New Energy Codes & High-Performance Homes

Mike Barcik
Southface Energy Institute

Matt Belcher
MO Energy Code Support

- Top Ten List
- Building Science
- Baseline Study
- Code Envelope Overview
- Mechanicals

Learning Objectives

- Design priorities for a High-Performance Home
- Identify opportunities resulting from
  Missouri Residential Energy Code Field Study
- Identify standards for insulation requirements and fenestration performance
- Define the building envelope and identify best practices for air sealing (and passing blower door test)
- Identify requirements and best practices for heating and cooling (mechanical and ductwork) and fresh air ventilation systems

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Energy Code Resources

Technical assistance or training requests:

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Energy Code Resources

Missouri Residential Building Energy Code Construction Practices Study:
https://energy.mo.gov/energy-codes/missouri-residential-building-codes-study
For additional information on other DOE Field Studies and participating states, please visit https://www.energycodes.gov/compliance/energy-code-field-studies.
Additional education resources are available at www.southfaceonlinetraining.org.

www.southface.org => Resources => GA Energy Code Resources
mikeb@southface.org

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Design Approach for a High-Performance Home

- **Building Science as guide**
  Understand physics of heat air and moisture flow
- **High Performance Enclosure**
  Sound structure, shell is tight, well-insulated and resilient
- **Air Distribution**
  Sealed & insulated ducts – located inside building envelope, intentional fresh air delivery
- **Reduced Equipment & Loads**
  Efficient Heating, Cooling, Hot Water, Lights, Appliances

The Key: It's not necessarily the stuff in the building — it's how it's all put together! (The house is a system)

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High Performance Top Ten List

1. Pay Attention to the Sun
2. Ductwork
3. Thermal Package
4. Equipment
5. Bulk Moisture & Cladding
6. Humidity Control
7. Indoor Air Quality
8. Appropriate Ventilation
9. Lighting and Plug Loads
10. Production for Zero Energy

Use Tools and Technology to help us!

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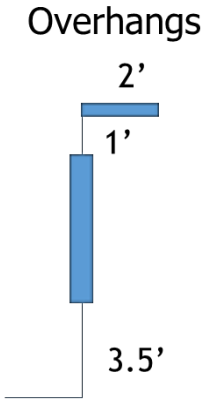
Top Ten List – the Sun

1. **Pay Attention to the Sun**
   Glazing on South and North (minimize East/West) – overhangs, exterior shading
   Glazing – DP low-e with wood, vinyl, Extruded Fiberglass frame
   Sun tubes vs. big skylights.
   Minimize Window Wall Ratio



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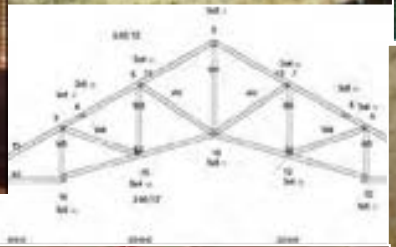
Top Ten List – Ducts

2. Ductwork

Ducts located inside building envelope – sealed with mastic
Returns – path from every room; upsized over supplies



"According to NREL researchers David Roberts and Jon Winkler, moving the ducts from a vented attic to a new location inside the conditioned space will reduce electricity used for cooling by 15% to 20%, and will reduce the size of the needed air conditioning equipment by 0.5 to 1 ton."

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Top Ten List – Insulation

3. Thermal Package

Exceed R-values from 2015/18 IECC prescriptive chart Walls ~R-20+
– prefer thermal break with rigid insulation (rock wool) & efficient framing
Insulate foundation walls versus floors – basements, conditioned crawlspaces

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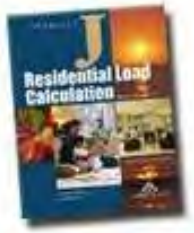
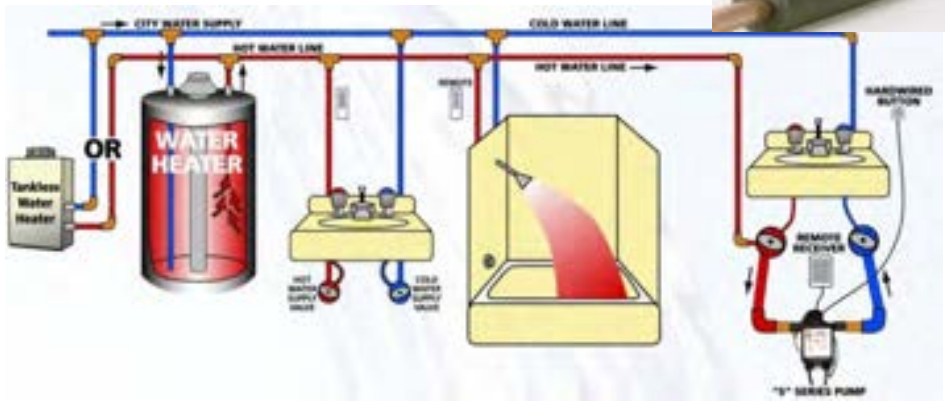
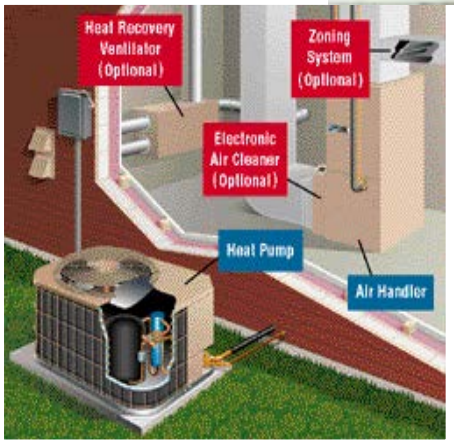
Top Ten List – Mechanical

4. Equipment

Heating – gas 95%, Cooling – Variable Speed – Right Sized furnaces & heat pumps, mini-splits
Hot Water – safe gas units, HP electric – insulate lines, distribution







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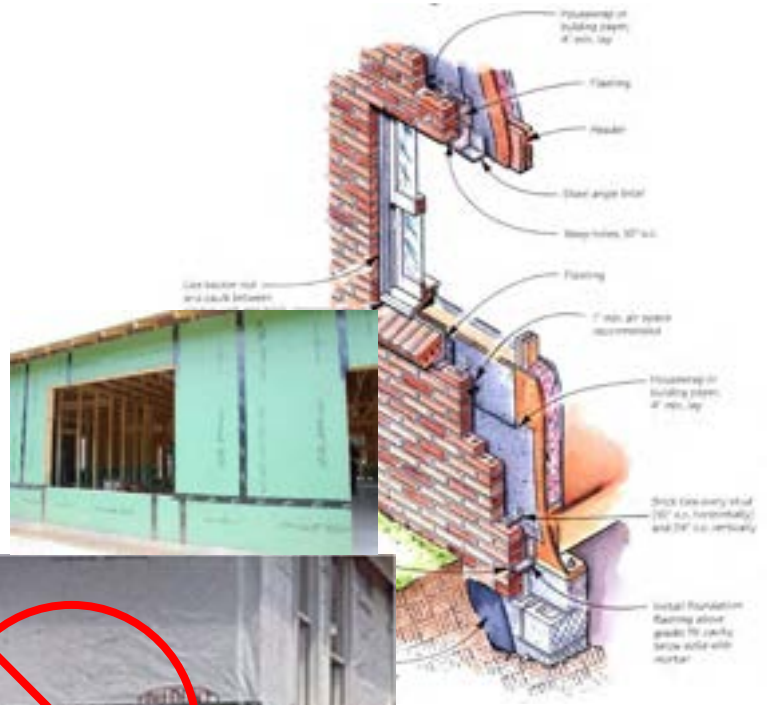
Top Ten List – Water

5. Bulk Moisture and Cladding

Sheathing seams sealed – air barrier and weather barrier – (ZIP)
Drainage plane behind all cladding. Foundation drainage details Flashing integrated with WRB



Top Ten - Humidity

6. **Humidity Control**
   Variable speed equipment
   Dedicated dehumidifier

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Top Ten List - IAQ

7. **Indoor Air Quality**
   Material selection – Salvaged, Recycled content
   EPP, avoid Red List
   Thick, pleated filters
   Tight envelope with Fresh Air system

QUFRESH BY Air King
Patents Pending

HVI CERTIFIED PERFORMANCE				
MODEL	DUCT SIZE	STATIC PRESSURE	SPEED	WATTS
QFAM	6"	0.2	40 CFM	12.9
			50 CFM	13
			60 CFM	15.1
			70 CFM	17.1
			80 CFM	19.5
			90 CFM	21.8
			100 CFM	26.3
			110 CFM	27.5
			120 CFM	30.1

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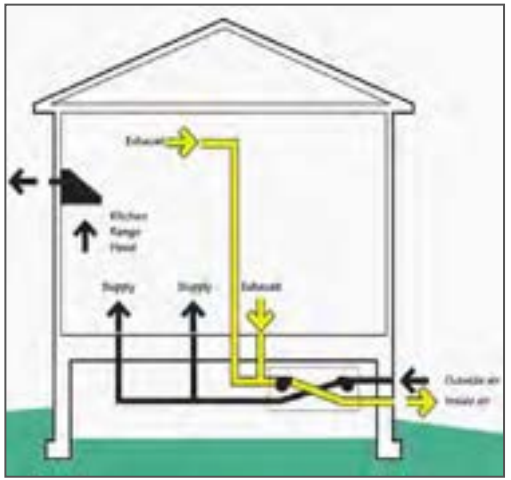
Top Ten List – Fresh Air

8. Appropriate Ventilation

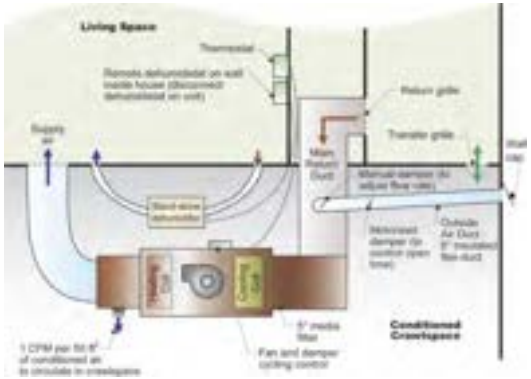
Positive / Balanced versus Exhaust Only
Smart Controls and sensors, ERV,
Ventilation Dehumidifiers



To house

Fresh air

From house



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Top Ten List – Plug Loads

9. Lighting and Plug Loads

100% good quality LED's – economic no-brainer
ENERGY STAR appliances – manage this (5 refrigerators?!)
Smart power strips and vampire loads

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Top Ten List – Renewables

10. **Production for Zero Energy**

    At least make the home solar ready – (structure, conduit)
    Solar PV is much more affordable - don't rely on solar to offset poor design
    New technologies include on-site storage (PowerWall) and EV's

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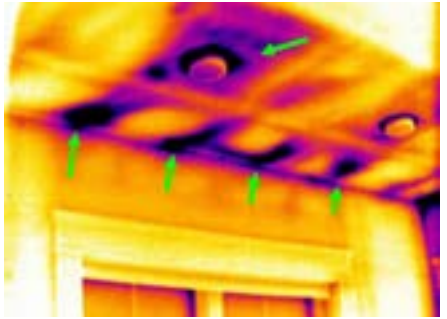
Technology / Programs Can Help

- **Use the Tools**
  - *Energy Modeling – target EUI's, Performance Monitoring, IAQ Sensors, IR Camera, Blower Door and Duct Leakage Testing, Inspections and Certifications*
  - *Beyond Code Programs*



ENERGY STAR CERTIFIED NEW HOME

LEED FOR HOMES

PHIUS

NAHB NATIONAL GREEN BUILDING PROGRAM

ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

earthcraft

2030 CHALLENGE Targets: U.S. Residential Regional Averages

U.S. Regional Averages for Site Energy Use and 2030 Challenge Energy Reduction Targets by Residential Space/Building Type (RECS 2001)

Residential Space/Building Type	Average Source-EUI	Average Site-EUI	2030 Challenge Site EUI Targets (kBtu/Sq.Ft./Yr) 50% Target	60% Target	70% Target	80% Target	90% Target
South							
Single-Family Detached	86.0	41.5	20.8	16.6			
Single-Family Attached	82.5	38.8	19.4	15.5			
Multi-Family, 2 to 4 units	113.6	46.9	23.5	18.8			
Multi-Family, 5 or more units	122.4	47.9	24.0	19.2			
Mobile Homes	162.0	63.3	31.6	25.3			

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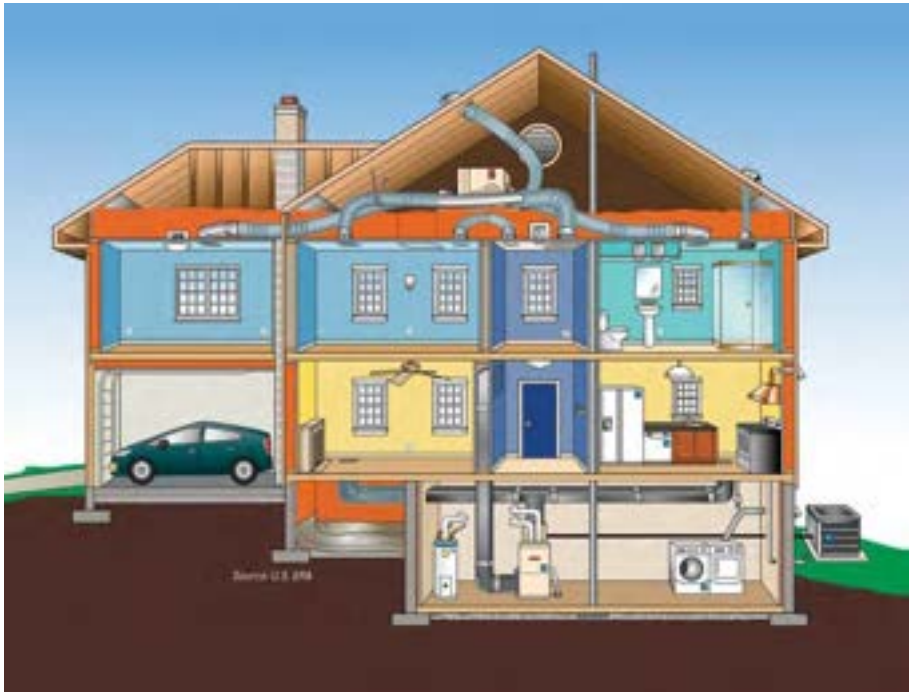
Building Science

A house is a system made up of interrelated parts:

- The building thermal envelope
- Systems
  - Heat and air conditioning
  - Ventilation
  - Water heating and distribution
- Lighting & appliances



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Building Thermal Envelope

IECC Definition

The basement walls, exterior walls, floor, roof and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

What parts of this house are enclosed by the thermal envelope?

Heat Transfer

- Heat is a form of energy
- Heat moves from hot to cold
- 3 types of heat transfer:
  - **Conduction** – heat moves through a material
  - **Convection** – heat energy carried by a fluid (including air)
  - **Radiation** – heat emits from a hot surface to a cooler surface

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Heat Transfer Problem

Your Choices:

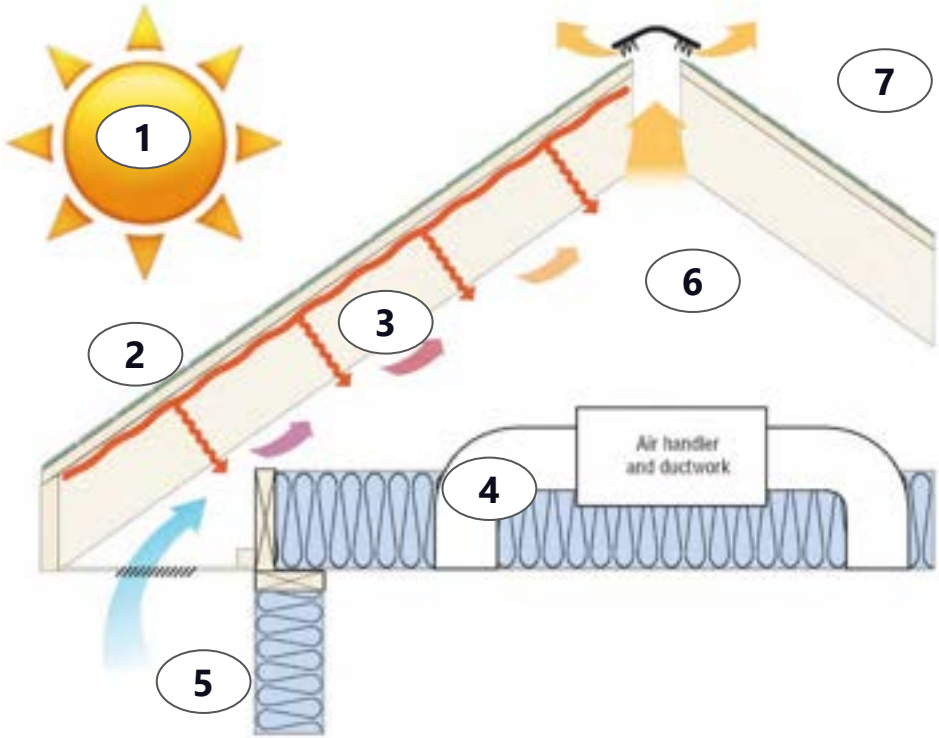
- **Radiation**
- **Conduction**
- **Convection**

1 → 2 = Radiation

2 → 3 = Conduction

3 → 4 = Radiation

5 → 6 → 7 = Convection



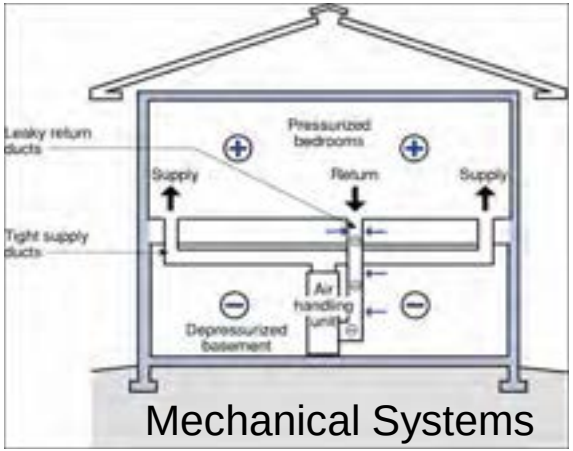
Why Foamed Houses?

The energy code allows for multiple ways of defining the building thermal envelope. This home's envelope is defined by the roof, not the ceiling. What's the advantage of this?

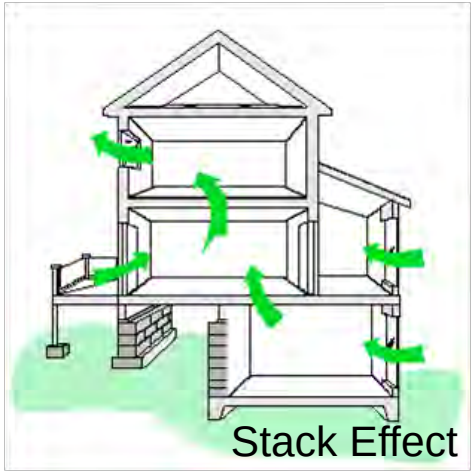
Air Flow

- Air moves from areas of higher pressure to areas of lower pressure.
- Natural and man-made forces that can create pressure differences cause air to flow.
- Whenever air moves out of a home, an equal amount of air enters the home (CFMin = CFMout).

Wind



Mechanical Systems



Stack Effect

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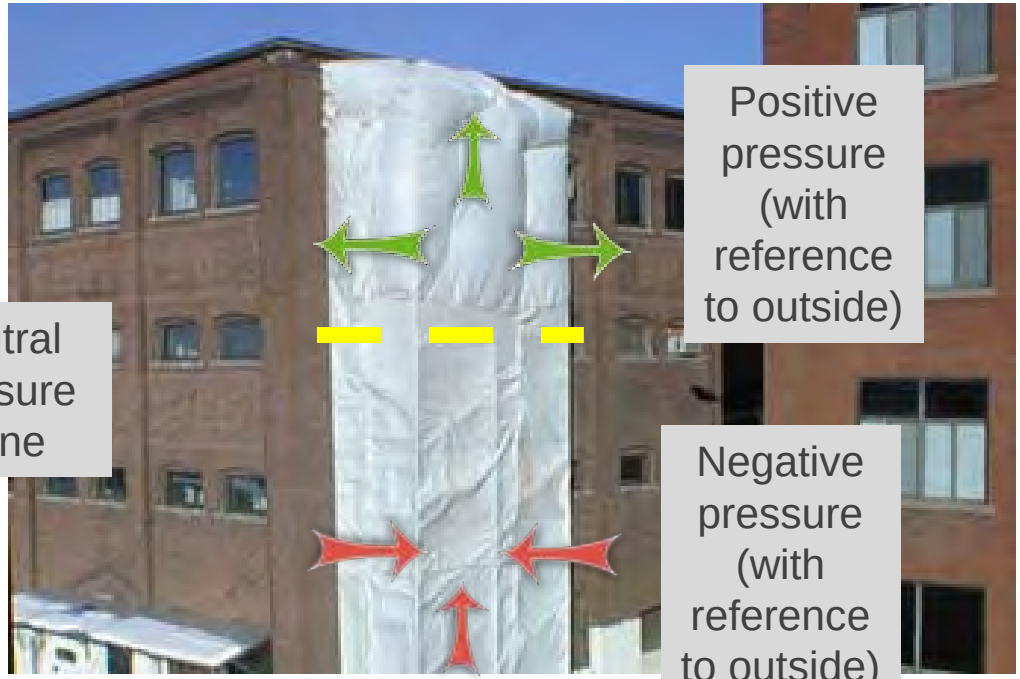
Stack Effect



Vermont Energy Investment Corp.

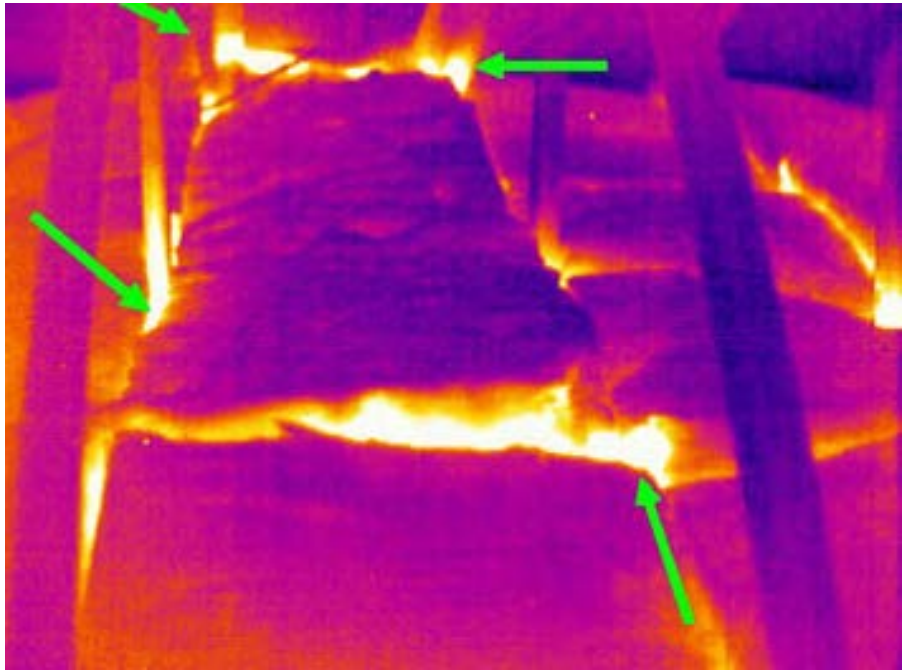
Thermal and Air Barriers

The thermal and pressure boundaries in the building envelope must be **complete** and **aligned.**

- Insulation products such as fiberglass batts must be completely enclosed on all sides.
- Insulation is most effective when it is continuous and located outside the structure.

Continuous Insulation & Air Barrier

Air barrier and insulation must be in contact.



Moisture Transport

Moisture moves…

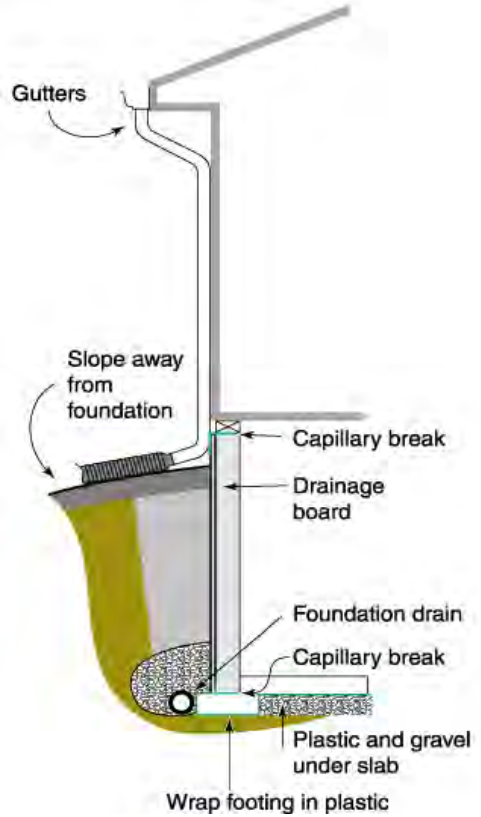
- From wet to dry
- As liquid or vapor
- By capillary action (wicking)

Geography matters! What works in one region may not work in another.

Appropriate measures for moisture control are essential!

Bulk Moisture Control

- Proper site drainage
- Foundation waterproofing
- Plastic ground cover
- Gutters channel water away from foundation



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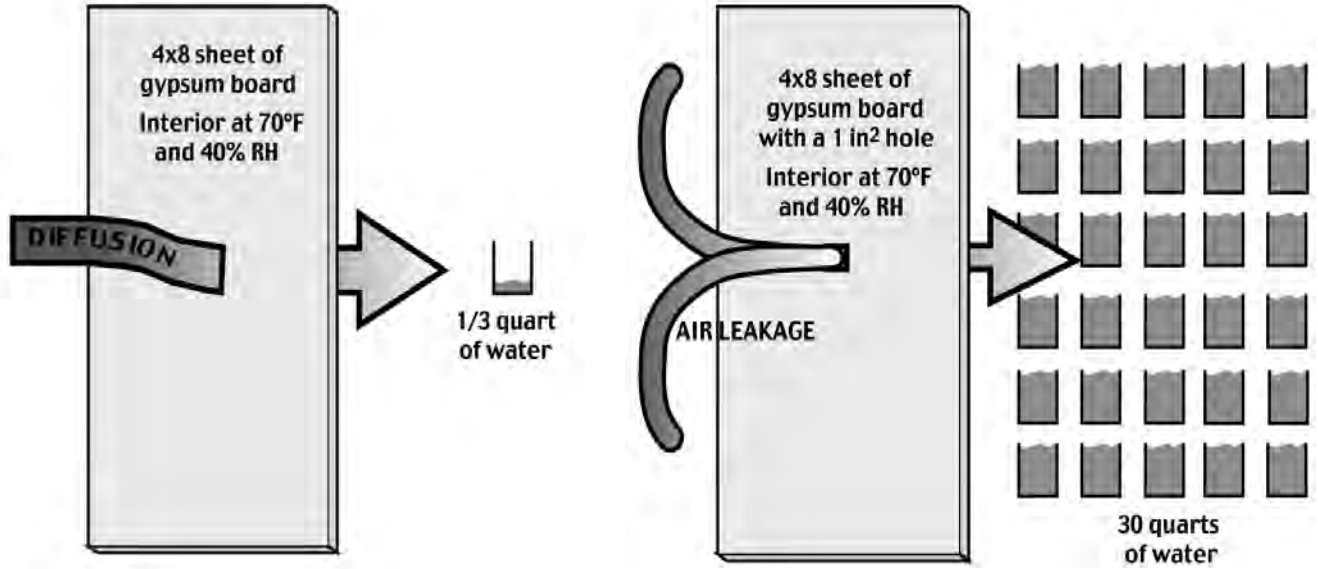
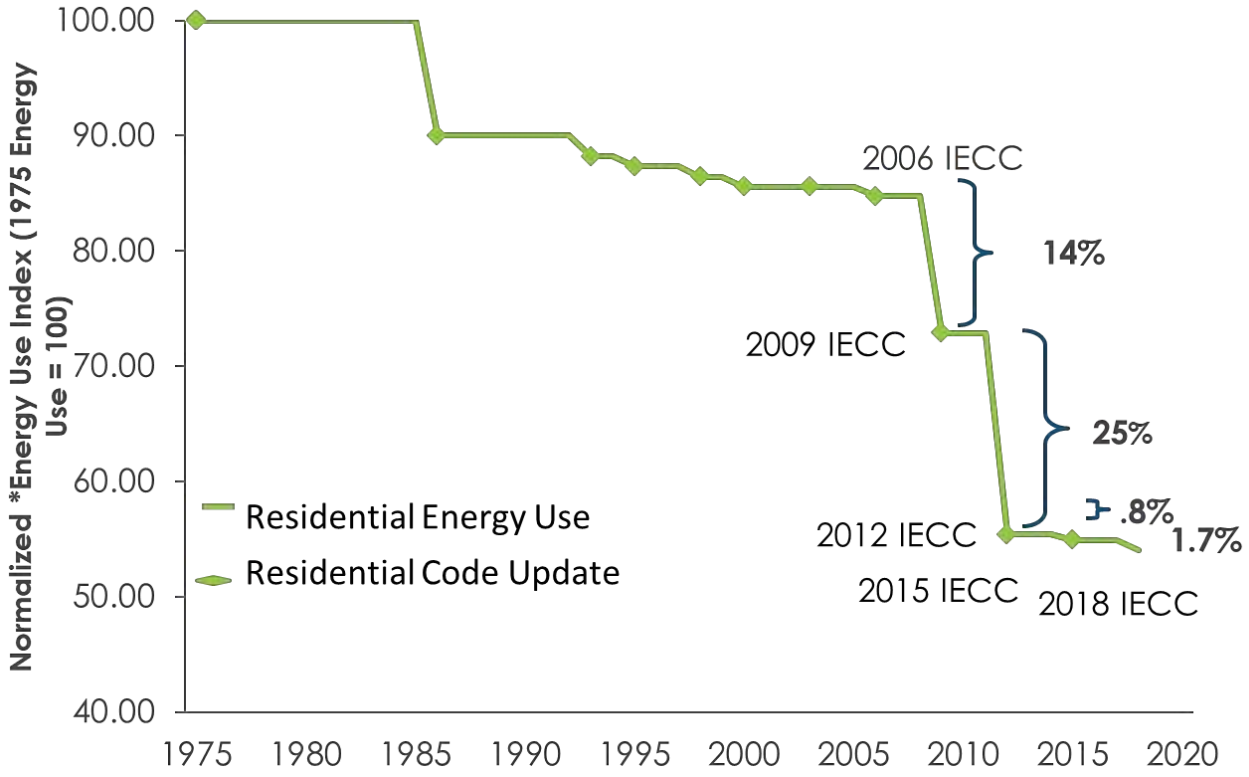
Diffusion Vs. Air Leakage



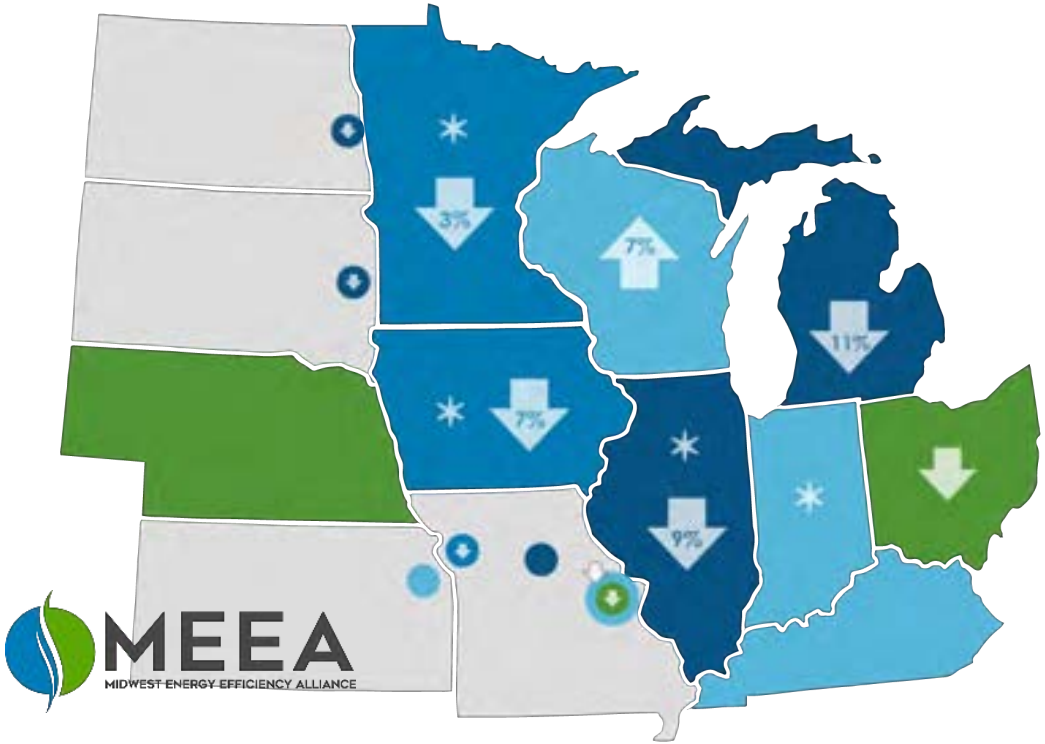
Particularly for a Mixed climate, air leakage is typically far more important a moisture transport mechanism than diffusion

Part 2

Residential Energy Code Background



Midwest Residential Energy Code Adoption



Key

- No mandatory code
- 2009 IECC
- 2012 IECC
- 2015 IECC
- 2018 IECC
- Less efficient than referenced code
- More efficient than referenced code
- code update in progress

MEEA
MIDWEST ENERGY EFFICIENCY ALLIANCE

As of May 2019

Percentage change is based on EUI of adopted code

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Energy Code: Residential Building

Applies to:

- New construction
- 1 and 2 family (R3)
- Multi-family, 3 stories and less (R2 and R4) – IECC 2009
- Additions, Alterations, Repairs

Exempt Buildings

- No conditioning
- Historical

CONDITIONED SPACE. For energy purposes, space within a building that is provided with heating and/or cooling *equipment* or systems capable of maintaining, through design or heat loss/gain, 50°F (10°C) during the heating season and 85°F (29°C) during the cooling season, or communicates directly with a *conditioned space*. For mechanical purposes, an area, room or space being heated or cooled by any *equipment* or *appliance*.

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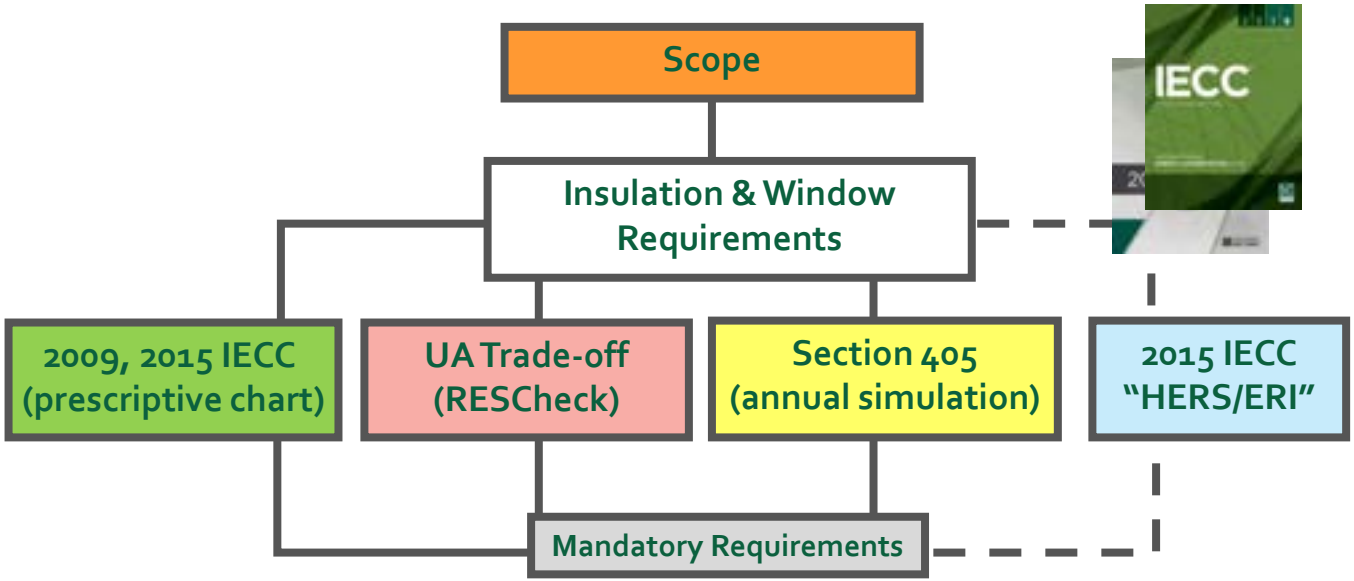
Scope of Residential Energy Code

- Focus is on building envelope
  - Ceilings, walls, windows, floors, foundations
  - Sets insulation levels, window U-factors and SHGC
  - Infiltration control
    - Caulk and seal to prevent air leaks
    - Verify envelope tightness with blower door test (or visual inspection for 2009 code)
- Ducts
  - No building cavities as ducts (post-2009)
  - Seal properly and insulate
    even if all ductwork is in conditioned space
  - Verify tight with duct pressurization test
- Lighting equipment
  - High-efficacy bulbs required (50%, 75%, 90%)
- HVAC equipment efficiencies covered by different DOE standard
- No appliance requirements

Compliance Paths



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

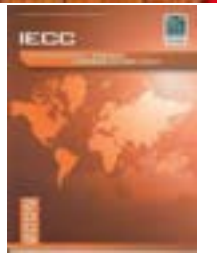
2009 IECC- Section 402.1

- One prescriptive “answer” for how to build per climate zone (CZ: 4 and 5)
- Includes lots of footnotes

2009

TABLE 402.1.1
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	CRA SPA WA *R*-VA
1	1.2	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, 2 ft	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	20 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



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2015 IECC vs. 2018 IECC

- One prescriptive “answer” for how to build per climate zone (CZ: 4 and 5)

TABLE R402.1.2
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT*

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[c] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
2015										
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
2018										
3	0.32	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.32	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.30	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.30	0.55	NR	49	20+5[h] or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19

402.1.4 is similar table for U-factors (get U-values from RESCheck)

IECC Code Differences – ‘15 to ’18

- Window Ufactors dropped slightly from U35 to U32 & U30 (CZ’s 4-5)
- Exception for log homes built according to ICC 400
- ERV/HRV ducts exempt from leakage testing (if independently ducted).
- Ducts allowed to be buried in ceiling insulation
  - Ducts R-8
  - Minimum surrounding insulation R-19 (R-13 for CZ1-3A, ducts >3’)
  - Effective R-25 when modeling
- Ducts in conditioned space
  - Completely inside thermal envelope
  - Buried ducts with AHU inside envelope plus < 1.5% Total Leakage plus threshold of ceiling insulation
- 90% Efficient Lighting (LED’s)
- ERI relaxed targets
  (62 for CZ4, 61 for CZ5, backstop penalty for renewables)

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2009 IECC Prescriptive Code R-Values

Values for Climate Zone 4

Sloped Ceilings **R-38**

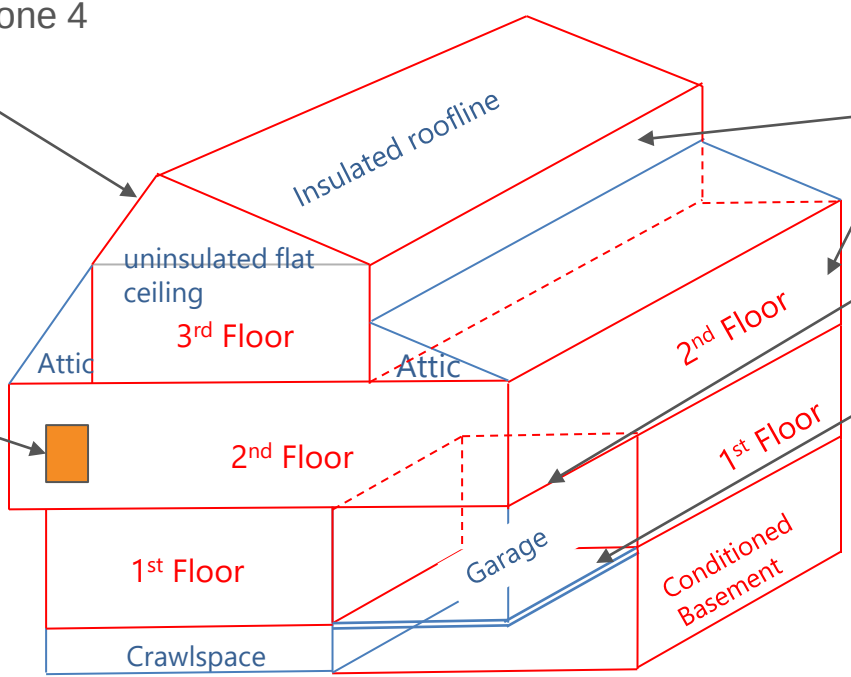
Attic Knee wall **R-13**

Flat Ceiling **R-38**

Window **U-0.35 SHGC- n/a**

Cantilever Floor **R-19**

Floor Over Crawl **R-19**



Exterior Wall **R-13**

Floor Over Garage **R-19**

Wall to Garage **R-13**

Basement Wall (continuous insulation) **R-10**

Conditioned Slab **R-10, 2'**

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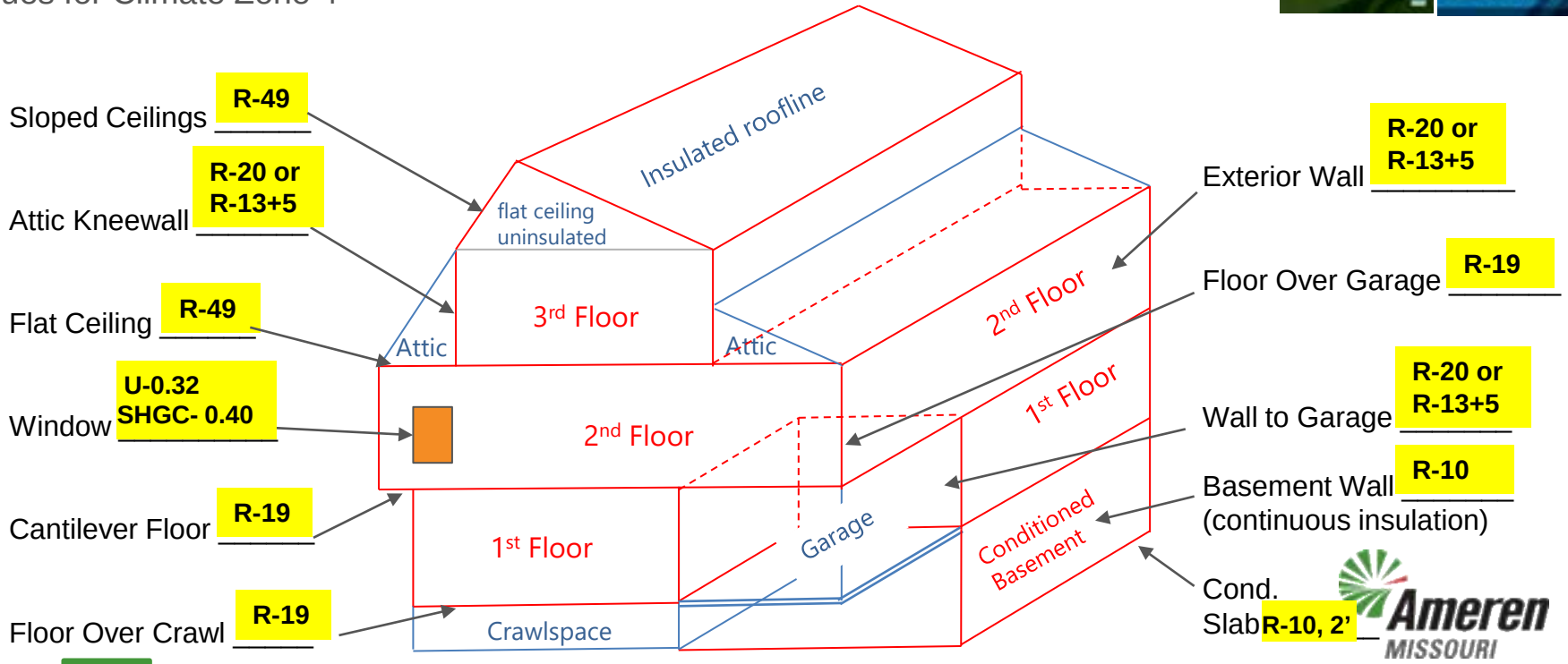
2018 IECC/IRC Prescriptive Code R-Values

Values for Climate Zone 4



Missouri Residential Energy Code Baseline Study

In 2016, the Midwest Energy Efficiency Alliance (MEEA) was contracted by the Missouri Department of Economic Development Division of Energy (DED/DE) to collect data about current Missouri residential construction practices as they relate to the **2009 International Energy Conservation Code (IECC).**

5

Patterns of Noncompliance

The study found five **"patterns of noncompliance"** in which buildings failed to meet 2009 standards:

1. **Duct Leakage** (unconditioned space)
2. **Duct Sealing** (conditioned space)
3. **Exterior Wall Insulation Installation Quality**
4. **High Efficacy Lights**
5. **Basement Wall Insulation**

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Section 402.2: Insulation Requirements

- Details for insulating various aspects of the building envelope:
  - **Ceilings with Attic – 402.2.1**
  - **Ceilings w/out Attic – 402.2.2**
  - **Eave baffles – 402.2.3**
  - **Access hatches and doors– 402.2.4**
  - Mass Walls – 402.2.5
  - Steel Framing – 402.2.6
  - Partial Structural sheathed walls – 402.2.7
  - **Floors – 402.2.8**
  - **Basement Walls – 402.2.9**
  - Slab-on-grade – 402.2.10
  - **Crawlspace Walls – 402.2.11**
  - Masonry Veneer – 402.2.12
  - Sunrooms – 402.2.13

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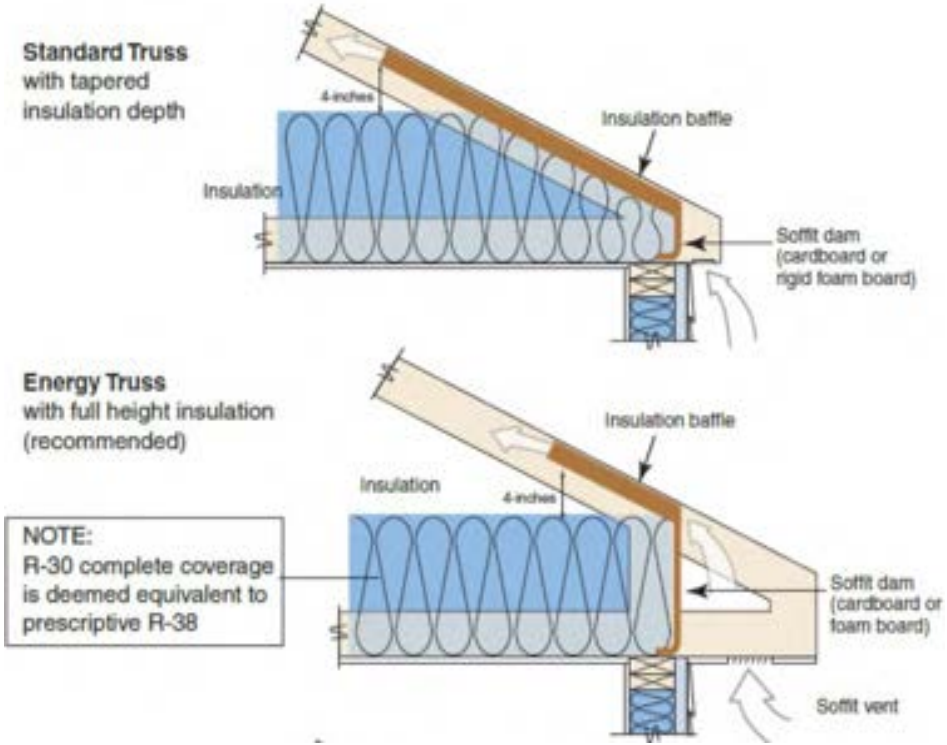
402.2.1 - Ceilings with Attics

- R-30 (CZ3) and R-38 (CZ4) is prescriptive requirement.
  - 2018 values are R-38 and R-49, respectively.
- Rulers required every 300 s.f.

402.2.1 Ceilings with Attics



R402.2.1 Ceilings with attic spaces. Where Section R402.1.2 would require R-38 insulation in the ceiling, installing R-30 over 100 percent of the ceiling area requiring insulation shall be deemed to satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Similarly, where Section R402.1.2 would require R-49 insulation in the ceiling, installing R-38 over 100 percent of the ceiling area requiring insulation shall be deemed to satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

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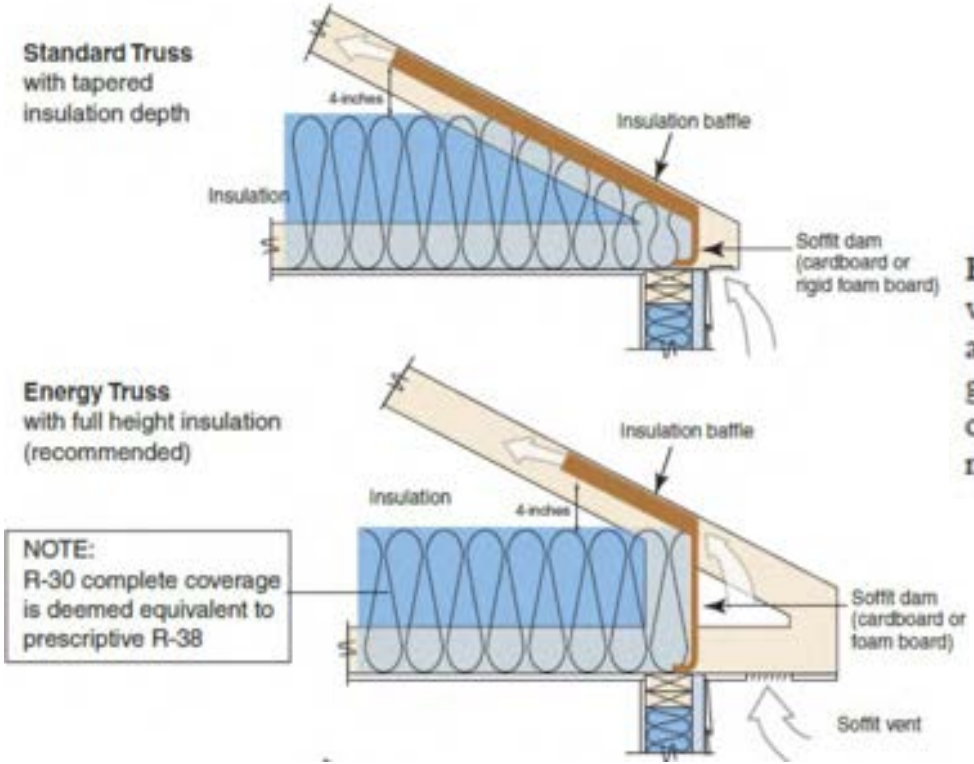
402.2.3 Eave Baffles



R402.2.3 Eave baffle. For air-permeable insulations in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain an opening equal or greater than the size of the vent. The baffle shall extend over the top of the attic insulation. The baffle shall be permitted to be any solid material.

402.2.2 - Ceilings without Attics

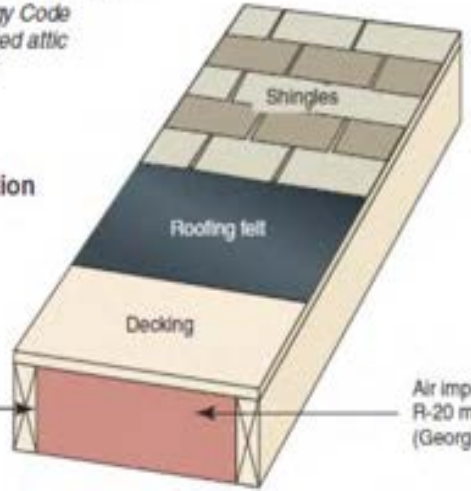
- R-30 for 20% (up to 500 s.f.) acceptable for CZ4&5
- Vaulted ceilings and foam sprayed rooflines will need to perform an R-value trade-off

Roofline Installed Insulation Options

Reference Table 402.1.1 and 402.1.6 in the Georgia Energy Code amendments to the 2015 IECC and Section 806.5 "unvented attic assemblies" in the IRC

R402.2.2 Ceilings without attic spaces. Where Section R402.1.2 requires insulation *R*-values greater than R-30 in the ceiling and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation *R*-value for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed. This reduction of insulation from the requirements of Section R402.1.2 shall be limited to 500 square feet (46 m²) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the Total UA alternative in Section R402.1.5.

Vaulted unvented attic – roofline air-impermeable insulation
(e.g., spray foam insulation)



Air impermeable insulation (e.g., open- or closed-cell spray foam)

Air impermeable insulation R-20 minimum if trade-offs are used (Georgia requirements)

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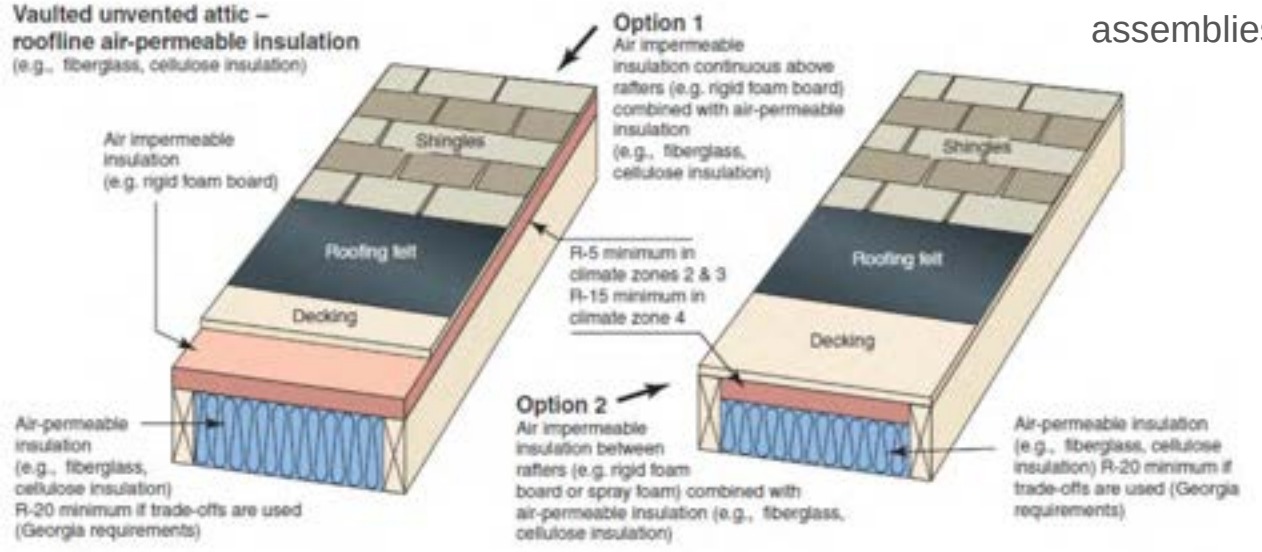
402.2.2 - Ceilings without Attics

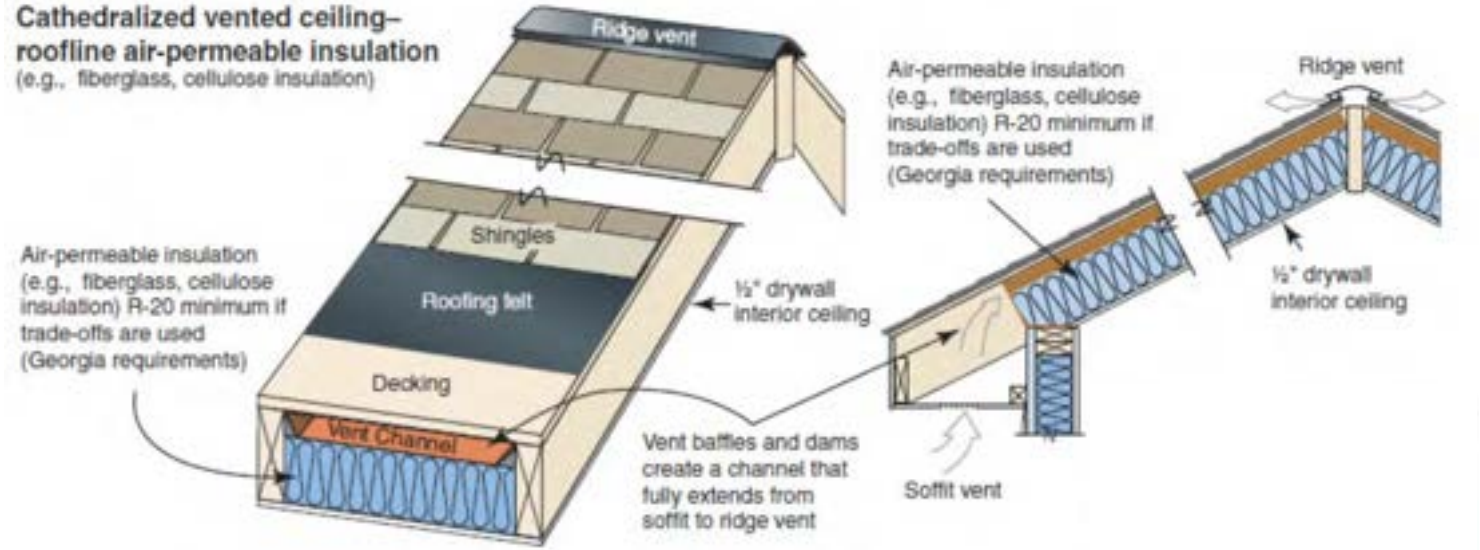
- Can use fiberglass or cellulose in vault for unvented roofs (air-permeable insulation) with added:
  - R-15 (CZ 4) rigid foam board

Reference IRC Section 806.5 unvented attic assemblies



402.2.2 - Ceilings without Attics

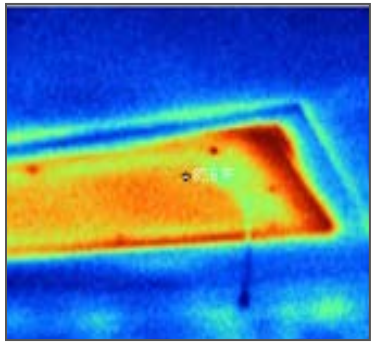
- Old school approach



402.2.4 Access Hatches and Doors

- Attic access cover at same R-value as ceiling

- For an attic with 990 s.f. = R-38, and 10 s.f. = R-1, Effective R-value = R-29!

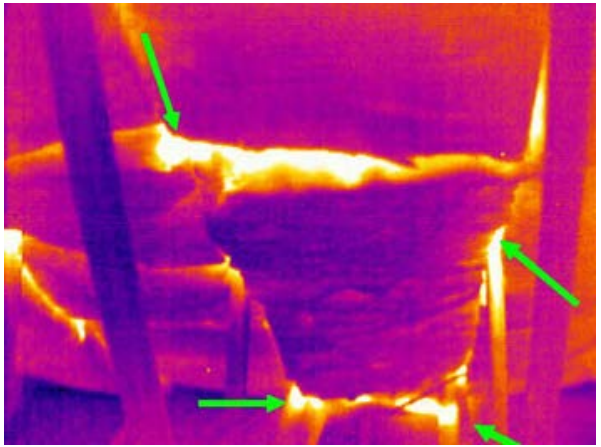


402.2.8 Floors

- Insulation must maintain ***continuous permanent*** contact against subfloor.

R402.2.8 Floors. Floor framing-*cavity insulation* shall be installed to maintain permanent contact with the underside of the subfloor decking.

Exception: As an alternative, the floor framing-*cavity insulation* shall be in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing where combined with insulation that meets or exceeds the minimum wood frame wall *R*-value in Table R402.1.2 and that extends from the bottom to the top of all perimeter floor framing members.



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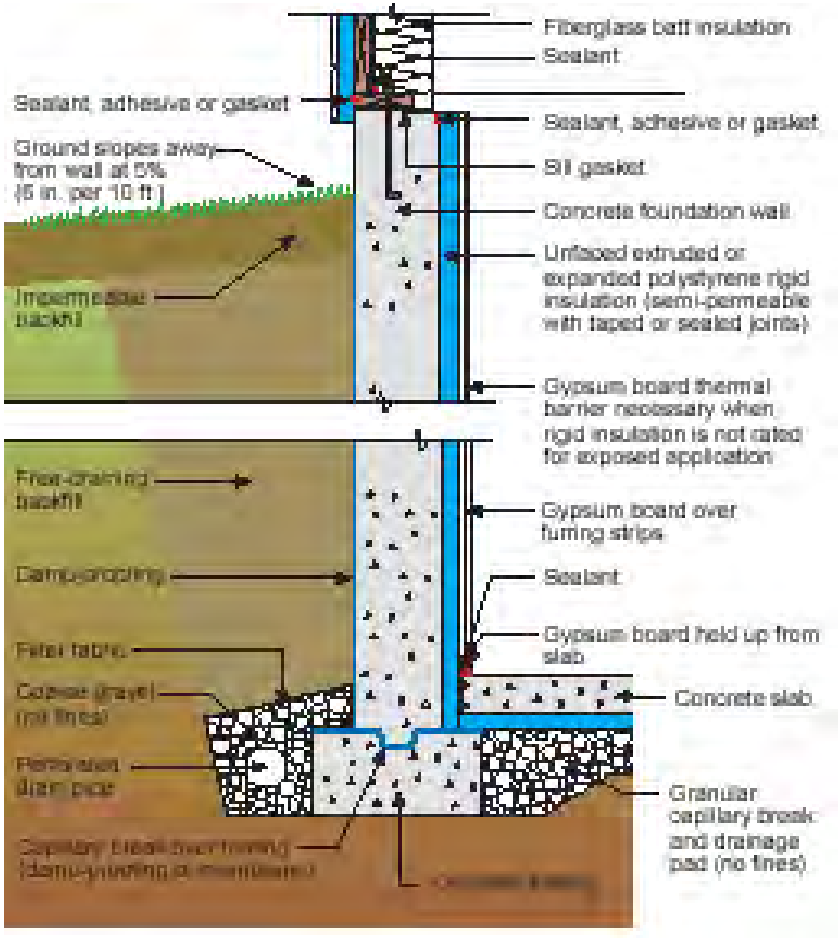
Reality of Underfloor Insulation

Insulating Basements

www.eeba.org
www.buildingscience.com



Systems Approach to Walkout Basements

Advantages to insulating *all* basement walls:

- Wall insulation lasts longer and works well (R-10 wall in CZ4 vs. R-19 floor)
- Ducts and AHU are brought inside envelope
- Main floor level is more comfortable
- Basement may be finished or unfinished

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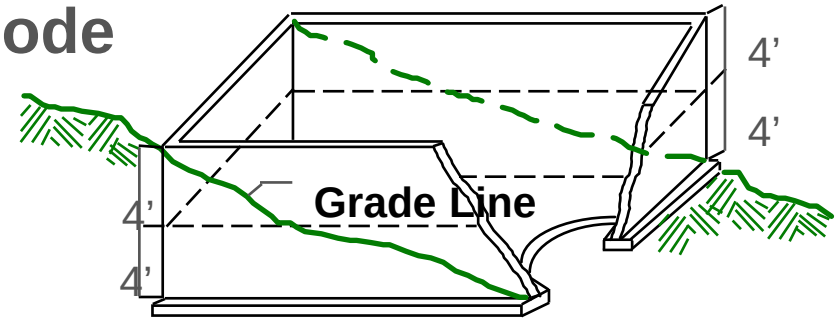
Definition and Prescriptive Code

- Basement Wall: Average gross wall must be > 50% below grade and enclose conditioned space
- CZ4-5: R-10 continuous or R-13 cavity
  - 2018 CZ5=R-15/19

Try to avoid cavity insulation; continuous insulation performs better



Interior Insulation Strategies

Cellulose blanket/batt

Rigid foil-faced poly-iso foam board

Fiberglass batt w/ vinyl backing

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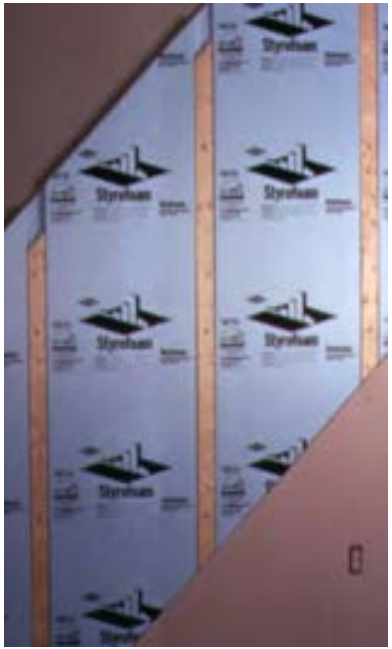
Interior Insulation Strategies

Rigid foam board



Fiberglass batt in AGW, foam board on concrete

Spray Polyurethane Foam

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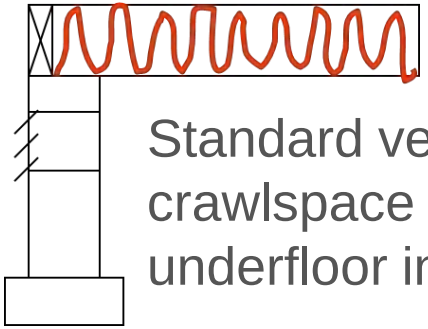
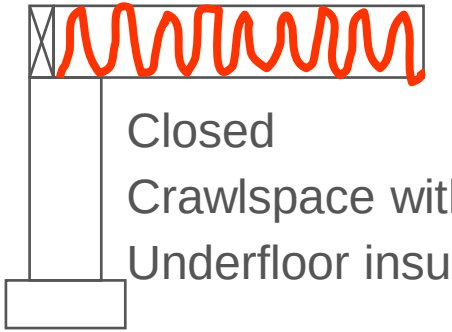
Interior Insulation Strategies

Blanket Basement Insulation Options

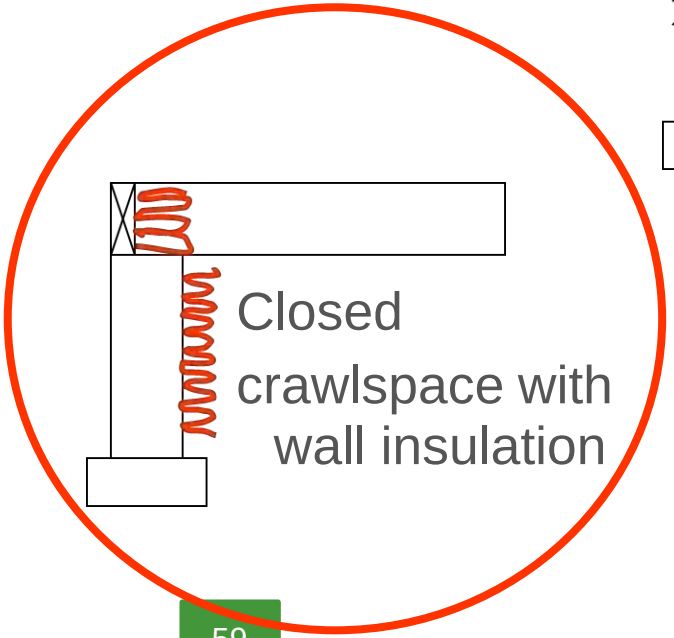
R402.2.11 Crawlspace Walls



Standard vented crawlspace - underfloor insulation



Closed Crawlspace with Underfloor insulation



Closed crawlspace with wall insulation

- **Note**: all crawspaces must meet vapor retarder requirements, as per IRC (exception for open crawlspaces)

R402.2.11 Crawlspace Walls

- Seal ground with 6-mil plastic (6” up walls, 6” overlaps)
- Insulate interior of walls to satisfy code (R-10 in CZ4, R-15 in CZ5)
- Eliminate all vents and leaks (access doors)
- Satisfy IRC exception to vent requirement (IRC section R408.3)

Venting Exceptions:

- Continuous exhaust (radon)
- Direct condition crawlspace (supply)
- Direct condition (dehumidifier)

Critical Details:

- No drainage problems
- Use a sealed combustion / direct vent furnace or install a Heat Pump
- Pest Control and Code Official awareness

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Insulation techniques – Walls

www.crawlspaces.org

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Insulation techniques – Band area

Open/
Closed
Cell Foam

Caulk and
Fiberglass
Batt

- Must air seal and insulate rim/band area in basements & crawlspaces

Blown
Bag /
Pillow

The band-joist area can be a challenge to insulat correctly, with some contractors opting for fiberglass batt rather than the complications of spray foam. For installers working with blown fiberglass or cellulose, National Fiber offers another option. Its Insul-Cube is a fire-rated bag can be filled with blown insulation on-site, then friction-fit between the joists. The amount of insulation used will vary according to the size of the space, and the cubes can be filled-in-place behind pipes or wires. National Fiber |

- Pest Control industry struggles with band area fully filled with SPF
- SPF that fills band blocks inspection for pest control
- Air seal and then insulate with movable insulation product (batts, pillows, rigid board, etc.)

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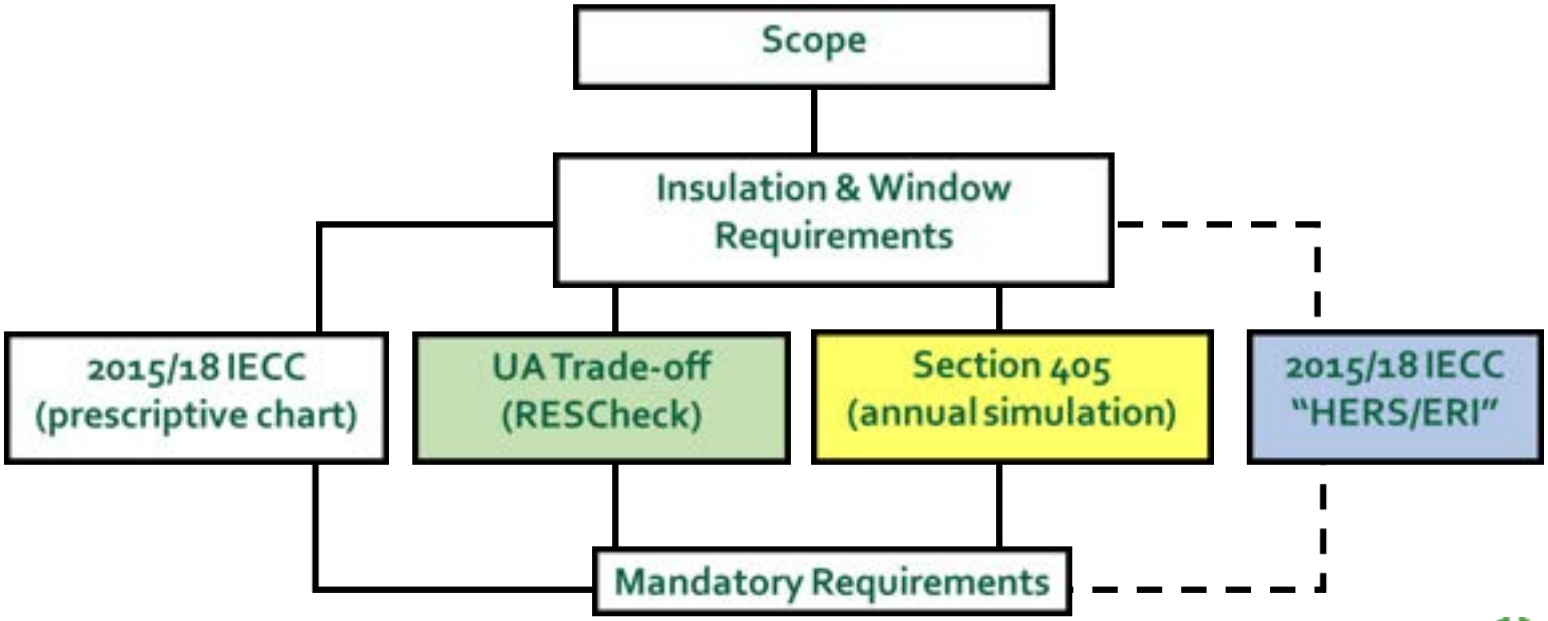
Envelope Tradeoff Options



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RECcheck Tradeoff Option

- www.energycodes.gov
- Software evaluates specific designs quickly
- Demonstrates SHGC compliance
- Allows trade-offs
  - Building envelope components
  - No trade-offs for better heating & cooling equipment efficiencies
- Specify code edition

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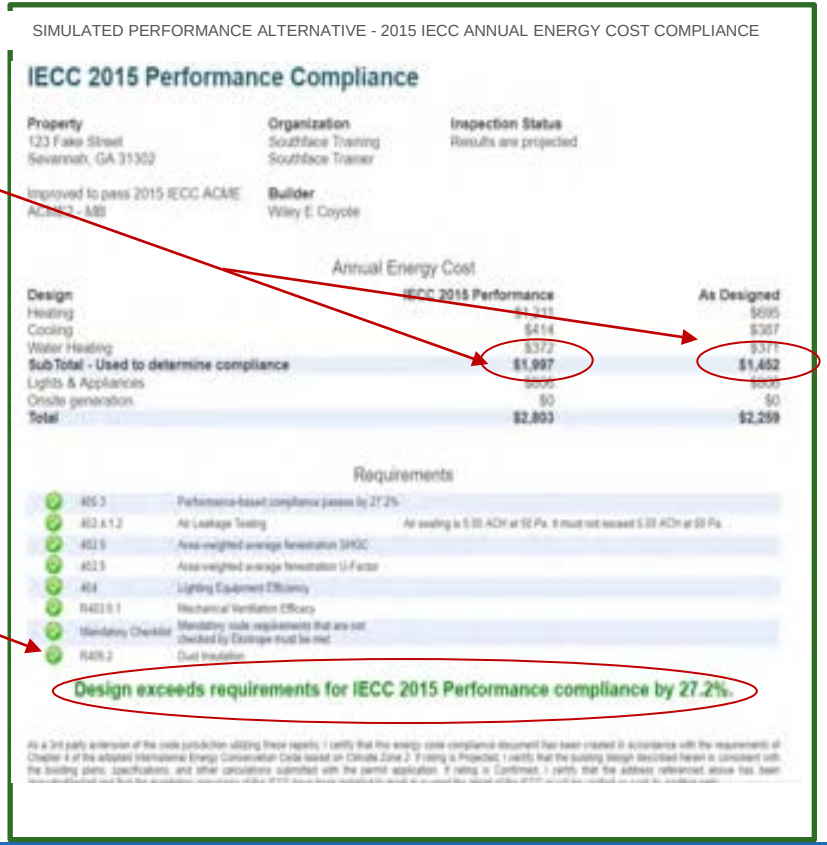
Section 405 Simulated Performance Alternative - Sample Report

- Annual energy usage simulation demonstrates that the proposed building's energy costs are ≤ "standard code" building
- No credit for mechanical efficiencies
- Likely to involve a HERS rater
- Ekotrope, REMrate & Energy Gauge are acceptable

- Compares total annual energy costs
  - Window U-factor and SHGC
  - Envelope and duct testing
  - Lighting, duct insulation
- Compares energy costs of actual home being built against 2015/18 IECC reference home's energy cost



SIMULATED PERFORMANCE ALTERNATIVE - 2015 IECC ANNUAL ENERGY COST COMPLIANCE

IECC 2015 Performance Compliance

Property	Organization	Inspection Status
123 Fake Street Savannah, GA 31302	Southface Training Southface Trainer	Results are projected

Improved to pass 2015 IECC ACME

Builder
Wiley E Coyote

Annual Energy Cost

Design	IECC 2015 Performance	As Designed
Heating	$1,318	$695
Cooling	$414	$387
Water Heating	$372	$371
SubTotal - Used to determine compliance	**$1,997**	**$1,452**
Lights & Appliances	$806	$806
Onsite generation	$0	$0
Total	**$2,803**	**$2,259**

Requirements

Design exceeds requirements for IECC 2015 Performance compliance by 27.2%.

Energy Rating Index (ERI) path

The ERI may allow more options in materials choice, technologies and innovative strategies than the simulated performance path

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

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How is the ERI determined?

- The ERI is a numerical integer value
- Lower index numbers indicate lower energy use
- The HERS Index is currently accepted for use as the ERI
- A HERS Index is generated from a HERS Rating using modeling software (e.g., Energy Gauge, REMRate, Ekotrope)
- HERS stands for *Home Energy Rating System*

RESNET HERS® INDEX

HERS was developed by the Residential Energy Services Network (RESNET)

www.resnet.us

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Determining 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)

Index = 100 x $PE_{fraction}$ x $\frac{\text{[}\textbf{\textit{Rated}}\text{ Home's Htg + Clg + WtrH + L.A.]}}{\text{[}\textbf{\textit{Refer}}\text{. Home's Htg + Clg + WtrH + L.A.]}}$ = 75

40 30 30 50

70 20 30 80

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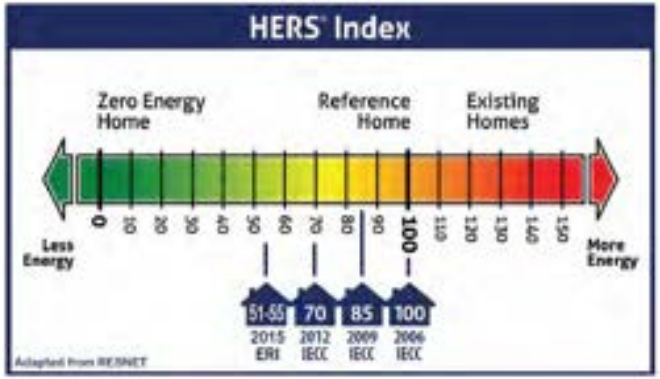
HERS / Energy Rating Index – What does it mean?

- HERS Index (lower is better)
- Rated home with Index of 100 = Reference home exactly meeting 2004/06 IECC
- Net Zero Energy Home = HERS Index of O



$$\textbf{Index} = 100 \times PE_{fraction} \times \frac{\underline{[\textbf{\textit{Rated}} \text{ Home's Htg} + \text{Clg} + \text{WtrH} + \text{L.A.}]}}{[\textbf{\textit{Refer}}. \text{ Home's Htg} + \text{Clg} + \text{WtrH} + \text{L.A.}]} = 75$$

40 30 30 50

70 20 30 80

$PE_{fraction}$ is ratio of renewables to purchased energy

(e.g, a home that produces 20% of its annual energy would have a $PE_{fraction}$ of 0.8)
In this example, 0.8 x 75 = **60**

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Energy Rating Index: Target Values

- The 2015/18 IECC sets a maximum ERI for each climate zone
- The ERI is not a “magic bullet” or “easy”
- However, it opens more options and allows builders more credit for innovative strategies (“*the ERI shall consider all energy used in the residential building*”)

TABLE R406.4
MAXIMUM ENERGY RATING INDEX

CLIMATE ZONE	ENERGY RATING INDEX	ENERGY RATING INDEX[a]
1	52	57
2	52	57
3	51	57
4	54	62
5	55	61
6	54	61
7	53	58
8	53	58

The rated design must have an ERI less than or equal to the above table to comply with 2015/18 IECC

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Summary of the Energy Rating Index

1. **2018 IECC targets**
   - Low 60's
2. **Who Can Do This?**
   - 3rd party – HERS Rater
   - Approved software
3. **Benefits**
   - Greater design flexibility
   - High efficiency equipment and appliances credited
4. **Backstops**
   - Envelope cannot be traded to be worse than 2009 IECC
   - Mandatory Requirements (air sealing, duct insulation, sealing, testing, etc.)

CLIMATE ZONE	ENERGY RATING INDEX[a]
4	62
5	61

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Blower Door Envelope Testing

- **IECC 2009 threshold: < 7 ACH50**
- **IECC 2012–18 threshold: < 3 ACH50**
- Quantifies the Amount of Leakage Across the Home's Thermal Boundary
- Should be administered by a Certified Professional (e.g., DET Verifier, BPI, HERS)
- Reported to Builder and Code Official via Certificate

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

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Approximate Leakage Area

Approximate hole size is a great way to describe what CFM_{50} really means.

Divide CFM_{50} by 7.495

- *For example:*
  4,247 CFM_{50} / 7.495
  = 567 sq. in.
- Divide by 144 to get ~**4 s.f.**

Southface Shortcut:

- Divide CFM_{50} by 1000
- *For example:*
  4,247 CFM_{50} / 1000
  = ~4.2 s.f.

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How to Fail a Blower Door Test

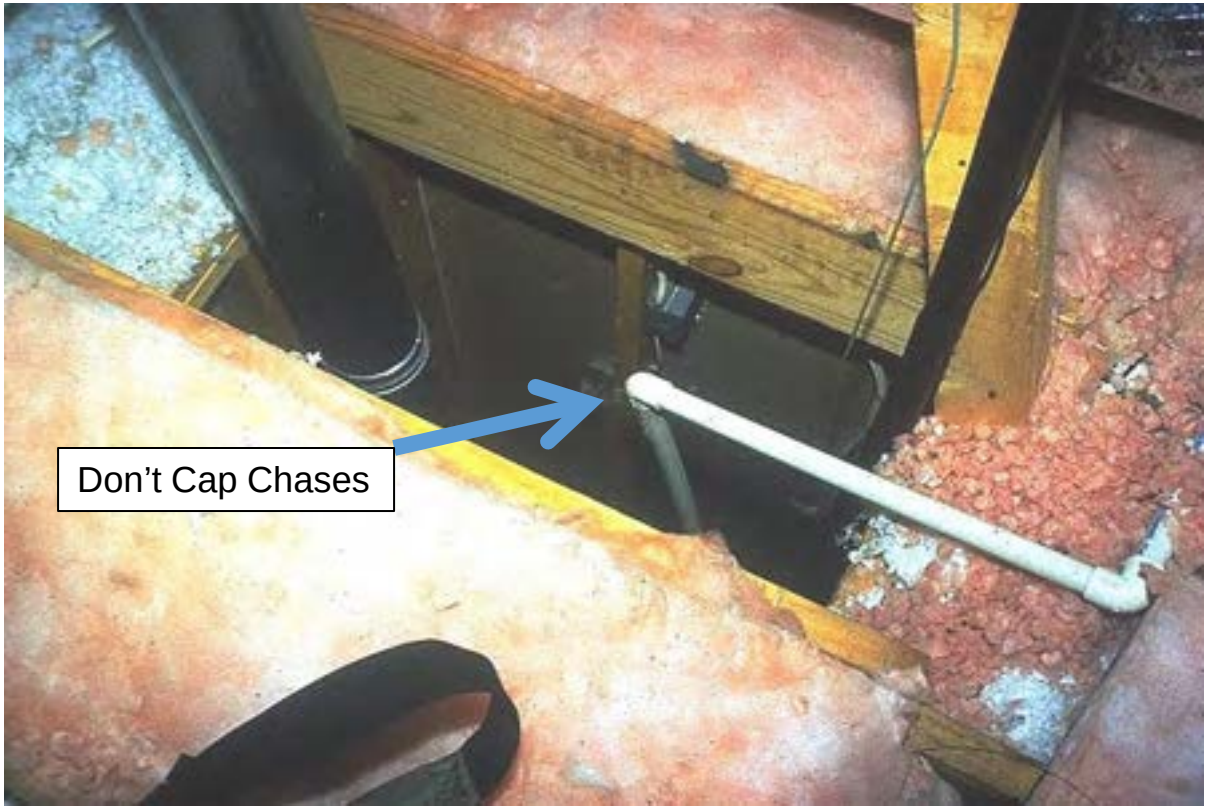
How to Fail a Blower Door Test

How to Fail a Blower Door Test

How to Fail a Blower Door Test

How to Fail a Blower Door Test

How to Fail a Blower Door Test



Air Sealing: Best Practices

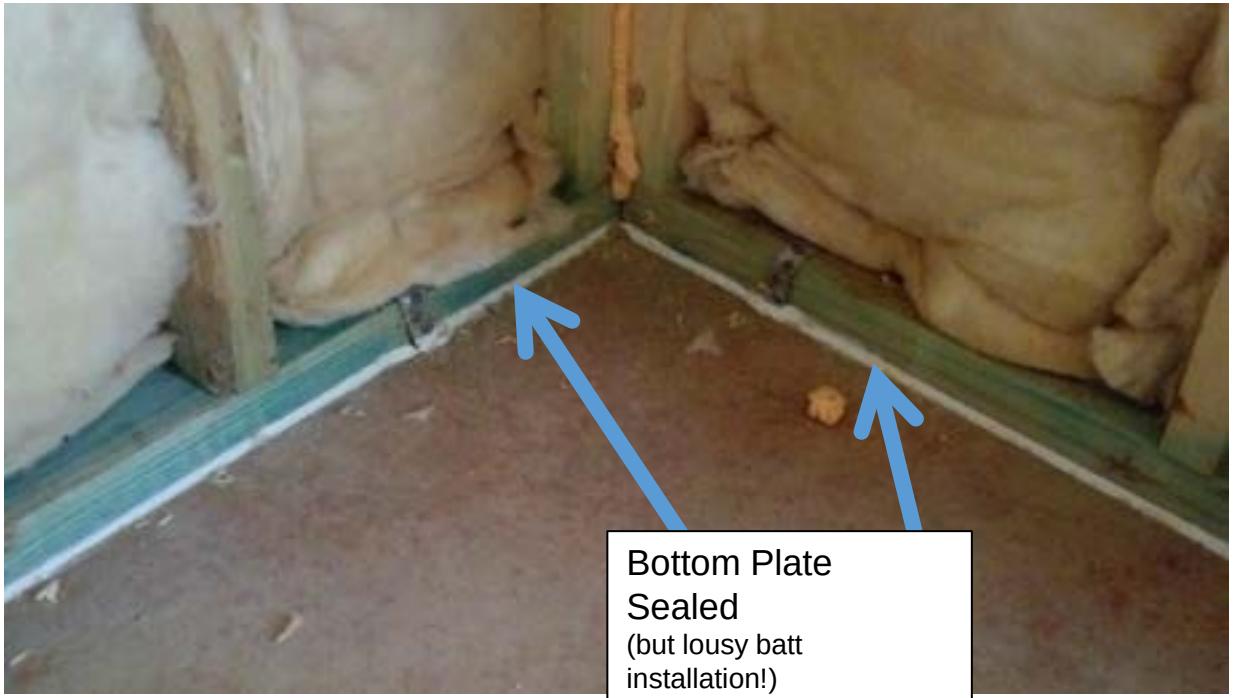
Chases

Chase capped and sealed around duct

Tubs

Framing & Penetrations

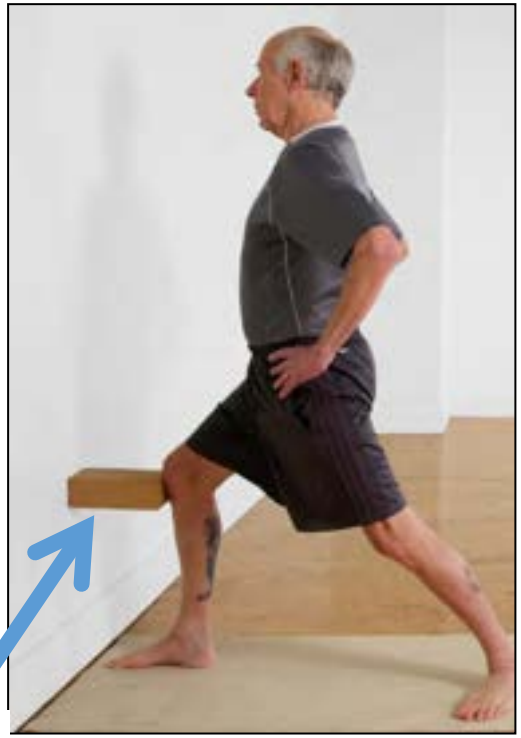
Bottom Plate



Kneewall Blocking

Install Kneewall Blocking

Not This!

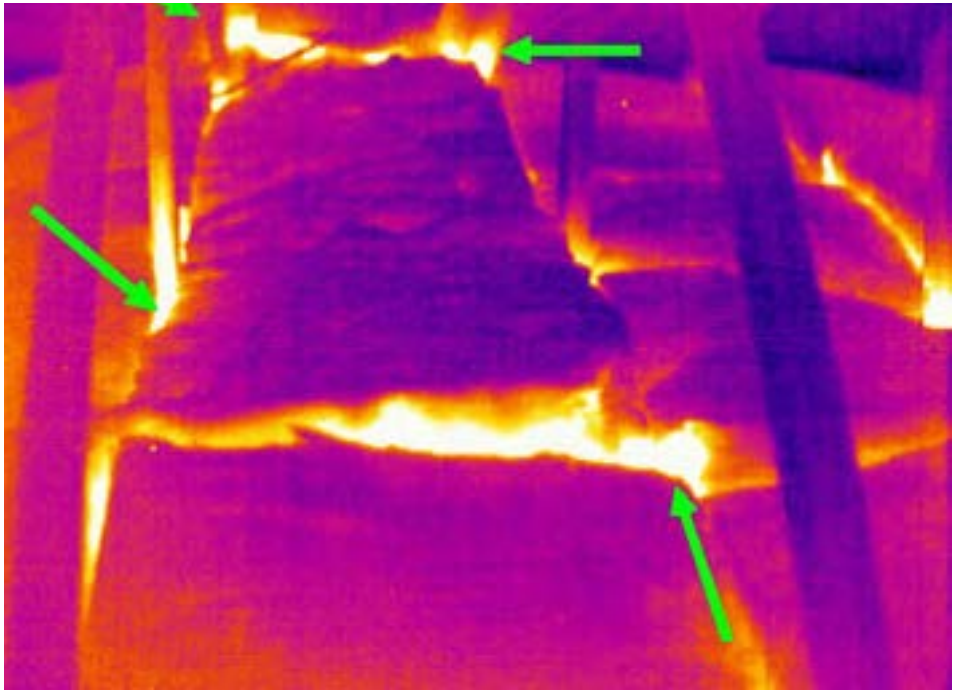


Installing Insulation

- Voids / Gaps
- Compression / Incomplete Fill

Continuous Insulation & Air Barrier

- Building Thermal Envelope
  (air barrier and insulation must be in contact)



What's Wrong with This Picture?

Insulation Installation: Grade I, II, or III

- Unless verified, assume Grade III (worst) – see RESNET Appendix A-11-16

installation shall be *at least* this good to be labeled as "Grade III":

No more than 2% of surface area of insulation missing is acceptable for "Grade II"

"Grade I":

Occasional very small gaps are acceptable for "Grade I".

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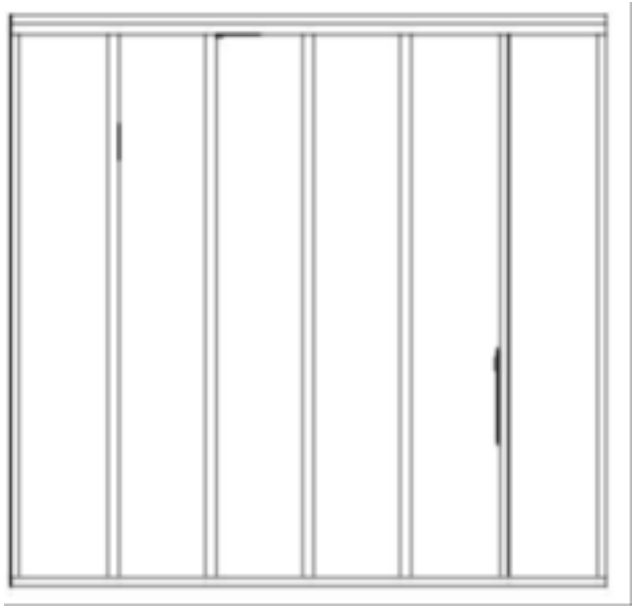
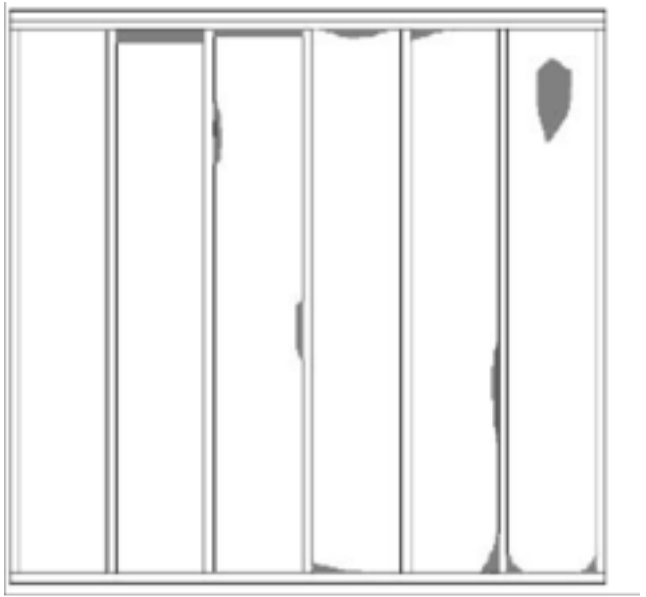
Grade I

RESNET Appendix A-11 - A-13

- occasional very small **gaps/voids**
- less than 2% **compression/incomplete fill**
  (which may not be more than 30% compressed)



Gaps

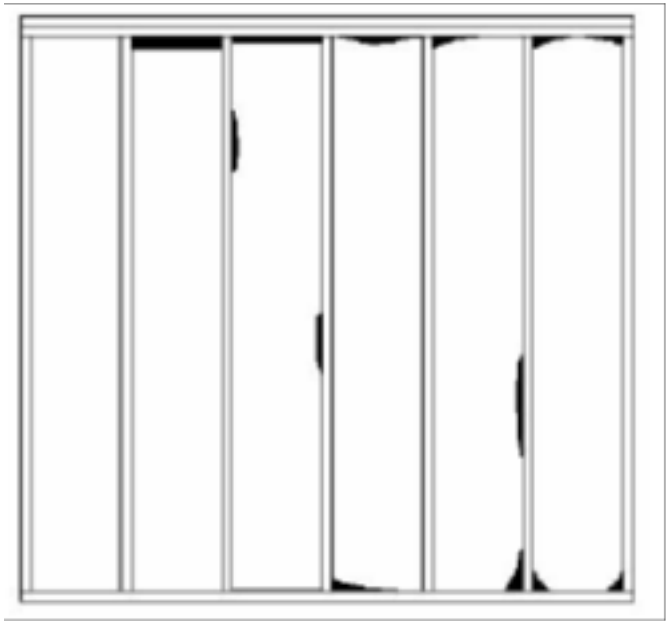


Compression

Grade II

RESNET Appendix A-13 - A-15

- <2% **gaps/voids**
- <10% **compression/incomplete fill**
  (which may not be more than 30% compressed)

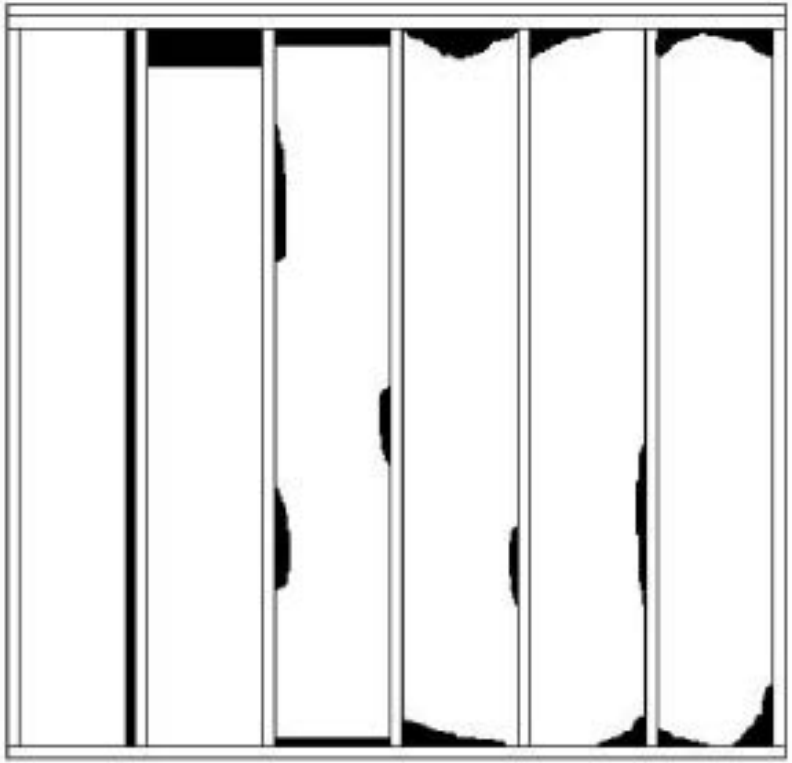


Gaps

Compression

Grade III

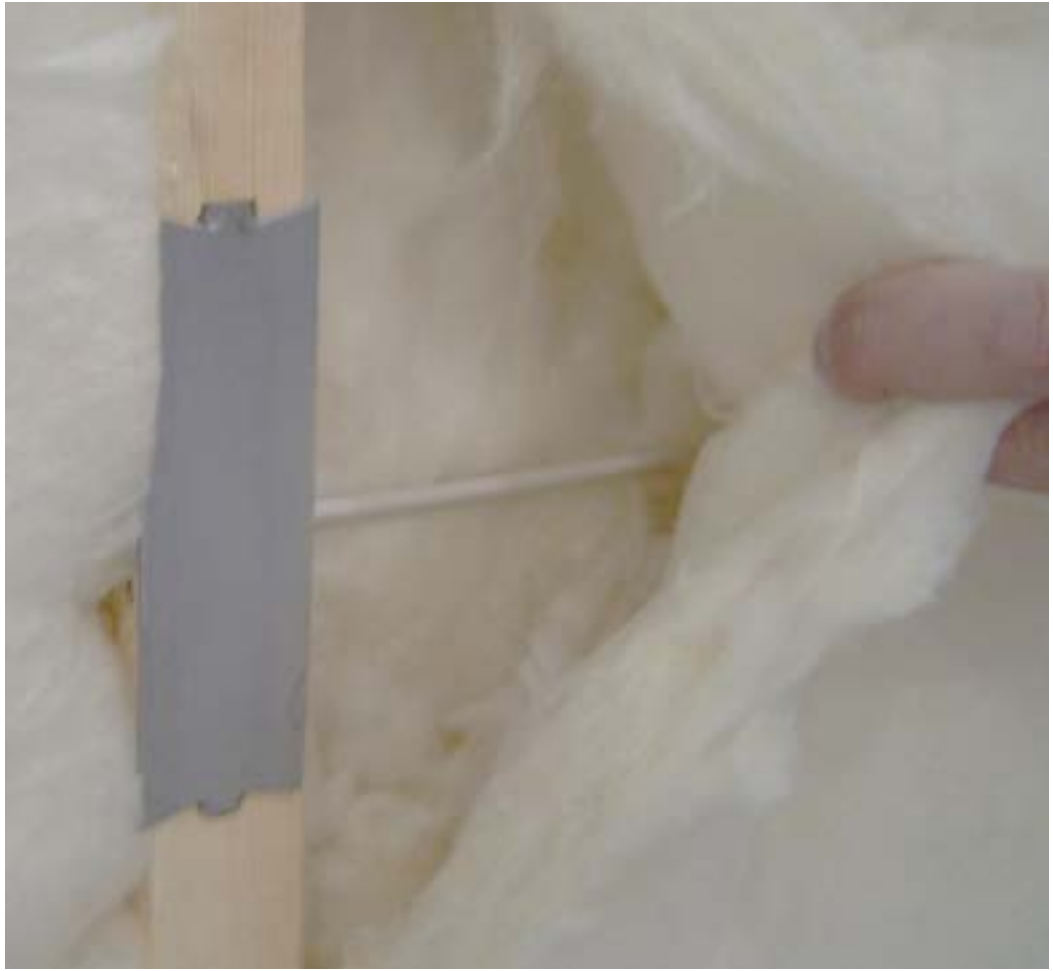
RESNET Appendix A-15 - A-16



Gaps

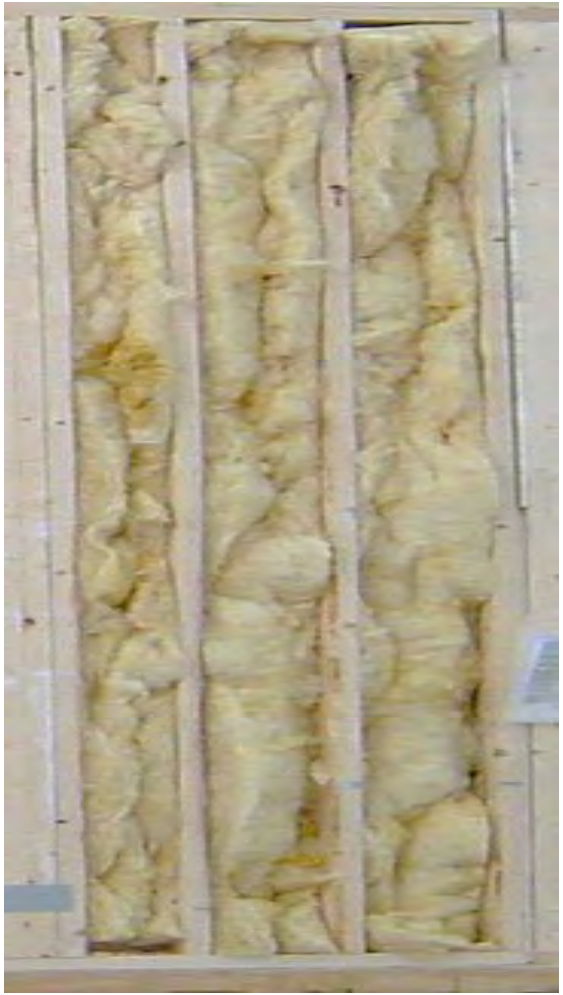
- > 2% and ≤ 5% **gaps/voids**
- (greater than 5% = downgraded R-value)
- 10% or worse **compression/incomplete fill**

What Grade?



What Grade?

What Grade?



What Grade?

What Grade?

What Grade?

What Grade ?

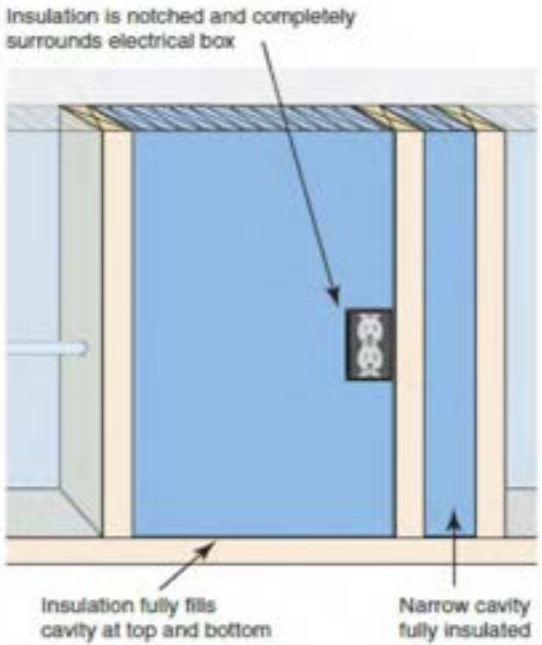
What Grade?

Voids & Gaps

Wall Insulation key points

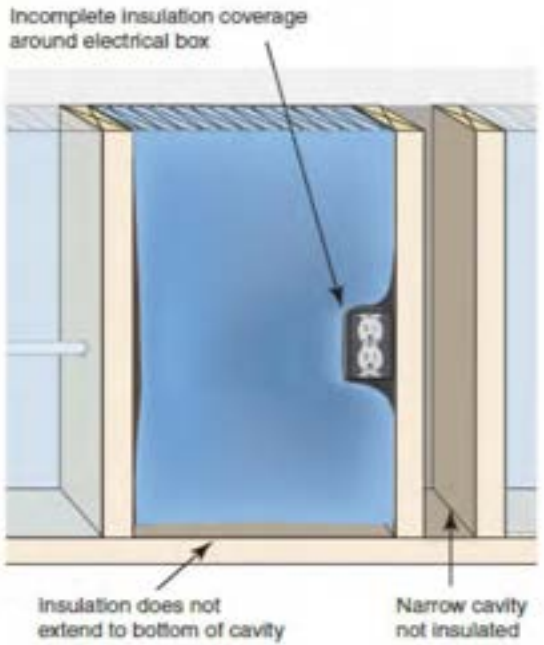
Voids / Gaps

Passing Grade



Good!!!

Unacceptable Installation



Bad!!!

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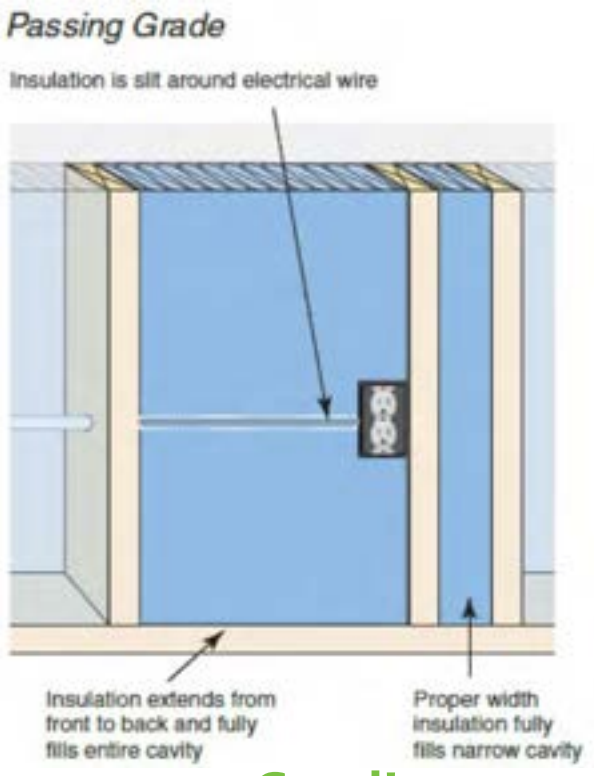
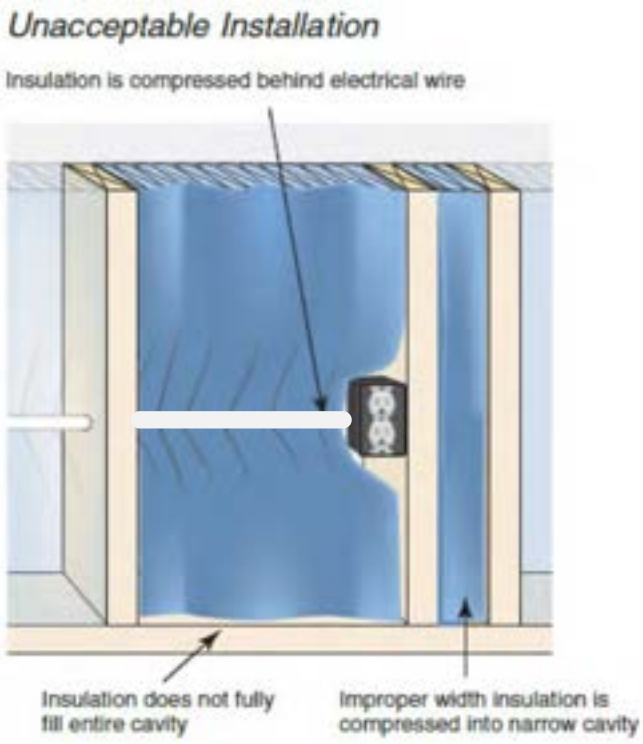
Compression & Incomplete Fill



Good!



Bad!

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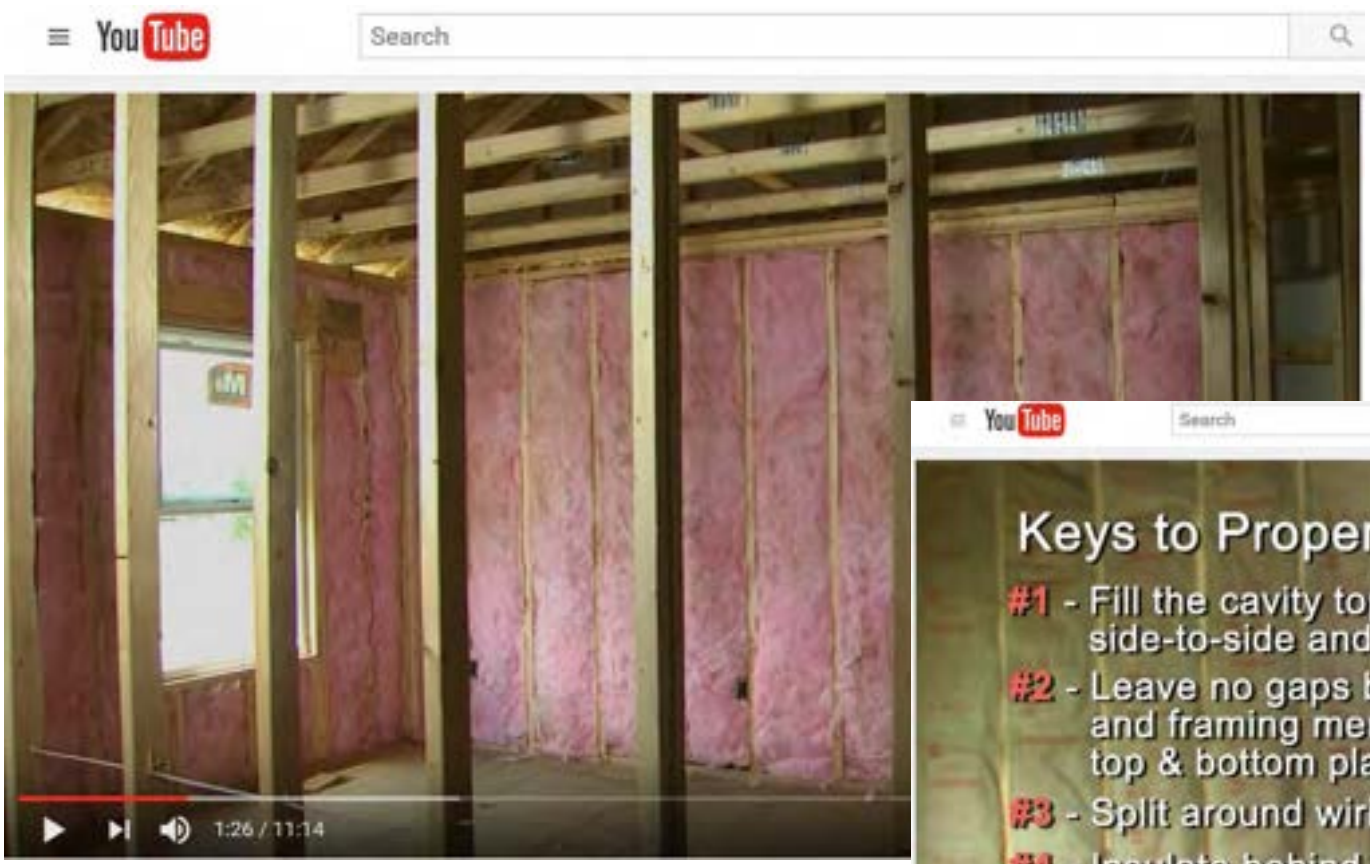
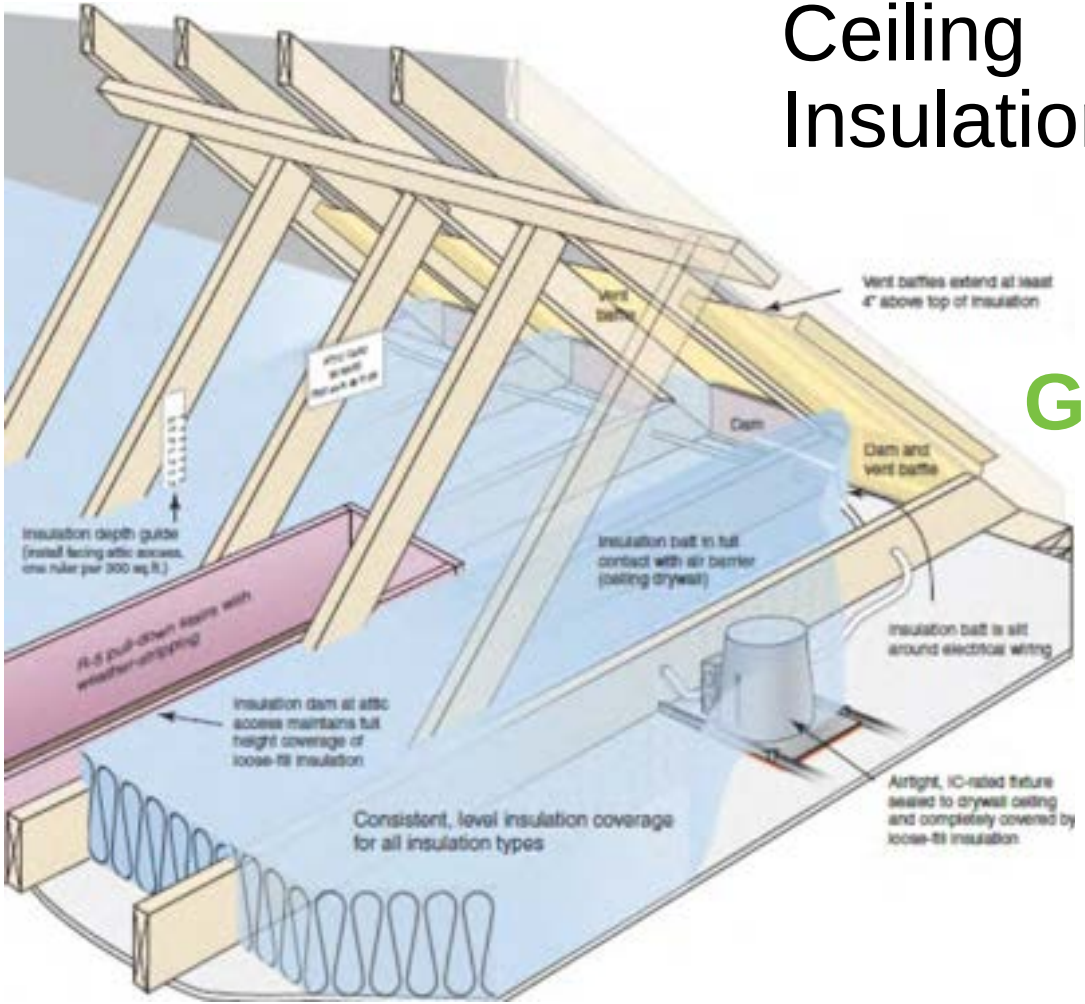
Installation Videos

Installation Videos



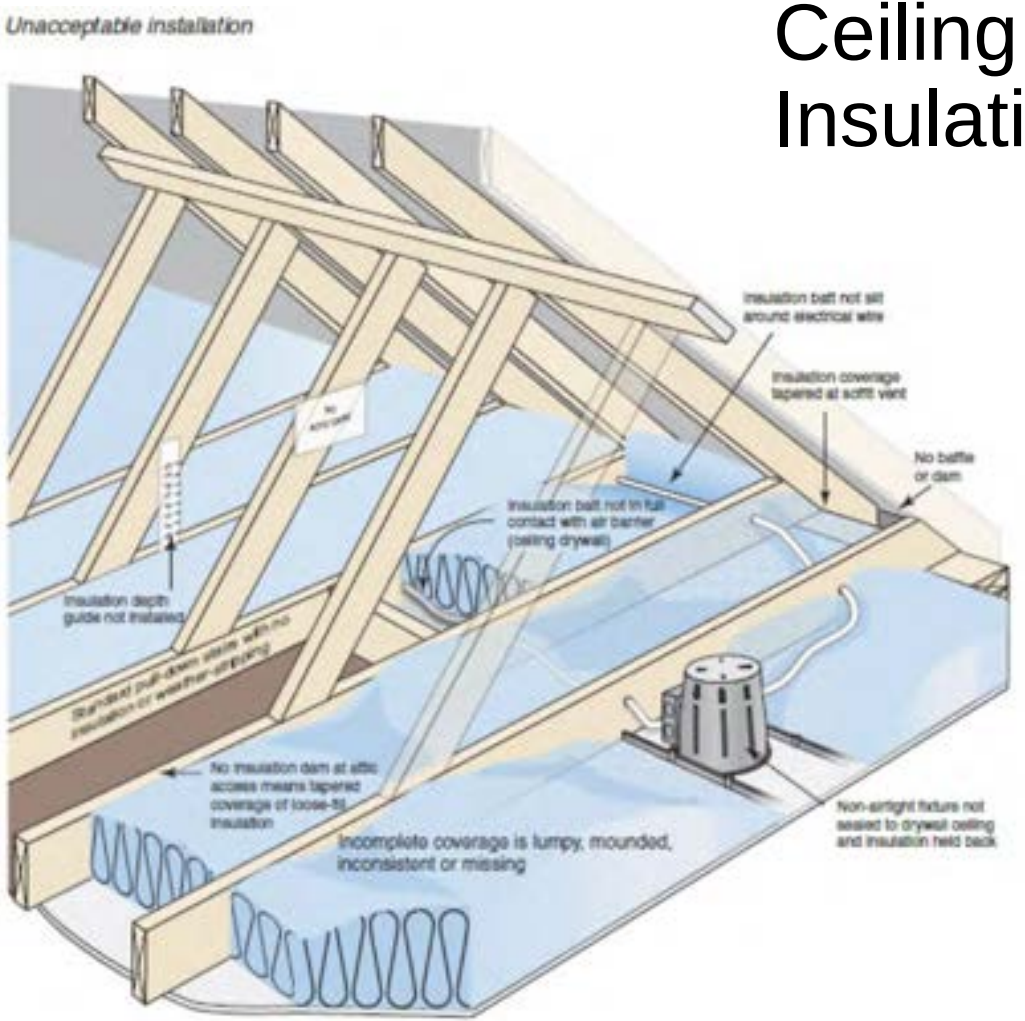
Ceiling Insulation



GOOD!

See IECC R303.1

Ceiling Insulation



BAD!

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Ugly Ceiling Insulation

Conduction Heat Flow

Heat transfer through a solid object: the formula for calculating conduction heat transfer is q = U x A x ΔT

q = heat flow (Btu/hr)

U = inverse of R-Value [U=1/R, R=1/U] (Btu/hr ft^2 °F)

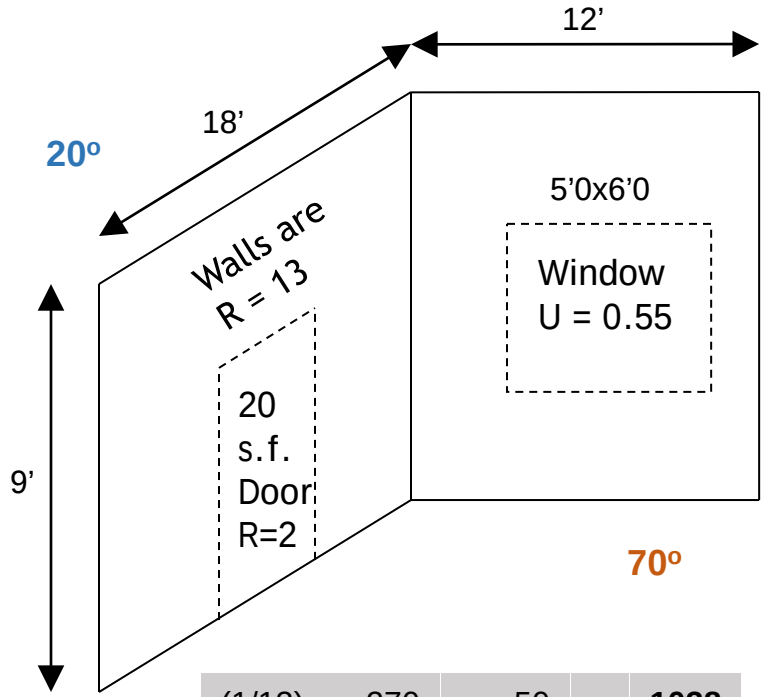
A = area (square feet)

ΔT = temperature difference across component (°F)

$$q = U \times A \times \Delta T$$

Manual J: q = A x HTM

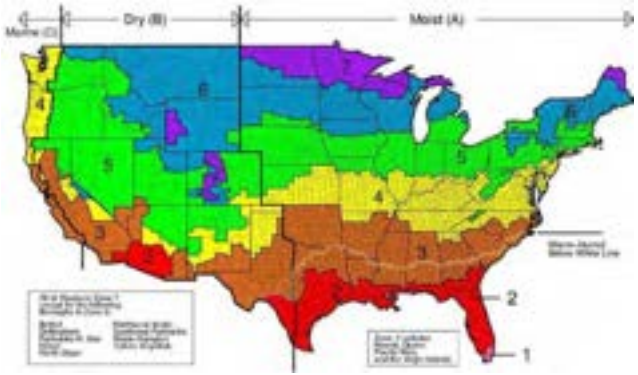
where HTM = UxΔT



	(1/13) x	270	x 50 =	**1038**
R	**U**	**Area**	**Delta T**	**q**
13	1/13	220	50	846
2	½	20	50	500
-	0.55	30	50	825
				2171

Climate and Energy Efficiency

Design Temps	W / S
Atlanta	24/92
St. Louis	14/91
Fairbanks	-40/78
Miami	51/90



- **Design Temperatures**
  - Heating, for 99% of the season the outdoor temperature is above this value
  - Only 1% of the Cooling season is hotter than this temperature value
- *Design Temp Example*
  - St. Louis Winter 70 – 14 = 56 F ΔT
  - St. Louis Summer 91 – 75 = 16 F ΔT
- **Load Calcs & Energy Code**
  - IECC 2009 Section 302.1: Interior design temperatures (72°F heating, 75°F cooling)
  - **MUST BE ACCURATE**

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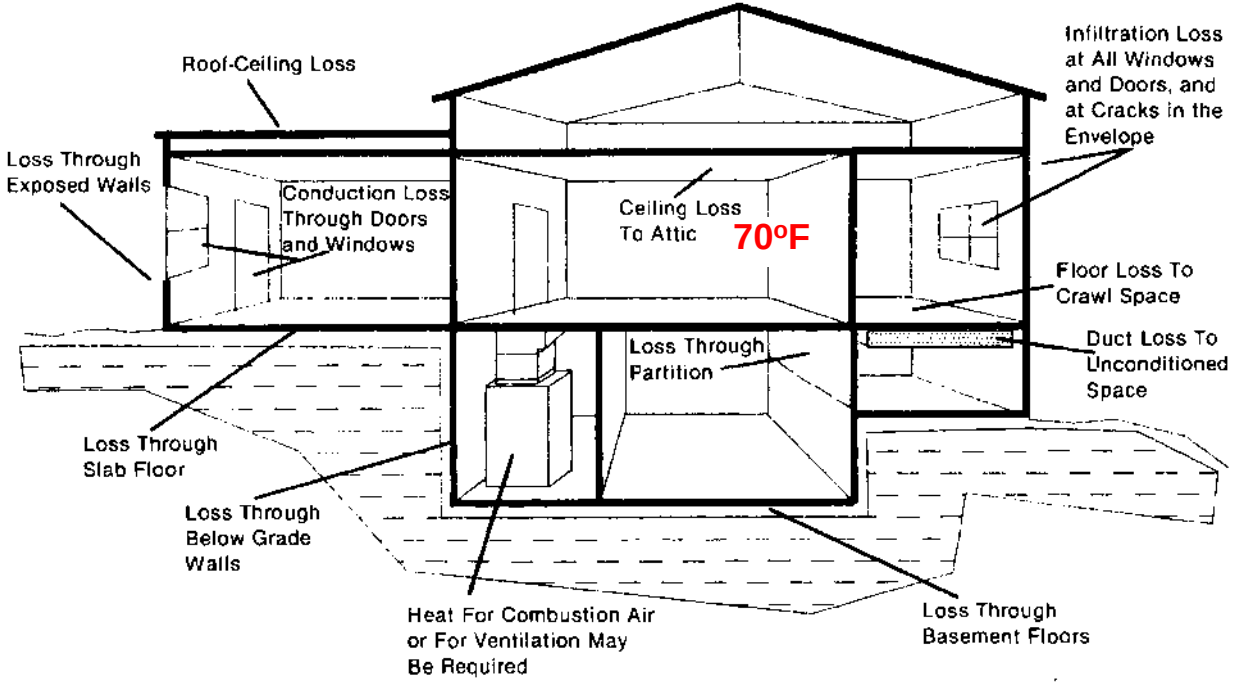
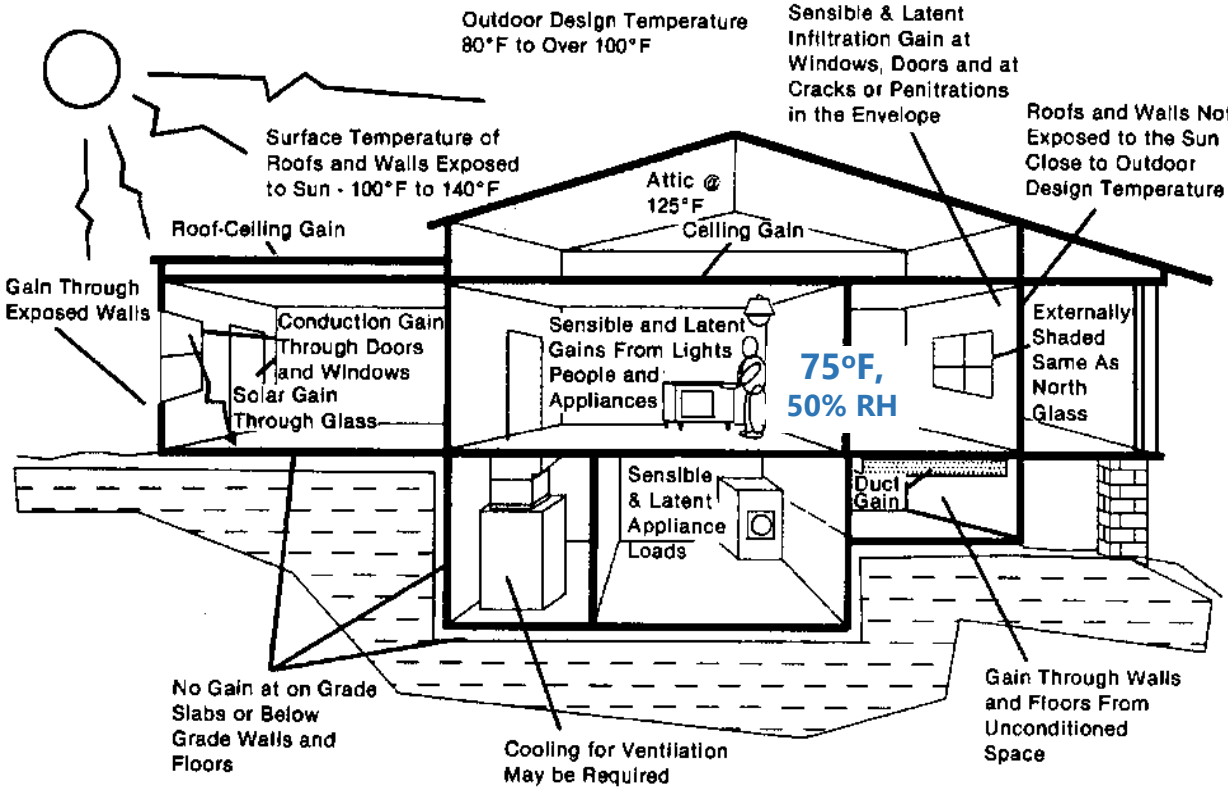
Manual J - Winter Loads



Winter Outdoor Design Temp

14ºF

Manual J- Summer Loads



Summer Outdoor Design Temp

91°F

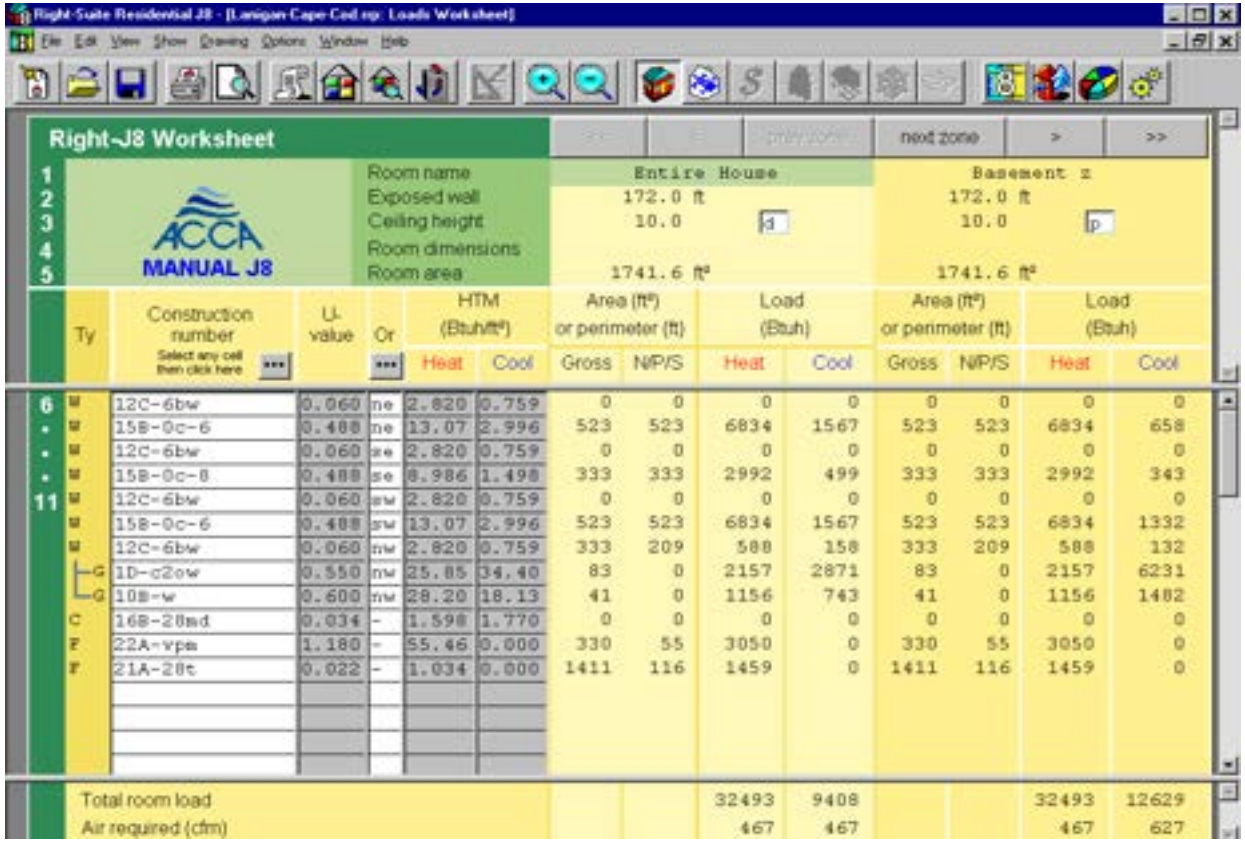
Sizing the System

“Heating and cooling equipment shall be sized in accordance with Section M1401.3”

“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.”
- 2015 IECC R403.7

- **Building orientation**
- **Glazing, walls, foundation & roof**
- **Design conditions**
- **Infiltration**
- **Internal loads**
- **Ventilation load**

Manual J Software



Right-Suite Residential J8 - [Lanigan Cape Cod.mjp: Loads Worksheet]

File Edit View Show Drawing Options Window Help

Right-J8 Worksheet

next zone > >>

ACCA MANUAL J8

							Entire House				Basement z			
1	Room name													
2	Exposed wall						172.0 ft				172.0 ft			
3	Ceiling height						10.0				10.0			
4	Room dimensions													
5	Room area						1741.6 ft²				1741.6 ft²			

	Ty	Construction number (Select any cell then click here)	U-value	Or	HTM (Btuh/ft²) Heat	HTM (Btuh/ft²) Cool	Area (ft²) or perimeter (ft) Gross	Area (ft²) or perimeter (ft) N/P/S	Load (Btuh) Heat	Load (Btuh) Cool	Area (ft²) or perimeter (ft) Gross	Area (ft²) or perimeter (ft) N/P/S	Load (Btuh) Heat	Load (Btuh) Cool
6	W	12C-6bw	0.060	ne	2.820	0.759	0	0	0	0	0	0	0	0
	W	15B-0c-6	0.488	ne	13.07	2.996	523	523	6834	1567	523	523	6834	658
	W	12C-6bw	0.060	se	2.820	0.759	0	0	0	0	0	0	0	0
	W	15B-0c-8	0.488	se	8.986	1.498	333	333	2992	499	333	333	2992	343
	W	12C-6bw	0.060	sw	2.820	0.759	0	0	0	0	0	0	0	0
	W	15B-0c-6	0.488	sw	13.07	2.996	523	523	6834	1567	523	523	6834	1332
	W	12C-6bw	0.060	nw	2.820	0.759	333	209	588	158	333	209	588	132
	G	1D-c2ow	0.550	nw	25.85	34.40	83	0	2157	2871	83	0	2157	6231
	G	10B-w	0.600	nw	28.20	18.13	41	0	1156	743	41	0	1156	1482
11	C	16B-28md	0.034	-	1.598	1.770	0	0	0	0	0	0	0	0
	F	22A-vpm	1.180	-	55.46	0.000	330	55	3050	0	330	55	3050	0
	F	21A-28t	0.022	-	1.034	0.000	1411	116	1459	0	1411	116	1459	0
	Total room load								32493	9408			32493	12629
	Air required (cfm)								467	467			467	627

Why is proper equipment sizing important?

- Equipment first-cost
- Longer/more efficient run times
- Limits equipment cycling
- Better dehumidification

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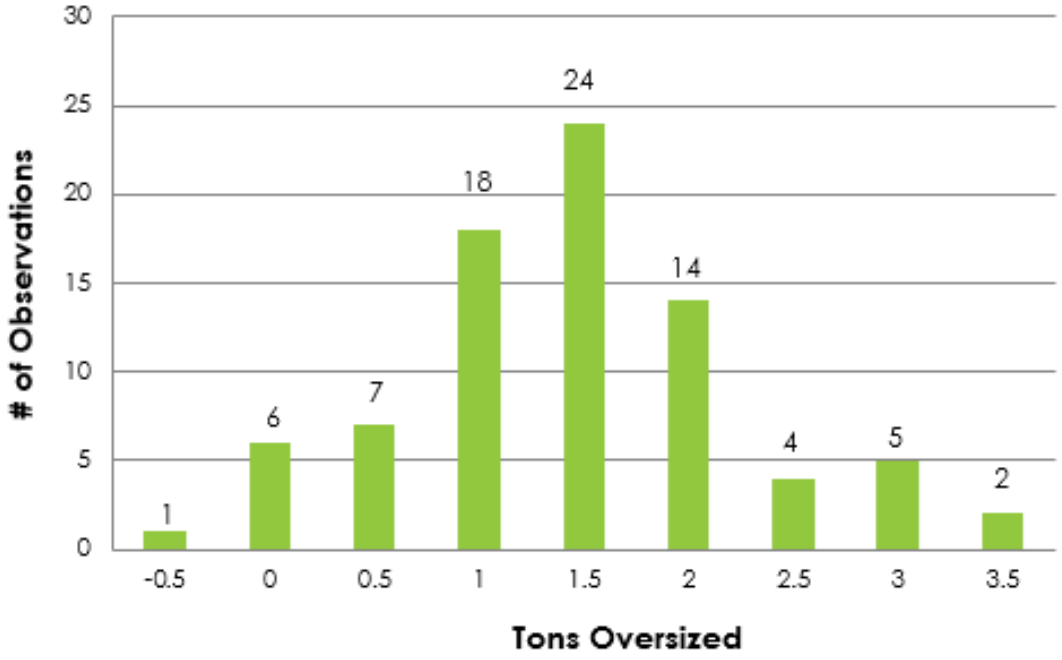
MO Equipment Sizing Study

Installed AC Units

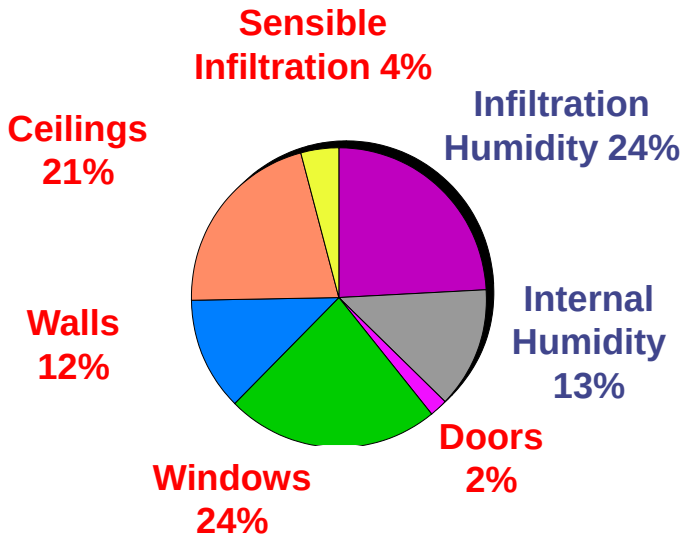
Tons Oversized



4 Factors Affecting Comfort

- Air Temperature – around the person
- Relative Humidity – ~50% is best
- Air flow - affects how easily evaporative cooling occurs
- Mean Radiant Temperature – the temperature of the surfaces surrounding people

Cooling Load Breakdown



- Sensible = Δ Temperature
- Latent = Δ Moisture
- Total = Sensible + Latent
- **SHF = S / Total**

Variable Speed Blowers

- Allow slower fan speeds in A/C mode to improve dehumidification
- Utilize ECM motors
  - Reduce fan wattage up to 1/10 at low speeds
  - Must operate most of the time at low for energy savings
  - Will consume more energy to satisfy flow if duct restrictions are high
- Permit modest upsizing
  - *Moisture removal is a function of the condensing unit, indoor coil, & fan speed (airflow)*
  - *Proper refrigerant charge is also critical*

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Equipment Location

- Locate the air handler within conditioned space to reduce energy penalty from leakage.
- Don’t have leaky air handler next to an atmospheric combustion appliance!!!

- Design Goal:
  Get all the ducts and the air handler within conditioned space so no energy penalty from leakage

How does duct leakage affect combustion safety?

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Ductwork

- Types
- Design
- Sealing
- Insulation

Types of Ductwork

- **Round Metal**: Minimal air pressure loss retards growth of fungus and mildew; joints leak unless well sealed; must be insulated (in unconditioned space only); installation is more expensive
- **Flex Duct**: Few joints to leak; inexpensive to install; poor design & installation can crimp duct and reduce air flow; easier to damage

Proper Flex Duct Installation

- Short straight runs from rigid trunk preferred
- Upsize diameter from rigid by 1”
- Support with 1” or wider straps spaced no more than 5’
- Sag no more than ½” per foot
- Cut duct to proper length
- Do not pinch duct to change direction or at connections

Types of Ductwork

- **Fiberglass Ductboard**: Must be sealed carefully to be airtight; good noise control; exposed fiberglass; less durable; can be field fabricated
- **Building Cavities**: panned ducts; shelf systems that support for air handler; often violated (not permitted in IECC2015+)

Site-Built Cavity Ducts

- Do not use as supply or return duct (example, toe-kick under cabinets should be fully ducted)

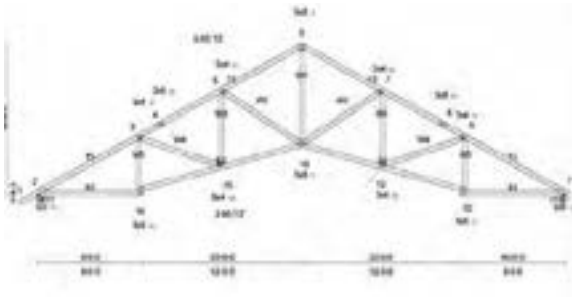
Violated ductwork

124

IAQ Issues?

Duct Design

- Try to locate the ductwork inside conditioned space



Duct Design

Proper Duct Design Details

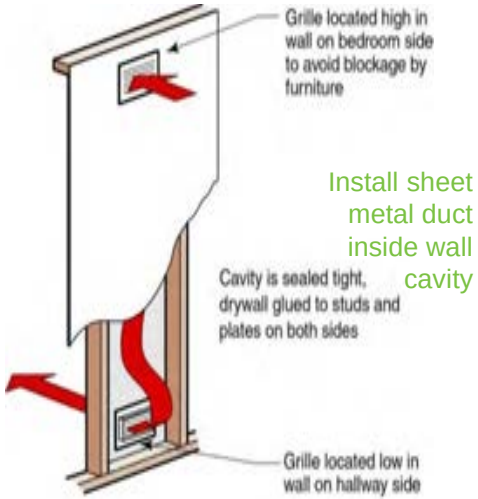
- Dampers allow easy alteration of flow to each room
- Hard metal elbows should be used for tight turns
- Flex ducts turns must be gradual (radius of turn must be > than the duct diameter)

Duct Design Details

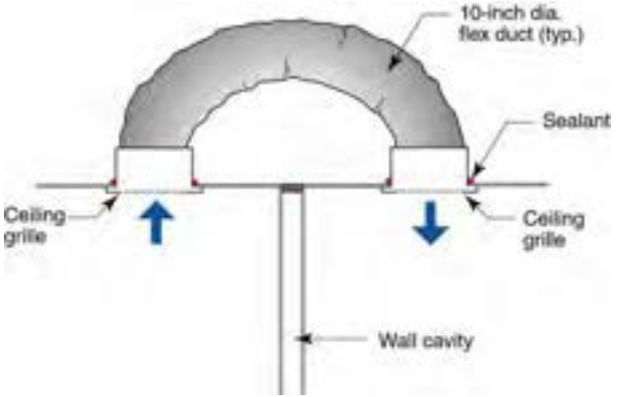
- Ducts should not originate from the plenum cap or within 6” of plenum cap

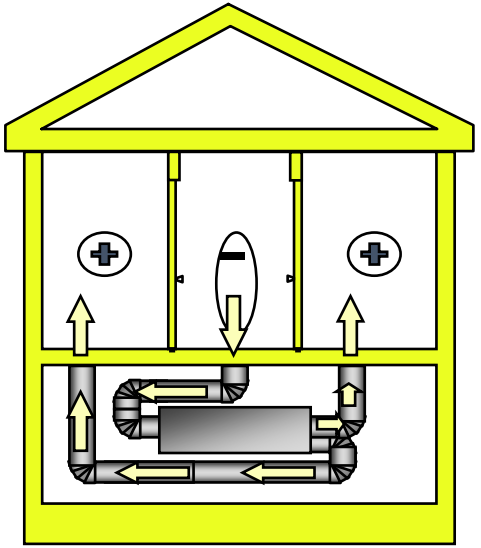
- Ducts should not originate from the end of or within 6” of the end of a trunkline

Duct Design-
Proper Return Path



Install sheet metal duct inside wall cavity





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Ducts in Buildings

- Don’t use building components (stud cavities or joist cavities) as ducts
- If air must run through these spaces, use ducts designed to fit inside those spaces

Duct Sizing

- Manual D
- Duct Calculator

Supply Branches for Entire House

Heating friction rate 0.070 in/100ft
Cooling friction rate 0.070 in/100ft

Duct Tree

Duct name	ST	RB	Heat (Btuh)	Cool (Btuh)	Ds. flow (cfm)		STEL (ft)	Pr. drop (in H2O)	Veloc (fpm)	Diam (in)		Rect. duct (in)		Matl
Bedroom 3	st1	rb1	2047	1244	h	68	246	0.17	346	p	6	0	0	VlFx
Bedroom 2	st1	rb1	1757	1248	c	68	246	0.17	344	p	6	0	0	VlFx
Laundry	st1	rb1	796	415	h	26	246	0.17	303	p	4	0	0	VlFx
Kitchen	st2	rb1	389	1644	c	89	246	0.17	333	p	7	0	0	VlFx
Dining	st2	rb1	1888	1135	h	63	246	0.17	319	p	6	0	0	VlFx
Foyer	st2	rb1	1263	718	h	42	246	0.17	308	p	5	0	0	VlFx
Master Bathroom	st3	rb1	1993	1058	h	66	246	0.17	337	p	6	0	0	VlFx
Master Bedroom	st3	rb1	3565	2272	c	123	246	0.17	353	p	8	0	0	VlFx
Living	st2	rb1	2915	1779	h	97	246	0.17	362	p	7	0	0	VlFx
Breakfast	st2	rb1	1220	668	h	41	246	0.17	297	p	5	0	0	VlFx

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Poor Duct Design…

Sealing Ductwork

- Mastic must be installed on seams & joints of ductwork, not the insulation!

Sealing Ductwork is Code

- Rigid fiberglass ducts must be sealed with UL181A-P tape, UL181A-M tape, UL181A-H tape, or water based mastic
- Flex duct must be sealed with UL181B-FX tape, UL181B-M tape or water based mastic

International Residential Code, M1601.3.1

"Tapes and mastics used with rigid fibrous glass ducts shall be listed and labeled in accordance with UL 181-A. Tapes and mastics used with flexible air ducts shall be listed and labeled in accordance with UL 181-B. "Duct tape" is not permitted as a sealant on any ducts."

Sealing Ductwork

Sealing end of rigid supply run with water based mastic

Sealing Ductwork

1. Put mastic on collar to plenum connection
2. Put mastic on sheet metal connection
3. Slide liner over connection and install compression strap (zip tie)
4. Mastic over liner & zip tie (about 1" on either side of liner edge
5. Pull insulation over connection and zip tie

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Sealing Ductwork

All duct connections must be sealed with mastic, including connections to:

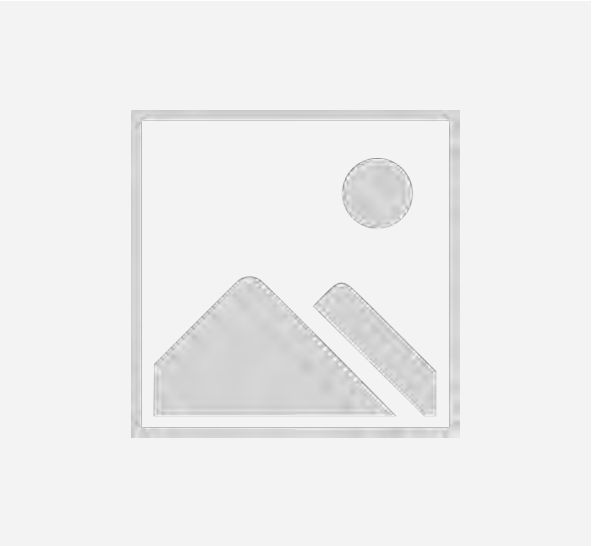
- Plenums
- Y-joints
- Boots

Sealing at the Unit Is Critical!

A 13 SEER A/C in a (30%) leaky duct system acts as an 8.5 SEER!
Neither the builder or homeowner get what they pay for!

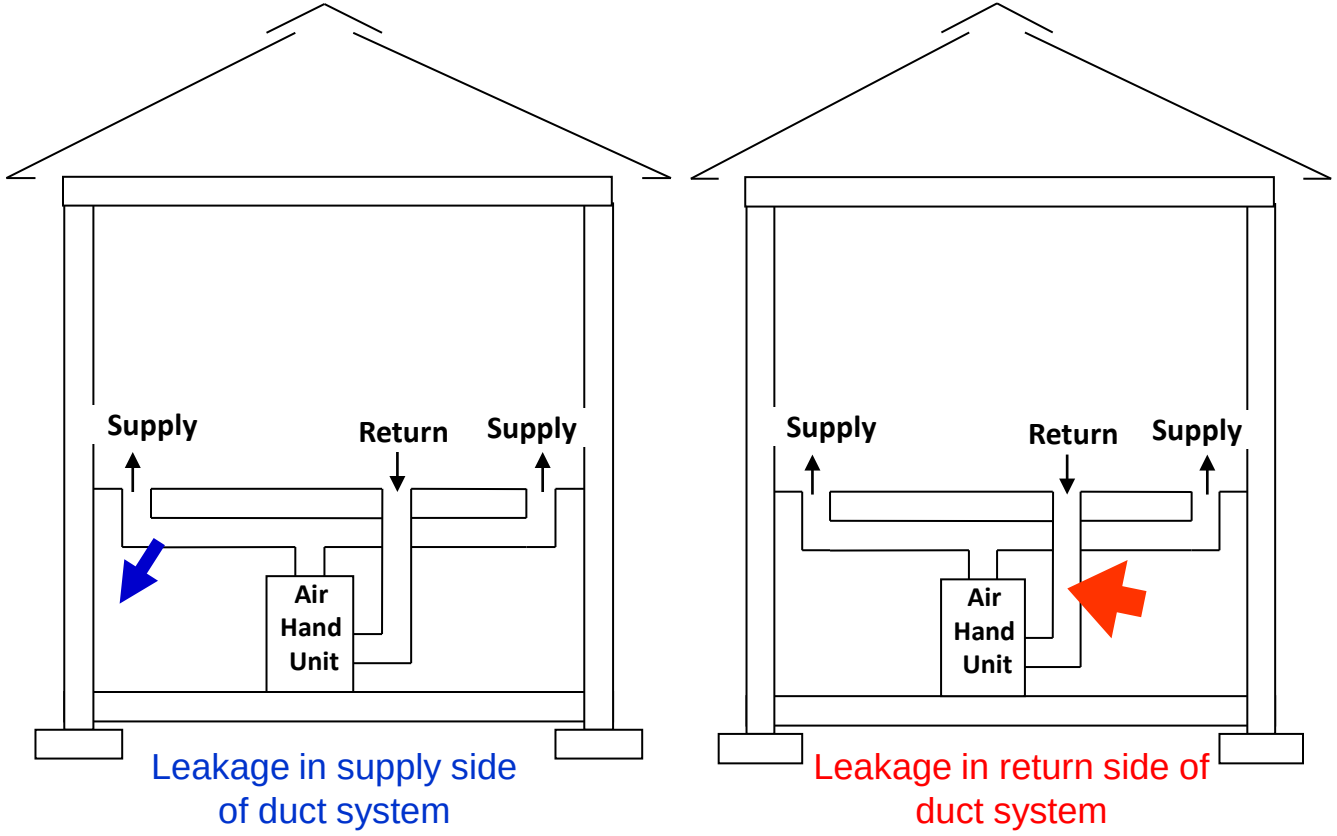
Duct Leakage Affects House Pressure

Leaky Supply Duct
(makes house pressure go negative)



Leaky Return Duct
(makes house pressure go positive)

Duct Leakage—Driving force for Infiltration



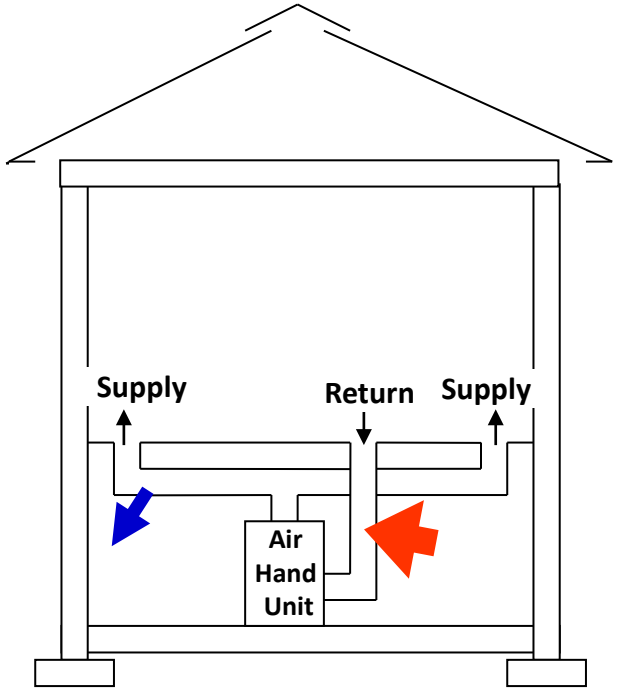
Leakage in supply side of duct system

Leakage in return side of duct system

Dominant Duct Leakage – Affects House Pressure

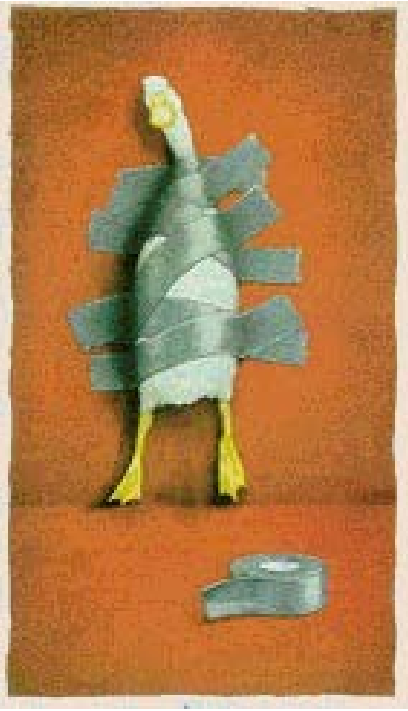
Impact on House pressure due to small supply and larger return duct leakage

What is the net effect on house pressure due to 100 cfm of supply and 300 cfm of return duct leakage?

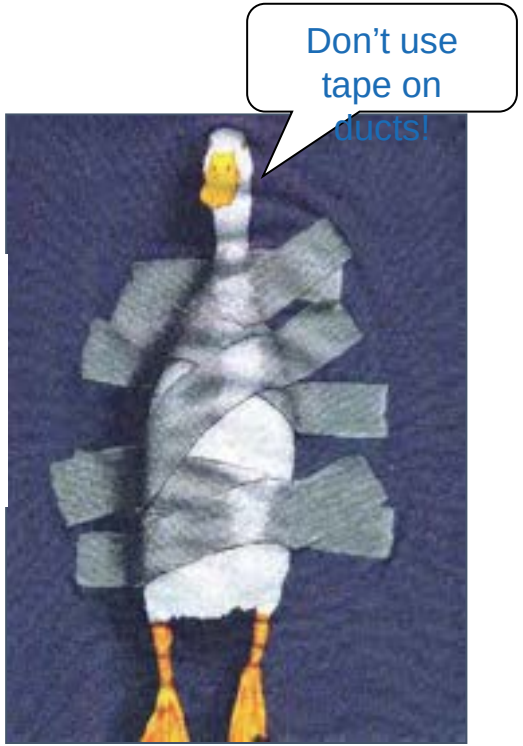


Some leaks in supply &
More leaks in return

Testing Duct Leaks



Although it is permitted in the code, Southface does not accept / endorse using UL181 tape to seal ducts!



IRC Reference—Duct Sealing

M1601.4.1 Joints and seams. Joints of duct systems shall be made substantially airtight by means of tapes, mastics, liquid sealants, gasketing or other approved closure systems. Closure systems used with rigid fibrous glass ducts shall comply with UL181A and shall be marked 181A-P for pressure-sensitive tape, 181A-M for mastic or 181A-H for heat-sensitive tape. Closure systems used with flexible air ducts and flexible air connectors shall comply with UL 181B and shall be marked 181B-FX for pressure-sensitive tape or 181B-M for mastic. All metal to metal connections shall be mechanically fastened. All duct connections shall be sealed. Mechanical fasteners for use with flexible nonmetallic air ducts shall comply with UL181B and shall be marked 181B-C. Crimp joints for round metal ducts shall have a contact lap of at least 11/2 inches (38 mm) and shall be mechanically fastened by means of at least three sheet-metal screws or rivets equally spaced around the joint. Closure systems used to seal metal ductwork shall be installed in accordance with the manufacturer's installation instructions.

Southface strongly recommends **mastic or mastic tape,** which works better in the real world than foil tape (mastic should be at least 2 mm thick)

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403.2.2 Duct Tightness Testing*

- Duct systems must be leak tested
  - When tested at rough-in
    - 4% Total leakage no AHU installed
    - 6% Total leakage w/ AHU
  - When tested at final
    - 12% Total Leakage
    - 8% Leakage to Outside

**Exception: Duct tightness test is not required if the air handler and all ducts are located within conditioned space*

Total Duct Leakage ≤ 4%

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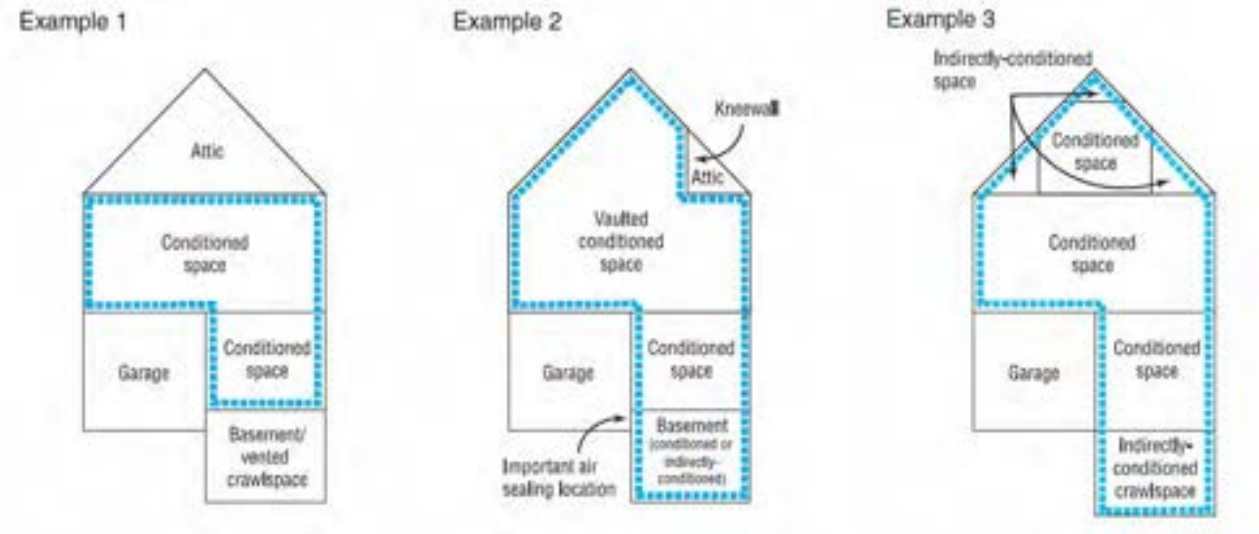
Building Thermal Envelope Impacts Duct Testing



- Although these three homes look identical from the outside, each has defined the building thermal envelope differently
- This affects the requirement for duct testing

Filters

- Change every leap year?
- El Cheapo vs. HEPA filters
- Want thicker, pleated filters
- Don’t accept installations that prohibit easy filter access
- Seal covers with foil tape
- MERV rating

Practical Pleat

www.filtrationmfg.com

www.anykindoffilter.com

“AKF003” is discount code

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IECC Section 403.3—Ducts

Mandatory Requirements:

- **Insulation** required for ducts outside of envelope
  - R-8 Insulation for supply ducts in attic
  - R-6 Insulation – all other ducts in unconditioned space
  - No Insulation required if ducts inside building thermal envelope (but should insulate to prevent condensation)
- Sealing required with mastic or UL 181 tape
- May not use building cavities as supply ducts

HVAC and Humidity

- Don’t expect HVAC to fix bad envelope moisture issues
- Remember Psychrometrics
  - “It ain’t the heat, it’s the humidity”
- HVAC controls can help
  - Variable speed blower
  - Variable capacity equipment (staged compressors, staged burners)
  - Dedicated dehumidifier

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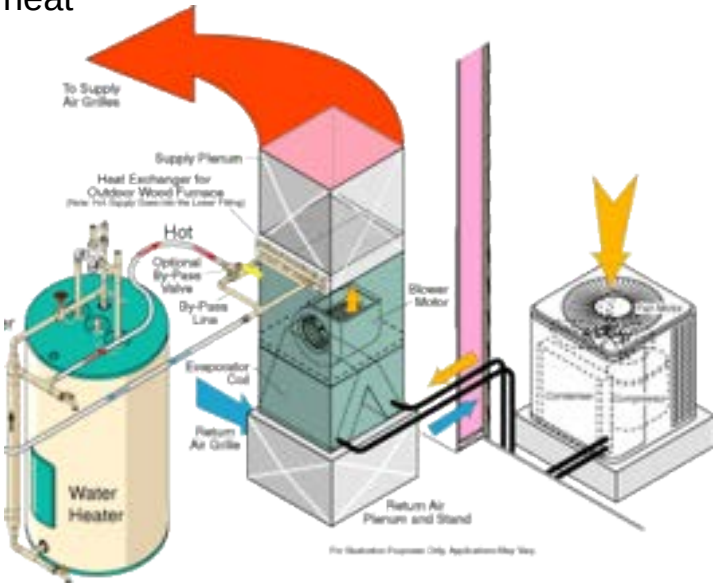
Section 403.1—HVAC Controls

Mandatory Requirement:

- **Programmable** thermostat required
- Heat Pump requires lockout capability to prevent unnecessary strip heat



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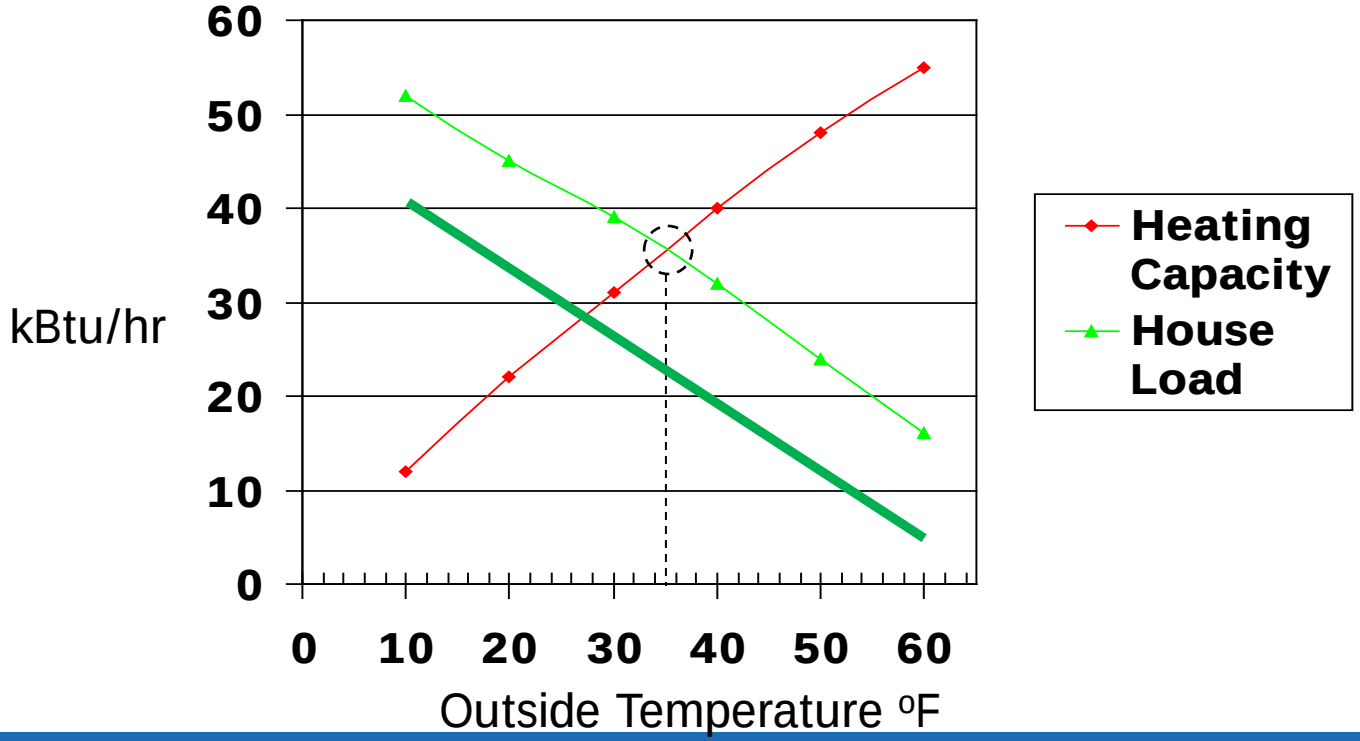
Heat Pump Balance Point

The winter outdoor temperature at which the heat pump can deliver exactly the same amount of Btu's that the house is losing



Major Changes for IECC 2018

2018 IECC

- Windows
  - U-0.32
- Lighting
  - 90% efficient bulbs
- ERI modifications
  - Adjusted target ERI:
    - 62 CZ-4
    - 61 CZ-5
  - Harder “backstop” for renewables

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Wrap up and Q&A

Thank you!

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mikeb@southface.org

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