COMMON COMPLIANCE CHALLENGES

ABOUT SOUTHFACE

Southface promotes sustainable homes, workplaces and communities through education, research, advocacy and technical assistance.

WHO ARE YOU?

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

LEARNING OBJECTIVES

- Identify common energy code compliance challenges & corresponding code requirements
- Define the building thermal envelope & identify the qualities of effective and ineffective building envelopes in homes
- Explain the relationship between air sealing & insulation
- Identify common missed opportunities for effective air sealing in homes
- Identify common challenges with insulation installation quality & workmanship
- Discuss common challenges and solutions for air sealing, insulation & ventilation in attics
- Discuss common challenges & solutions for air sealing, insulation & vapor barrier installation in crawlspaces & basements
- Identify common challenges & solutions in residential weather barrier installation
- Summarize the code requirements and benefits of high efficacy lighting
- Identify common challenges and solutions for HVAC system & ductwork installation

AGENDA

Morning:

1. Introduction
2. The systems approach
3. Code requirements for air sealing
4. Common air sealing challenges
5. Insulation & air sealing
6. Code requirements for insulation
7. Common insulation challenges

Afternoon:

- Attic inspection
- Crawlspace/basement inspection
- Shell inspection
- HVAC inspection
- Lighting/baseload inspection
- Additional resource

Please set phones to silent!

We will have breaks!

THE SYSTEMS APPROACH

A house is a system made up of interrelated parts:

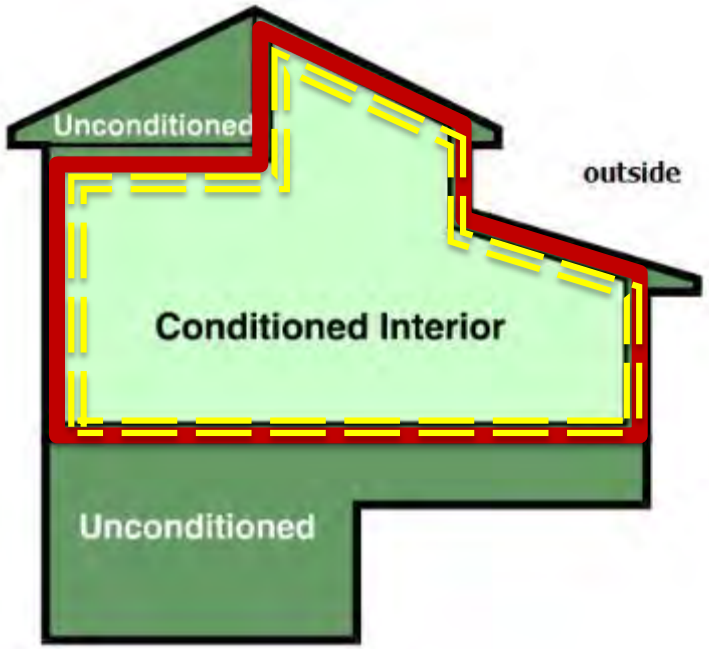
- The building envelope
- Heating & cooling
- Ventilation (controlled)
- Water heating & distribution
- Lighting & appliances

www.energystar.gov

THE BUILDING ENVELOPE

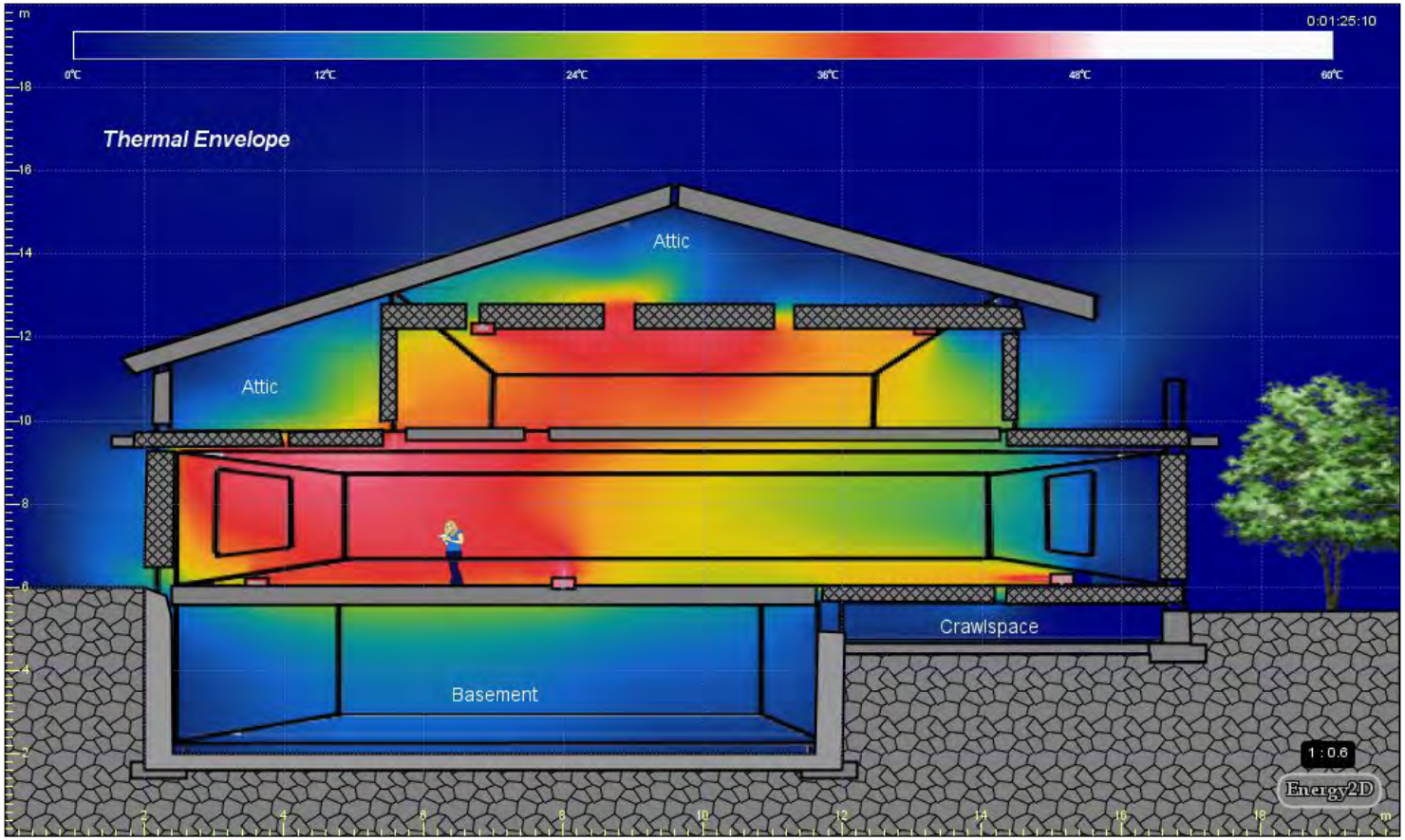
Building Envelope

- Continuous Air Barrier (Pressure Boundary)
- Complete Insulation Coverage (Thermal Boundary)



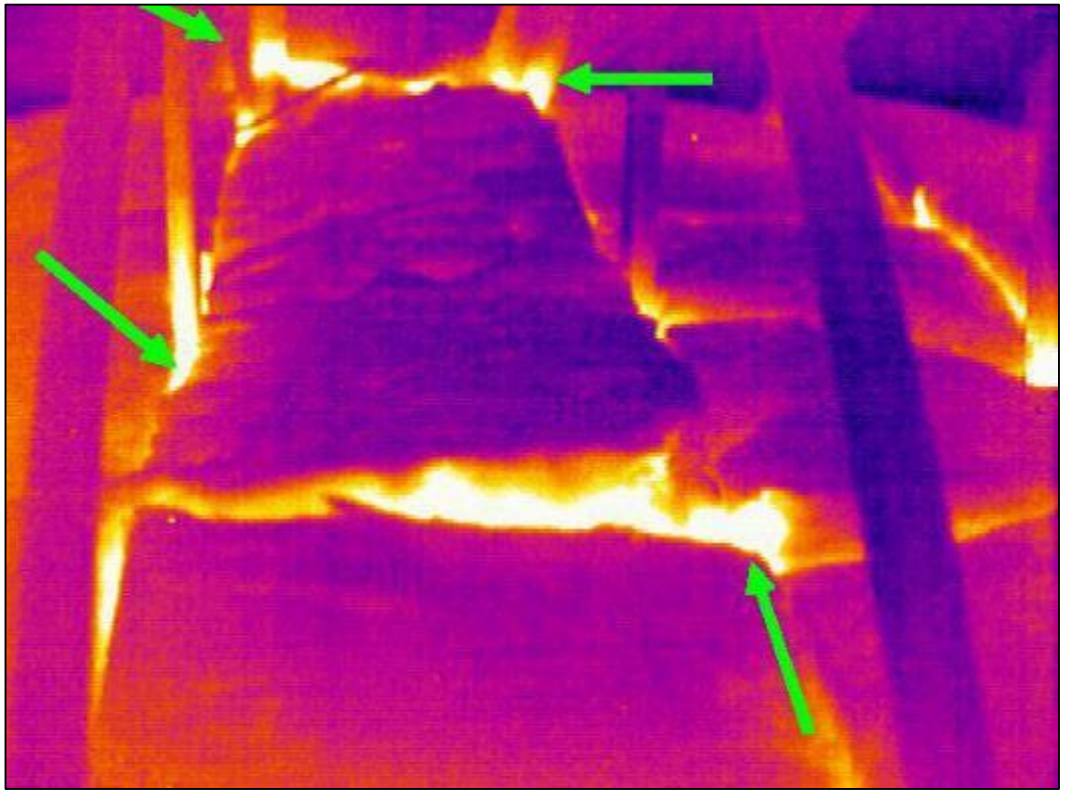
Thermal and Pressure Boundaries Make up the Building Envelope

THE EFFECTS OF THERMAL BYPASSES



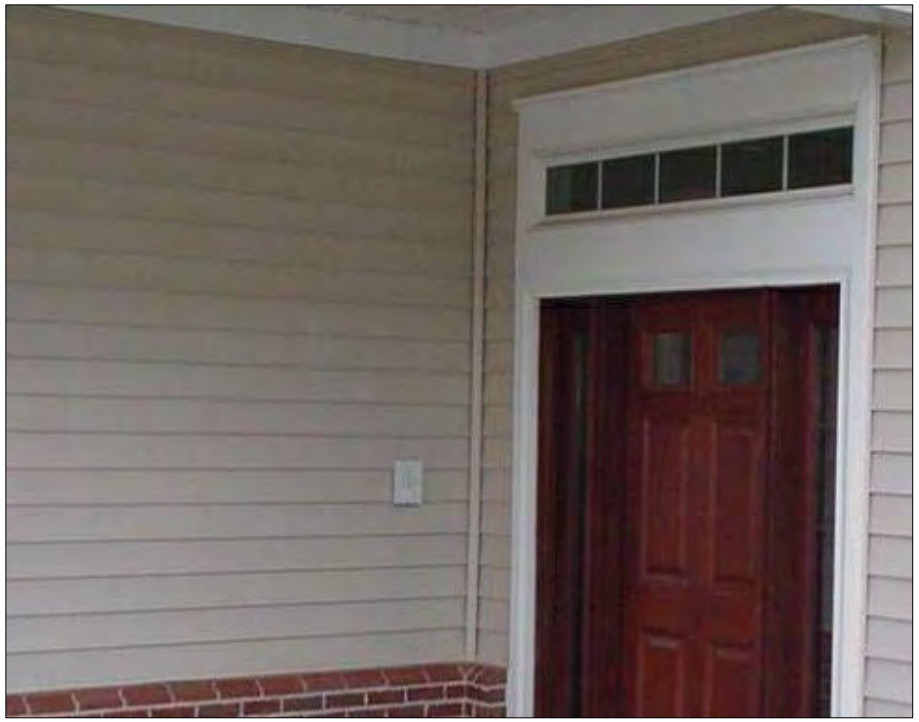
HEAT TRANSFER

- Conduction
- Radiation
- Convection



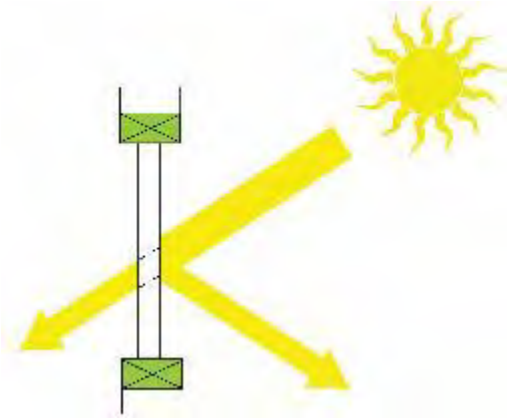
HEAT FLOW: CONDUCTION

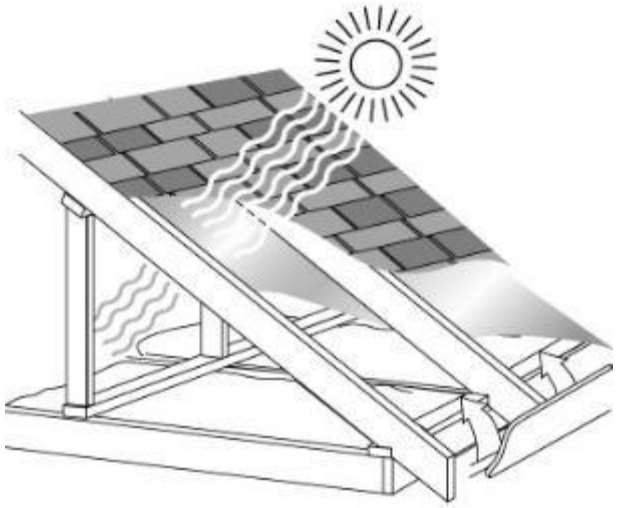
Conduction is heat flowing through a solid material (insulation slows conduction)



HEAT TRANSFER: RADIATION

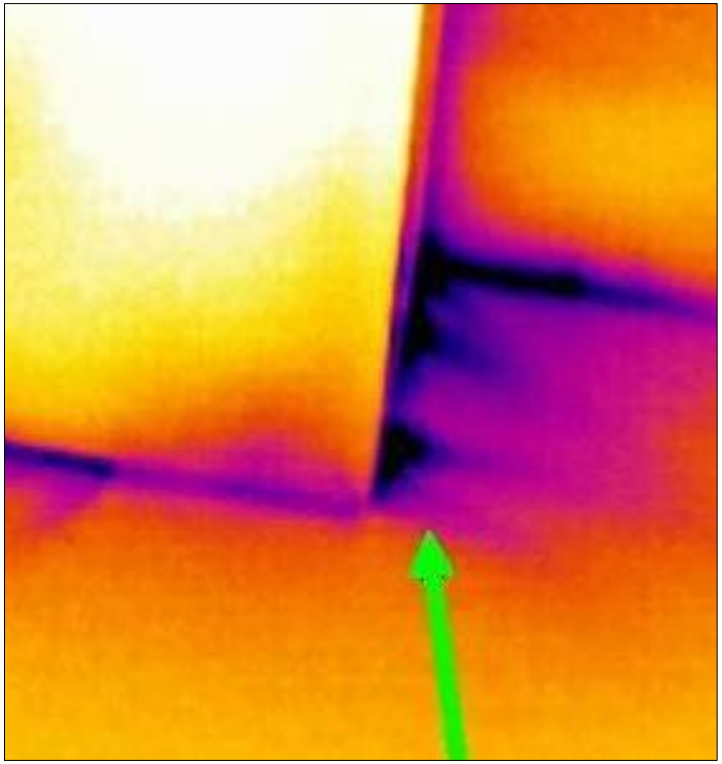
Radiation is the movement of heat energy from a hot surface to a cooler surface with nothing solid or opaque in between (low-emitting surfaces retard radiation)





HEAT TRANSFER: CONVECTION

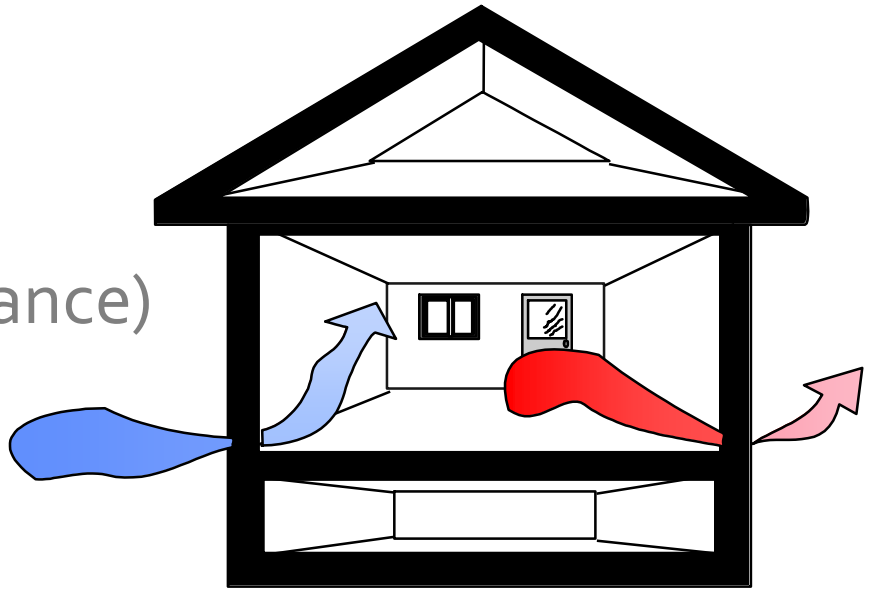
Convection is the transfer of heat caused by the movement of a fluid, like water or air (air barriers slow convection)



THE IMPORTANCE OF AIR SEALING

The effects of air leakage:

- Air carries heat, moisture & pollutants
- Transfers heat (directly & by reducing insulation performance)
- Causes poor comfort (heat & humidity)
- Moisture & pollutants affect Indoor Air Quality (IAQ)



AIR MOVEMENT – BASIC TERMS

Infiltration: Unintentional air movement into a building (drafts)

Exfiltration: Unintentional air movement out of a building (drafts – again)

Ventilation: Intentional & controlled air movement into and out of a building designed to provide fresh air to the occupants (healthy indoor air quality)

Air Changes*:* Air entering and leaving a building, replacing the inside air with air from the outside.

ACH: Air Changes per Hour – a rate of air exchange

CFM: Cubic Feet per Minute – a rate of air movement

Every time air enters a building, air will also exit the building at a different location– infiltration and exfiltration always happen simultaneously

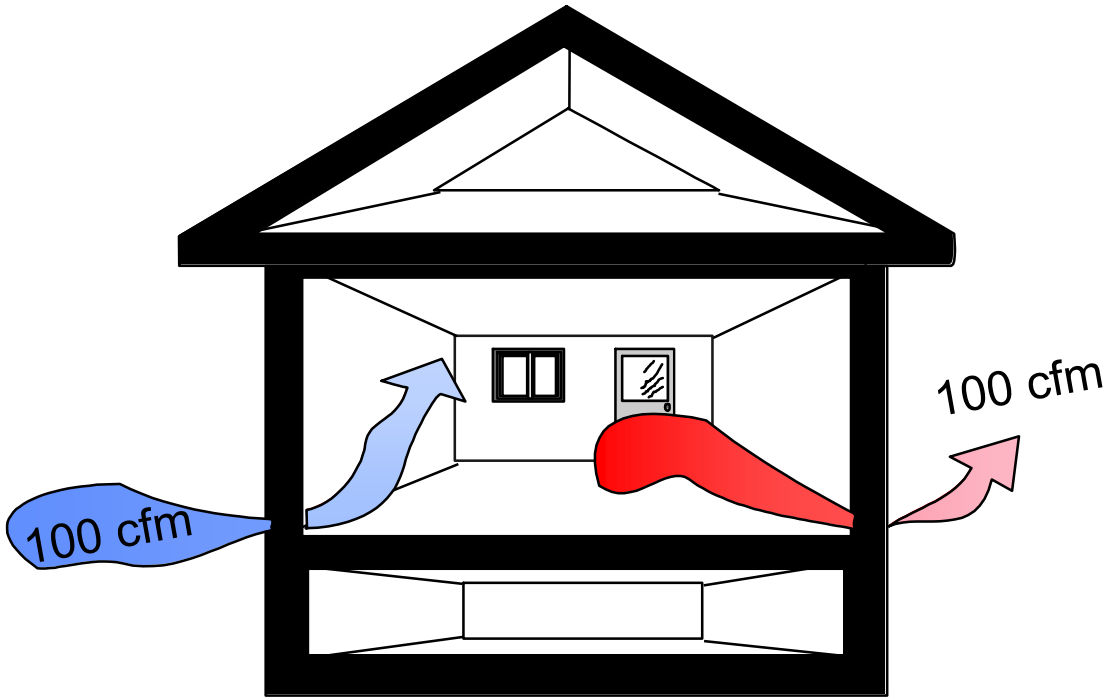
AIR FLOW

High pressure → Low pressure

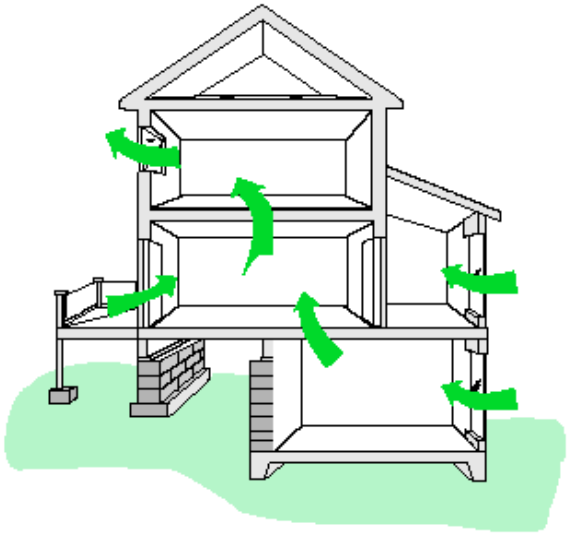
Conditions for Air Infiltration

- Pathways for air movement (hole)
- Pressure difference (driving force)

Quantity of air out = quantity of air in

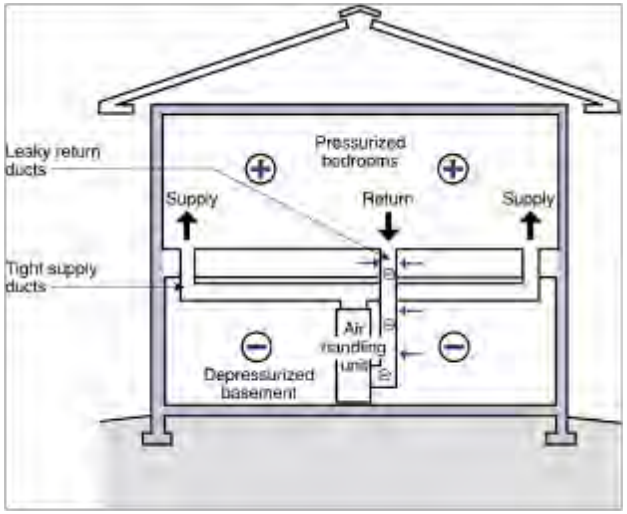


WHAT DRIVES AIR MOVEMENT?



Stack Effect

Wind



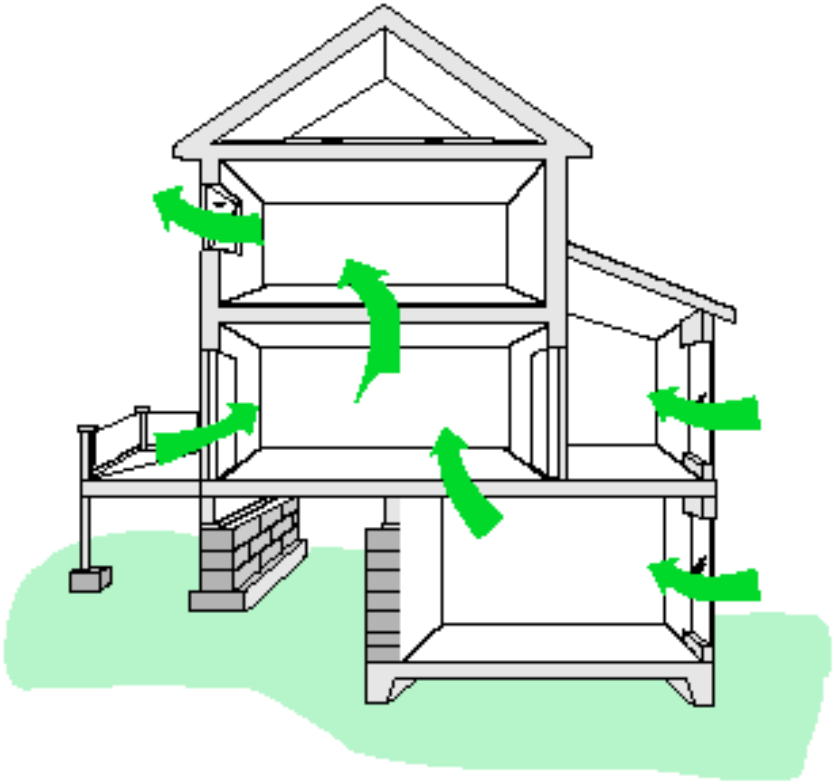
Mechanical Systems

Things that create pressure differences

(natural & mechanical)

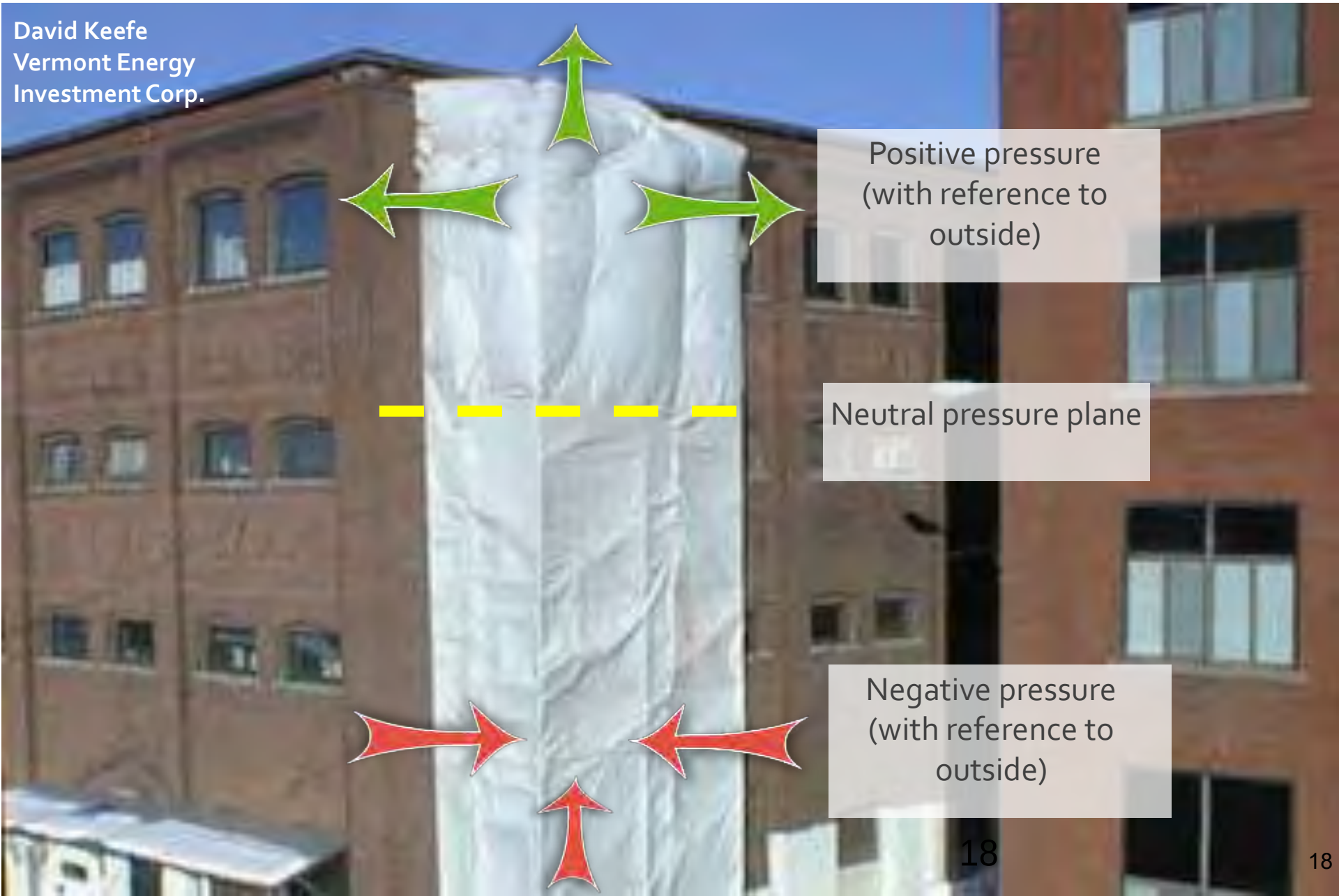
NATURAL DRIVING FORCES FOR INFILTRATION

Wind



Stack Effect

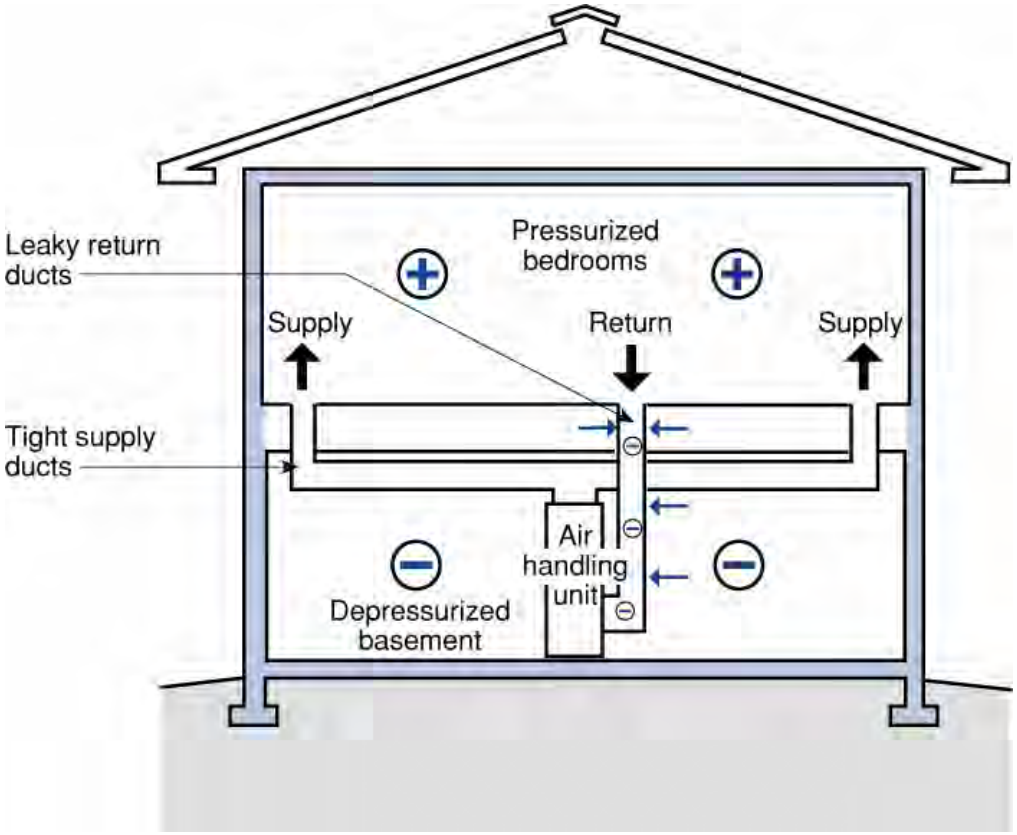
Stack Effect



18

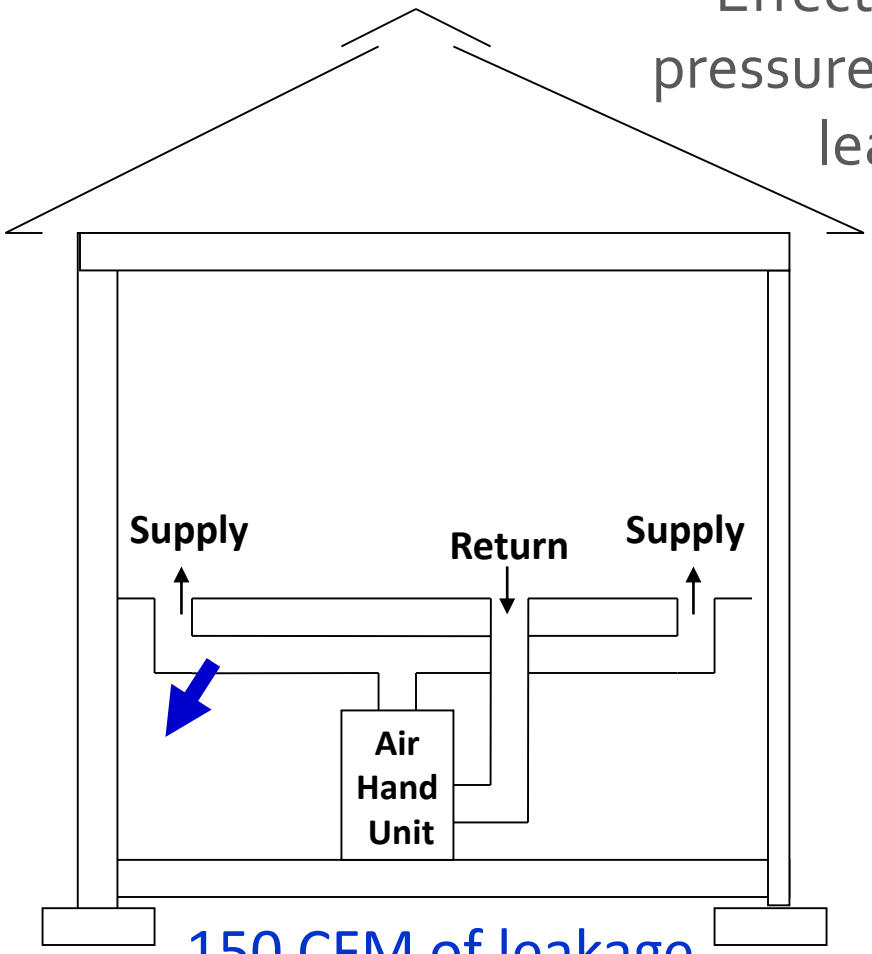
FANS—DRIVING FORCES FOR INFILTRATION

Device	CFM
Bath	50
Range hood	150
Downdraft hood	500
"Emeril" Hood	1500
Dryer	200
Air Handler	400 / ton

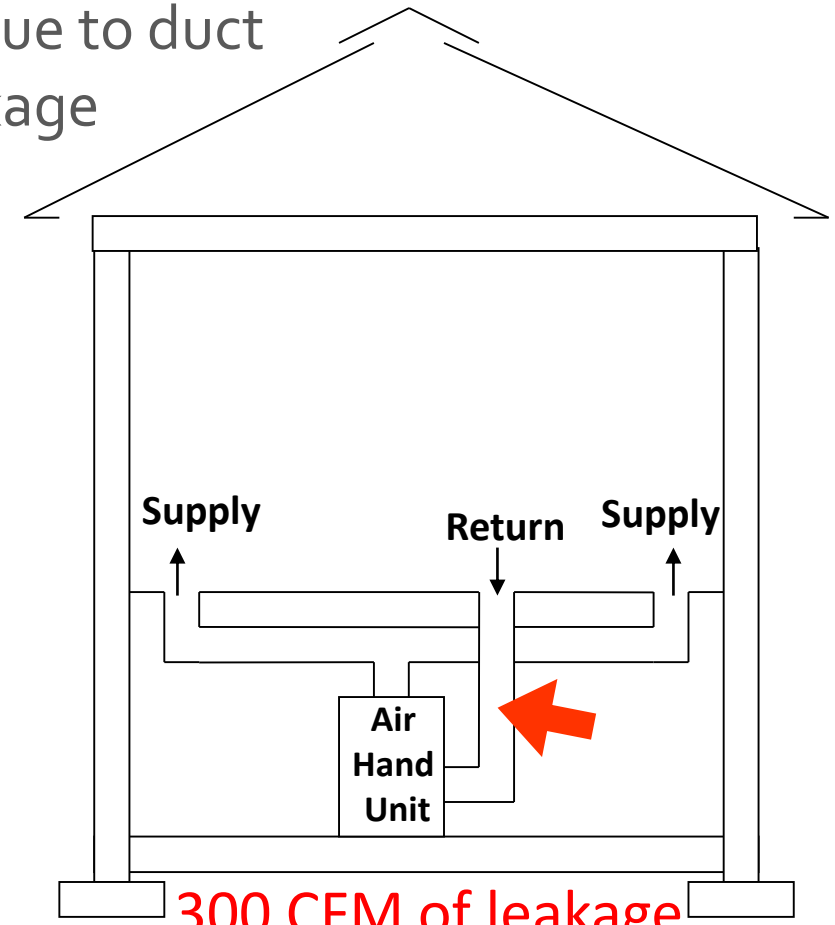


DUCT LEAKAGE— DRIVER FOR INFILTRATION

Effect on house pressure due to duct leakage



150 CFM of leakage in supply

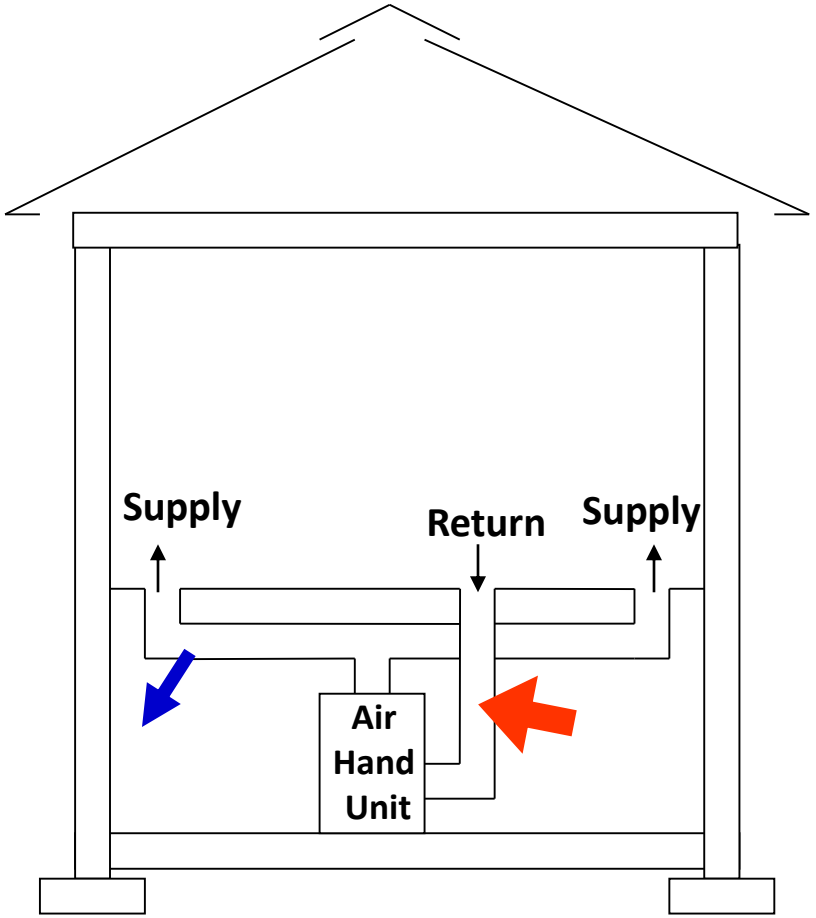


300 CFM of leakage in return

DUCT LEAKAGE— DRIVER FOR INFILTRATION

Dominant Duct Leakage

What is the net effect on House pressure due to 150 cfm of supply and 300 cfm of return duct leakage?



150 CFM of leaks in supply &
300 CFM of leaks in return

MOISTURE FLOW

Bulk

Capillarity

Diffusion

Infiltration

MOISTURE TRANSPORT IN BUILDINGS

Moisture flows from WET to DRY in two forms:

LIQUID and **VAPOR**

Bulk

Liquid water (rain, drainage, plumbing leaks)

Diffusion

Molecules of water moving through porous materials

Capillarity

Wicking through porous materials (concrete, wood, fiberglass and cellulose insulation)

Infiltration

Moisture laden air brought into the house

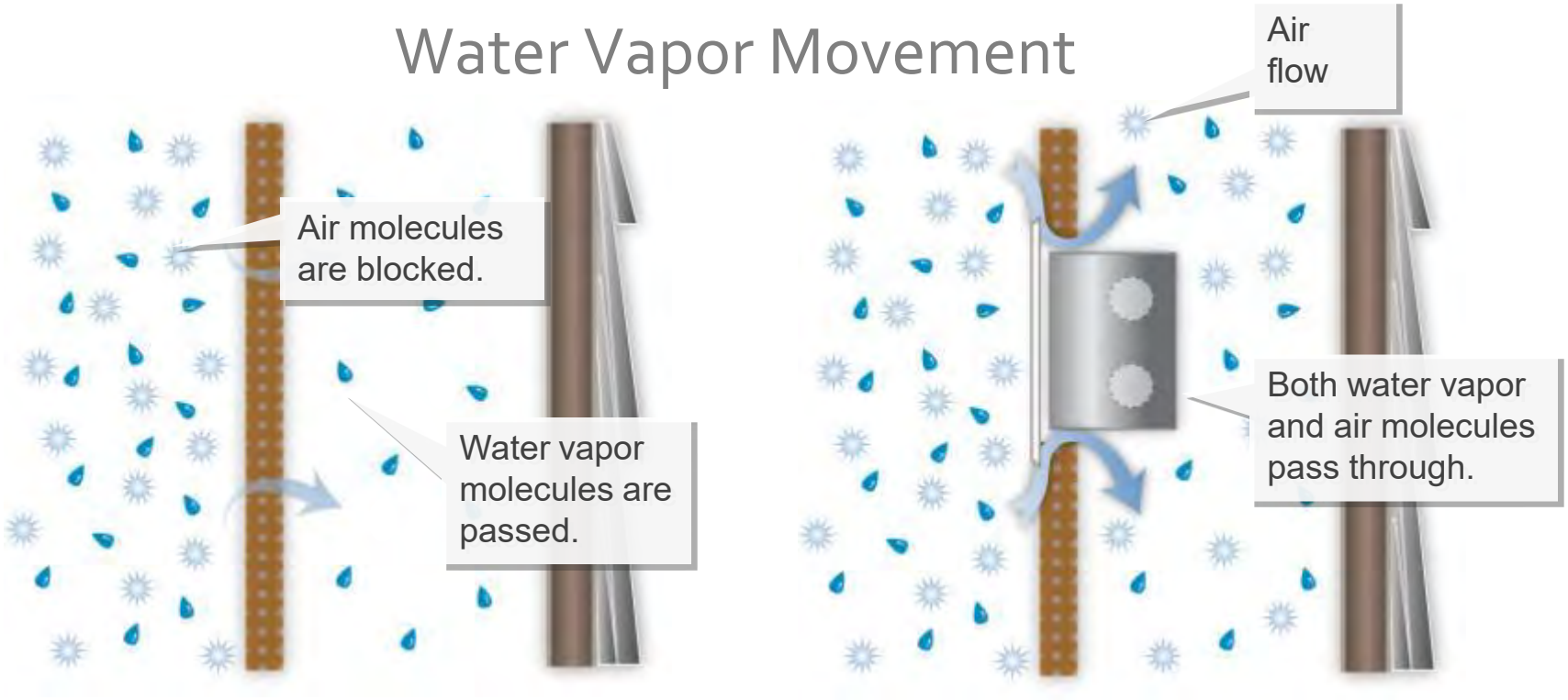
MOISTURE PROBLEMS

Building decay .....100% RH
Interior Mold.....RH > 70%
Dust Mites.....RH > 50%
Static Electricity, dry sinus .....RH < 25%

Ideal Health & Comfort is 30%-50% RH at room temperature (~72° F)

MOISTURE FLOW IN BUILDINGS

Water Vapor Movement

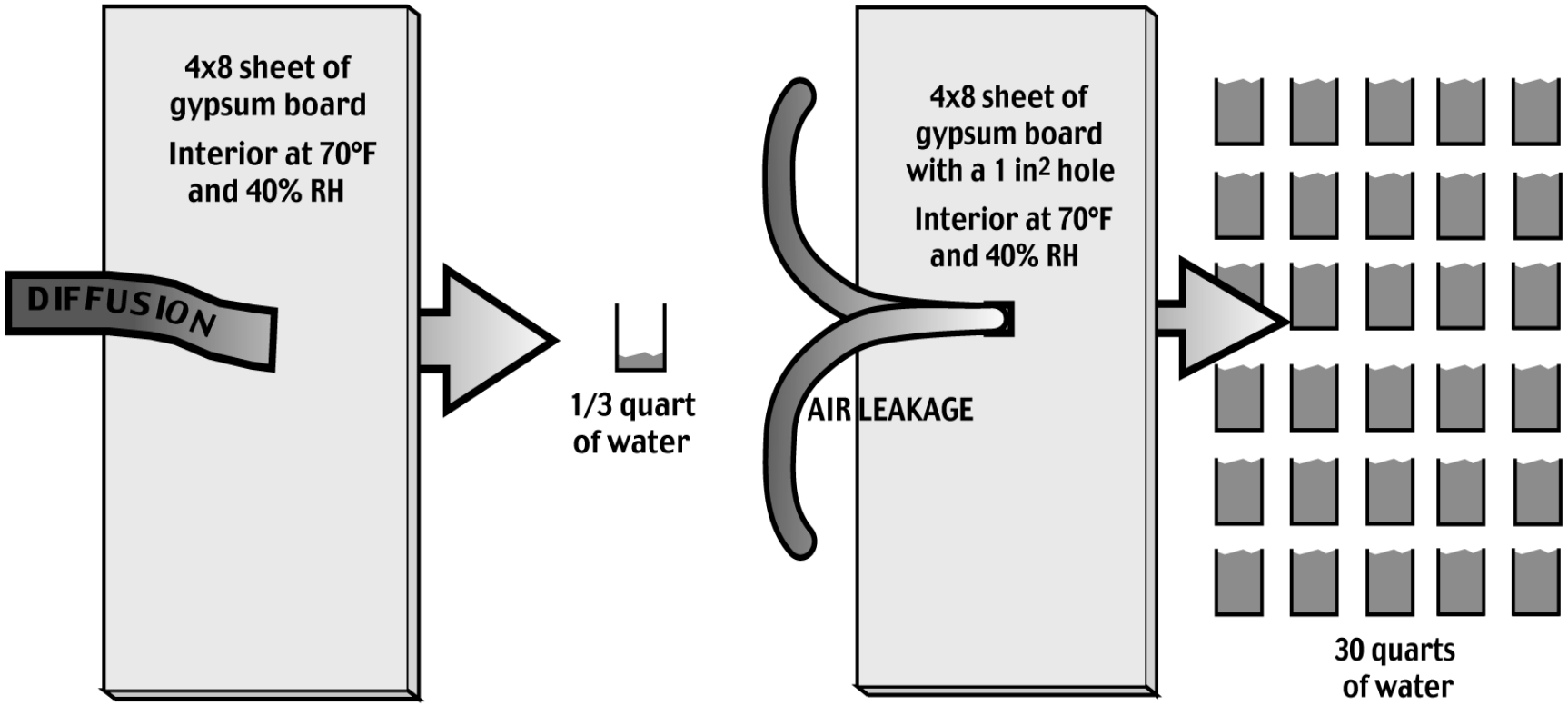


Diffusion Through Surface

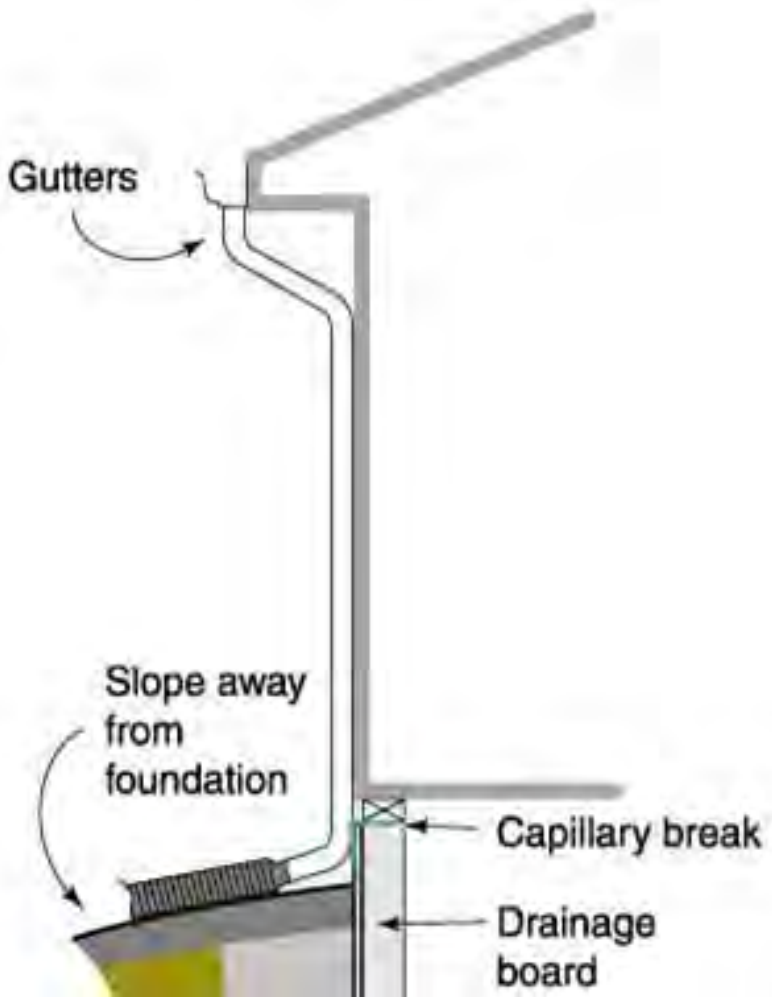
Convection Through Holes

The measurement of the permeability of a material is its **Perm Rating**

VAPOR DIFFUSION VS. AIR LEAKAGE



MANAGING BULK MOISTURE



- Plastic ground cover in crawlspaces
- Gutters channel water away from foundation
- Proper site drainage
- Weather barriers installed to keep moisture out
- Assemblies designed to dry if wetted

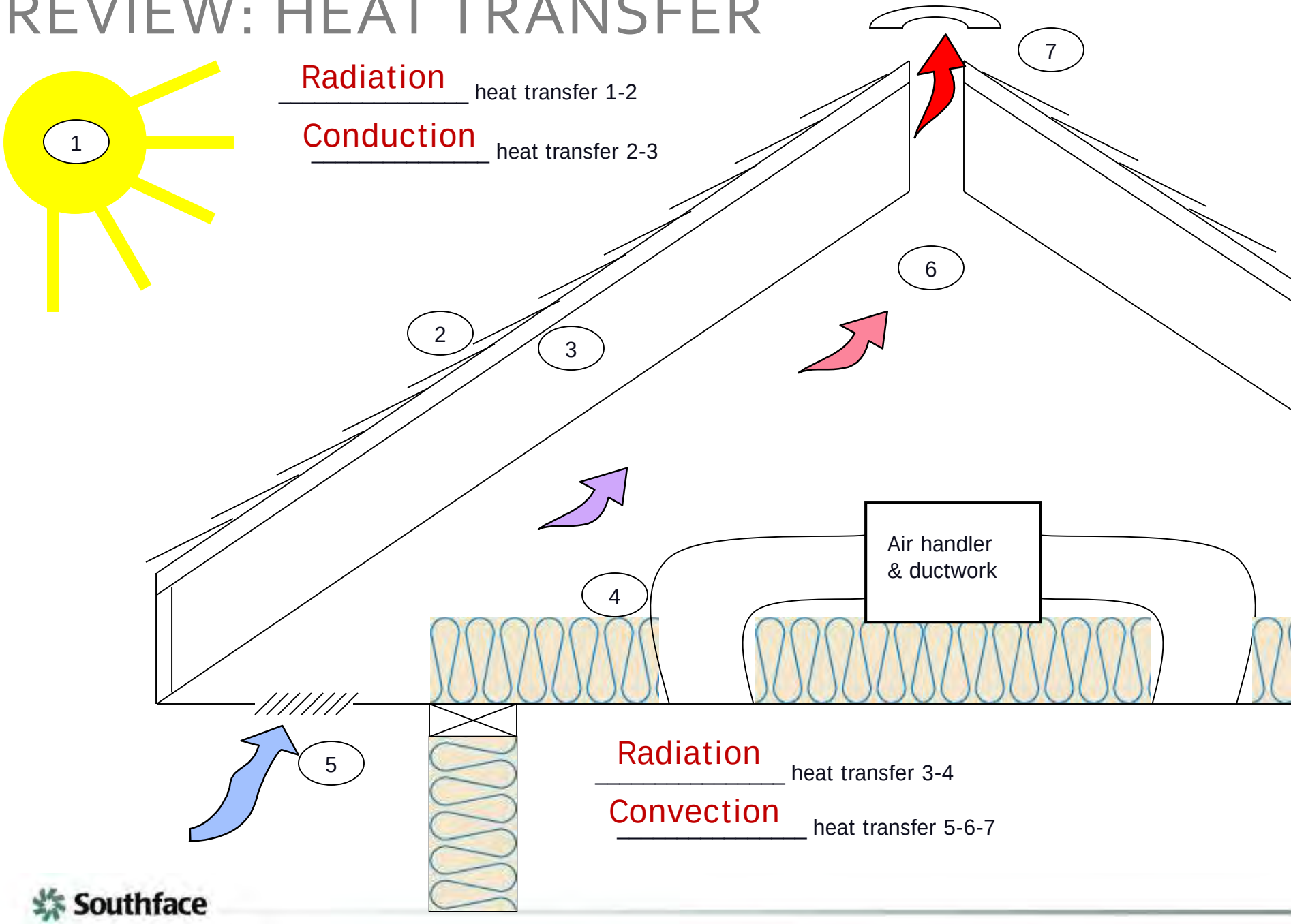
CRAWLSPACE VAPOR BARRIER

WEATHER BARRIERS

PERM RATINGS OF MATERIALS

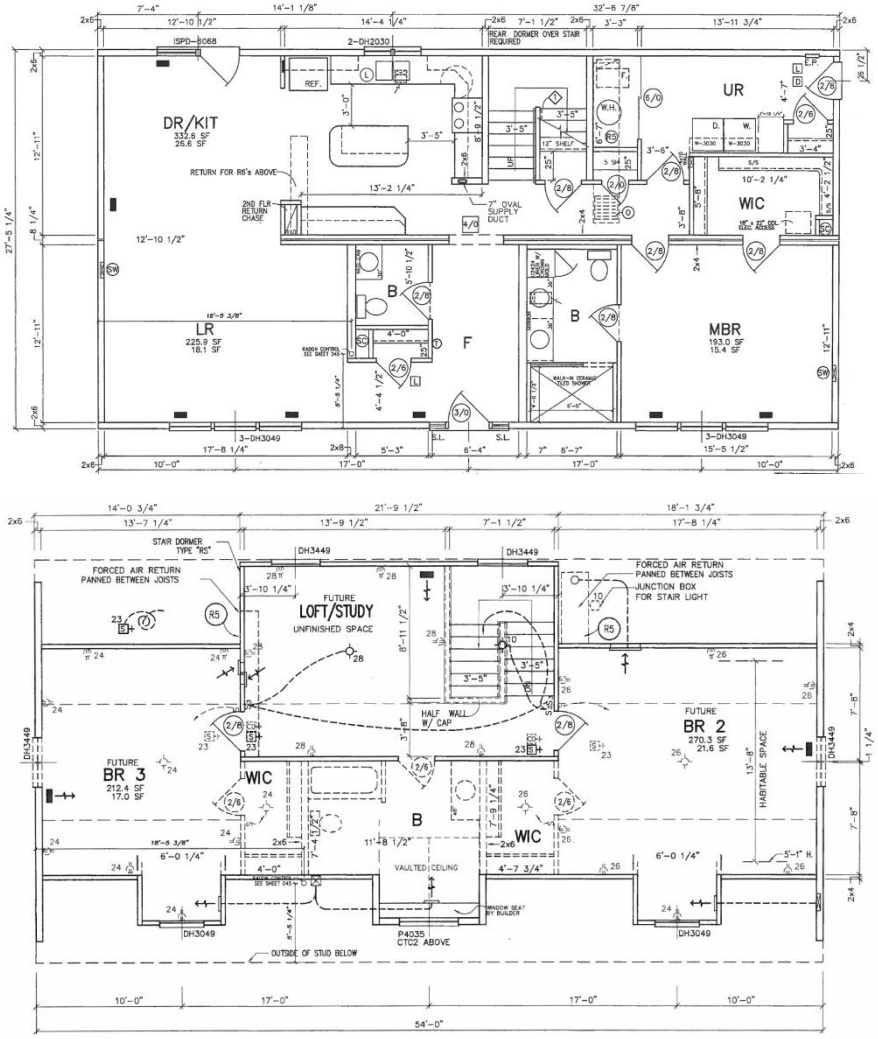
Drywall.....30-50
Housewrap.....5-50
Semi-gloss latex enamel.....6.6
Primed & Painted Drywall.....2-3
Interior plywood.....1.9
15 pound asphalt felt.....1-4
Insulated foam sheathing.....0.4-1.2
Exterior plywood/OSB.....0.7
Vapor retarder paint.....0.6-0.9
Asphalt coated kraft paper.....0.4
Polyethylene.....0.06

REVIEW: HEAT TRANSFER



REVIEW: BUILDING ENVELOPE ACTIVITY

- Highlight the building envelope on your handout
- What are the characteristics of an effective building envelope?
- What components comprise the building envelope in this home?



402.4 AIR LEAKAGE

Mandatory Requirement:
Air Sealing

- Detailed list
- Fireplaces
- Fenestration
- Recessed light fixtures: airtight, IC-rated

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.

2009 IECC- SECTION 402.4.2

Two options to prove air sealing:

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

1. Testing of house leakage
   - Blower door result must be less than 7 ACH_{50}

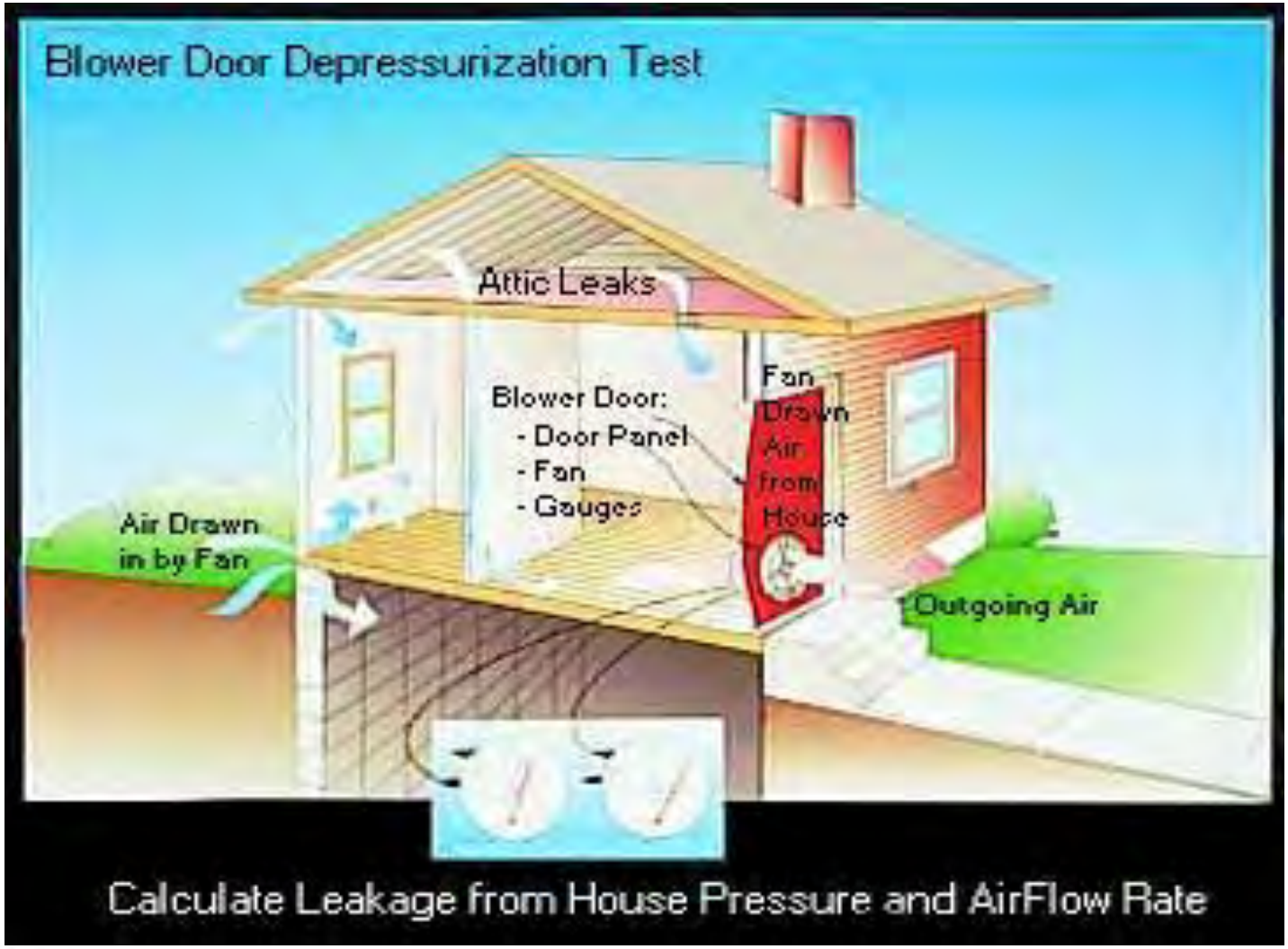
2. Visual Inspection
   - No ACH_{50} requirement
   - Use Code Checklist (thermal bypass)
   - Requires multiple inspections
     - Framing stage / pre-drywall
     - Final

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 sealed. 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.

BLOWER DOOR TESTING

- One of the options allowed by code to verify air sealing
- Provides a measurement of the actual infiltration rate
- Code requires < 7 ACH50
- The BD also helps identify leak paths

BLOWER DOOR OPERATION

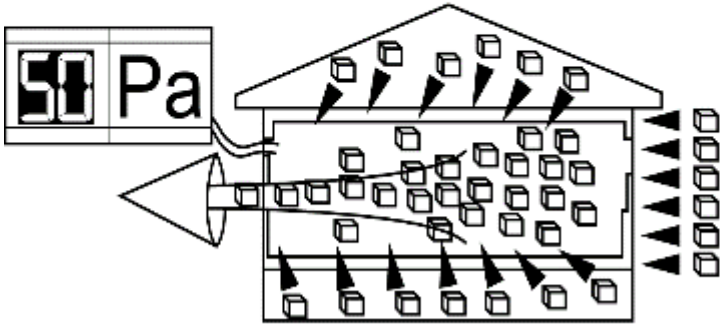


DEPRESSURIZING HOUSE

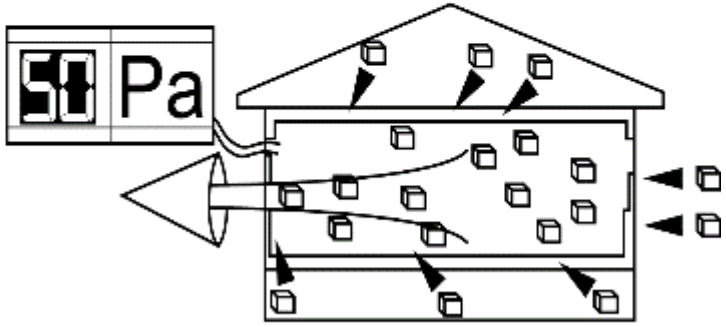
- CFM = Cubic Feet of air per Minute
- 1 CFM out = 1 CFM in
- 1000 CFM_{50} = 1 s.f. hole in envelope

Blower Door Depressurizing House

To 50 Pascals with Respect to Outside



Leaky House



Tight House

CAN YOU BUILD A HOUSE TOO TIGHT?

WHERE DOES THE "FRESH" AIR COME FROM?

ATTIC

Insulation fibers, dust, coal soot, rodent scat

OUTSIDE

Pollen, auto fumes, dust, moisture

GARAGE

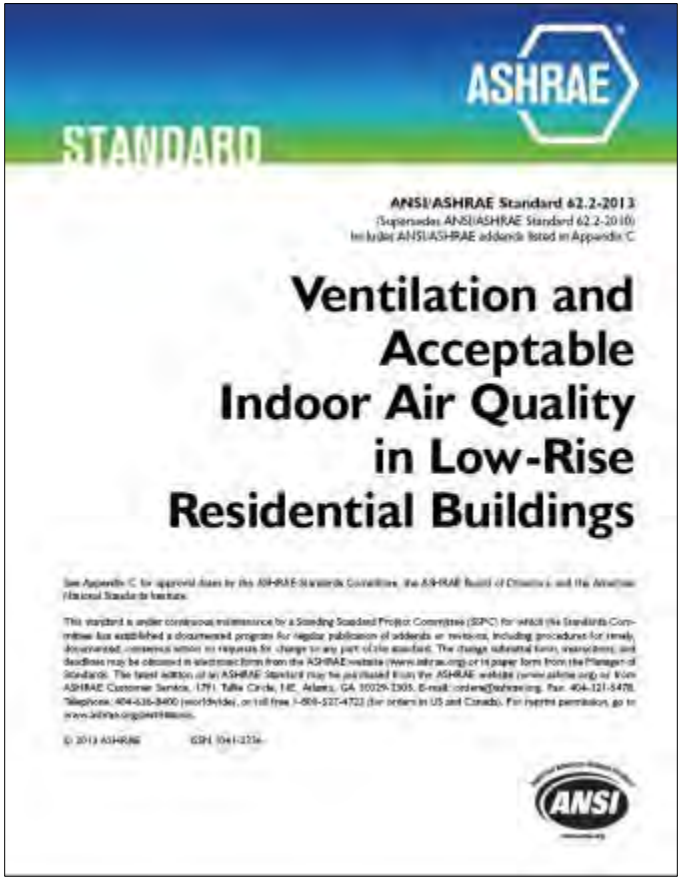
Carbon monoxide, pesticides, gasoline, fertilizers

CRAWLSPACE

Mold, dust, lead, radon, moisture, termiticide

Build tight, Ventilate right

ASHRAE STANDARD 62.2

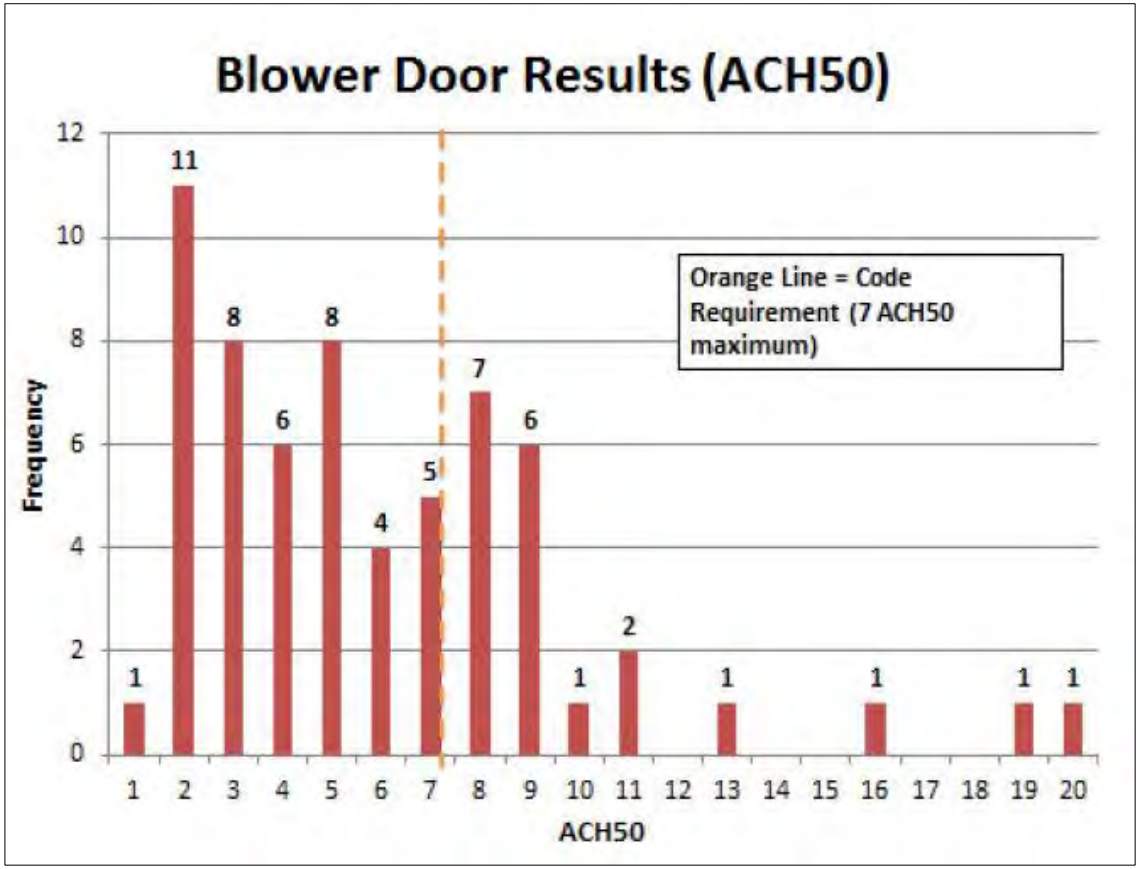


ASHRAE 62.2-2013

7.5 cfm/person + 3 cfm / 100 s.f.

VENTILATION CODE REQUIREMENTS

- Whole house ventilation is not just a good idea, it may be required by code!
- 2012 IRC requires homes with < 5 ACH_{50} have a whole house ventilation system
- There are houses being built in KY that meet this requirement!



COMBUSTION SAFETY

Combustion safety is very important for sealed homes

- Fans have bigger effect on pressures
- Appropriate equipment selection, location & installation is essential
- Safety tests can be performed by qualified individuals

TOP FIVE AIR SEALING CHALLENGES

In your experience, what are the most common challenges when air sealing homes?

TABLE 402.4.2
AIR BARRIER AND INSULATION INSPECTION COMPONENT CRITERIA

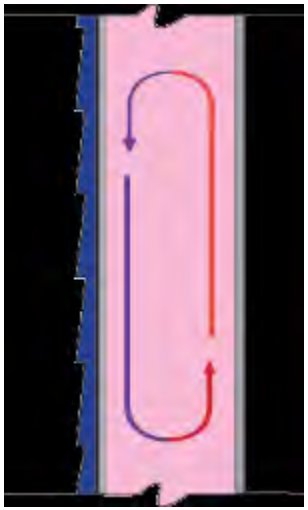
COMPONENT	CRITERIA
Air barrier and thermal barrier	Exterior thermal envelope insulation for framed walls is installed in substantial contact and continuous alignment with building envelope air barrier. Breaks or joints in the air barrier are filled or repaired. Air-permeable insulation is not used as a sealing material. Air-permeable insulation is inside of an air barrier.
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.
Walls	Corners and headers are insulated. Junction of foundation and sill plate is sealed.
Windows and doors	Space between window/door jambs and framing is sealed.
Rim joists	Rim joists are insulated and include an air barrier.
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.
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.
Shafts, penetrations	Duct shafts, utility penetrations, knee walls and flue shafts opening to exterior or unconditioned space are sealed.
Narrow cavities	Batts in narrow cavities are cut to fit, or narrow cavities are filled by sprayed/blown insulation.
Garage separation	Air sealing is provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures are air tight, IC rated, and sealed to drywall. Exception—fixtures in conditioned space.
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.
Shower/tub on exterior wall	Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall.
Electrical/phone box on exterior walls	Air barrier extends behind boxes or air sealed-type boxes are installed.
Common wall	Air barrier is installed in common wall between dwelling units.
HVAC register boots	HVAC register boots that penetrate building envelope are sealed to subfloor or drywall.
Fireplace	Fireplace walls include an air barrier.

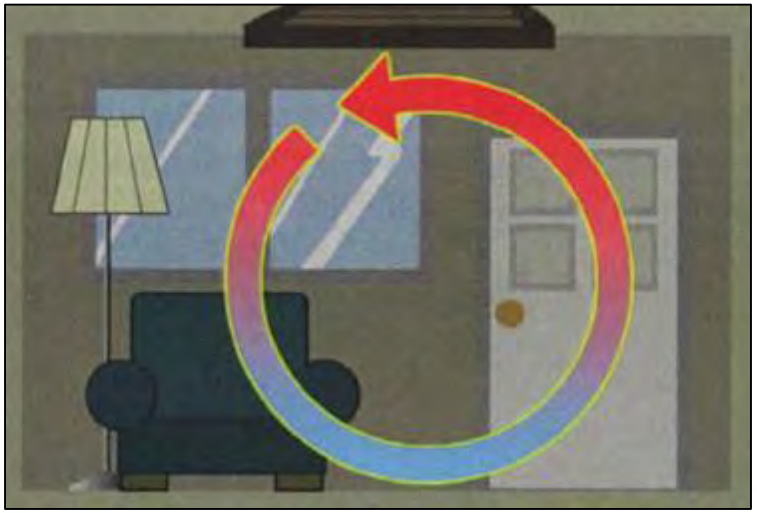
AIR SEALING & INSULATION

- Air sealing & insulation go hand in hand
- Both are necessary for an effective building envelope

CONVECTIVE LOOP

- Air movement due to temperature gradients (temperature is related to pressure)
- Air rises along warm surface and falls along cold surface
- Creates circular movement of air within enclosed space (wall cavity, band between floors, even a room within living space!)
- Transfers heat and can reduce effectiveness of insulation





IS INSULATION AN AIR BARRIER?

Insulation is not an air barrier!*

*Except…

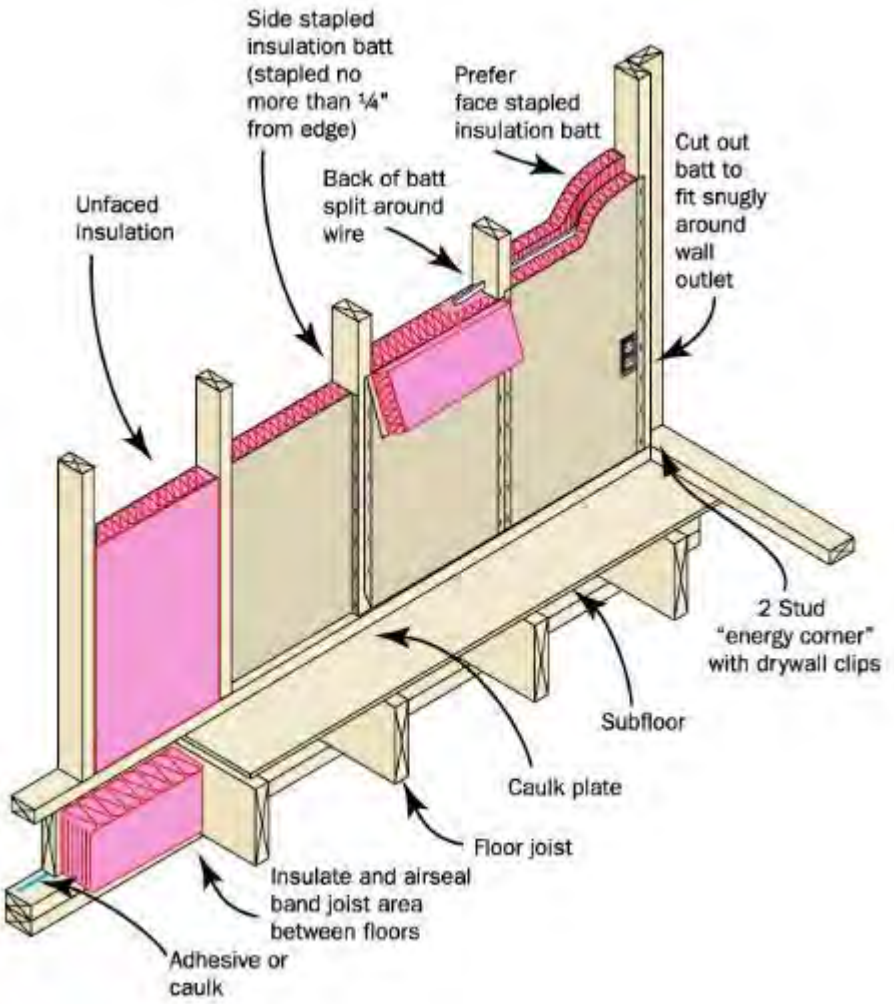
- Spray foam
- Dense pack cellulose (3.5 lb/cu.ft.)
- Rigid foam board (sealed seams)

THE IMPORTANCE OF INSULATION

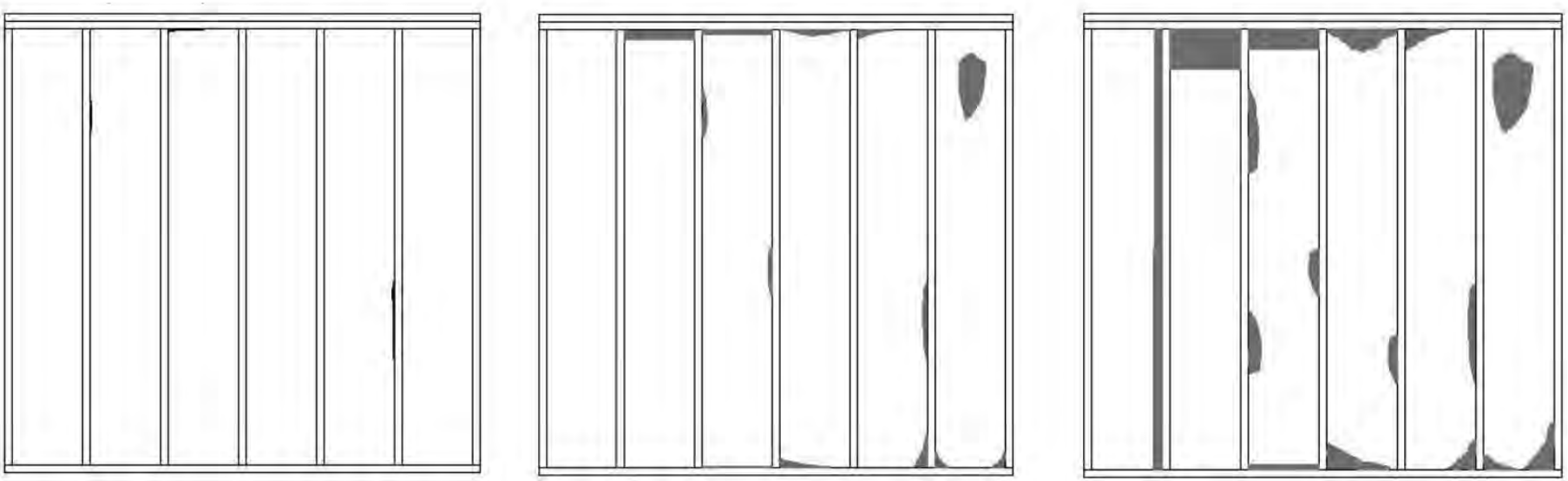
- Energy efficiency
- Comfort
- Durability
- Noise reduction

INSTALL INSULATION CORRECTLY

- No gaps
- Cut around plumbing, electrical wiring and outlets
- Compressed insulation reduces R-Value



INSPECTION



Grade I: Almost no gaps

Grade II: Up to 2%

Grade III: 2% - 5%

RESNET protocol for the effect of missing insulation on installation grade

Diagrams from the HERS Standards

NAIMA: insulationinstitute.org
Building America: basc.pnnl.gov

EXAMPLES OF INSULATION

Kraft-faced fiberglass batt insulation

EXAMPLES OF INSULATION

Loose fill insulation (typically fiberglass or cellulose)

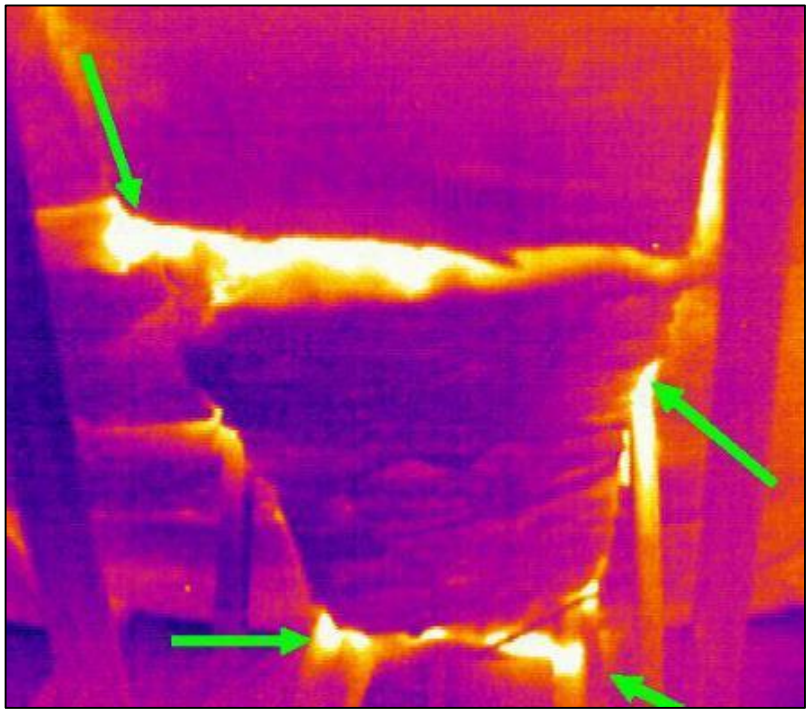
EXAMPLES OF INSULATION

Spray Polyurethane Foam (SPF)

EXAMPLES OF INSULATION

FLOOR INSULATION

Rare Problems with Floor Insulation?



INSULATING IN CRAWLSPACES

By choosing where to locate your air-sealing and insulation you can include or exclude the crawlspace from the building envelope

Closed (encapsulated) crawlspace:
Insulate & air seal crawlspace **walls**

Open (vented) crawlspace:
Insulate & air seal **subfloor** above

2009 IECC PRESCRIPTIVE REQUIREMENTS

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	CRAWL SPACE[c] WALL *R*-VALUE
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

2009 IECC Insulation and window efficiencies table

R-VALUES OF INSULATION

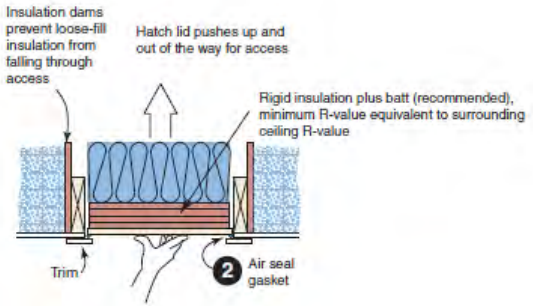
Typical Insulation R-values

Insulation Type	R-value per inch	Typical Applications
Cellulose, loose fill	3.7	Attic Floor
Cellulose, high density	3.2	Walls, Enclosed Cavities, Framing Transitions
Fiberglass, batts	3.0*	Basement Ceiling, Open Stud Walls, Attic Floor*
Fiberglass, loose fill	2.8	Attic Floor, Walls (existing)
Fiberglass, loose fill, fluffed below manufacturer's standards	uncertain	Do not install, or correct by blowing over with higher density
Rockwool	3.0	Attic Floor, Walls, Basement Ceiling (may be loose or batts)
Vermiculite	2.7	Attic Floor
Poly-isocyanurate, rigid board	7.0	Foundation Walls, Attic Access Doors
Polystyrene, expanded rigid board	4.0	Foundation Walls, Sill Plate
Polystyrene, extruded rigid board	5.0	Foundation Walls, Sub-Slab, Sill Plate
Low Density Urethane, sprayed foam	3.7	Attics, Walls (new construction); Sill Plate, Band Joist, Framing Transitions
Urethane, sprayed foam	6.0	Attics, Walls (new construction); Sill Plate, Band Joist, Framing Transitions
Urea Formaldehyde Foam	4.0	Attics, Walls (existing)

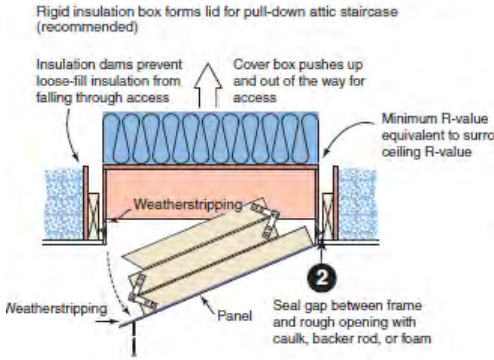
FOCUS: ATTICS

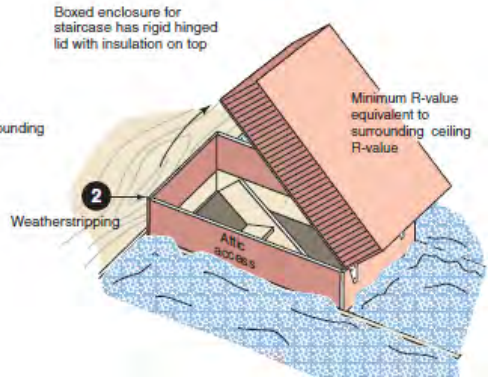
AIR SEALING ATTIC ACCESS

Attic scuttle

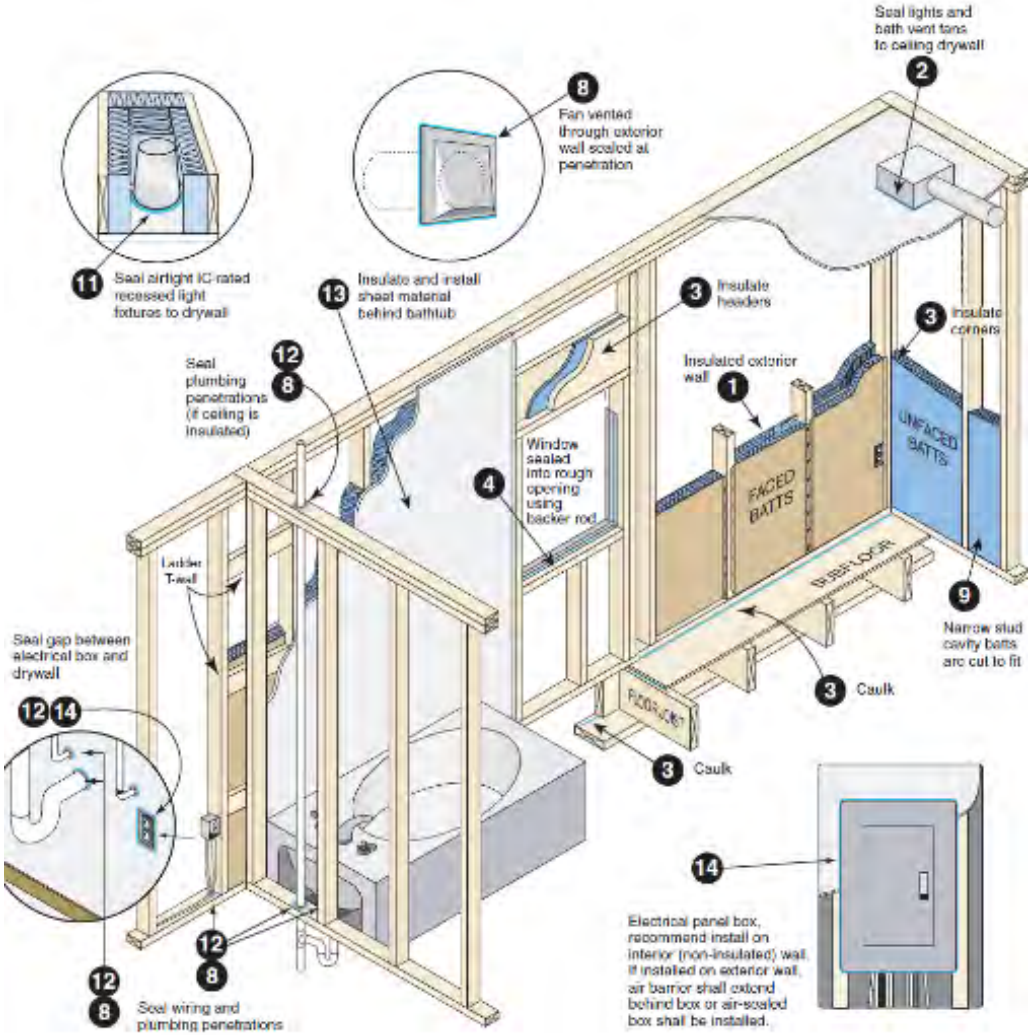


Attic pull-down stairs





AIR SEALING


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

402.4.5 RECESSED LIGHTS

Standard Can Light

Air-tight and IC Rated

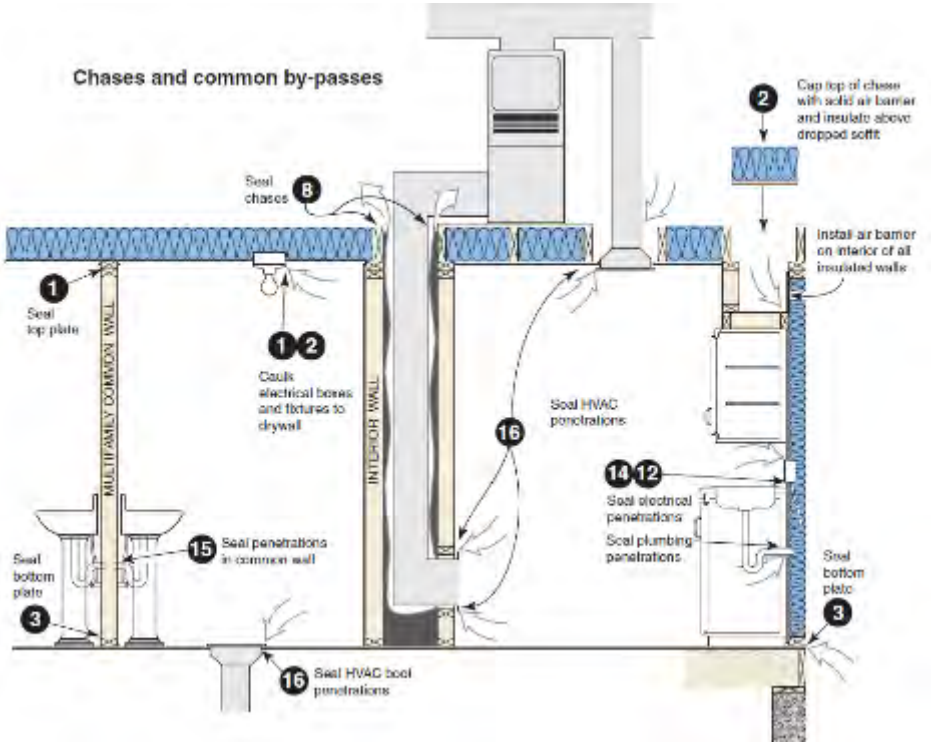
402.4.5 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as meeting ASTM E 283 when tested at 1.57 psf (75 Pa) pressure differential with no more than 2.0 cfm (0.944 L/s) of air movement from the *conditioned space* to the ceiling cavity. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

PRACTICAL AIR SEALING - EXAMPLES

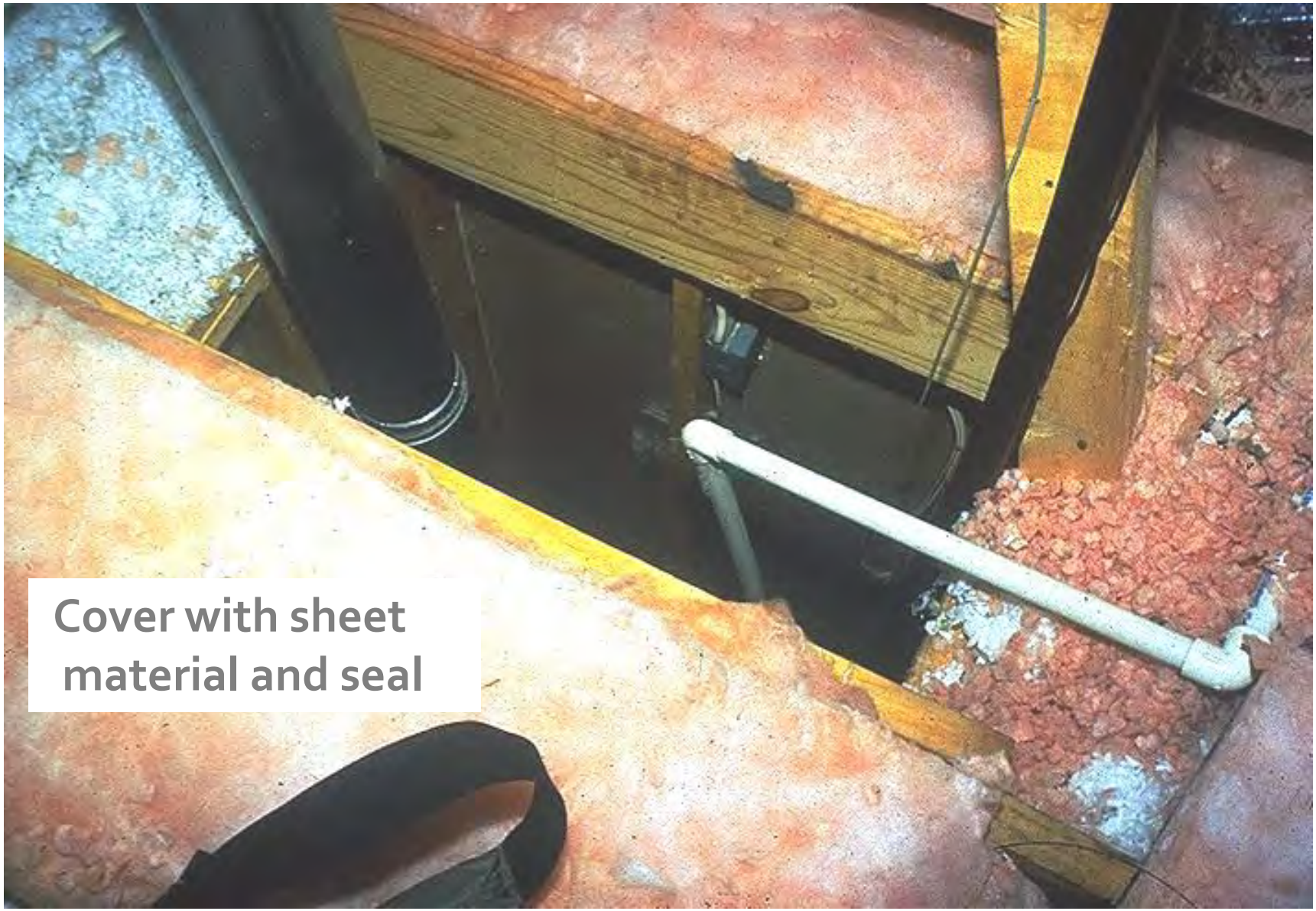
A home performance crew moved the attic insulation aside to access the gaps at the **top plates**

The crew sealed the gaps with **one part foam** and will install insulation on top of the sealed pressure boundary

AIR SEALING


Chases and common by-passes
2
Cap top of chase with solid air barrier and insulate above dropped soffit
Seal chases
8
Install air barrier on interior of all insulated walls
1
Seal top plate
1 2
Caulk electrical boxes and fixtures to drywall
MULTI-FAMILY COMMON WALL
INTERIOR WALL
Seal HVAC penetrations
16
14 12
Seal electrical penetrations
Seal plumbing penetrations
15
Seal penetrations in common wall
Seal bottom plate
3
Seal bottom plate
3
16
Seal HVAC boot penetrations

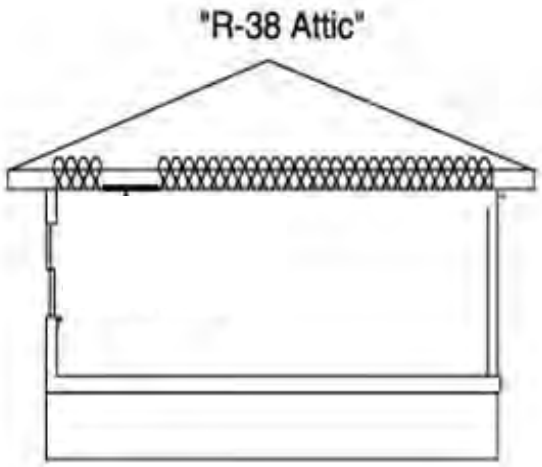
PRACTICAL AIR SEALING - EXAMPLE



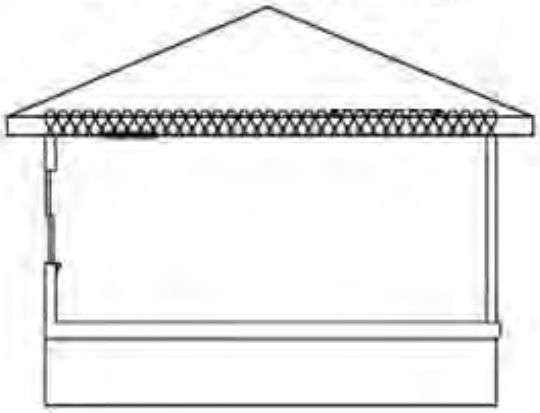
CEILING INSULATION

- Rulers and attic card in each attic space
- Blown insulation should not block soffit vents – use baffles

ATTIC DECKING - COVERAGE IS KEY!



R-28 – Full Coverage

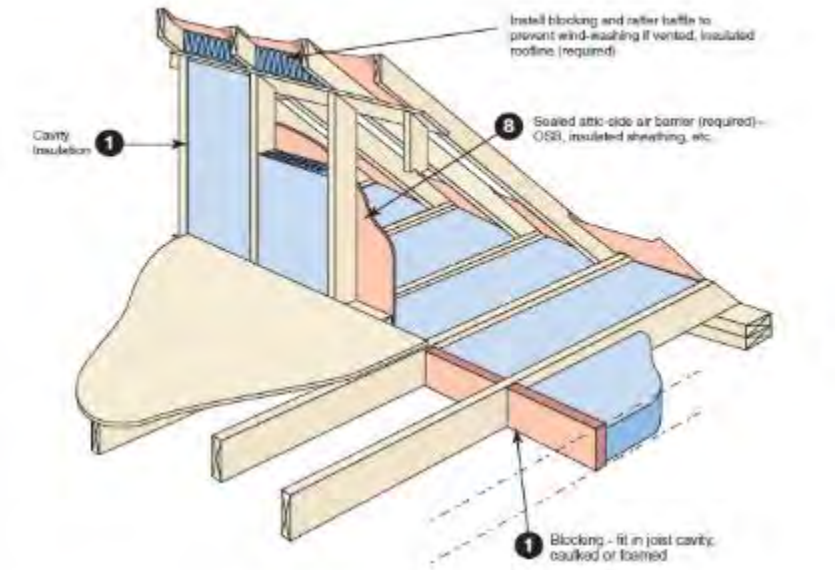


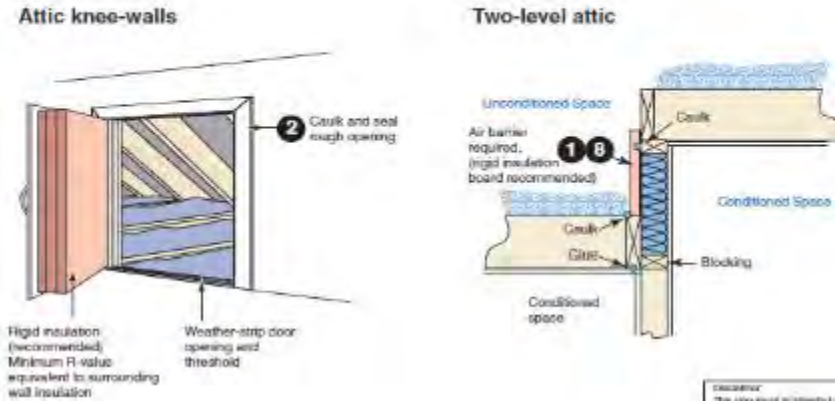
$$U_{avg} = \frac{U_1 \times A_1 + U_2 \times A_2}{A_{Total}}$$

The effective R-value of an attic floor with missing insulation can be calculated

An attic has a total area of 1000 ft². If 990 ft² is installed with R-38 while 10 ft² is an uninsulated area underneath attic decking (R-1), the average R-value of the entire attic is reduced to R-27!

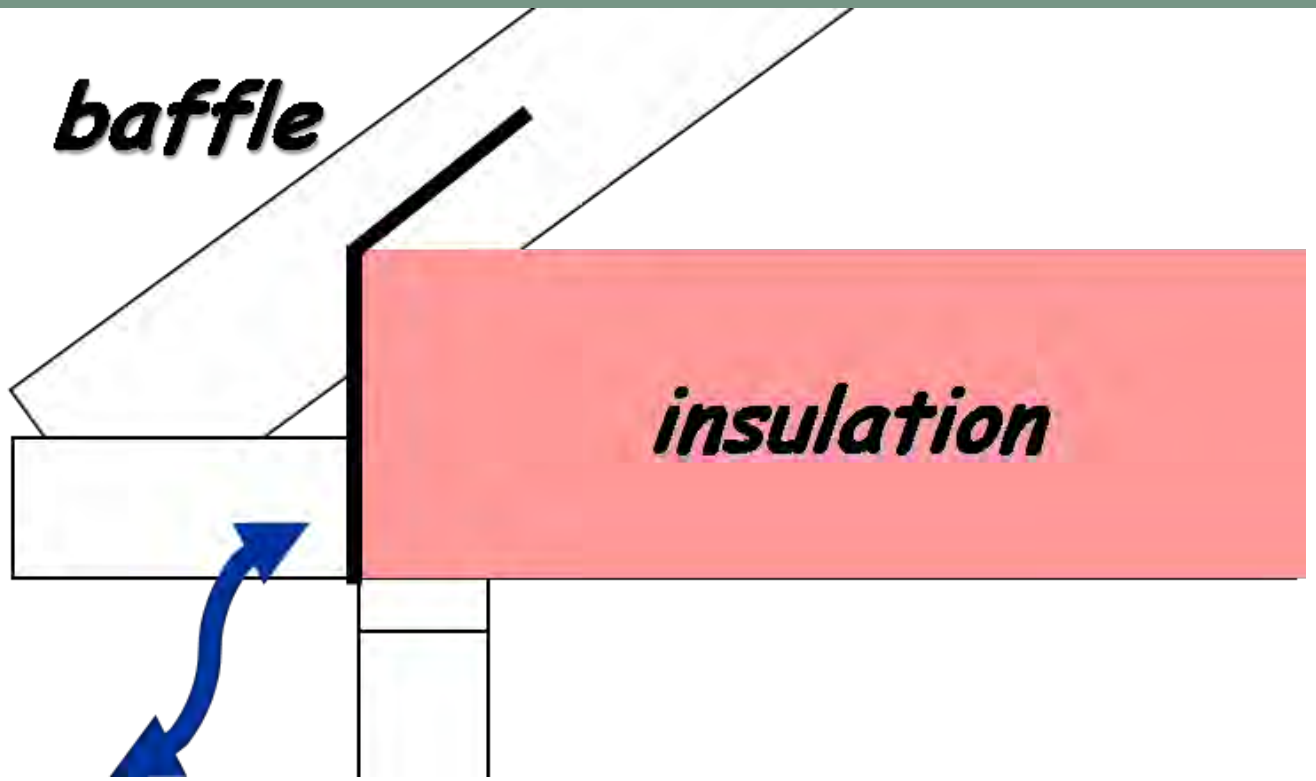
AIR SEALING KNEEWALLS





PROPER INSULATION INSTALLATION?

INSULATION: BAFFLES

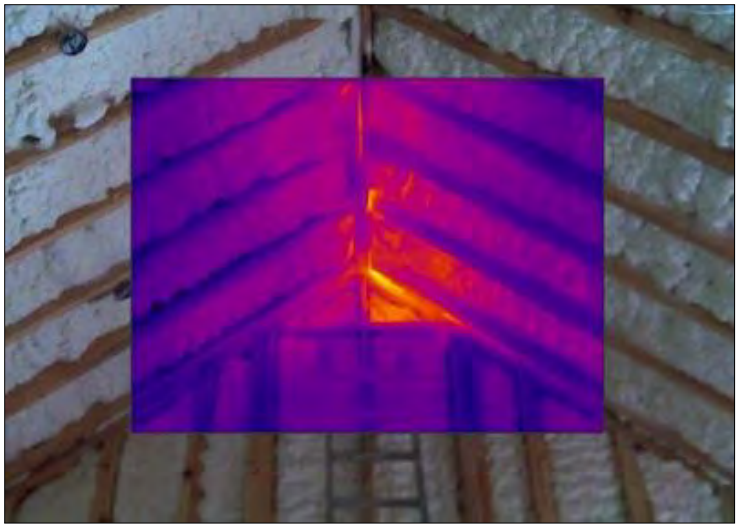


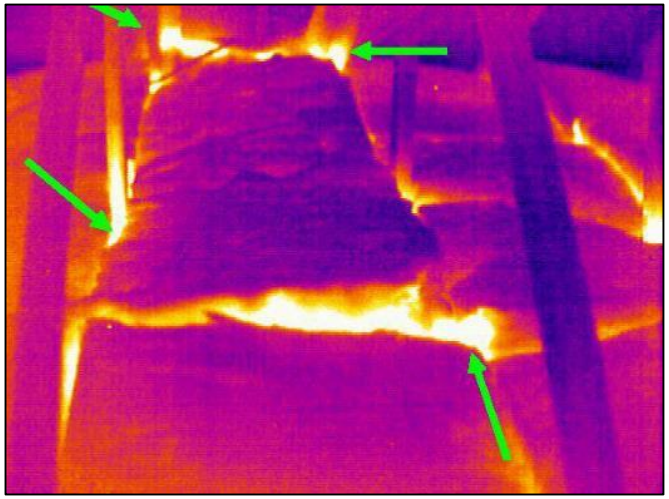
- Protects insulation from wind-wash
- Ensures proper ventilation by preventing insulation from blocking soffit vent

INSULATING THE ROOFLINE

INSTALLATION

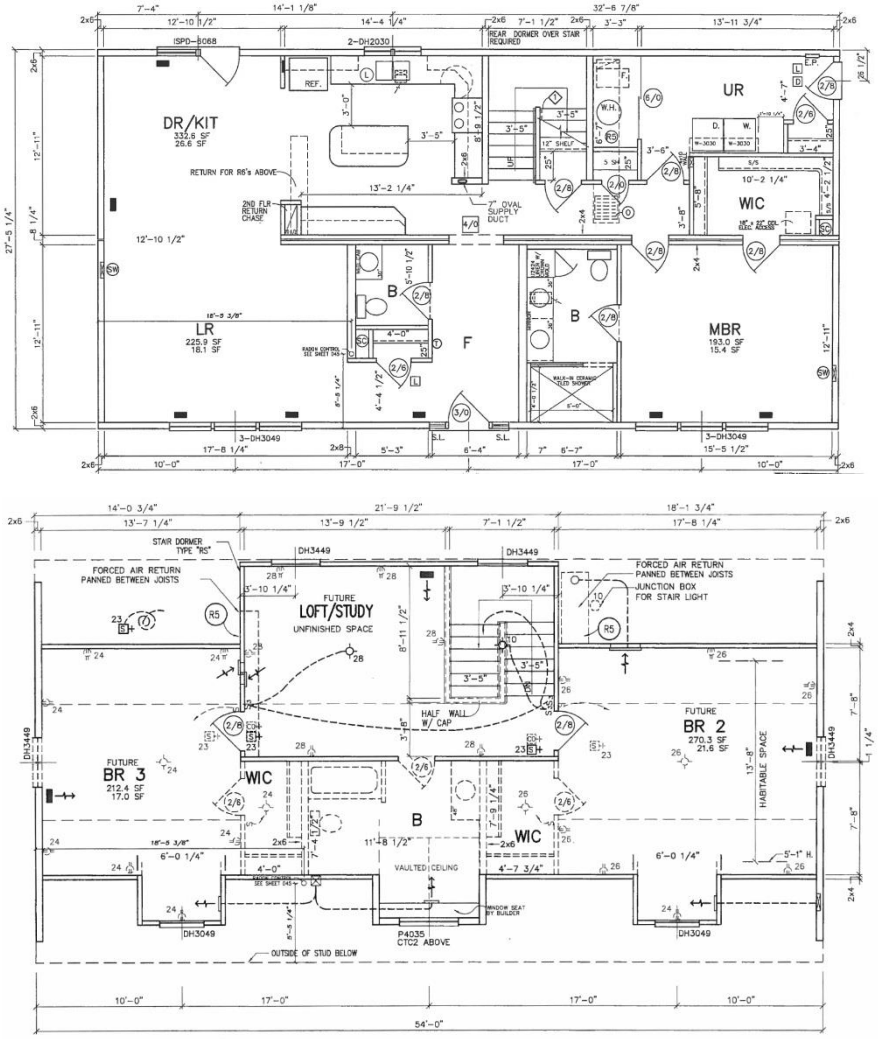
- It is possible to meet code and achieve effective results with a variety of products:
  - Fiberglass batts
  - Loose fill
  - Dense pack
  - Rigid board
  - Spray foam
- Regardless of type, all insulation must be properly installed to be effective!





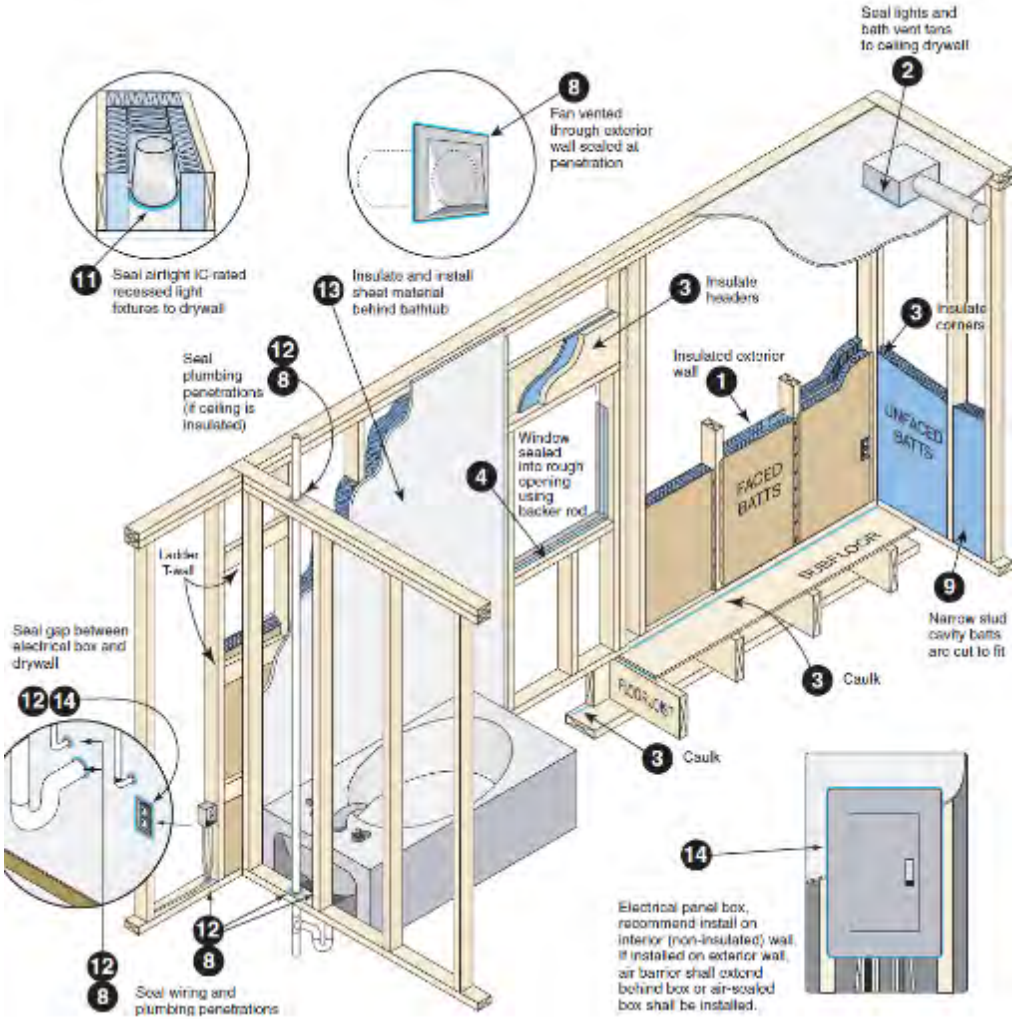
REVIEW: BUILDING ENVELOPE ACTIVITY

- Identify the attic kneewalls on the handout
- Describe the air sealing and insulation code requirements for kneewalls
- Are there alternative ways to define the building envelope that do not create kneewalls?

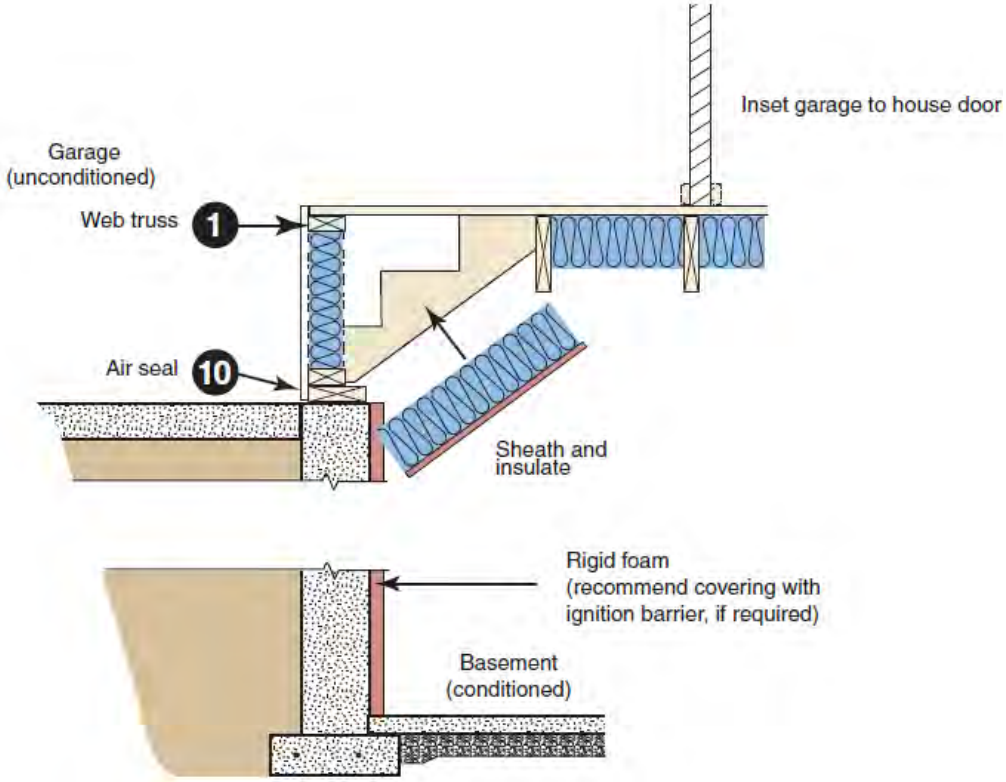


FOCUS: CRAWLSPACE/BASEMENT

AIR SEALING


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

AIR SEALING


Inset garage to house door
Garage
(unconditioned)
Web truss
1
Air seal
10
Sheath and
insulate
Rigid foam
(recommend covering with
ignition barrier, if required)
Basement
(conditioned)

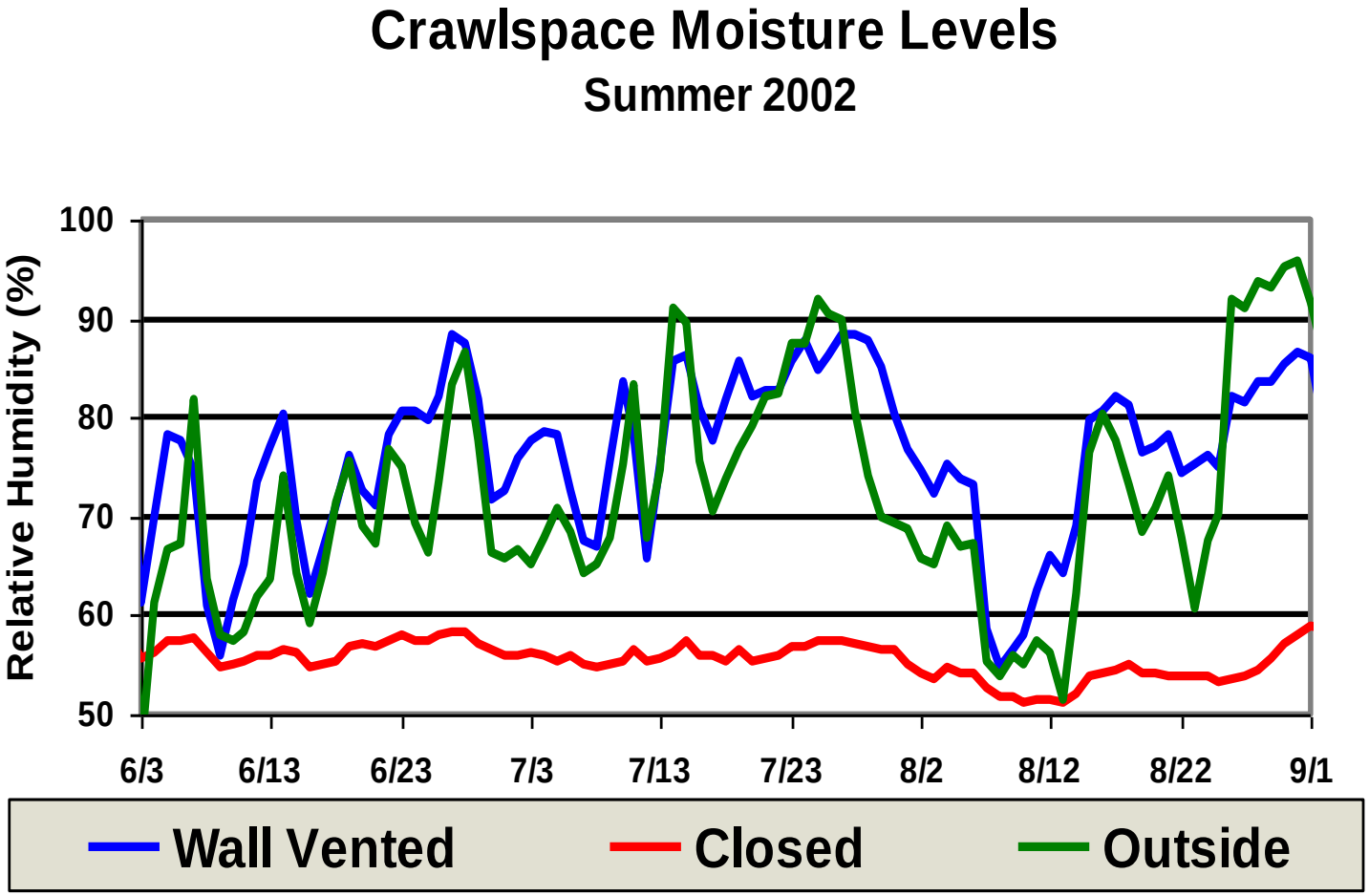
INSULATING IN CRAWLSPACES

By choosing where to locate your air-sealing and insulation you can include or exclude the crawlspace from the building envelope

Closed (encapsulated) crawlspace:
Insulate & air seal crawlspace **walls**

Open (vented) crawlspace:
Insulate & air seal **subfloor** above

SEALED CRAWLSPACE STUDY



Advanced Energy - crawlspaces.org

CODE SAYS TO VENT, BUT OFFERS AN EXCEPTION…

SECTION R408
UNDER-FLOOR SPACE

R408.1 Ventilation. The under-floor space between the bottom of the floor joists and the earth under any building (except space occupied by a *basement*) shall have ventilation openings through foundation walls or exterior walls. The minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m^2) for each 150 square feet (14 m^2) of under-floor space area, unless the ground surface is covered by a Class 1 vapor retarder material. When a Class 1 vapor retarder material is used, the minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m^2) for each 1,500 square feet (140 m^2) of under-floor space area. One such ventilating opening shall be within 3 feet (914 mm) of each corner of the building.

R408.2 Openings for under-floor ventilation. The minimum net area of ventilation openings shall not be less than 1 square foot (0.0929 m^2) for each 150 square feet (14 m^2) of under-floor area. One ventilation opening shall be within 3 feet (915 mm) of each corner of the building. Ventilation openings shall be covered for their height and width with any of the following materials provided that the least dimension of the covering shall not exceed $^1/_4$ inch (6.4 mm):

1. Perforated sheet metal plates not less than 0.070 inch (1.8 mm) thick.
2. Expanded sheet metal plates not less than 0.047 inch (1.2 mm) thick.
3. Cast-iron grill or grating.
4. Extruded load-bearing brick vents.
5. Hardware cloth of 0.035 inch (0.89 mm) wire or heavier.
6. Corrosion-resistant wire mesh, with the least dimension being $^1/_8$ inch (3.2 mm) thick.

- 1:150 s.f. just vents

1:1500 s.f. with Class I vapor retarder installed
(e.g., 6 mil poly)

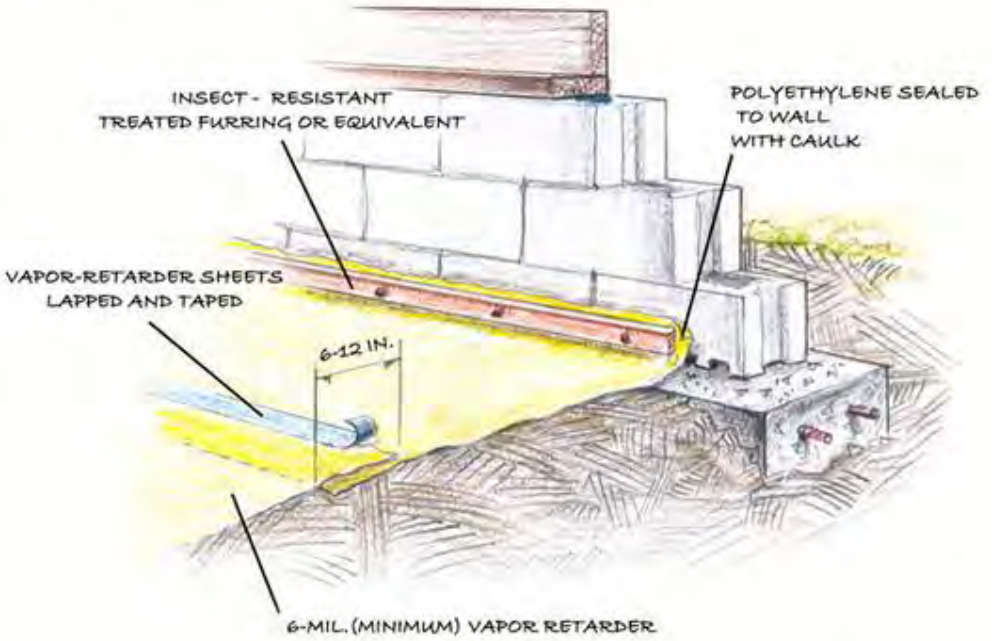
UNVENTED OPTION, PART 1

R408.3 Unvented crawl space. Ventilation openings in under-floor spaces specified in Sections R408.1 and R408.2 shall not be required where:

1. Exposed earth is covered with a continuous Class I vapor retarder. Joints of the vapor retarder shall overlap by 6 inches (152 mm) and shall be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall or insulation; and

Photo thanks to Donnie Holmes

EPA Indoor airPLUS | MOISTURE CONTROL 1.2
www.epa.gov/indoorairplus



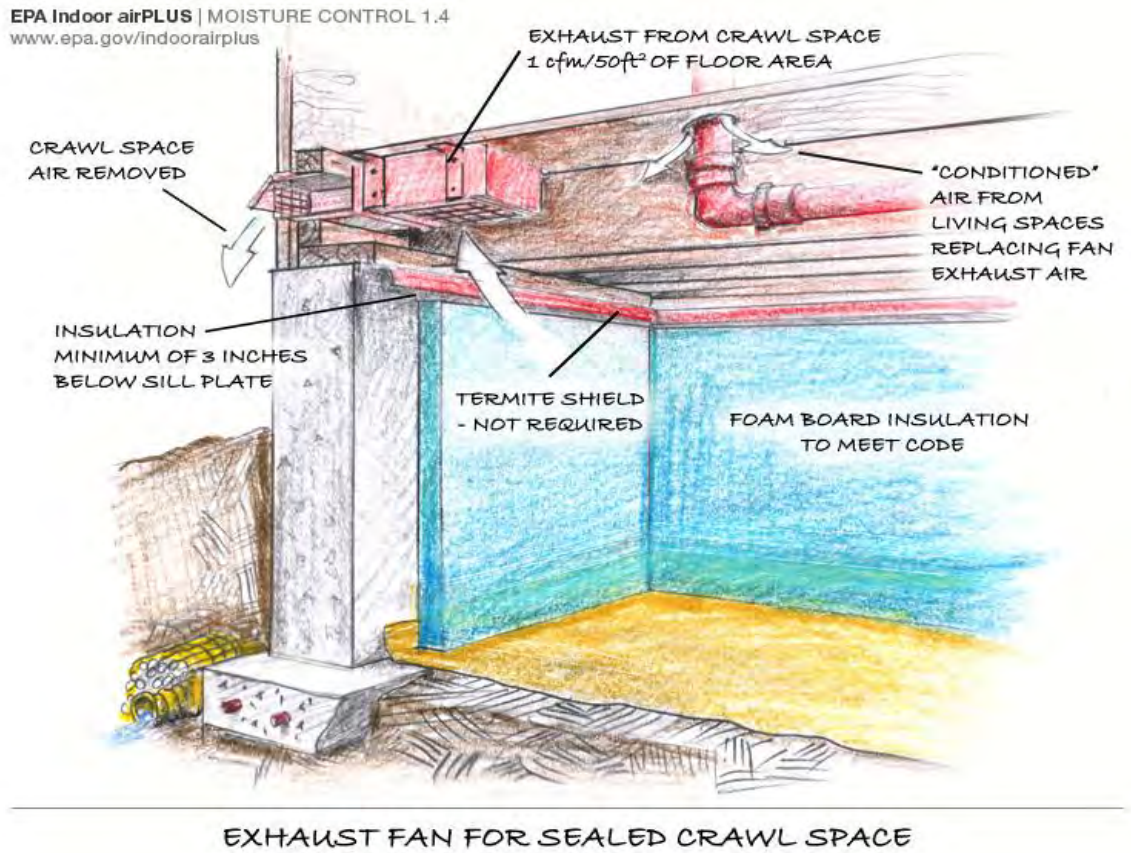
CRAWL SPACE - VAPOR RETARDER OVER SOIL

UNVENTED EXCEPTION, PART 2.1

2. One of the following is provided for the under-floor space:

   2.1. Continuously operated mechanical exhaust ventilation at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7m^2) of crawlspace floor area, including an air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1103.2.1 of this code;

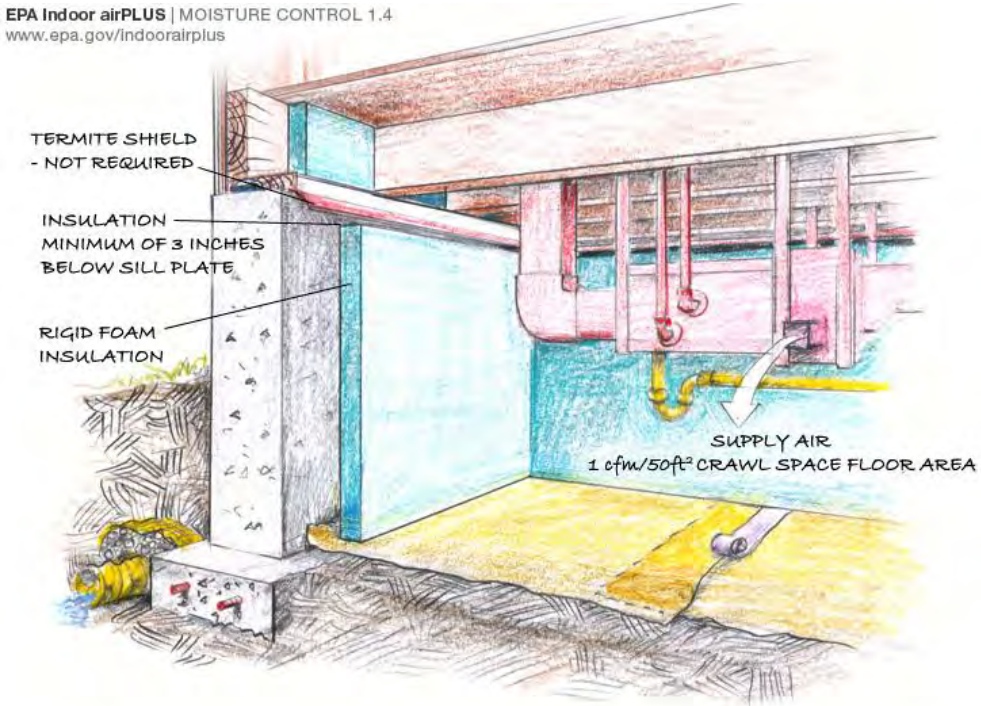
- Arguably, an active radon remediation system could be deemed continuously operated mechanical exhaust ventilation



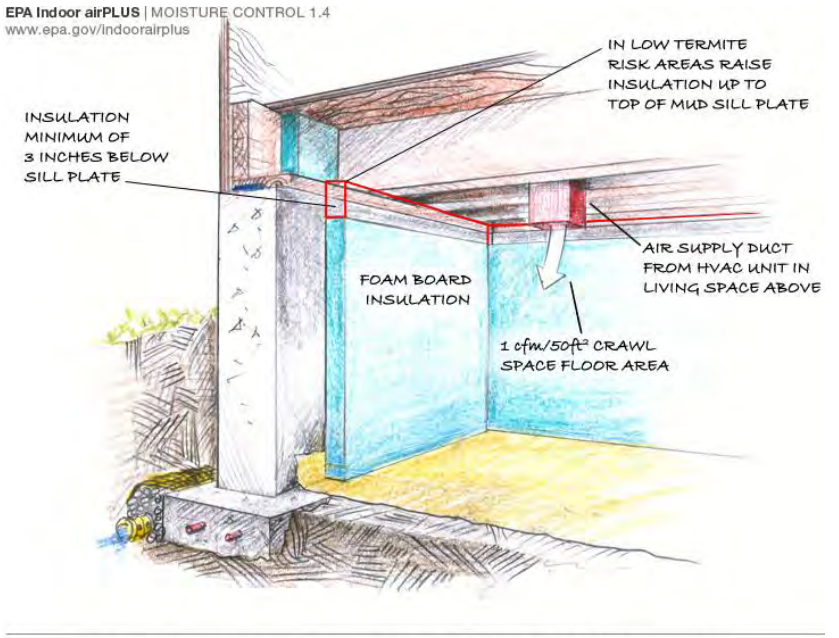
EXHAUST FAN FOR SEALED CRAWL SPACE

UNVENTED EXCEPTION, PART 2.2

2.2. *Conditioned air* supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m^2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2 of this code;



CONDITIONED AIR SUPPLY TO SEALED CRAWL SPACE



CONDITIONED AIR SUPPLY TO SEALED CRAWL SPACE

UNVENTED EXCEPTION, PART 2.2 (WITH A BIT OF AN INTERPRETATION)

2.2. *Conditioned air* supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m^2) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2 of this code;

- Arguably, a crawlspace can be "conditioned" by installing a dehumidifier that is delivering the required cfm
- Especially in mixed or warmer climates,
  - drying the crawl air is more important
  - since the walls are insulated, the crawlspace temperature should remain reasonable (above 60 ° F)
  - duct leakage contributes to "conditioning"
- Our preferred approach since crawl gets what it needs (moisture control) based on sensor located in the crawlspace itself

UNVENTED EXCEPTION, PART 2.3

2.3. Plenum in existing structures complying with Section M1601.5, if under-floor space is used as a plenum.

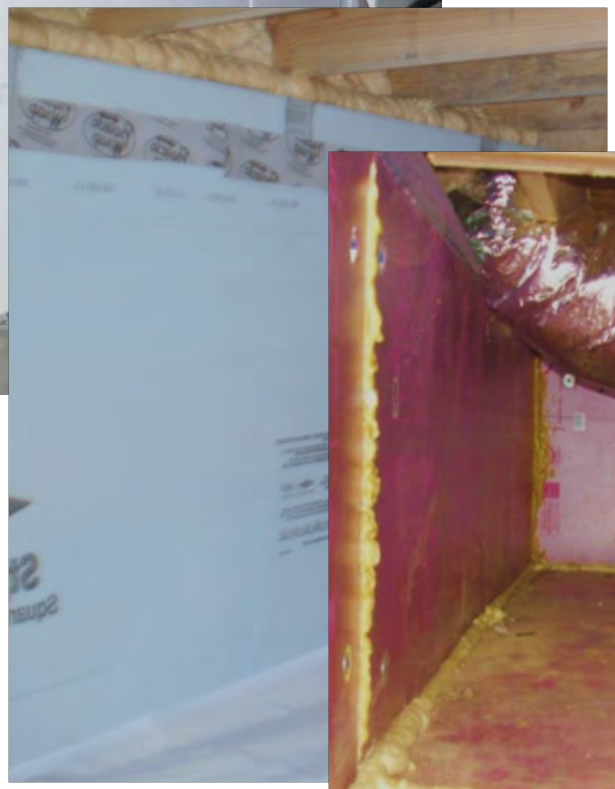
TO CLOSE UP OR NOT?

Is it practical to close all crawlspaces?

- Drainage problems
- Combustion safety
- Pest control

INSULATION TECHNIQUES – RIGID FOAM

EPS foam
with borate



XPS foam

Poly-iso
foam

A desirable insulation installation is one that will stay in place, be resilient in case of moisture issues, and have low cost

INSULATION TECHNIQUES - SPRAYED

Open cell

Closed cell

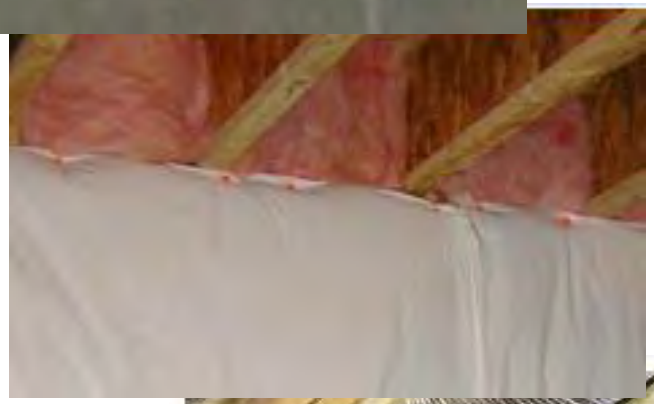
High-borate cellulose

A desirable insulation installation is one that will stay in place, be resilient in case of moisture issues, and have low cost

INSULATION TECHNIQUES – BAND AREA

Closed cell foam

Air seal & insulate rim/band area



Fiberglass batt

Blown bag

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 |

DETAILS FOR UNVENTED CRAWLSPACES

Gap for pest inspection

Photos thanks to Donnie Holmes

SF suggestion: taped, hinged "plug" of rigid insulation board in gap

CONTROL MOISTURE!

Whether open or closed, a vapor barrier must be installed!

- Completely seal ground with plastic

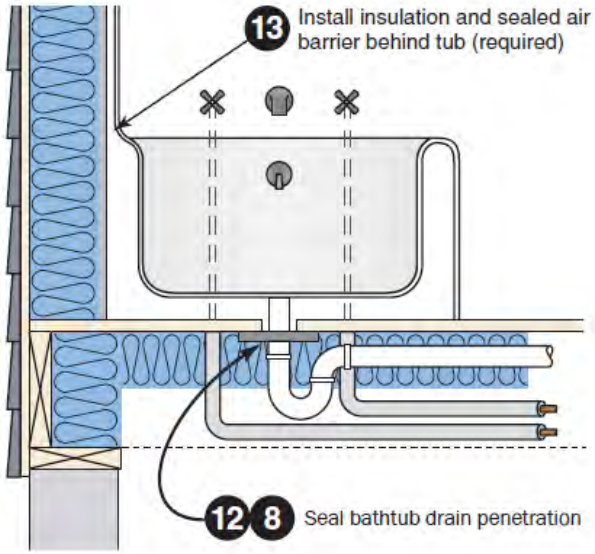
  (recommend >6 mil reinforced)
- Overlap seams at least 6”
- Seal all seams and foundation attachment points
- Seal plastic to foundation walls at least 6” above grade

BASEMENT AIR SEALING & INSULATION

FOCUS: THE SHELL

AIR SEALING BLOCKING & SHEATHING

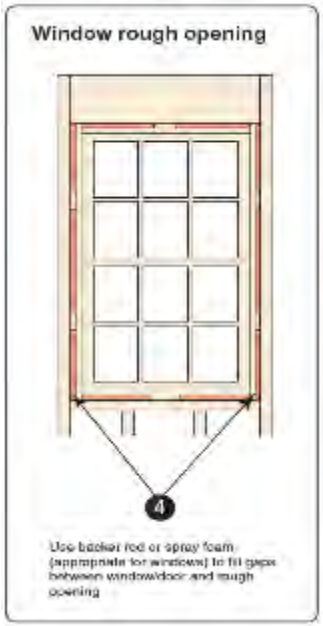
Solid sheet behind tubs & showers on insulated walls

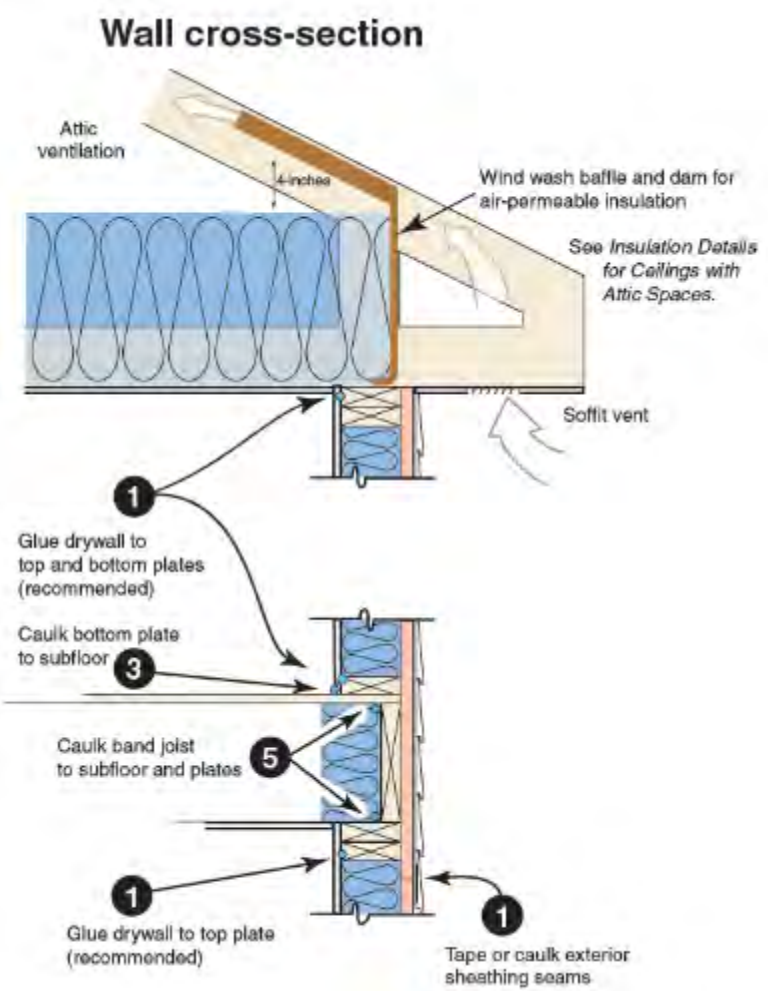


Call back waiting to occur

Call back prevention

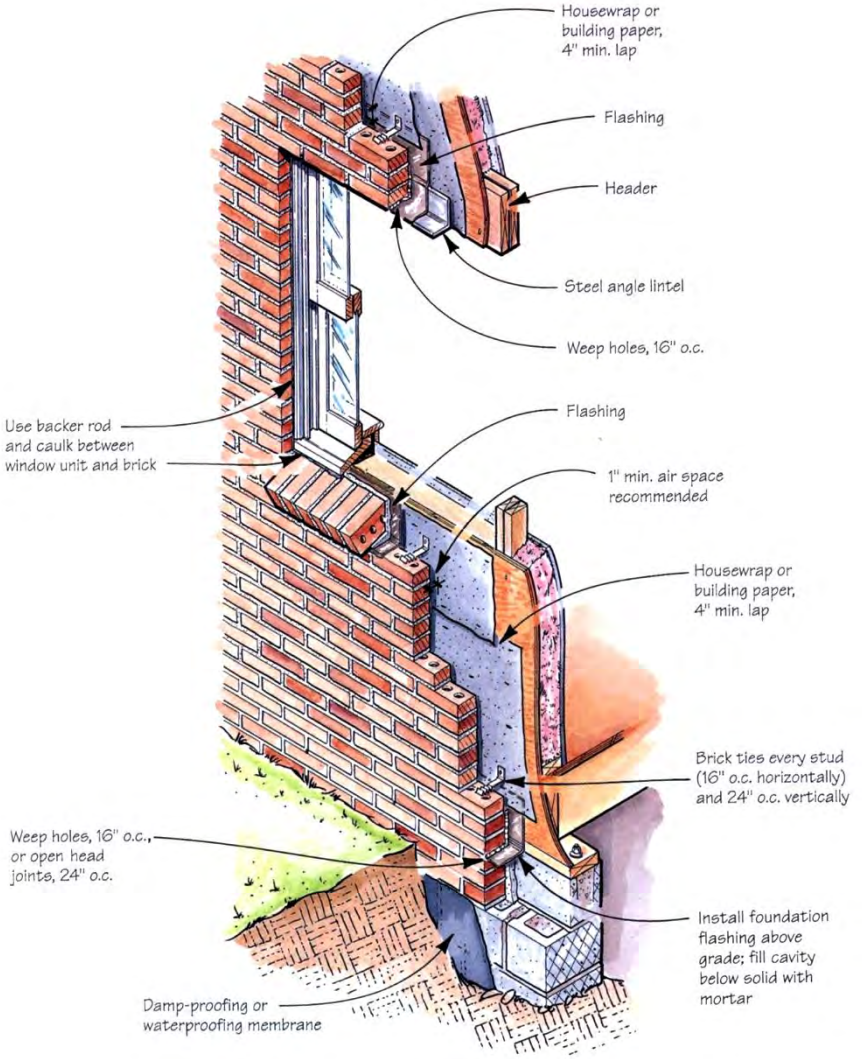
AIR SEALING WINDOWS & WALLS





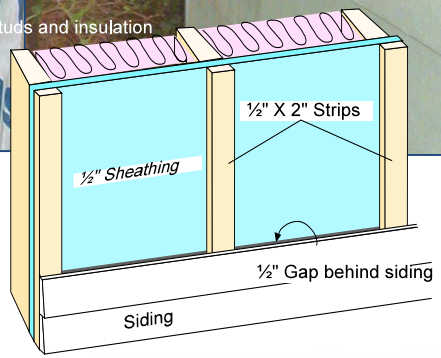
402.4.4- Windows, skylights and doors ≤ 0.3 cfm/s.f.,
Swinging doors ≤ 0.5 cfm/s.f.
Exception: site built

CLADDING – BRICK VENEER



CLADDING – BRICK VENEER

RAIN SCREEN / DRAINAGE PLANE



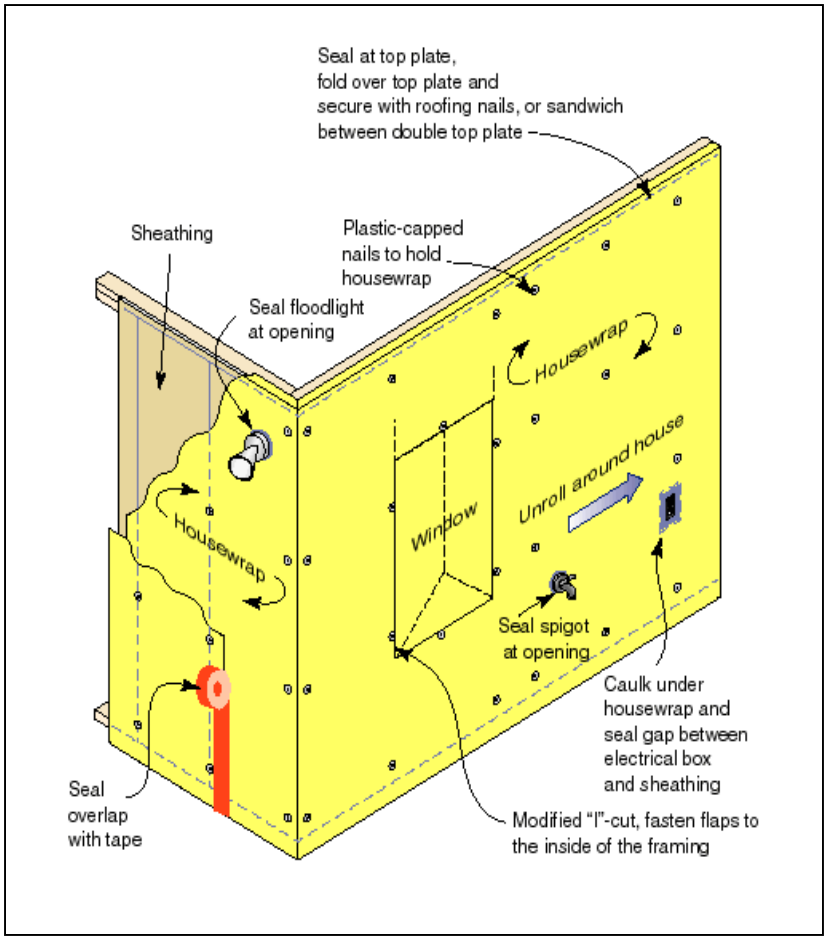
HOUSEWRAP: DETAILS ARE CRITICAL

Top Sash after trim removed

Rotten Header

Windows (incorrectly) have flange over housewrap

HOUSEWRAP AS A WEATHER BARRIER



Technology Fact Sheet

WEATHER-RESISTIVE BARRIERS

How to select and install housewrap and other types of weather-resistive barriers

INTRODUCTION

Weather-resistive barriers are a part of exterior wall systems that protect building materials from exterior water penetration. They perform like a shell for buildings—liquid water that has

WHEN AND HOW TO USE WEATHER-RESISTIVE BARRIERS

As part of a whole-wall design, weather-resistive barriers need to be integrated with other wall system components, including structure,

DURABILITY AND WRB'S

Flashing integrated with wall and roof drainage plane surfaces

NO WEATHER BARRIER – AIR LEAKAGE

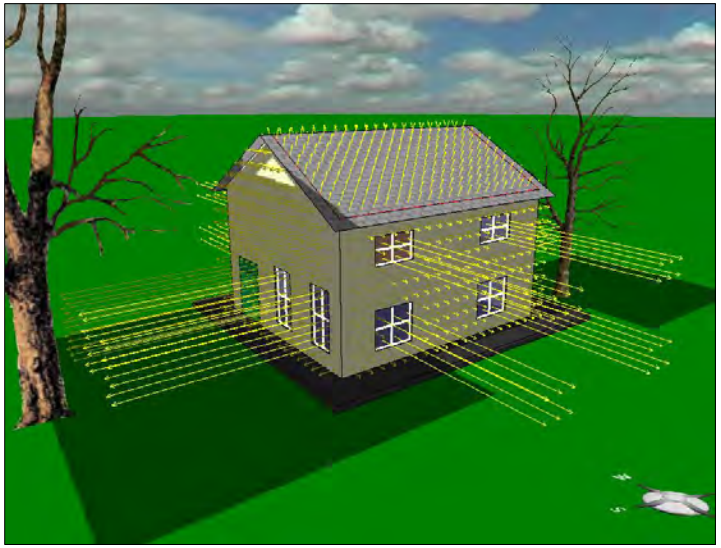
ALTERNATIVE WR BARRIERS

FLUID-APPLIED WEATHER RESISTIVE BARRIER

FOCUS: HVAC

FUNCTION – HEATING & COOLING

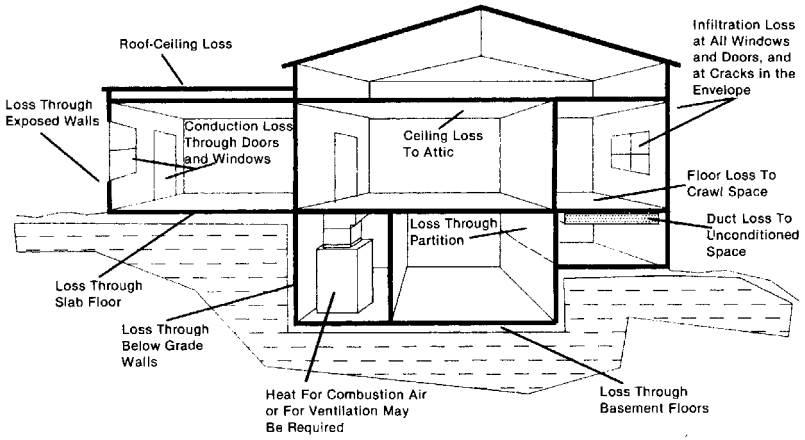
- There a variety of types of heating and cooling systems
- We will focus on forced air ducted systems
- Furnaces & heat pumps essentially replace heat that is lost across the building envelope
- Air conditioning removes heat & moisture (sensible & latent)

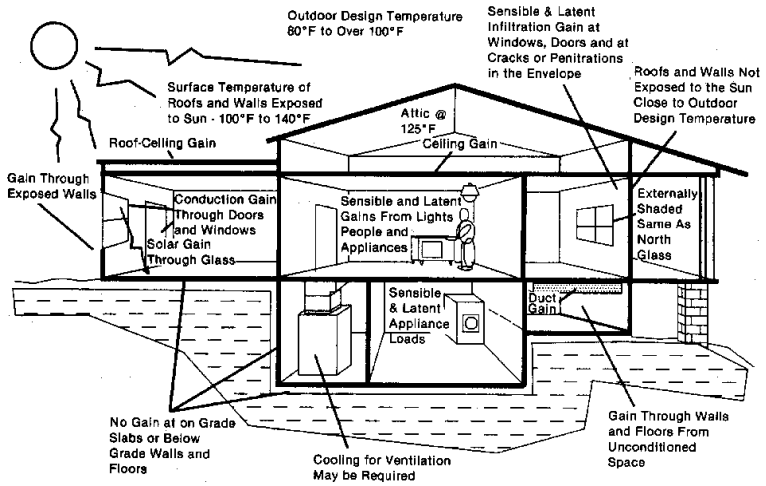


HOW AIR CONDITIONING REMOVES MOISTURE

- Warm humid indoor air is blown across a cold coil
- Water vapor in the air condenses on the coil, collects, then exits the home through the condensate line
- This process takes time
- Oversized systems reach the thermostat set point before moisture is removed from home

HVAC EQUIPMENT SIZING





Source: ACCA Manual J (2011)
Used courtesy of ACCA

Systems are sized in order to best fulfill their function

- Heating is sized at a rate to replace lost BTUs
- AC sized for both sensible & latent
- Climate is important (design temps)

HAZARDS OF IMPROPER SIZING

Improper sizing can create a variety of problems
This is especially important for air conditioning!

Tendency to oversize AC results in:

- Ineffective moisture removal
- Poor comfort
- IAQ concerns
- Durability issues

Heating:

- Too small – poor comfort
- Too big – short cycling

SYSTEM AIRFLOW

Proper system airflow rates are essential for effective HVAC performance

- Too fast – poor comfort & ineffective moisture removal
- Too slow – poor comfort and equipment issues

BEST OF BOTH WORLDS

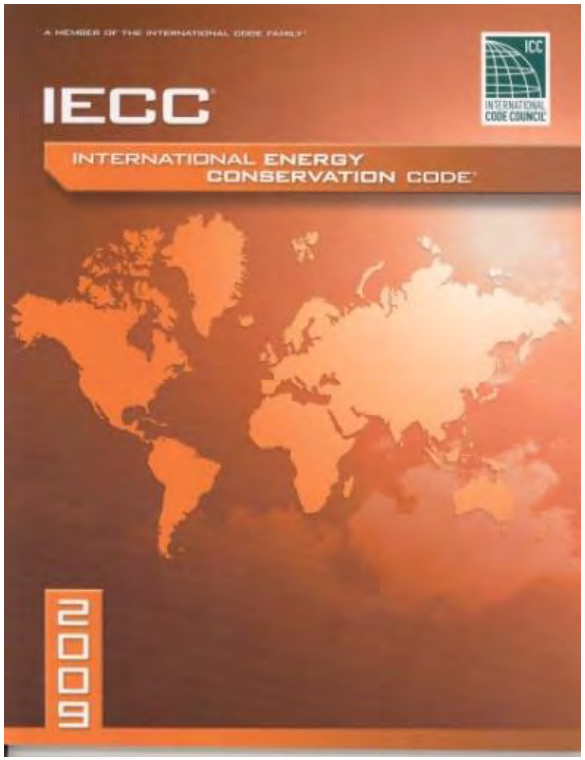
Variable speed systems:

- Provide effective strategies for consistent performance
- But performance can be compromised by poor duct design, sizing & installation (also filters)
- Proper design & installation is essential for advanced equipment

DUCT SEALING IS CRITICAL!

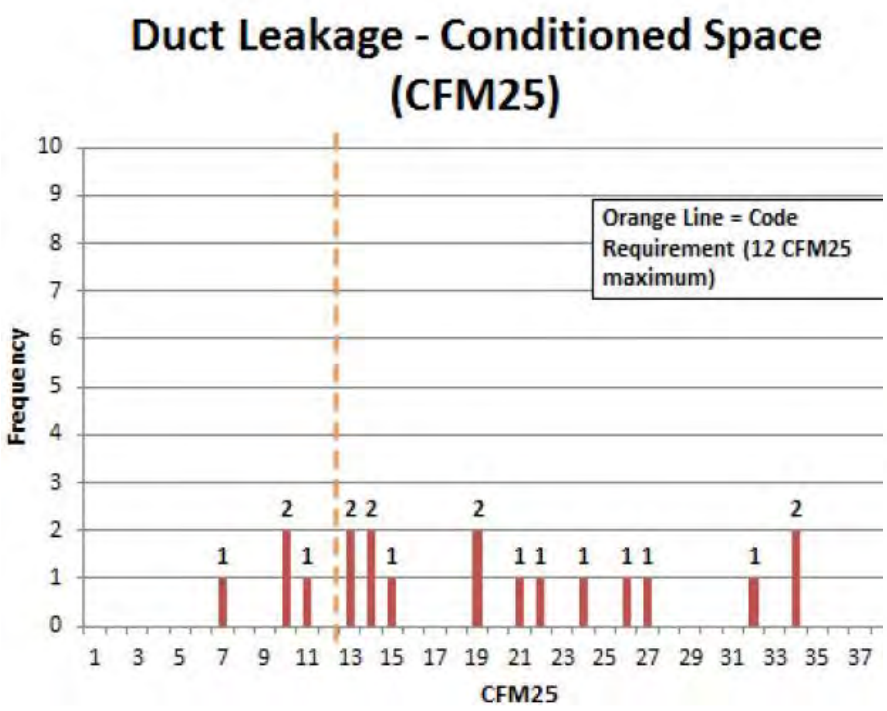
- Duct sealing & testing are required by code
- Ducts must be sealed regardless of location
- Mastic is the preferred material for sealing

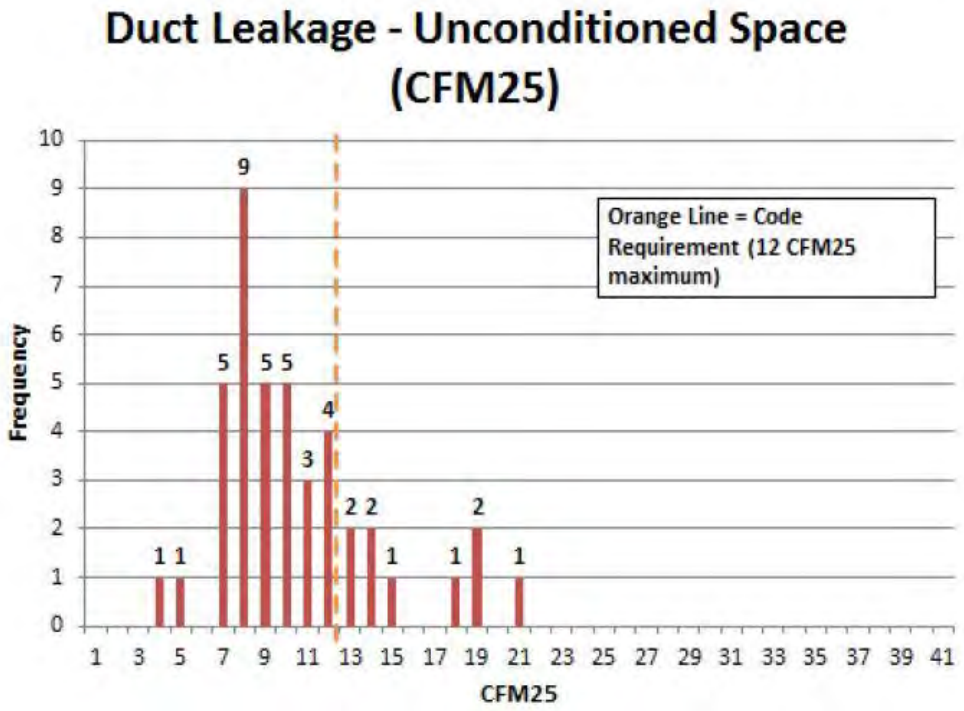
DUCT TESTING REQUIREMENTS



- Kentucky code requires leakage testing of ducts (unless located within conditioned space)
- Even if ductwork is exempt from testing, it still must be sealed

ROOM FOR IMPROVEMENT!





Kentucky code requires leakage testing of ducts (unless located within conditioned space)

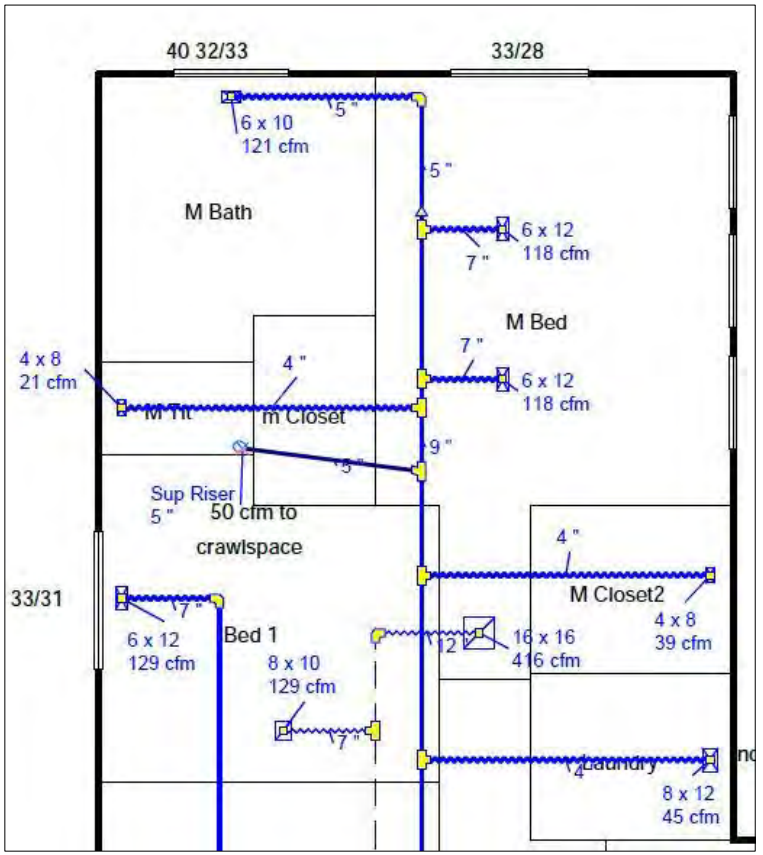
DUCT TESTING REQUIREMENTS

Duct leakage must meet one of the following:

- Post-construction duct leakage to outdoors ≤ 8 cfm per 100 ft2
- Post-construction total duct leakage ≤ 12 cfm per 100 ft2
- Rough-in total duct leakage w/AHU ≤ 6 cfm per 100 ft2
- Rough-in total duct leakage without AHU ≤ 4 cfm per 100 ft2

DUCT INSTALLATION

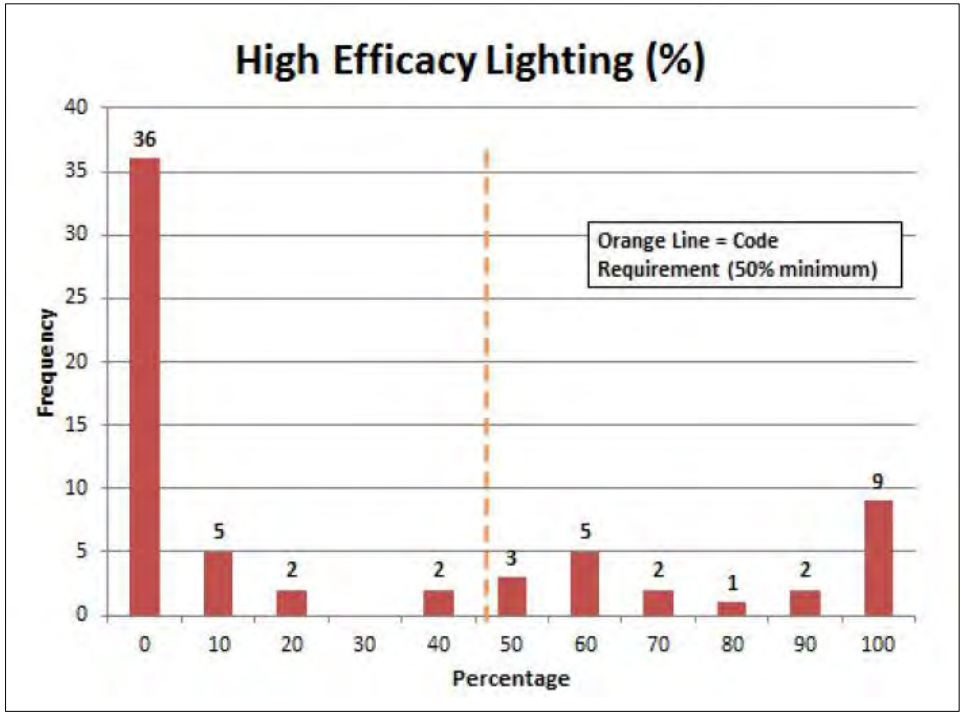
- ACCA Manual D should be used for duct design
- Ducts should be properly sized
- Ducts should be short, straight, and well supported



DUCT INSTALLATION

FOCUS: LIGHTING

404.1 Lighting equipment (Prescriptive). A minimum of 50 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps.



Compliance is low in KY – why?

INCANDESCENT VS. CFL VS. LED

$$60 \text{ watts} \times \frac{10 \text{ hrs}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \text{ kwh}}{1000 \text{ wh}} = \mathbf{219} \frac{\text{kwh}}{\text{year}}$$

$$13 \text{ watts} \times \frac{10 \text{ hrs}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \text{ kwh}}{1000 \text{ wh}} = \mathbf{47.5} \frac{\text{kwh}}{\text{year}}$$

$$9 \text{ watts} \times \frac{10 \text{ hrs}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \text{ kwh}}{1000 \text{ wh}} = \mathbf{32.9} \frac{\text{kwh}}{\text{year}}$$

SIMPLE PAYBACK FOR HIGH EFFICACY BULB

- Builders may have to raise asking price to recoup extra money spent on high efficacy lighting.
- How can a builder justify a higher price to the homeowner?

At *$0.10 / kwh*, how long will it take an LED light bulb to pay for itself?

Bulb cost = **$5.00**

Energy cost =

32.9 kwh/yr x $0.10 / kwh = **$3.29/year**

Energy cost for Incandescent =

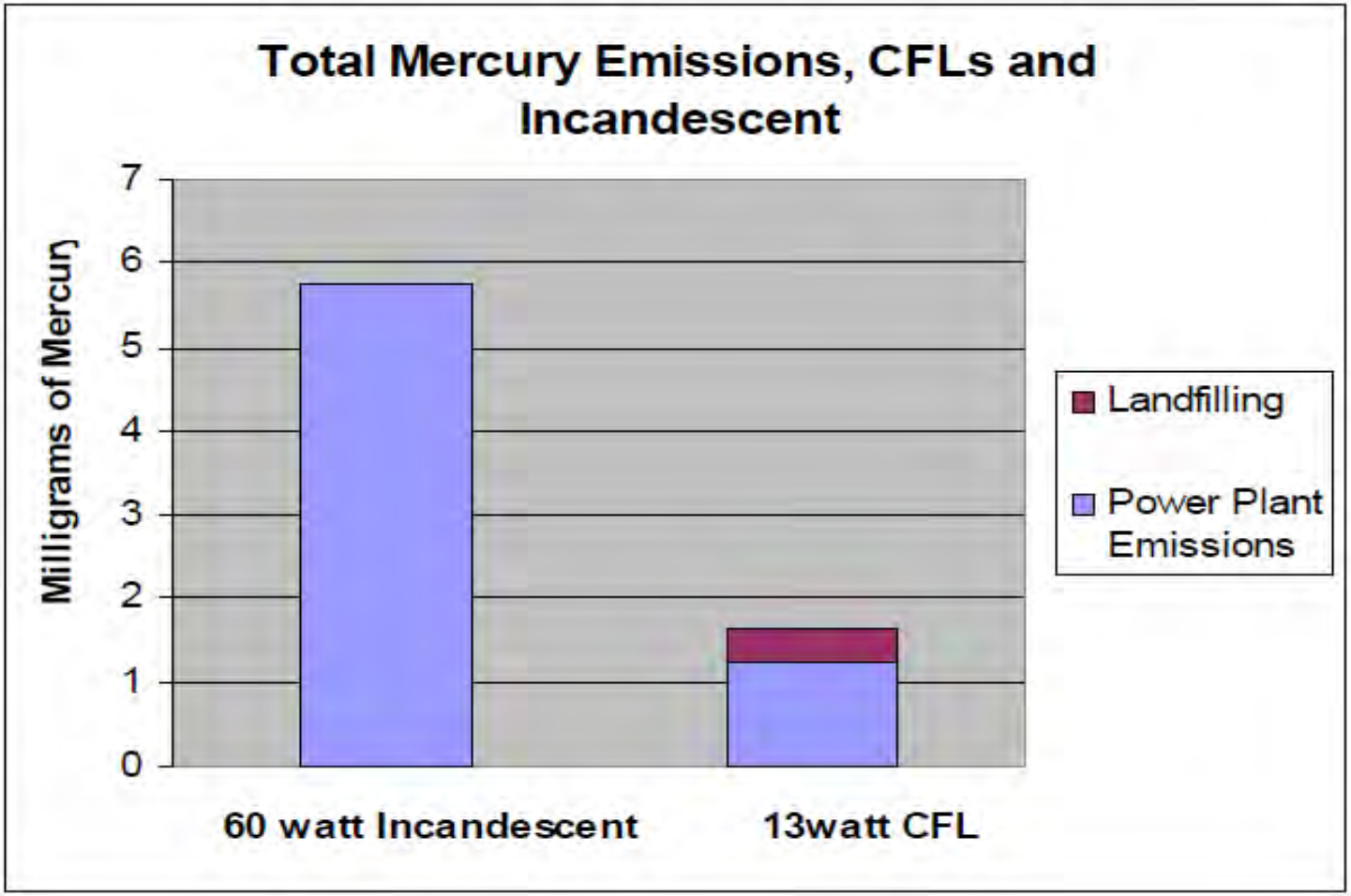
219 kwh/yr x $0.10 / kwh = **$21.90/year**

Annual savings for LED: **$18.61**

Simple Payback = Cost/Savings

$5.00 / $18.61 = 0.27 years = **14 weeks**

CFL MERCURY CONCERNS



www.energystar.gov

SUMMARY

- Energy code compliance challenges present opportunities for improvement in construction & inspection processes – targeted resources are available to help produce quality products
- Energy codes are based on building science and provide multiple benefits to builders, homeowners, and society
- Houses are systems with complex interacting components
- The building thermal envelope is comprised of pressure and thermal boundaries and proper air sealing & insulation installation are essential for optimal performance
- In addition to an effective building envelope, proper ground vapor barrier and weather barrier installation is essential for moisture control
- Practical options exist to meet energy code lighting requirements (50% high efficacy)
- Proper design, equipment selection, and duct sealing are essential to meet code requirements and achieve optimal HVAC performance

QUESTIONS OR COMMENTS?