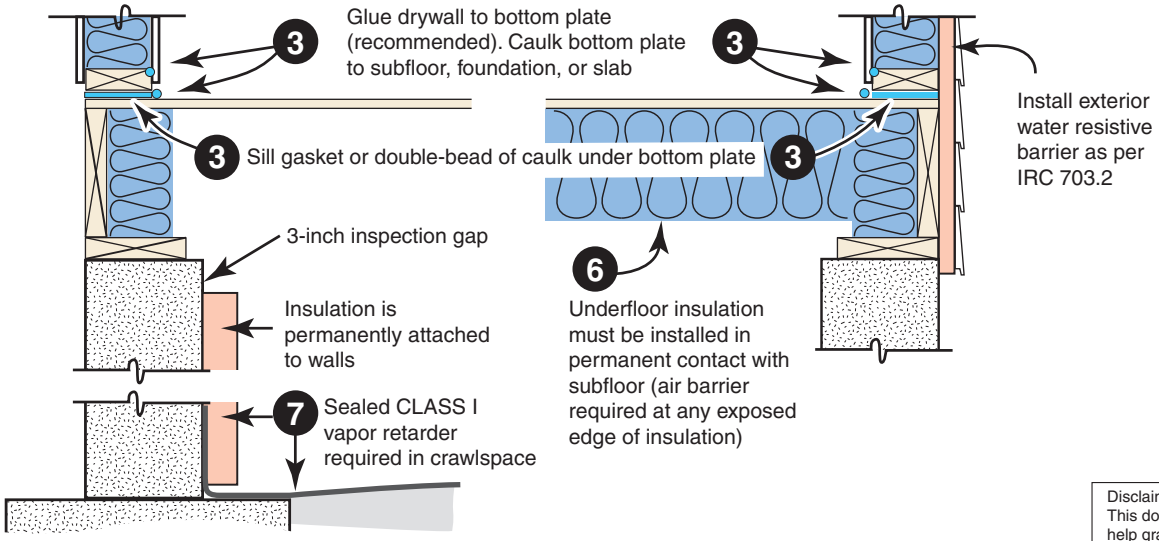
Window rough opening



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

Wall cross-section





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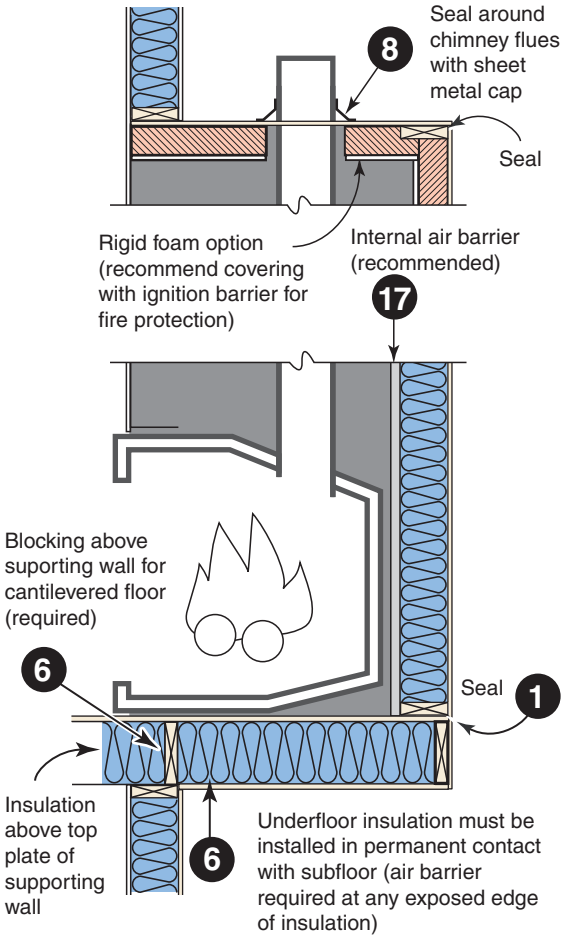
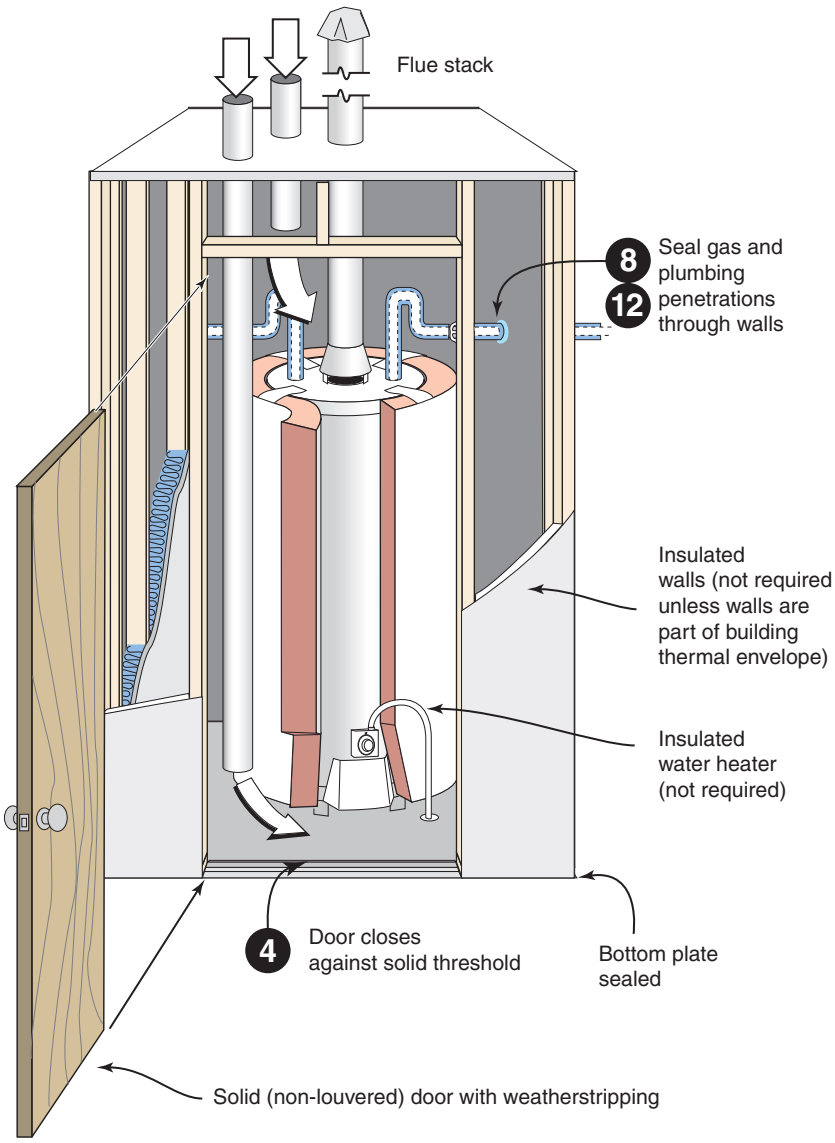
Air sealing key points *continued*

Combustion chase penetrations

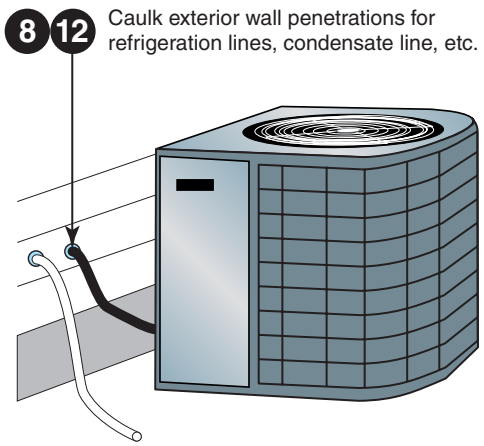


Combustion closet

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



Exterior penetrations



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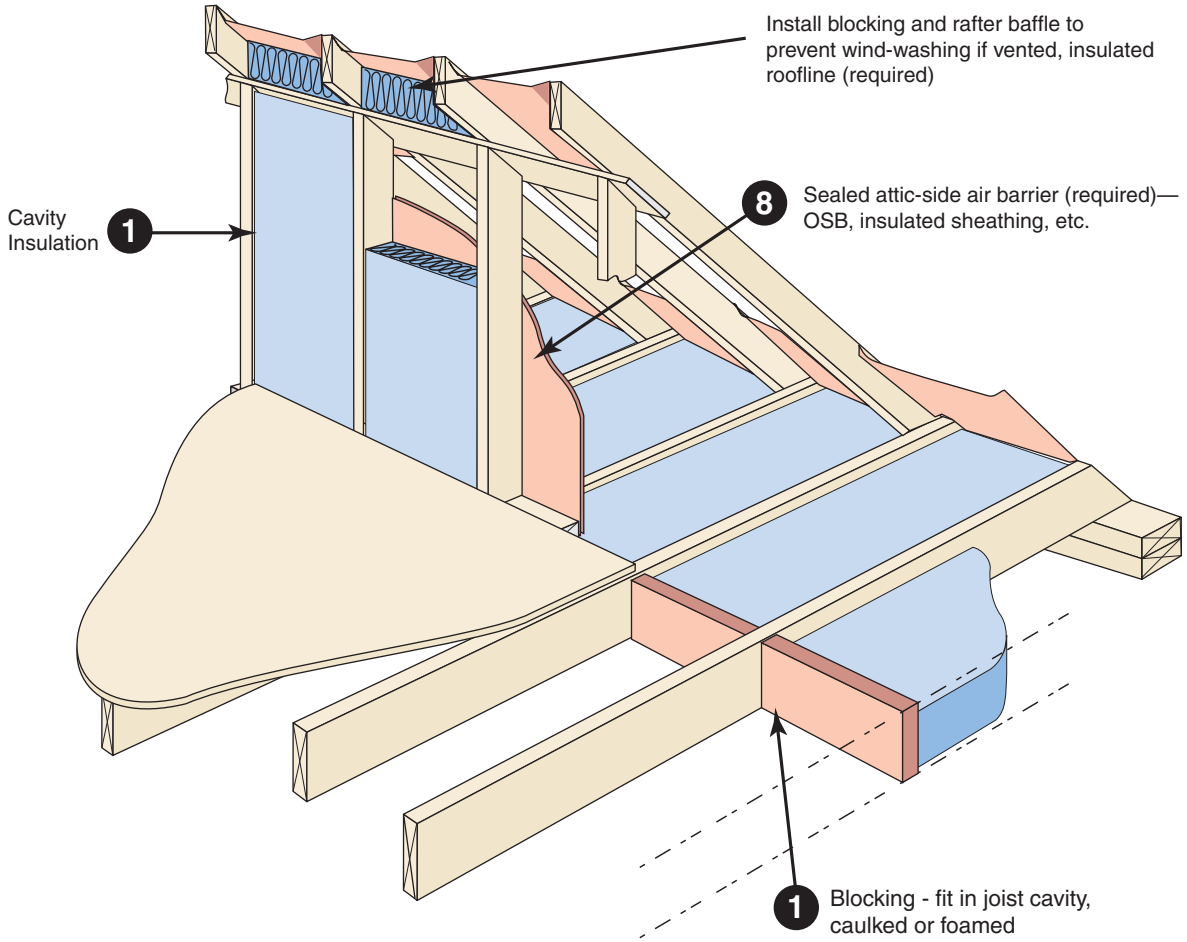
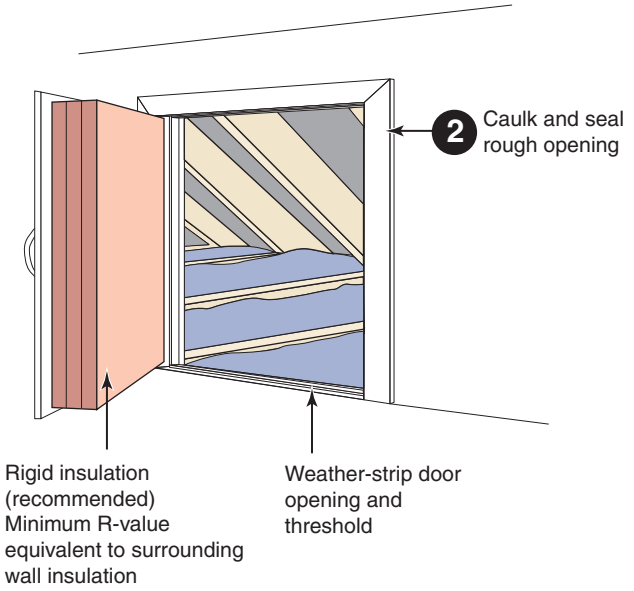
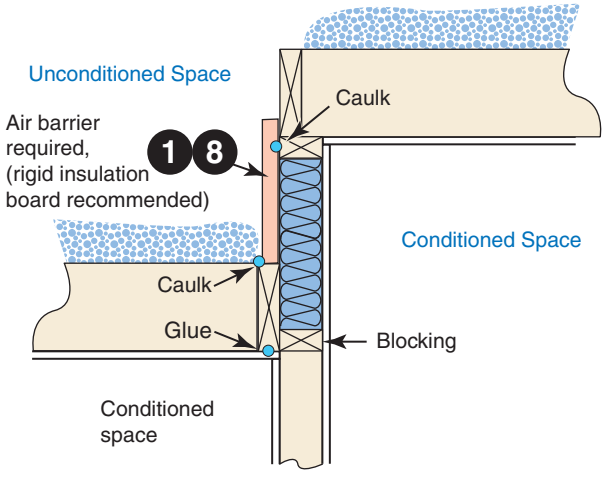
Air sealing key points *continued*



Attic knee-walls



Two-level attic



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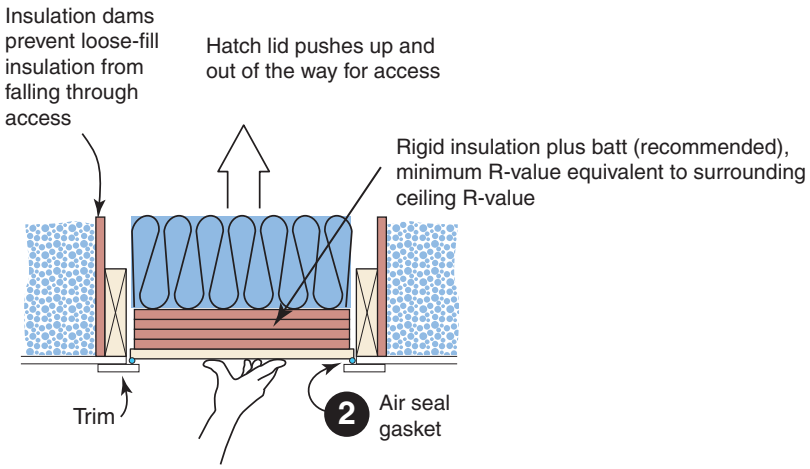
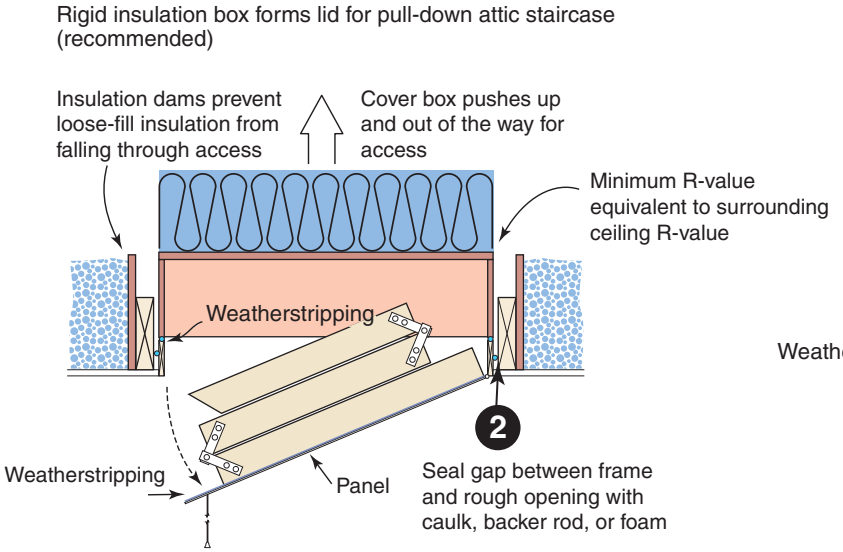
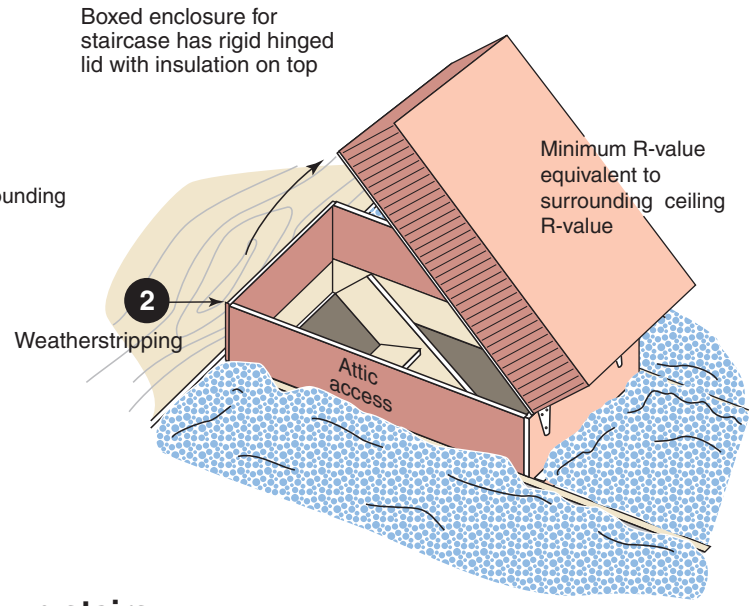
Air sealing key points *continued*

Attic scuttle

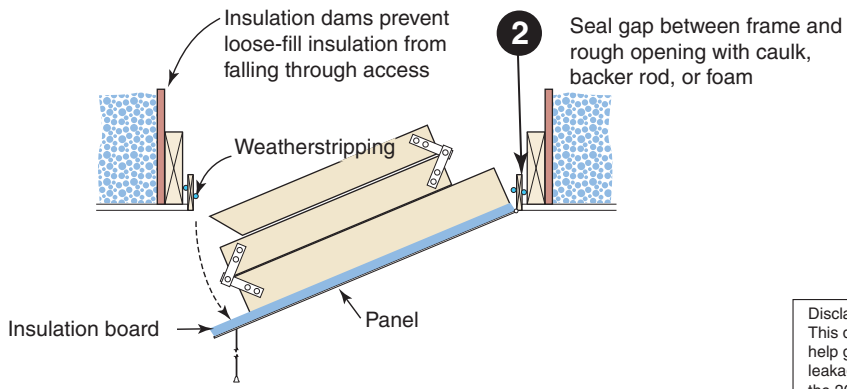


Attic pull-down stairs





Attic pull-down stairs



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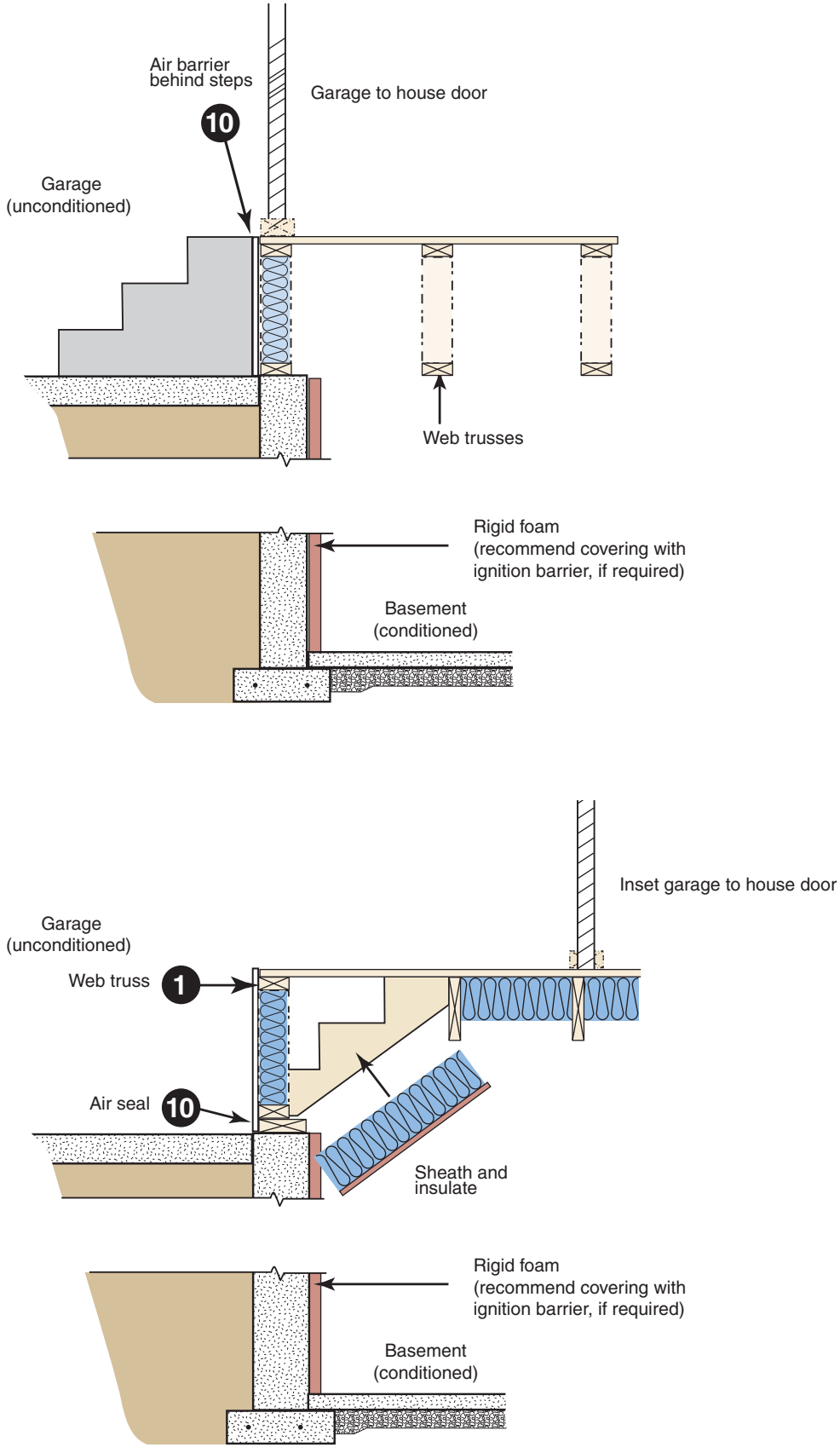
Air sealing key points *continued*



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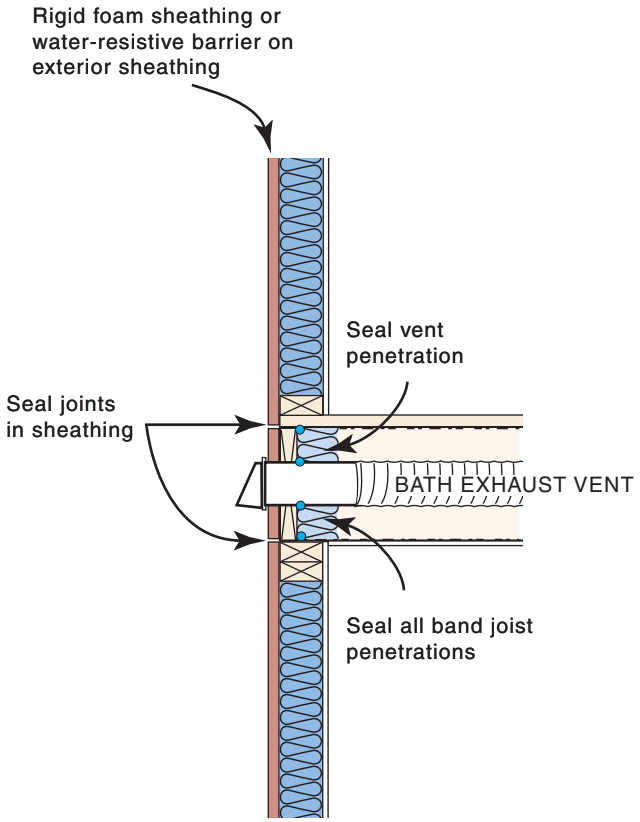
Air sealing key points *continued*

Multifamily

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)



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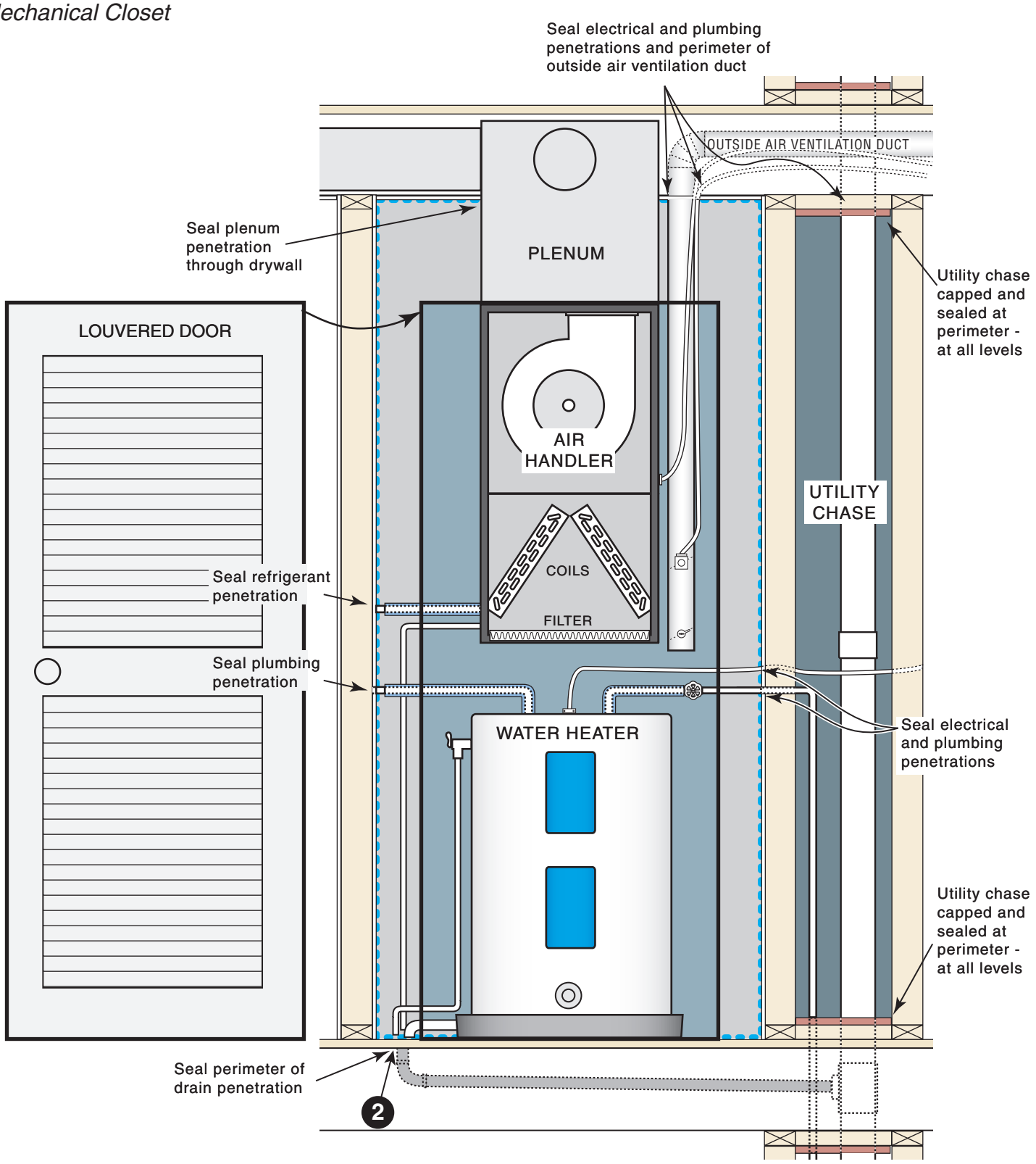
Air sealing key points *continued*

Mechanical Closet



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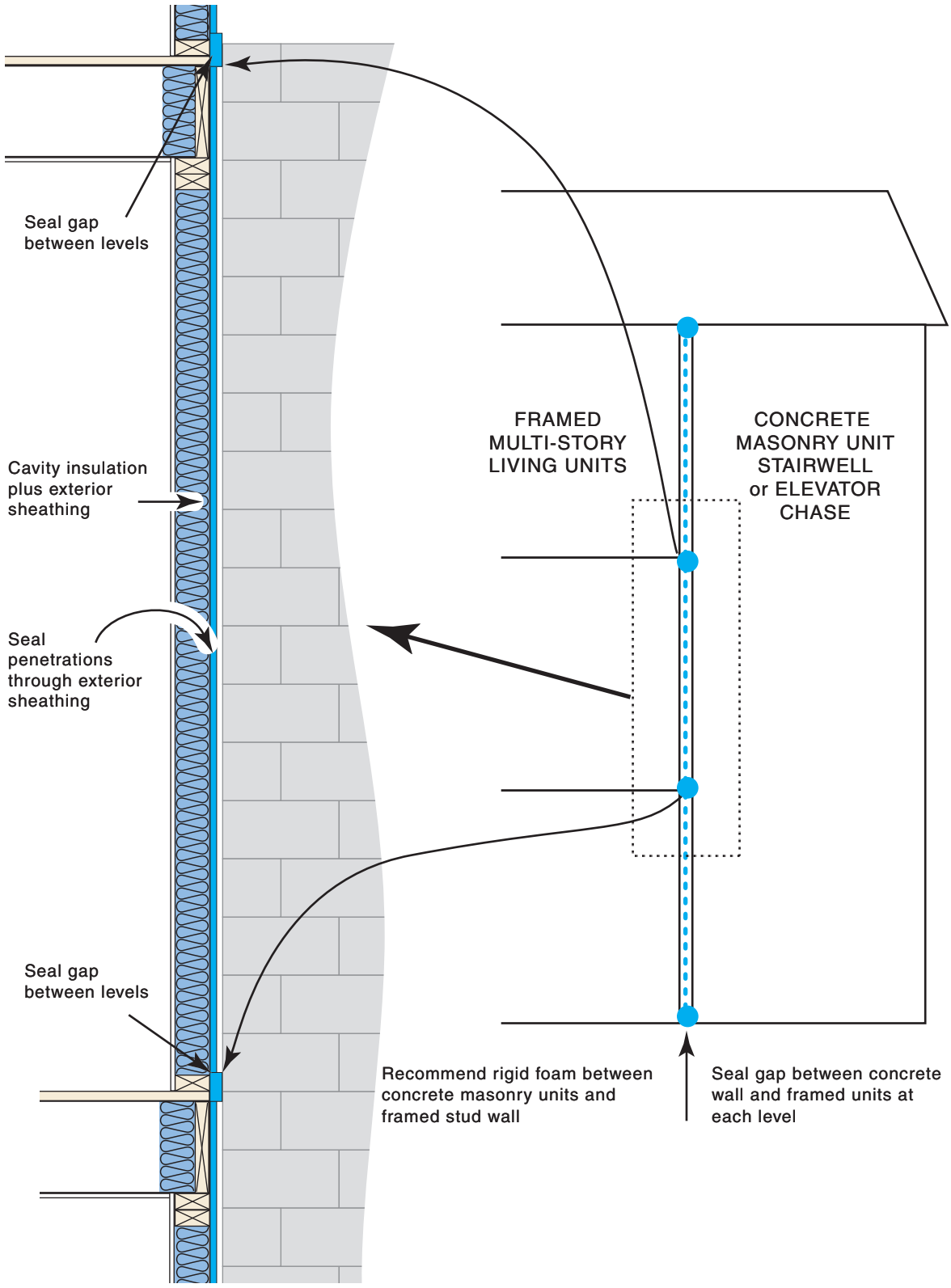
Air sealing key points *continued*

Multifamily



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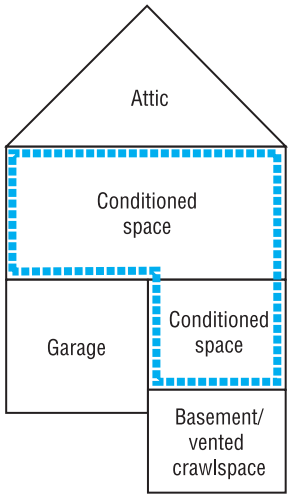
2009 IECC

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

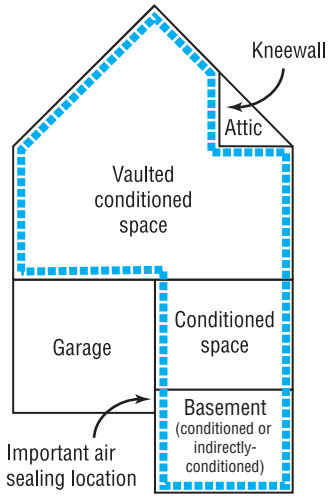


This is a conventional approach that likely locates all ductwork in unconditioned spaces.

Example R-values[1]

- ☐ Flat ceiling: R-30
- ☐ Exterior walls: R-13 + R-3 sheathing
- ☐ Floor over garage and basement/ crawl: R-19
- ☐ Ductwork sealed with mastic and insulated to R-8 in attic, R-6 in basement/crawlspace
- ☐ Garage[2], attic and basement/crawl are unconditioned spaces

Example 2

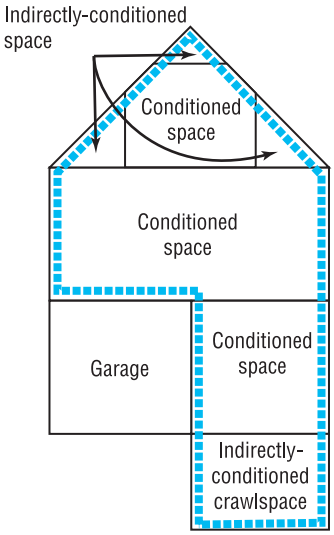


If supply registers deliver conditioned air to basement, it is considered conditioned. With no supply air, it is considered an indirectly-conditioned space.

Example R-values[1]

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

Example 3



The top conditioned floor functions as a vaulted ceiling with interior walls althought 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
- ☐ Exterior walls: R-13 + R-3 sheathing
- ☐ Crawlspace walls: R-5
- ☐ Ductwork sealed with mastic and insulated to R-6
- ☐ Garage[2] is unconditioned space

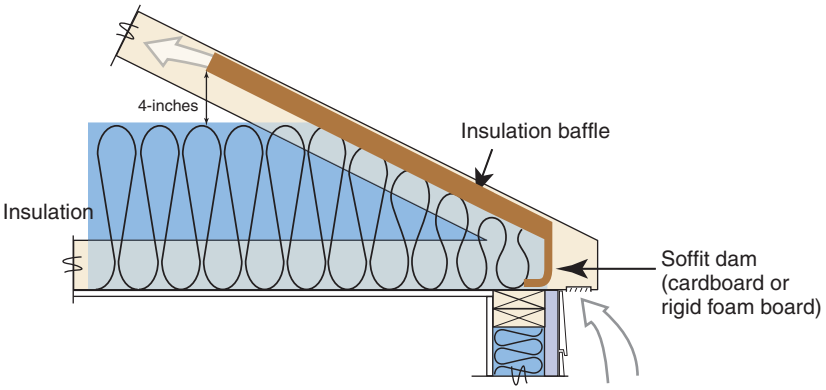
1 R-values shown are examples and not code requriements. Refer to table 402.1.1 for specific prescriptive insulation requirements.

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.

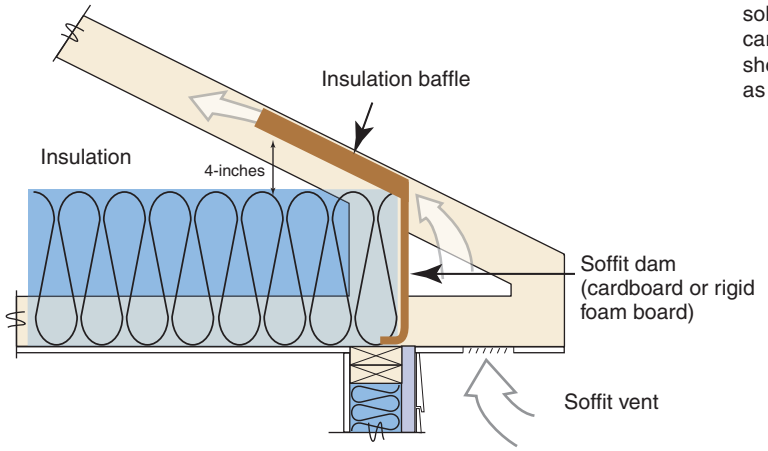
Insulation Details for Ceilings with Attic spaces

Rafter and Truss

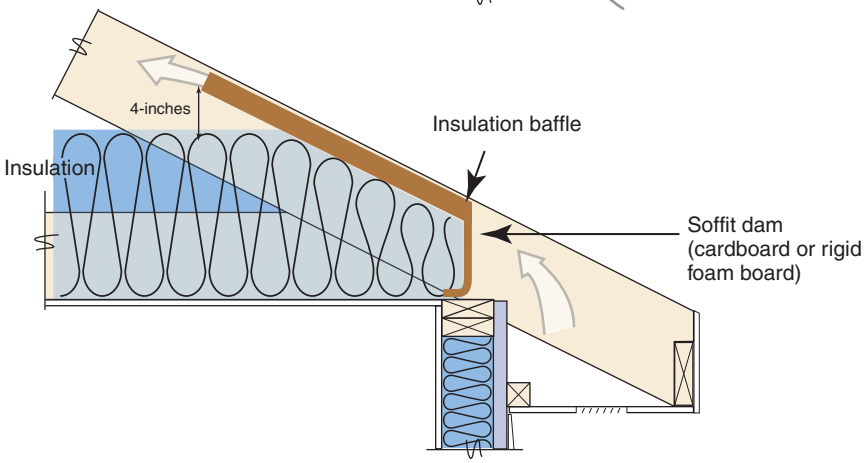
Standard Truss
with tapered
insulation depth



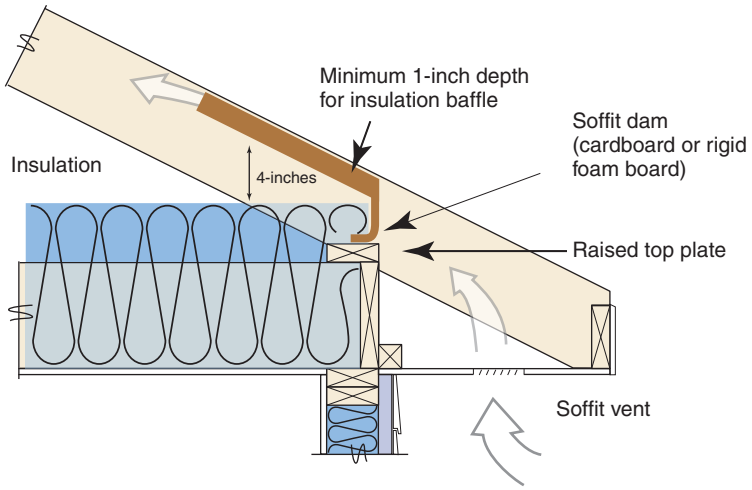
Energy Truss
with full height insulation
(recommended)



Standard rafter and top plate
with tapered
insulaton 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.

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Why is air sealing so important?

Southface

- 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 Air leakage (Mandatory).

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

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

2012 IECC

402.4.1.1 Air Barrier & Insulation Inspection Checklist is mandatory

	AIR BARRIER AND INSULATION INSTALLATION	
	COMPONENT	CRITERIA[a]
1.	Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
2.	Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
3.	Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
4.	Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.
5.	Rim joists	Rim joists shall be insulated and include the air barrier.
6.	Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
7.	Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawlspace walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
8.	Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.
9.	Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
10.	Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
11.	Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
12.	Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
13.	Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
14.	Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
16.	HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the sub-floor or drywall.
17.	Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

402.4.3 Wood Burning Fireplaces

Southface

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

  **”site-built masonry” – unofficial letter*

R402.4.2 Fireplaces. New wood-burning fireplaces shall have tight-fitting flue dampers or doors, and outdoor combustion air. Where using tight-fitting doors on factory-built fireplaces listed and labeled in accordance with UL 127, the doors shall be tested and listed for the fireplace. Where using tight-fitting doors on masonry fireplaces, the doors shall be listed and labeled in accordance with UL 907.

2015 IECC

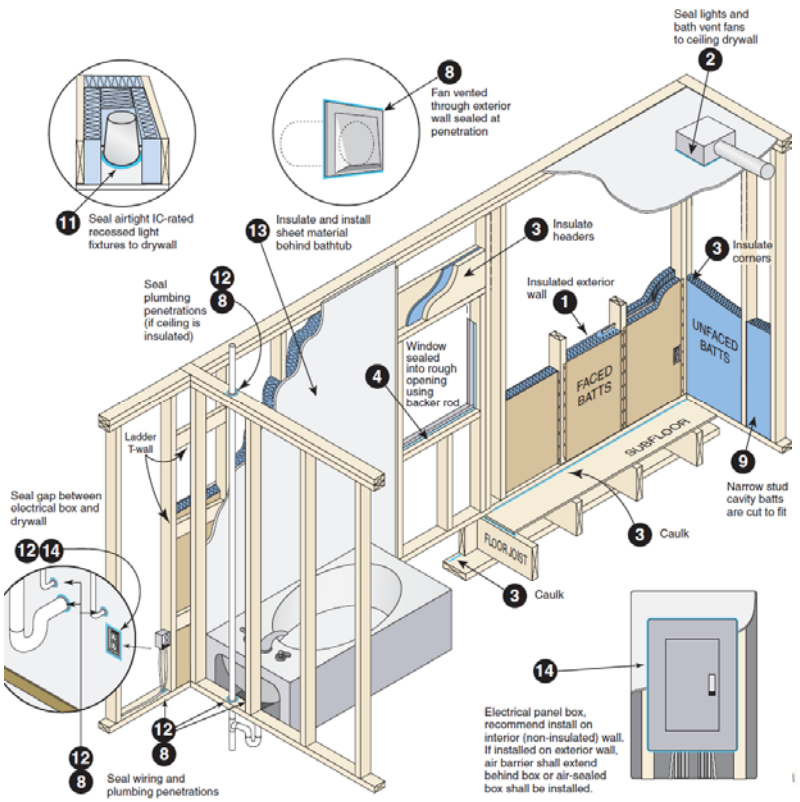
402.4.1.1 Air Barrier & Insulation Inspection Checklist is mandatory

TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION

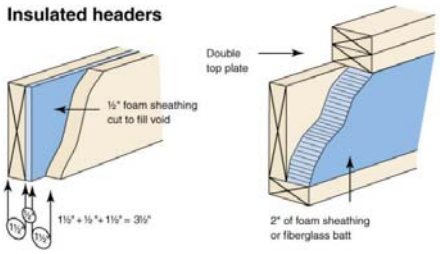
COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
General requirements	A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed. Access openings, drop down stairs or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. Knee walls shall be sealed.	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance of R-3 per inch minimum. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
Windows, skylights and doors	The space between window/door jambs and framing, and skylights and framing shall be sealed.	
Rim joists	Rim joists shall include the air barrier.	Rim joists shall be insulated.
Floors (including above garage and cantilevered floors)	The air barrier shall be installed at any exposed edge of insulation.	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking, or floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing and extends from the bottom to the top of all perimeter floor framing members.
Crawl space walls	Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.	Where provided instead of floor insulation, insulation shall be permanently attached to the crawlspace walls.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.	
Narrow cavities		Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.	
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be sealed to the drywall.	Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated.
Plumbing and wiring		Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	The air barrier installed at exterior walls adjacent to showers and tubs shall separate them from the showers and tubs.	Exterior walls adjacent to showers and tubs shall be insulated.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air-sealed boxes shall be installed.	
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall.	
Concealed sprinklers	When required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.	

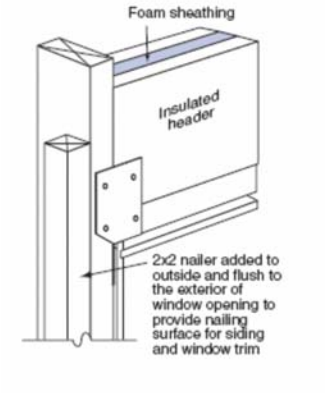
Air Sealing General (p. 2)

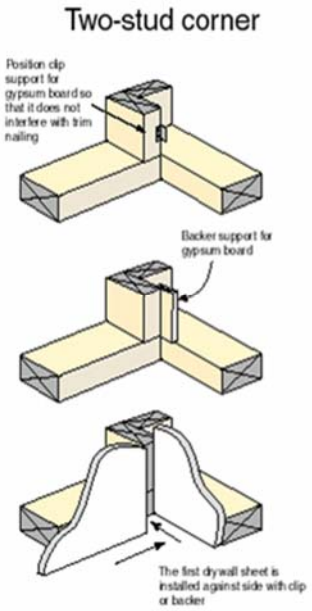
Southface

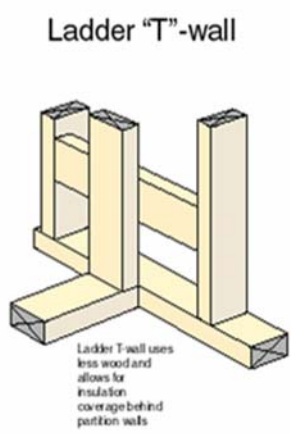


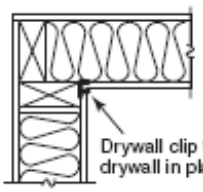
Advanced Framing











Air Sealing Chases (p. 3)

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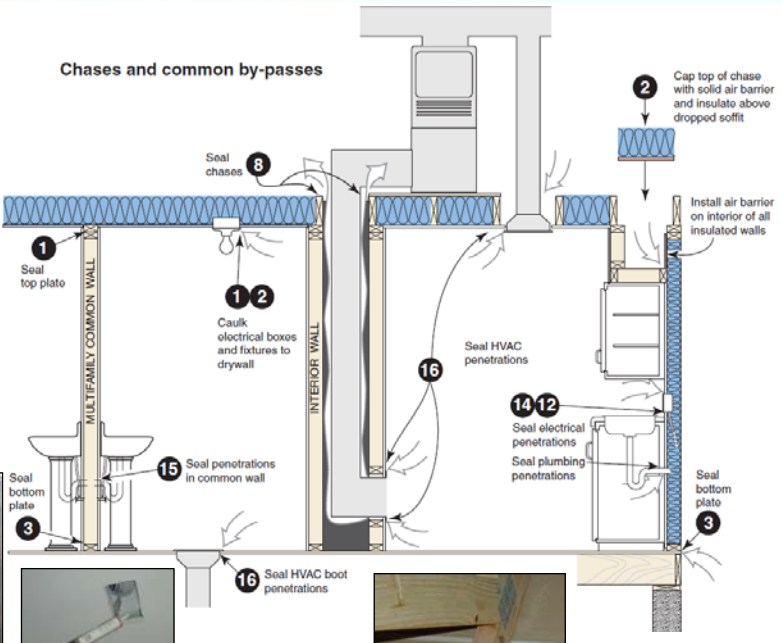

Air Sealing Blocking & Sheathing (p. 3)

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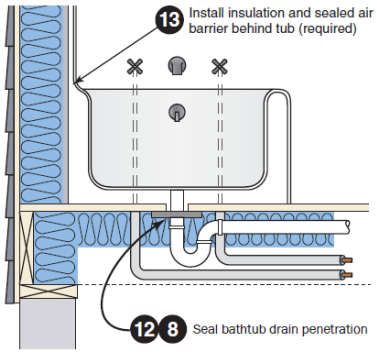
Solid sheet behind tubs & showers on insulated walls



Call back waiting to occur

Call back prevention

Air Sealing - Tubs

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Air Sealing Windows (p. 4)

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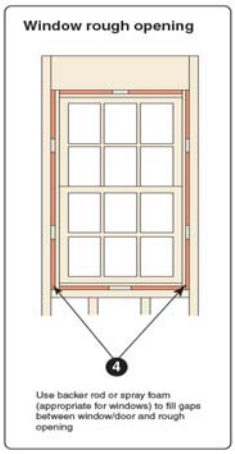
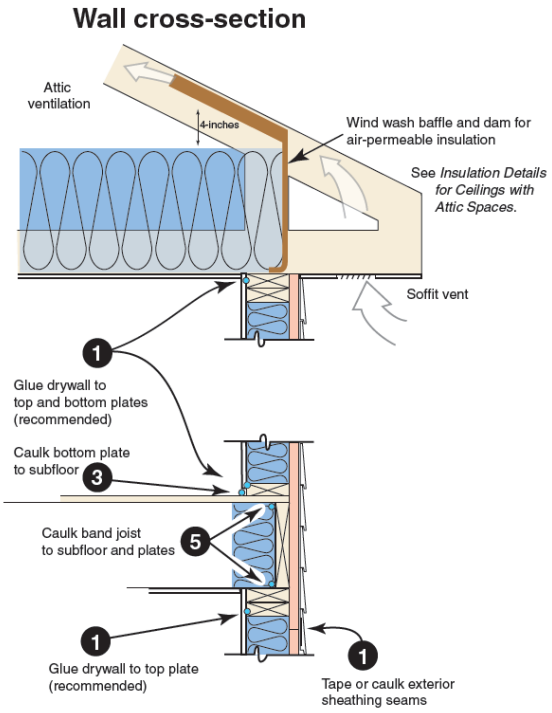


402.4.4- Windows, skylights and doors ≤ 0.3 cfm/s.f., Swinging doors ≤ 0.5 cfm/s.f. Exception: site built



Air Sealing Exterior Walls

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Air Sealing Exterior Walls

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Air Sealing Combustion (p. 5)

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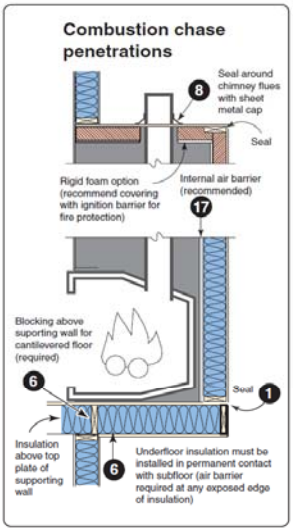

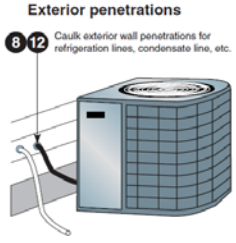

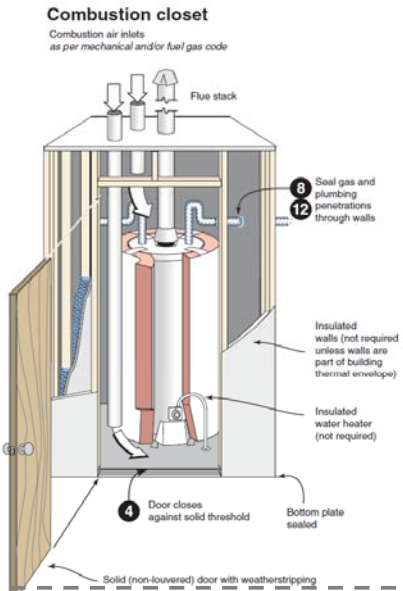

402.4.3- *Site built masonry* wood-burning fireplaces must have gasketed doors and outdoor combustion air

Air Sealing Kneewalls (p. 6)

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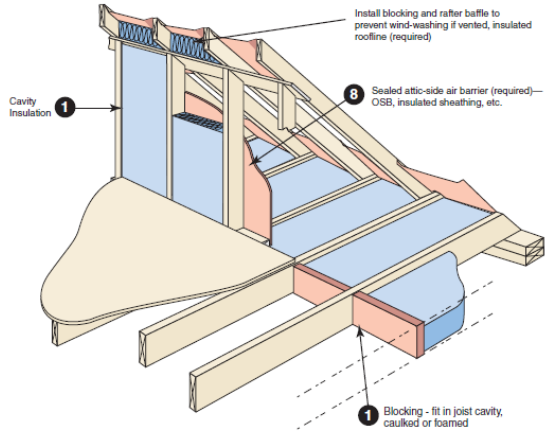

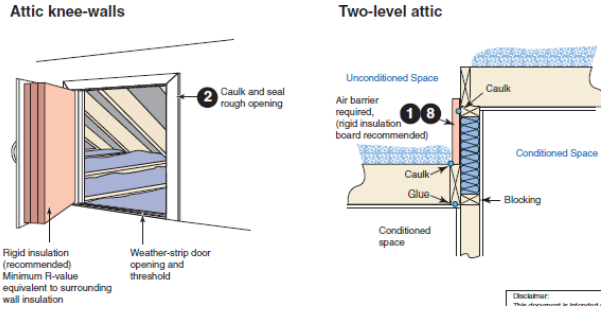

Kneewall – WX photo shows need for blocking

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Kneewall – Pics shows need for blocking & sheathing

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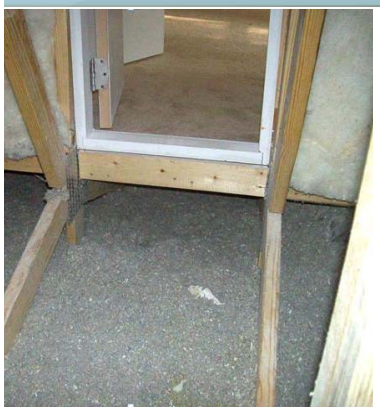

Kneewall – Sheathed and blocked as per GA Code

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Air Sealing Attic Access (p. 7)

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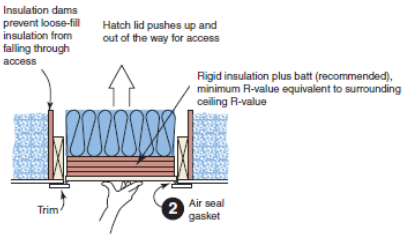
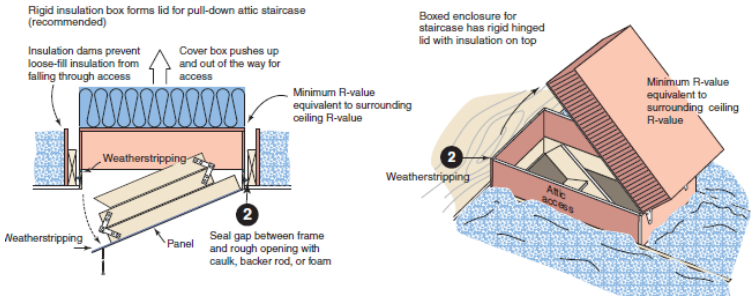
Attic scuttle



Attic pull-down stairs



Air Sealing - Adjacent Garage

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Air Barrier at the Ceiling

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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

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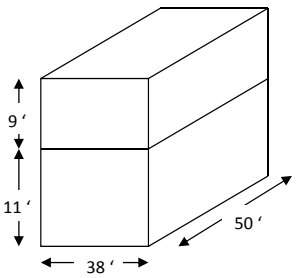
REQUIRED Blower Door test

- 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



1st Floor: 38x50x11 = 20,900 c.f.
2nd Floor: 38x50x9 = 17,100 c.f.
Total Volume: 38,000 c.f.

$$ACH_{50} = \frac{CFM50 \times 60}{Volume}$$

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

$$ACH_{50} = \frac{4305 \times 60}{38{,}000} = \mathbf{6.8}$$

2012 IRC

Southface

- Whole House Mechanical Ventilation is **REQUIRED**
  - Any home tighter than **5 ACH_{50}**
- 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)

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

DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0 – 1	2 – 3	4 – 5	6 – 7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 – 3,000	45	60	75	90	105
3,001 – 4,500	60	75	90	105	120
4,501 – 6,000	75	90	105	120	135
6,001 – 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

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

(#BR+1) x 7.5 cfm
+ 1 cfm / 100 s.f.

(Suggest state amendment with 62.2 as alternative approach)

For SI: 1 square foot = 0.0929 m^2, 1 cubic foot per minute = 0.0004719 m^3/s.

TABLE M1507.3.3(2) INTERMITTENT WHOLE-HOUSE MECHANICAL VENTILATION RATE FACTORS[a, b]

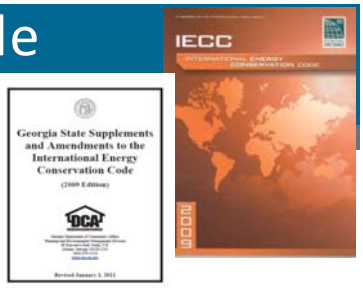
RUN-TIME PERCENTAGE IN EACH 4-HOUR SEGMENT	25%	33%	50%	66%	75%	100%
Factor[a]	4	3	2	1.5	1.3	1.0

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.

Compliance with GA Energy Code

2009 IECC with 2011 GA Supplements

ASHRAE 62.2 & IRC 2012 Ventilation



2015 Energy Code Field Study in GA:

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

$$ACH_{50} = \frac{CFM50 \times 60}{Volume}$$

403.5 Mechanical Ventilation

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- Ventilation is REQUIRED
  - Any home tighter than **5 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

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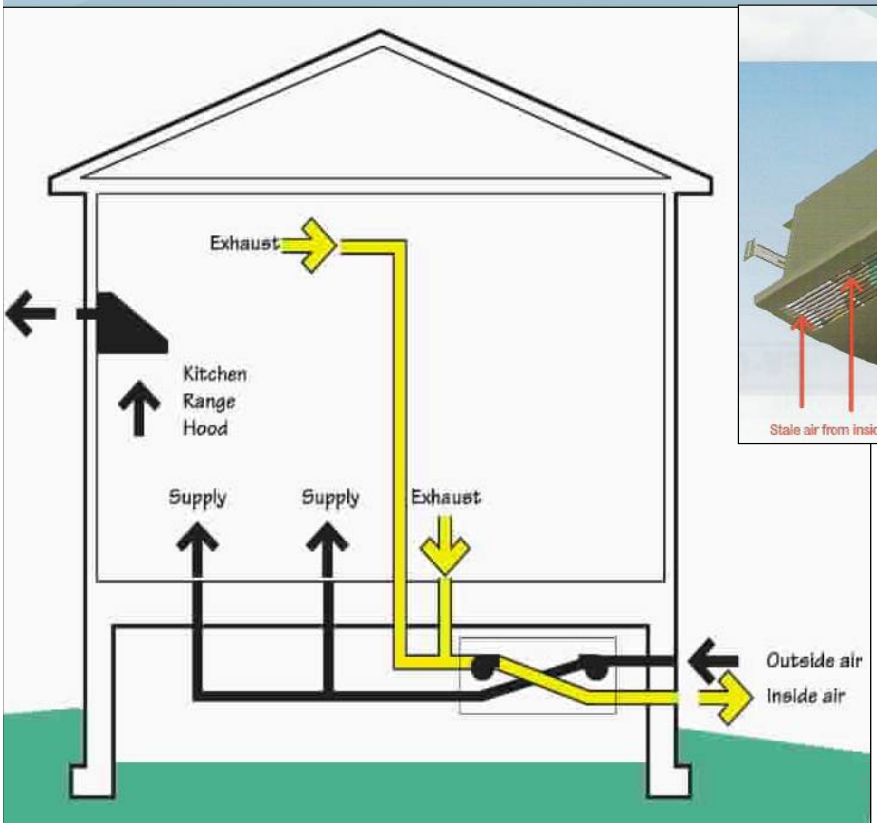

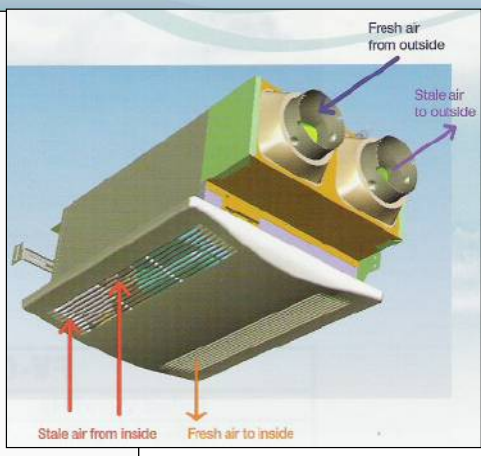

ERV - energy recovery ventilator

Positive Ventilation

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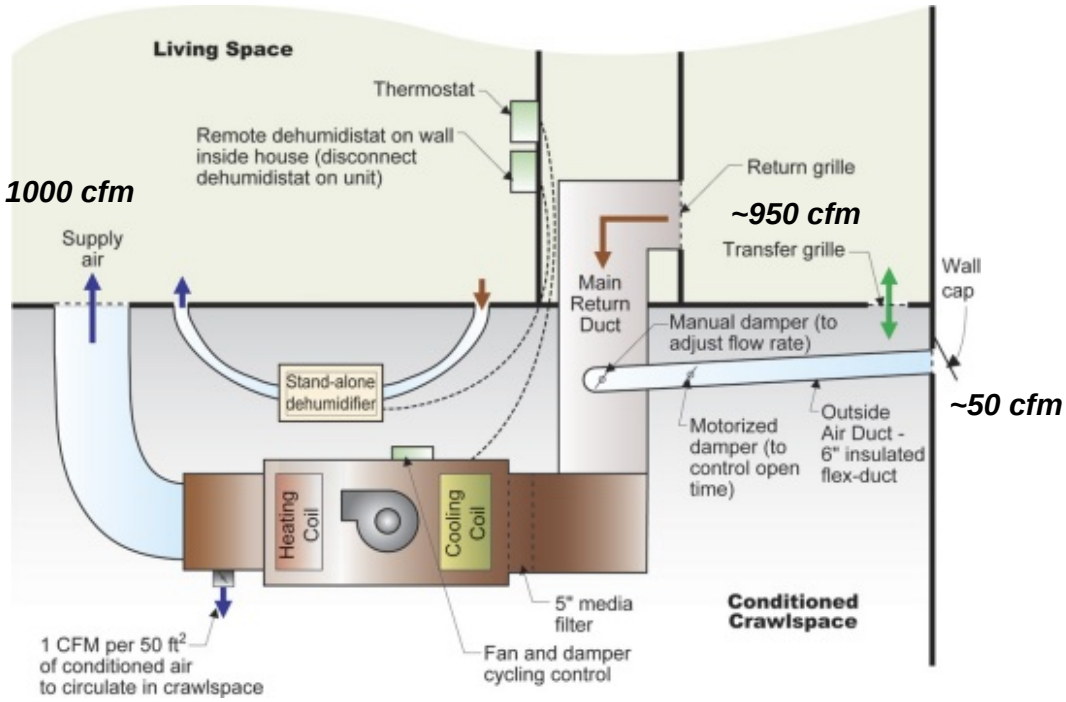

Positive Ventilation Supplied via O.A. Ducted to Return

403.2.2. Duct Tightness Testing

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- 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

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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

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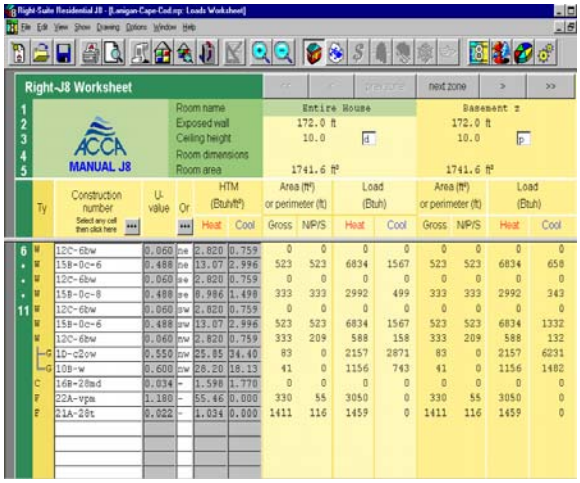
- Load Calcs & Sizing
  - –Per Mechanical section of IRC
  - –ACCA Manual J or approved equivalent, i.e., ASHRAE Fundamentals
  - –MUST BE ACCURATE
  - –Permits 72 and 75 as indoor design temps



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

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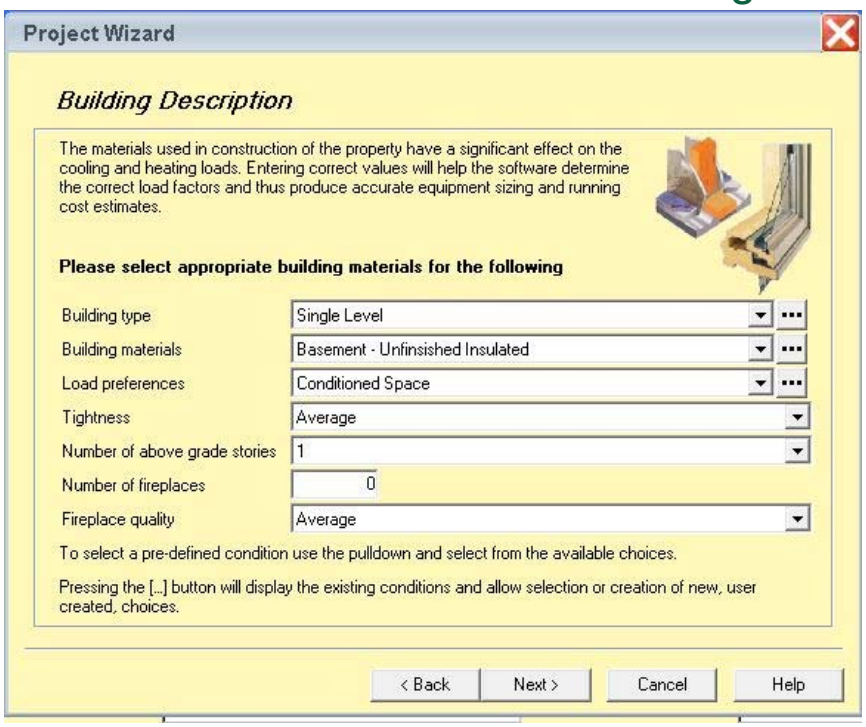
- Load Calcs – how to enter air leakage



Choices are

- *Tight*
- *Semi-tight*
- *Average*
- *Semi-loose*
- *Loose*

403.6 Equipment Sizing

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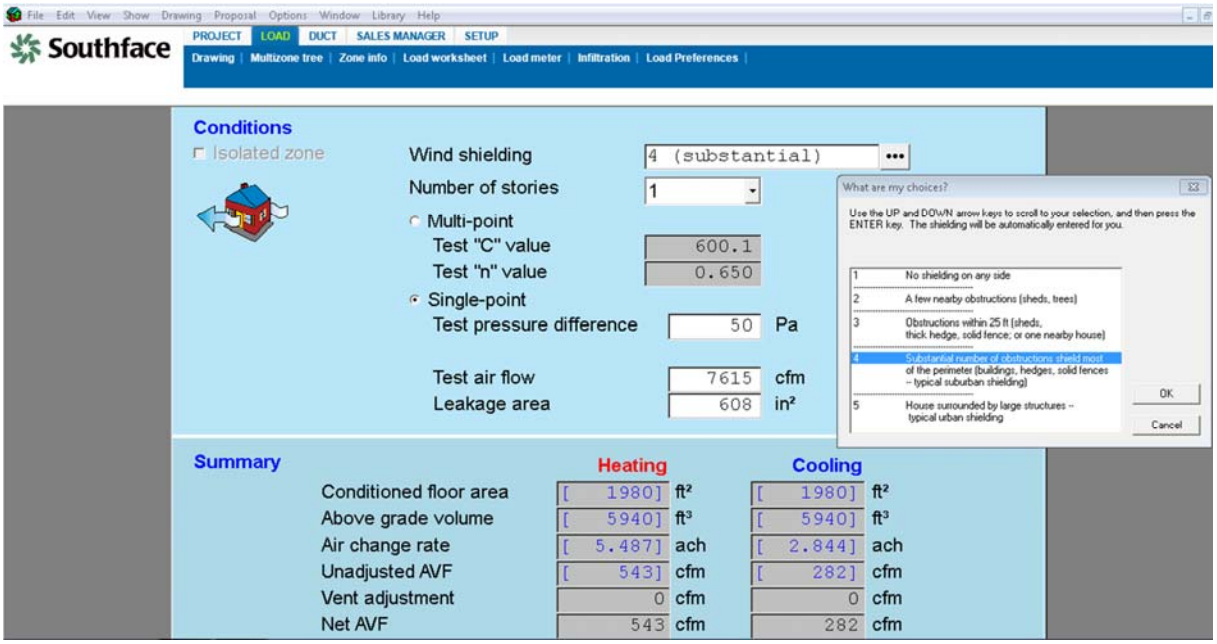
- Load Calcs – how to enter air leakage



Home Heating & Cooling Energy

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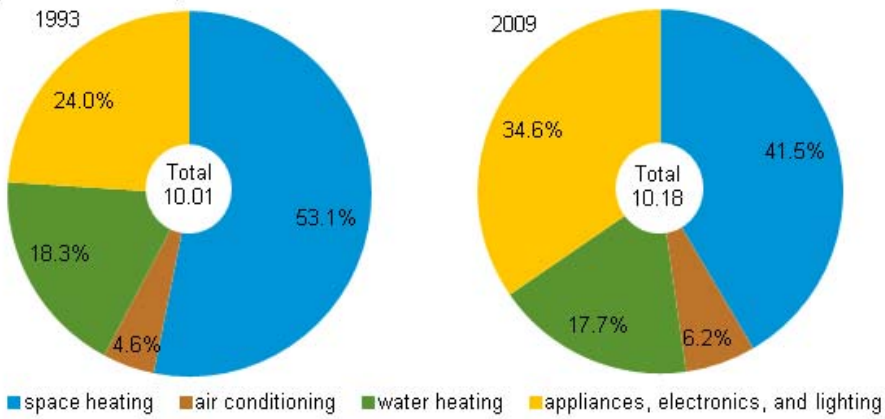
-Shrink the pie!

-Usage shifts

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

Energy consumption in homes by end uses
quadrillion Btu and percent

eia



Source: U.S. Energy Information Administration, Residential Energy Consumption Survey.
Note: Amounts represent the energy consumption in occupied primary housing units.

Duct and Envelope Tightness (DET) Verifier

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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

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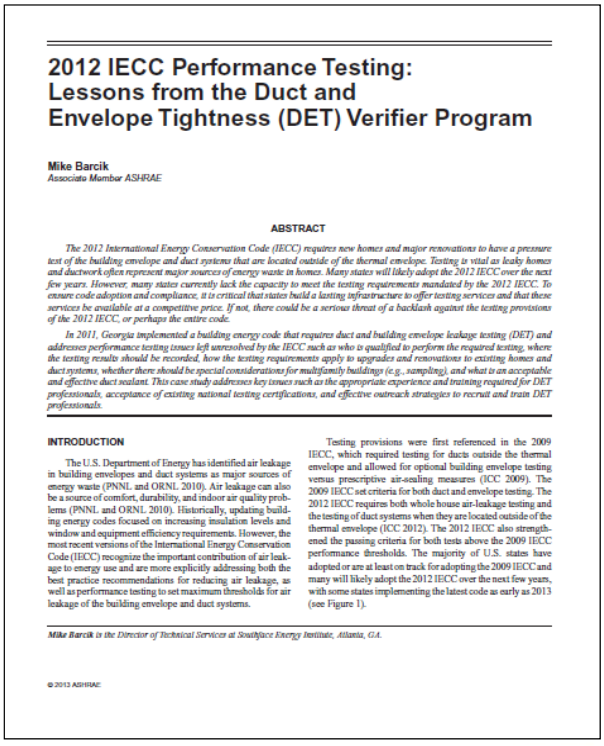
Buildings XII Conference – Lessons from DET Verifier program

(available from southface.org)

Results from first year of statewide testing and deployment of testing requirements



2012 IECC Performance Testing: Lessons from the Duct and Envelope Tightness (DET) Verifier Program

Mike Barcik
Associate Member ASHRAE

ABSTRACT

The 2012 International Energy Conservation Code (IECC) requires new homes and major renovations to have a pressure test of the building envelope and duct systems that are located outside of the thermal envelope. Testing is vital as leaky homes and ductwork often represent major sources of energy waste in homes. Many states will likely adopt the 2012 IECC over the next few years. However, many states currently lack the capacity to meet the testing requirements mandated by the 2012 IECC. To ensure code adoption and compliance, it is critical that states build a lasting infrastructure to offer testing services and that these services be available at a competitive price. If not, there could be a serious threat of a backlash against the testing provisions of the 2012 IECC, or perhaps the entire code.

In 2011, Georgia implemented a building energy code that requires duct and building envelope leakage testing (DET) and addresses performance testing issues left unresolved by the IECC such as who is qualified to perform the required testing, where the testing results should be recorded, how the testing requirements apply to upgrades and renovations to existing homes and duct systems, whether there should be special considerations for multifamily buildings (e.g., sampling), and what is an acceptable and effective duct sealant. This case study addresses key issues such as the appropriate experience and training required for DET professionals, acceptance of existing national testing certifications, and effective outreach strategies to recruit and train DET professionals.

INTRODUCTION

The U.S. Department of Energy has identified air leakage in building envelopes and duct systems as major sources of energy waste (PNNL and ORNL 2010). Air leakage can also be a source of comfort, durability, and indoor air quality problems (PNNL and ORNL 2010). Historically, updating building energy codes focused on increasing insulation levels and window and equipment efficiency requirements. However, the most recent versions of the International Energy Conservation Code (IECC) recognize the important contribution of air leakage to energy use and are more explicitly addressing both the best practice recommendations for reducing air leakage, as well as performance testing to set maximum thresholds for air leakage of the building envelope and duct systems.

Testing provisions were first referenced in the 2009 IECC, which required testing for ducts outside the thermal envelope and allowed for optional building envelope testing versus prescriptive air-sealing measures (ICC 2009). The 2009 IECC set criteria for both duct and envelope testing. The 2012 IECC requires both whole house air-leakage testing and the testing of duct systems when they are located outside of the thermal envelope (ICC 2012). The 2012 IECC also strengthened the passing criteria for both tests above the 2009 IECC performance thresholds. The majority of U.S. states have adopted or are at least on track for adopting the 2009 IECC and many will likely adopt the 2012 IECC over the next few years, with some states implementing the latest code as early as 2013 (see Figure 1).

Mike Barcik is the Director of Technical Services at Southface Energy Institute, Atlanta, GA.

DET Verifier Code Comparison

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Table 1: Duct and Envelope Tightness Requirements

Issue	2009 IECC	2011 GA Energy Code	2012 IECC
Envelope Testing – Single Family	Optional: Blower door (BD) test or Visual Inspection checklist	Mandatory BD test with optional Visual Inspection checklist	Mandatory BD test and Visual Inspection checklist
Envelope Testing – Multifamily	Optional: BD test or Visual Inspection checklist	Optional – Visual Inspection or BD test. Sampling 1 in 4 units per floor permitted or RESNET protocol	Mandatory BD test (no mention of sampling)
Envelope passing criteria	< 7 ACH_{50} all Climate Zones (CZ)	< 7 ACH_{50} all CZ (2-4)	≤ 3 ACH_{50} in CZ 3-8 ≤ 5 ACH_{50} in CZ 1-2
Clarify if envelope test required on alteration or renovation	No guidance	"When construction affects all aspects of building envelope (gut renovation)	No guidance
Duct Testing criteria at Rough-in (RI) (Total)	4% - RI Total no Air Handler 6% - RI Total w/ Air Handler	6% - RI Total w/ Air Handler	3% - RI Total no Air Handler 4% - RI Total w/ Air Handler
Duct Testing criteria at Post Construction—Post Construction Total (PCT) or Post Construction to Outside (PCO)	12% - PCT 8% - PCO	12% - PCT 8% - PCO	4% PC (no incentive for testing at final or To Outside)

DET Verifier - Code Comparison

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Table 1: Duct and Envelope Tightness Requirements

Issue	2009 IECC	2011 GA Energy Code	2012 IECC
Record /Display Test Results	Not required	On Energy Code certificate – template provided	On Energy Code certificate – no specifics on what to provide
Exempt from Duct Testing	Ducts and Air Handler Unit (AHU) entirely inside building Thermal Envelope	Ducts and AHU entirely inside building Thermal Envelope	Ducts and AHU entirely inside building Thermal Envelope
Duct pressure test required when modifying an existing system	No guidance	When > 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	No guidance
Building cavities allowed as ducts	Only for returns	Not allowed for supply or returns	Not allowed for supply or returns
Duct sealing material	UL tape, mastic, etc.	No UL tape, only mastic and mastic tape	UL tape, mastic, etc.
Qualified testers	No guidance	DET verifiers and RESNET and BPI certified professionals	No guidance

DET Verifier – Lessons Learned

Southface

Eight items for consideration:

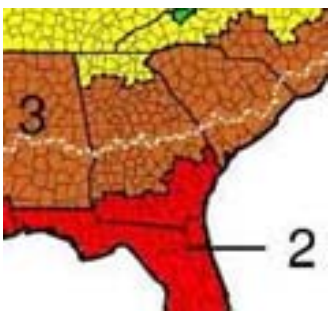
1) Ventilation now “required”
2) Multi-day training – 2 days is needed
3) Central database of DET Verifiers
4) Quality Assurance and continuing education
5) Equipment loan program
6) Reciprocity
7) Issue of 3rd party testing
8) Consistent curriculum

DET Verifier Test Data Study

Southface

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



DET Verifier Test Data Study

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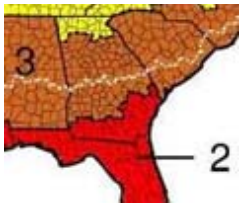
Envelope Testing Results

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.



DET Verifier Test Data Study

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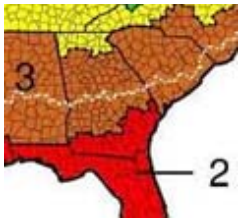
Duct Leakage Testing Results

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.



DET Verifier Test Data Study

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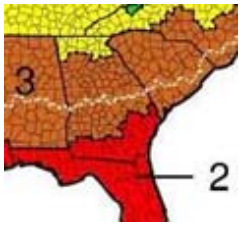
Additional

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."



DET Verifier Lessons Learned

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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

Southface

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

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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 ACH50
    - 1000-3000 s.f. – 3 ACH50
    - Over 3000 s.f. – 2 ACH50

Possible future amendment

- Under 1,200 s.f. < 5 ACH50
- 1,200-3,000 s.f. < 4 ACH50
- Over 3,000 s.f. < 3 ACH50

Envelope Leakage Ratio - ELR

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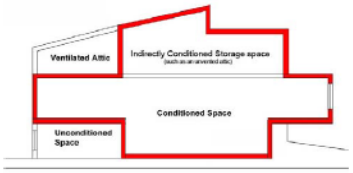
$$ELR_{50} = \frac{CFM50}{\text{Shell Area}}$$

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

Building Thermal Envelope

The building thermal envelope is the portion of the building envelope that is comprised of the continuous air barrier and insulation and separates conditioned space from unconditioned space.



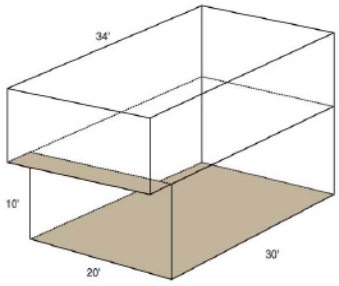
Example Calculation

A 1,280 square foot building has an SFBE of 3,224 square feet and a measured fan flow of 1,483 at CFM_{75}. Determine the Envelope Leakage Ratio at 75 Pa by dividing the cubic feet per minute of air volume moved through the fan by the total square footage of the building thermal envelope.

Top Flat Ceiling Area
$20'x\ 34' = 680ft^2$

Building Envelope Floor Area (includes shaded area)
$20'x\ 30' + 20'x\ 4' = 680ft^2$

Gross Exterior Insulated Wall Area $= 1,864ft^2$
1st Floor: $(20' + 30' + 20' + 30) \times 10' = 1,000ft^2$
2nd Floor: $(20' + 34' + 20' + 34') \times 8' = 864ft^2$



$SFBE = 680ft^2 + 680ft^2 + 1864ft^2 = 3,224ft^2$

$Fan\ Flow\ Measurement = 1,483\ CFM_{75}$

$$ELR_{75} = \frac{CFM_{75}}{SFBE}$$

$$ELR_{75} = \frac{1,483\ CFM_{75}}{3,224\ sf}$$

$ELR_{75} = 0.46$ *Envelope Passes*

DET Testing – ELR vs. ACH

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Volume vs. Shell										(shell area)			
	CFA s.f.	per floor s.f.	width	length	ceil. ht	walls	ceiling	floor		SFBE		Volume	
Unit A	750 s.f.	750	30	25	8	880	750	750		2380		6000	
		Blower Door	300	cfm50					ELR50	0.13	ACH50	3.00	IECC-12
		Blower Door	500	cfm50					ELR50	0.21	ACH50	5.00	
		Blower Door	700	cfm50					ELR50	0.29	ACH50	7.00	IECC-09
		Blower Door	750	cfm50					ELR50	0.32	ACH50	7.50	
		Blower Door	1000	cfm50					ELR50	0.42	ACH50	10.00	
Unit B	1050 s.f.	1050	30	35	9	1170	1050	1050		3270		9450	
		Blower Door	475	cfm50					ELR50	0.15	ACH50	3.02	IECC-12
		Blower Door	600	cfm50					ELR50	0.18	ACH50	3.81	
		Blower Door	800	cfm50					ELR50	0.24	ACH50	5.08	
		Blower Door	1100	cfm50					ELR50	0.34	ACH50	6.98	IECC-09
		Blower Door	1300	cfm50					ELR50	0.40	ACH50	8.25	
Unit C	1500 s.f.	1500	30	50	9	1440	1500	1500		4440		13500	
		Blower Door	680	cfm50					ELR50	0.15	ACH50	3.02	IECC-12
		Blower Door	900	cfm50					ELR50	0.20	ACH50	4.00	
		Blower Door	1100	cfm50					ELR50	0.25	ACH50	4.89	
		Blower Door	1400	cfm50					ELR50	0.32	ACH50	6.22	
		Blower Door	1600	cfm50					ELR50	0.36	ACH50	7.11	IECC-09

$$ACH_{50} = \frac{CFM50 \times 60}{\text{Volume}}$$

$$ELR_{50} = \frac{CFM50}{\text{Shell Area}}$$

DET Testing – ELR vs. ACH

Southface

Volume vs. Shell										(shell area)			
	CFA s.f.	per floor s.f.	width	length	ceil. ht	walls	ceiling	floor		SFBE		Volume	
Unit D	2400 s.f.	1200	30	40	18	2520	1200	1200		*4920*		*21600*	
		Blower Door	1100	cfm50					ELR50	0.22	ACH50	3.06	IECC-12
		Blower Door	1300	cfm50					ELR50	0.26	ACH50	3.61	
		Blower Door	1600	cfm50					ELR50	0.33	ACH50	4.44	
		Blower Door	2000	cfm50					ELR50	0.41	ACH50	5.56	
		Blower Door	2500	cfm50					ELR50	0.51	ACH50	6.94	IECC-09
Unit E	3200 s.f.	1600	32	50	18	2952	1600	1600		*6152*		*28800*	
		Blower Door	1450	cfm50					ELR50	0.24	ACH50	3.02	IECC-12
		Blower Door	1700	cfm50					ELR50	0.28	ACH50	3.54	
		Blower Door	2000	cfm50					ELR50	0.33	ACH50	4.17	
		Blower Door	2800	cfm50					ELR50	0.46	ACH50	5.83	
		Blower Door	3400	cfm50					ELR50	0.55	ACH50	7.08	IECC-09
Unit F	4800 s.f.	2400	40	60	18	3600	2400	2400		*8400*		*43200*	
		Blower Door	2200	cfm50					ELR50	0.26	ACH50	3.06	IECC-12
		Blower Door	2500	cfm50					ELR50	0.30	ACH50	3.47	
		Blower Door	2800	cfm50					ELR50	0.33	ACH50	3.89	
		Blower Door	3800	cfm50					ELR50	0.45	ACH50	5.28	
		Blower Door	5000	cfm50					ELR50	0.60	ACH50	6.94	IECC-09

$$ACH_{50} = \frac{CFM50 \times 60}{Volume} \qquad ELR_{50} = \frac{CFM50}{Shell\ Area}$$

Wrap up and Q&A

Southface

Thank you!

Steve Herzlieb
sherzlieb@southface.org
Mike Barcik
mikeb@southface.org

www.southface.org

Building Energy Codes Program

www.energycodes.gov

BECP help desk

http://www.energycodes.gov/resource-center/help-desk