

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/load 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

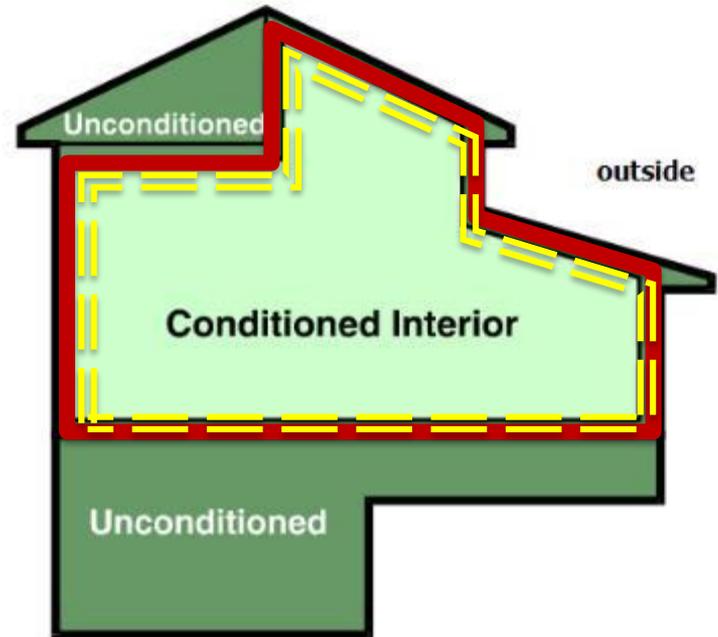


www.energystar.gov

THE BUILDING ENVELOPE

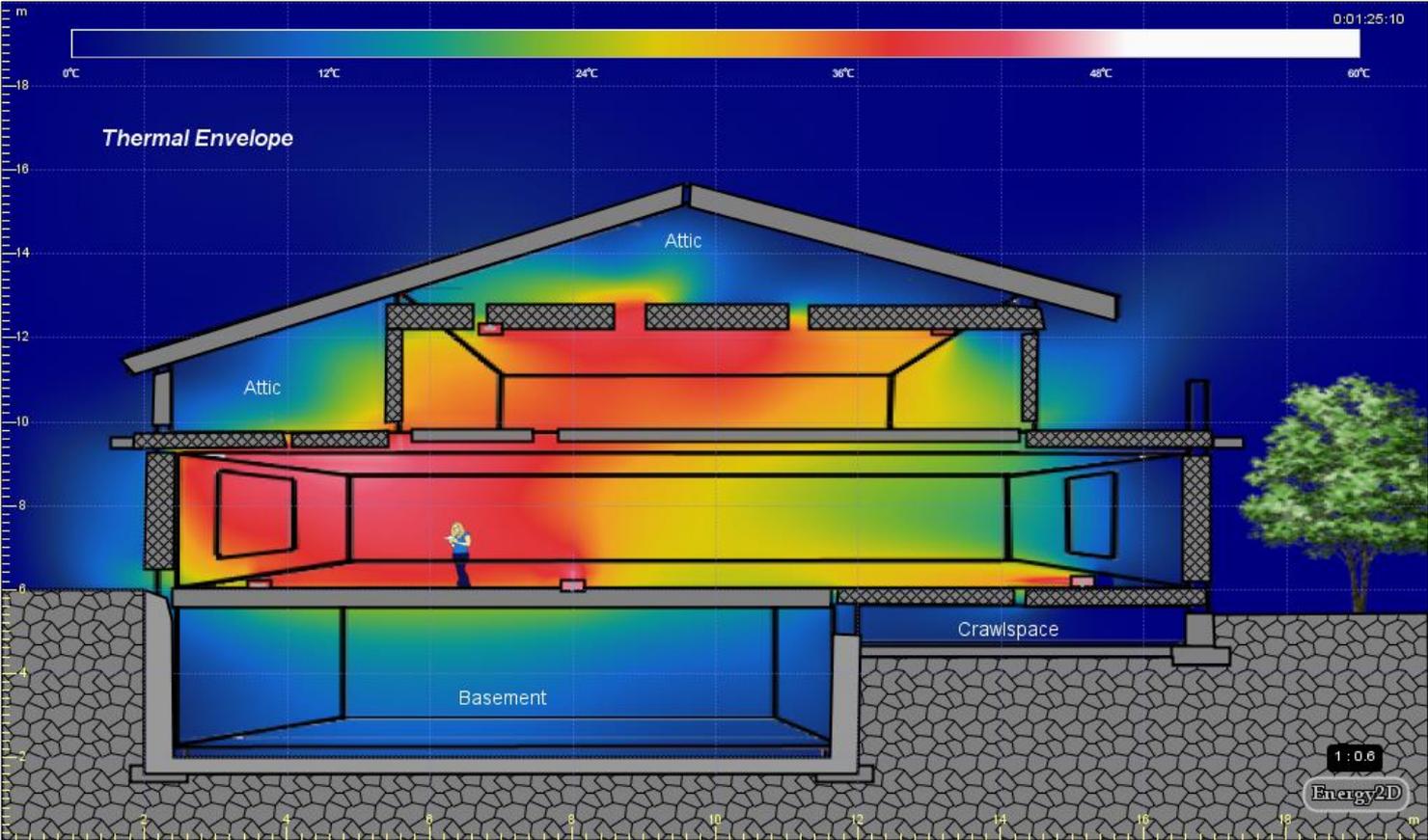
Building Envelope

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



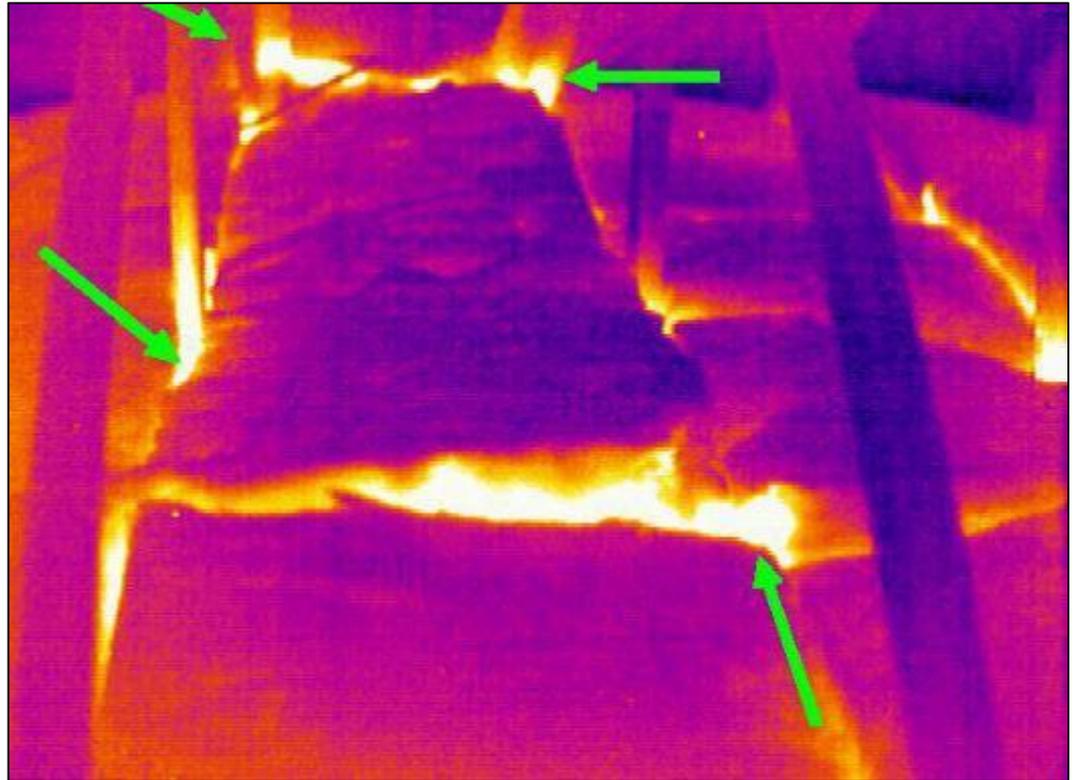
Thermal and Pressure Boundaries
Make up the Building Envelope

THE EFFECTS OF THERMAL BYPASSES



HEAT TRANSFER

- Conduction
- Radiation
- Convection



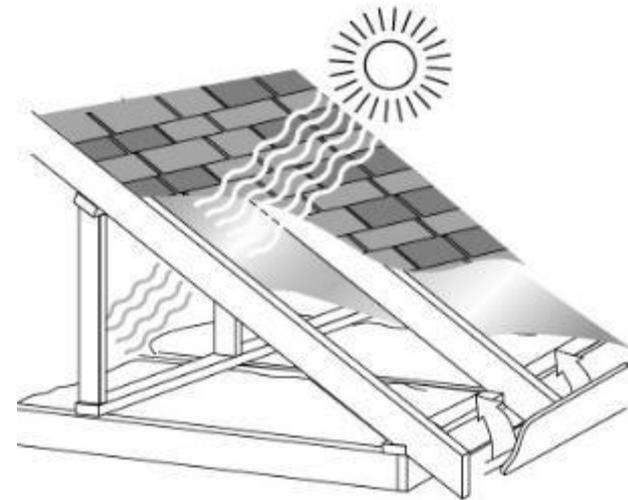
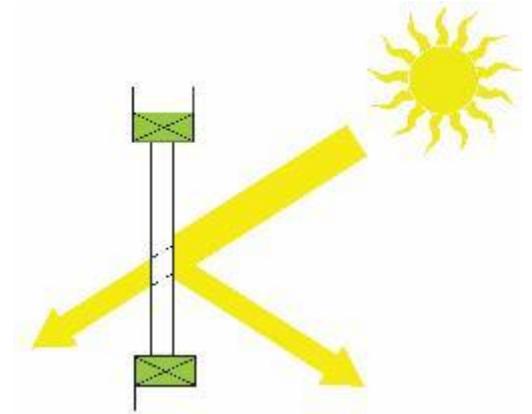
HEAT FLOW: CONDUCTION

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



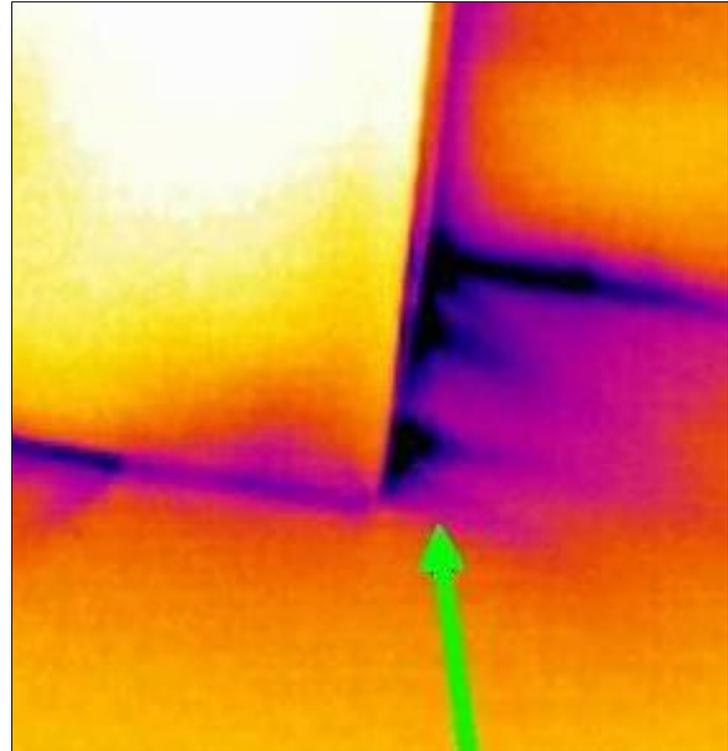
HEAT TRANSFER: RADIATION

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

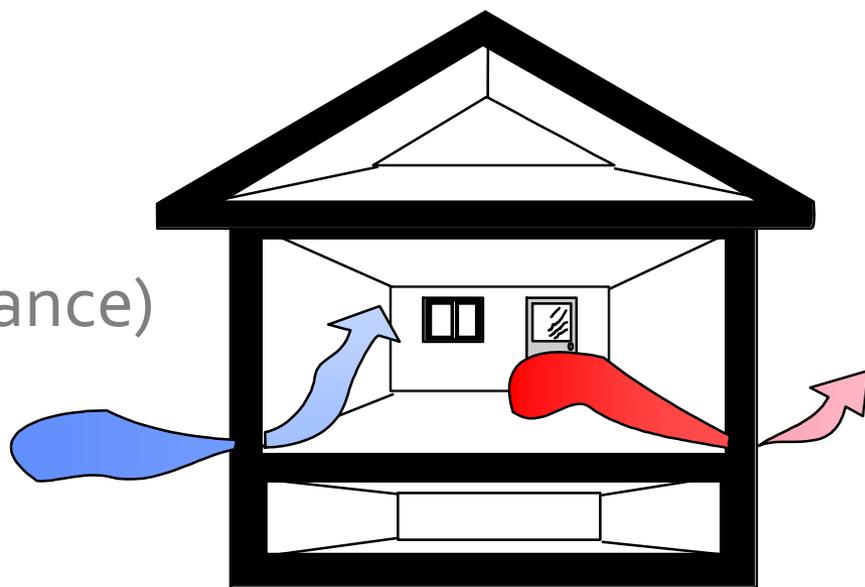
Convection is the transfer of heat caused by the movement of a fluid, like water or air (air barriers slow convection)



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.

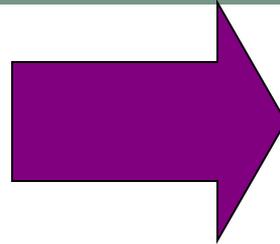
ACH: Air Changes per Hour – a rate of air exchange

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

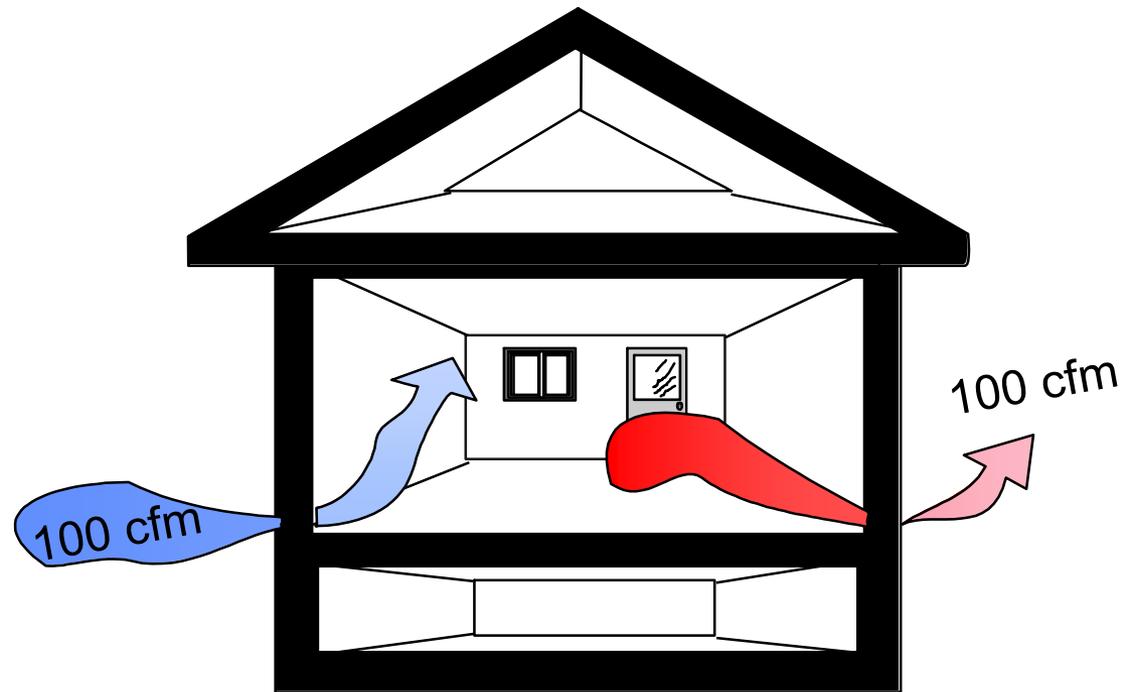


Low
pressure

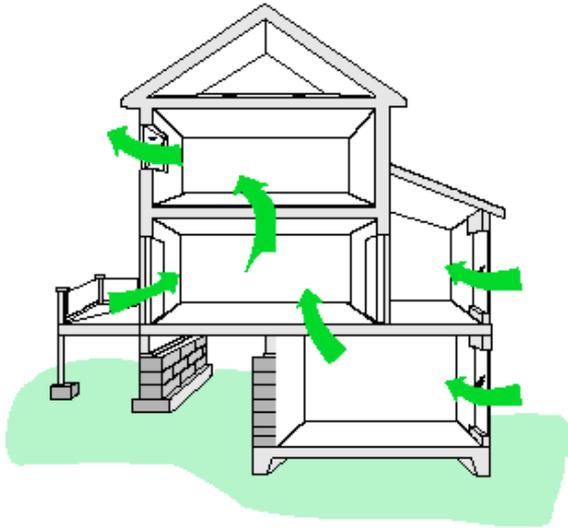
Conditions for Air Infiltration

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

Quantity of air out
= quantity of air in



WHAT DRIVES AIR MOVEMENT?

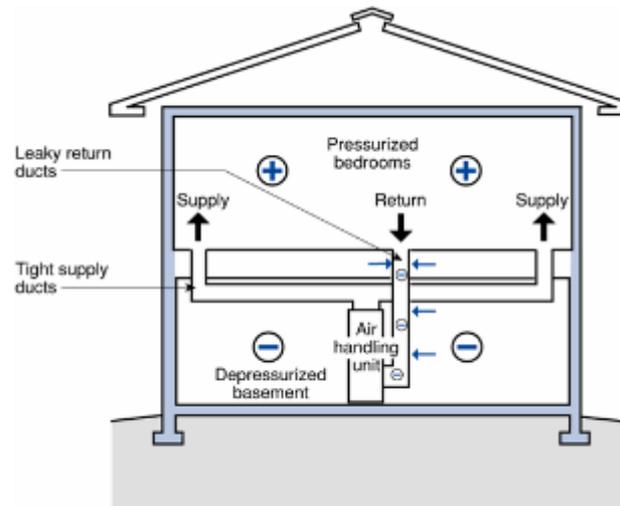


Stack Effect



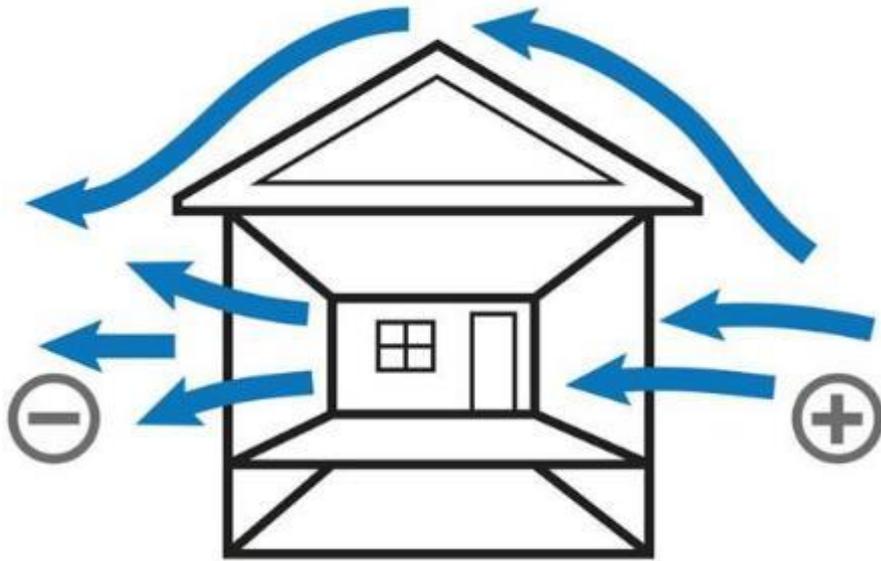
Wind

Things that create pressure differences (natural & mechanical)

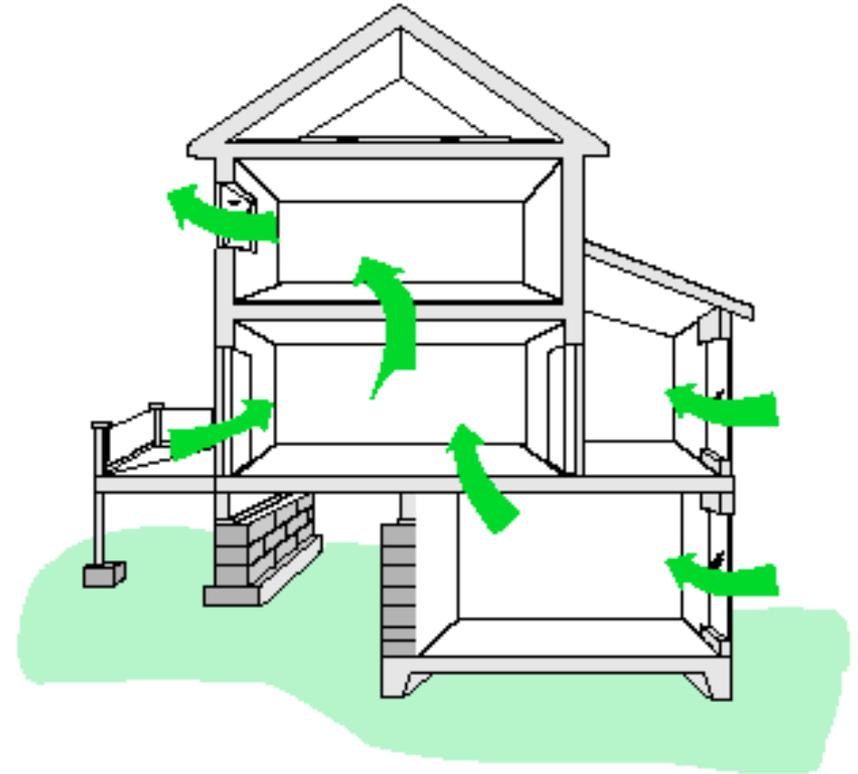


Mechanical Systems

NATURAL DRIVING FORCES FOR INFILTRATION



Wind



Stack Effect

Stack Effect

David Keefe
Vermont Energy
Investment Corp.



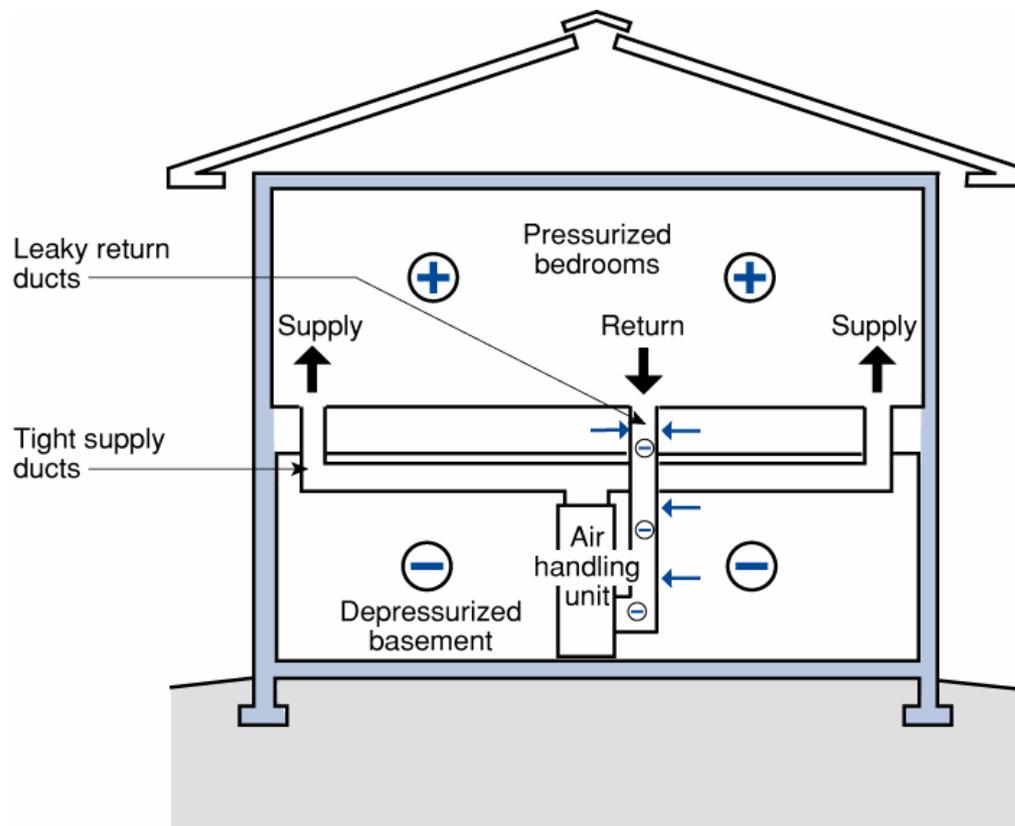
Positive pressure
(with reference to
outside)

Neutral pressure plane

Negative pressure
(with reference to
outside)

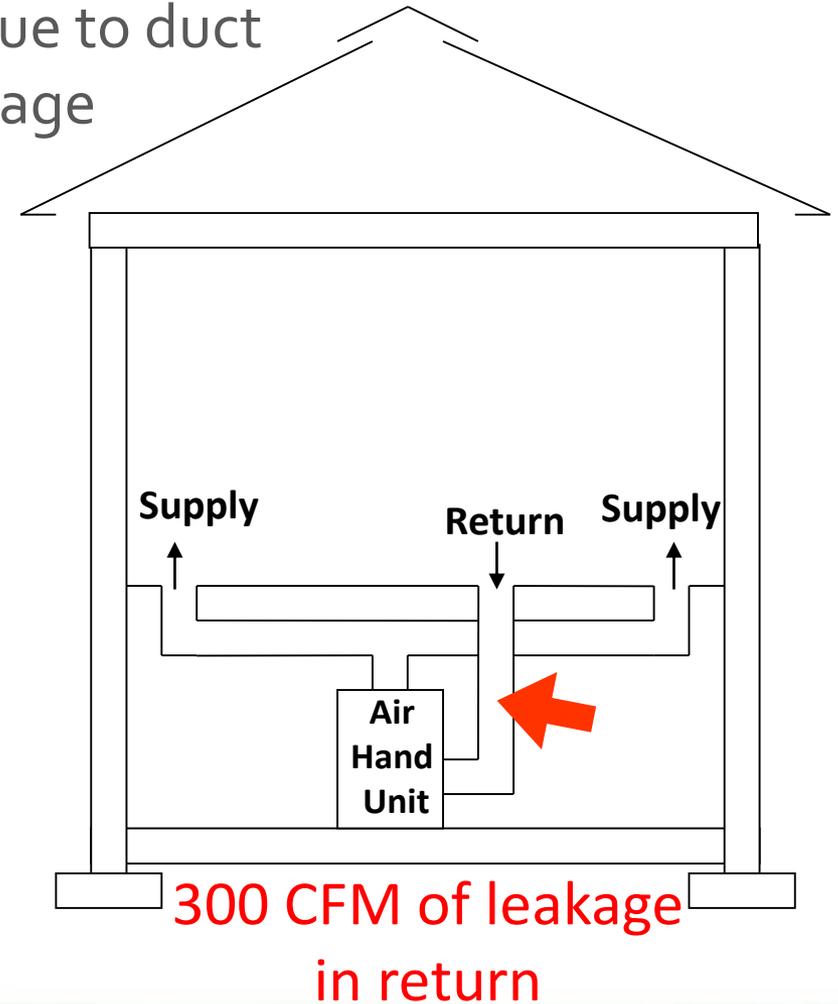
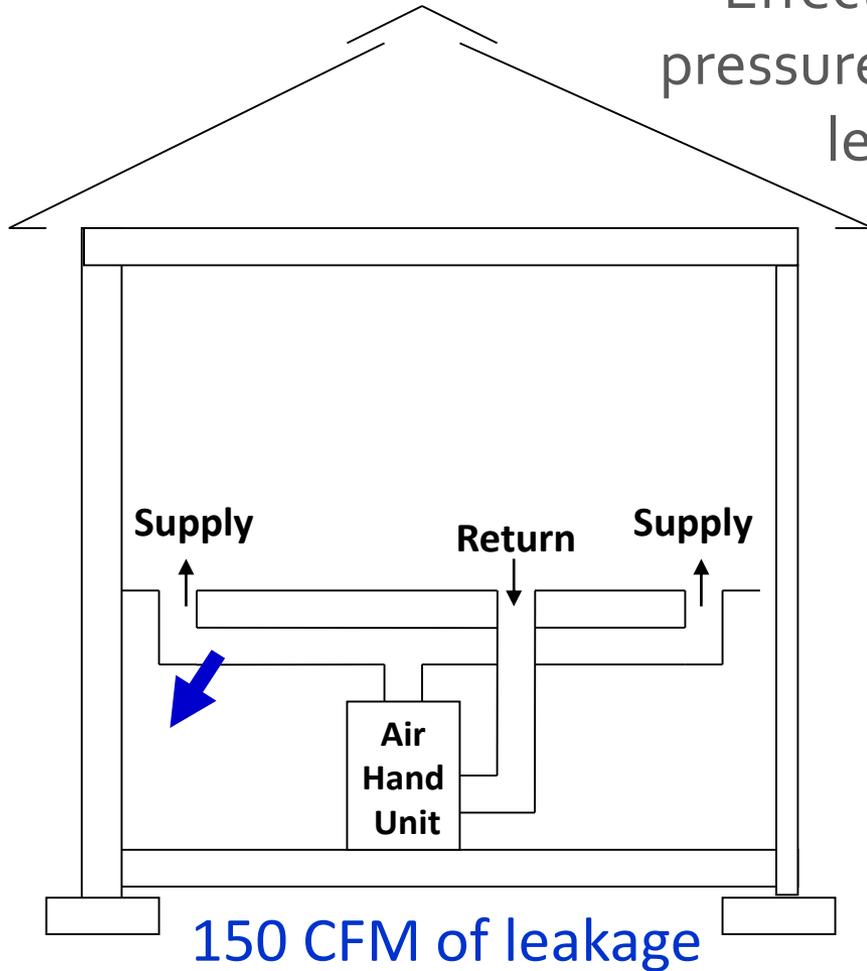
FANS—DRIVING FORCES FOR INFILTRATION

| Device | CFM |
|----------------|-----------|
| Bath | 50 |
| Range hood | 150 |
| Downdraft hood | 500 |
| “Emeril” Hood | 1500 |
| Dryer | 200 |
| Air Handler | 400 / ton |



DUCT LEAKAGE— DRIVER FOR INFILTRATION

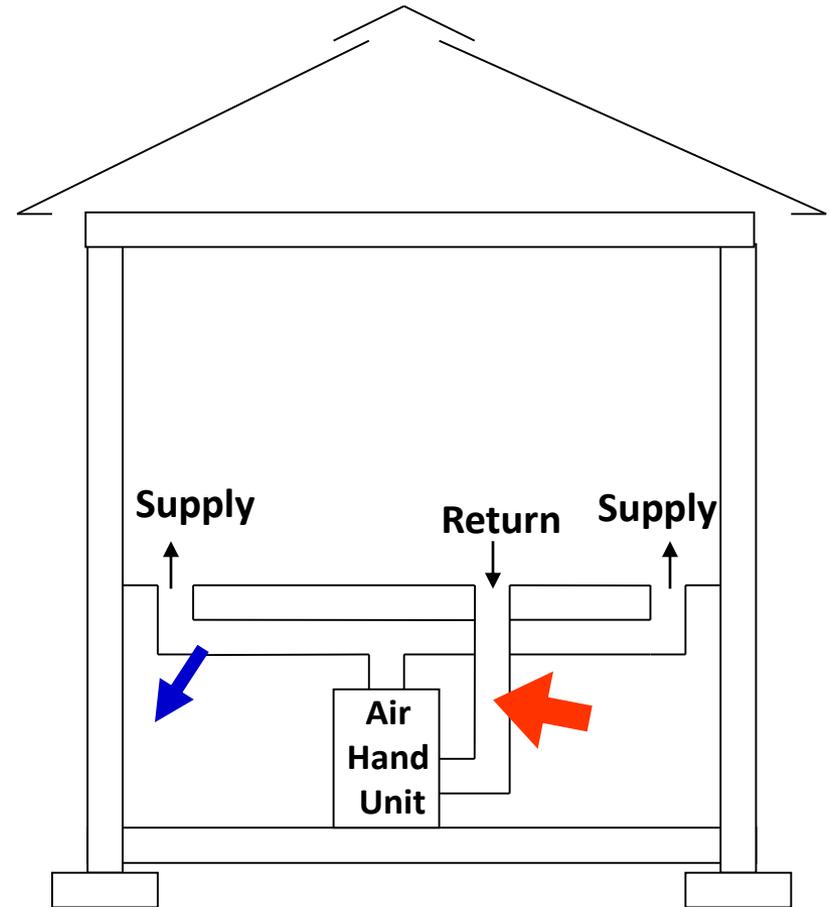
Effect on house
pressure due to duct
leakage



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

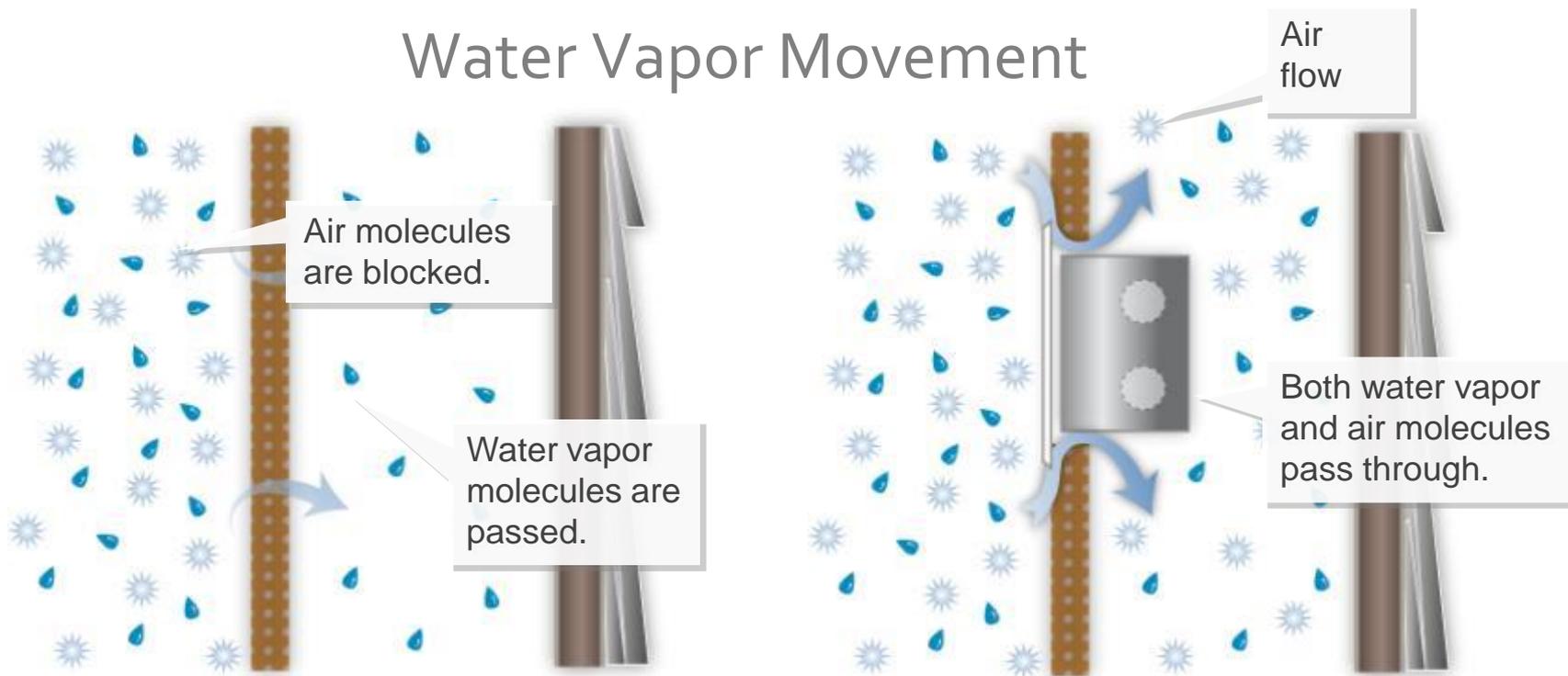
MOISTURE PROBLEMS

| | |
|-------------------------------------|----------|
| 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

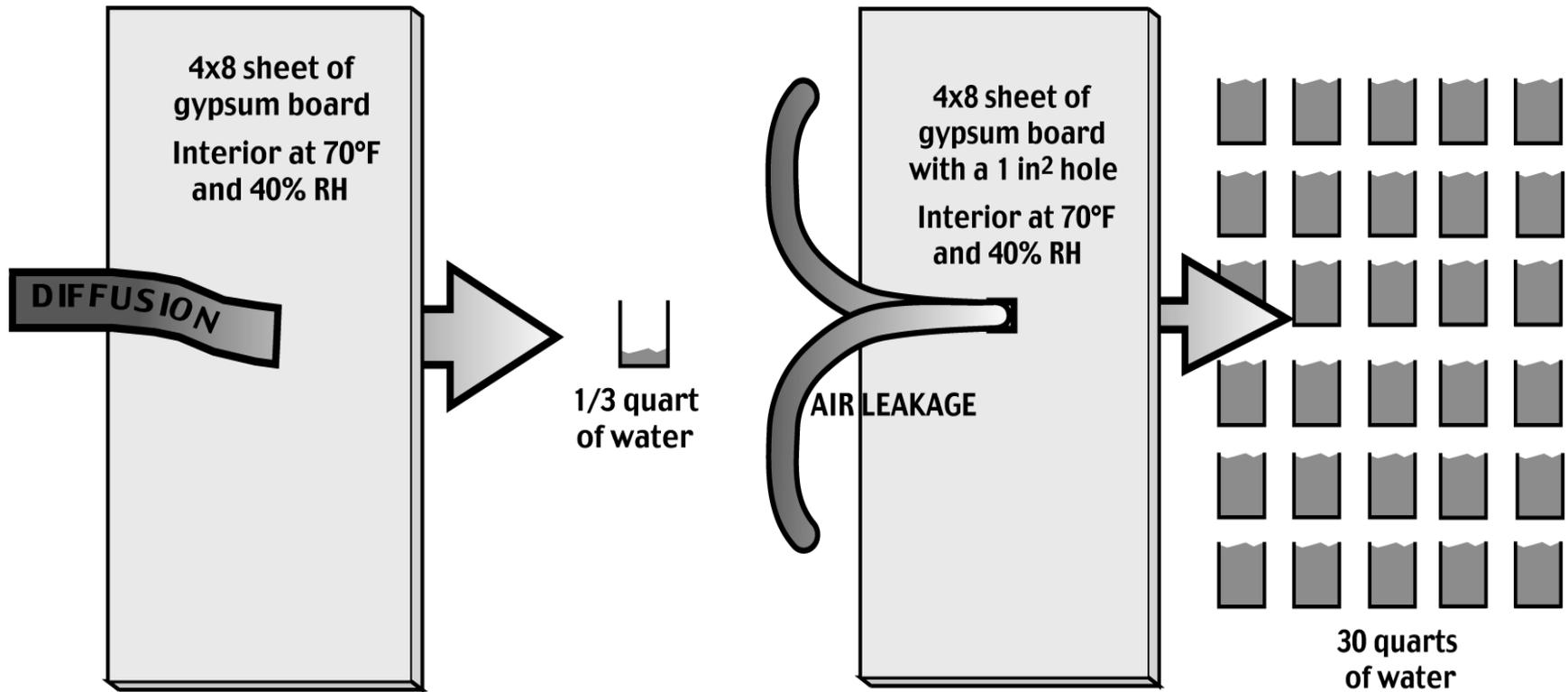


Diffusion Through Surface

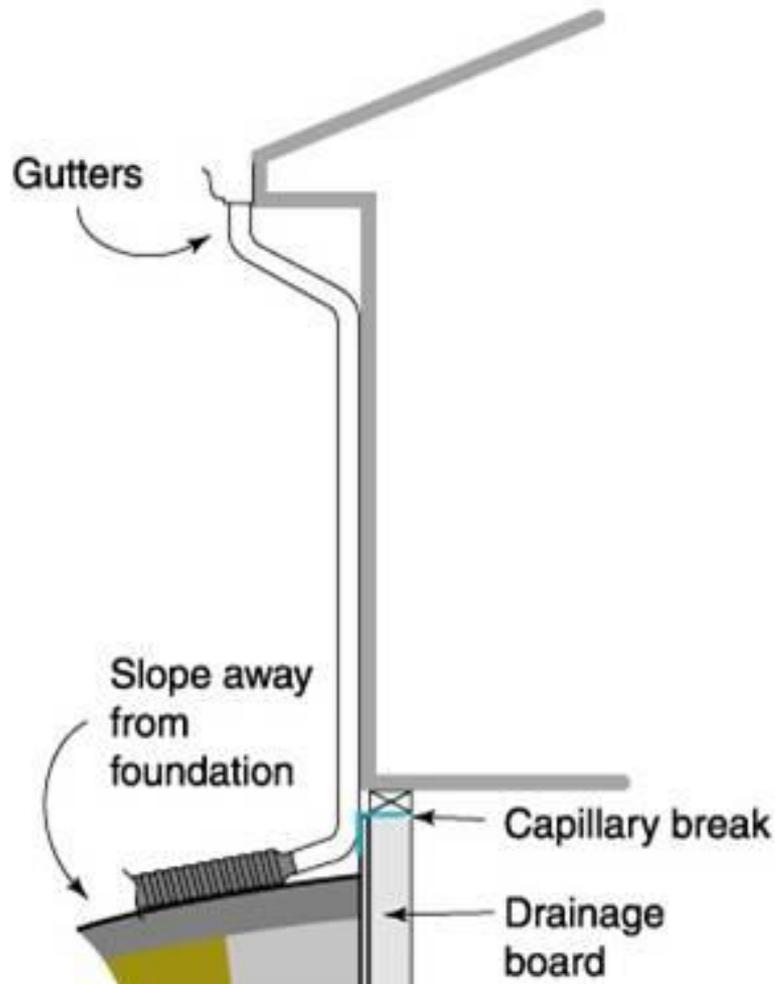
Convection Through Holes

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

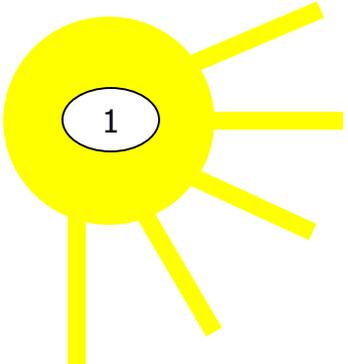


PERM RATINGS OF MATERIALS

| | |
|---------------------------------|---------|
| 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 |

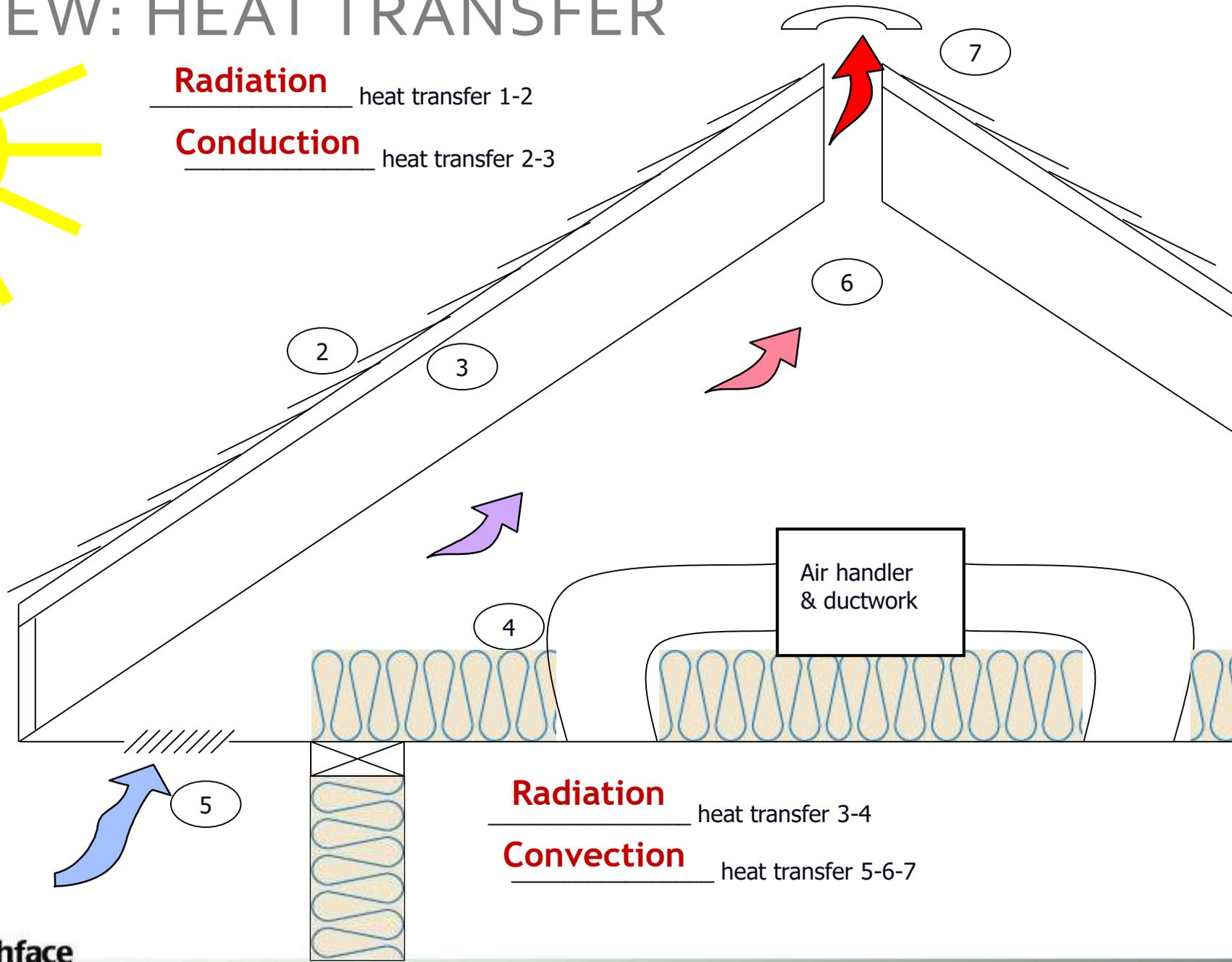


REVIEW: HEAT TRANSFER



Radiation heat transfer 1-2

Conduction heat transfer 2-3

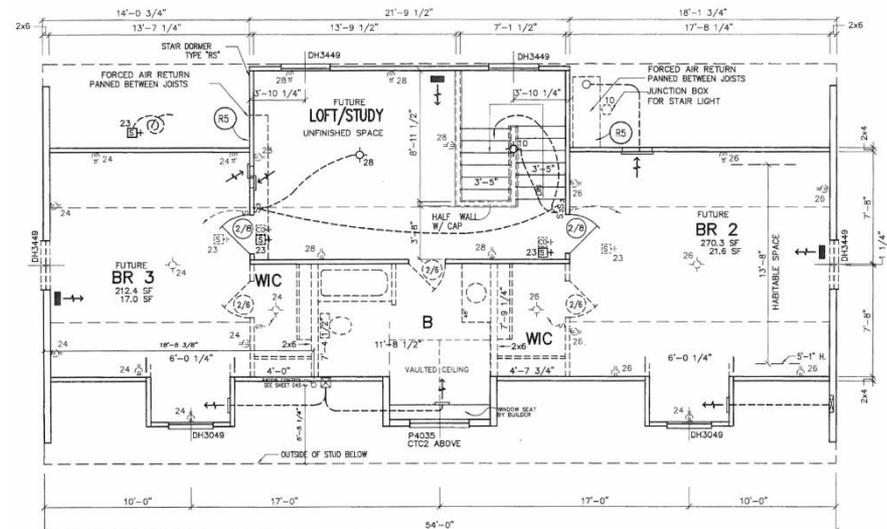
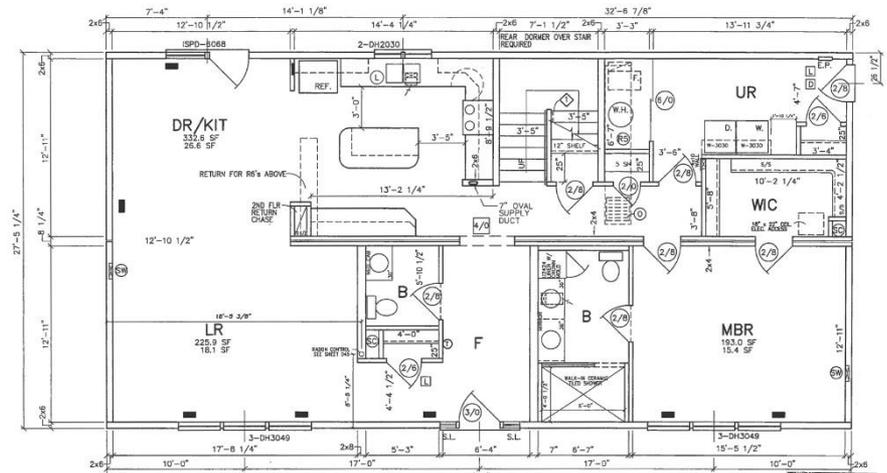


Radiation heat transfer 3-4

Convection heat transfer 5-6-7

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:

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



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

| 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. Recesses or joints in the air barrier are filled or repaired. Air permeable insulation is not used as a sealing material. Air permeable insulation is inside of an air barrier. |
| 2 | Ceiling/soffits | Air barrier in any dropped ceiling/soffit is substantially signed with insulation and any gaps are sealed. Attic trusses (except unvented attic) knees wall door, or drop down stud 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 joints 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. Lapsoed earth in unvented crawl spaces is covered with Class I vapor retarder with overlapping joints taped. |
| 8 | Shells, 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 | Showers on exterior wall | Showers and tubs on exterior walls have insulation and an air barrier separating them from the exterior wall. |
| 14 | Fire/telephone 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. |

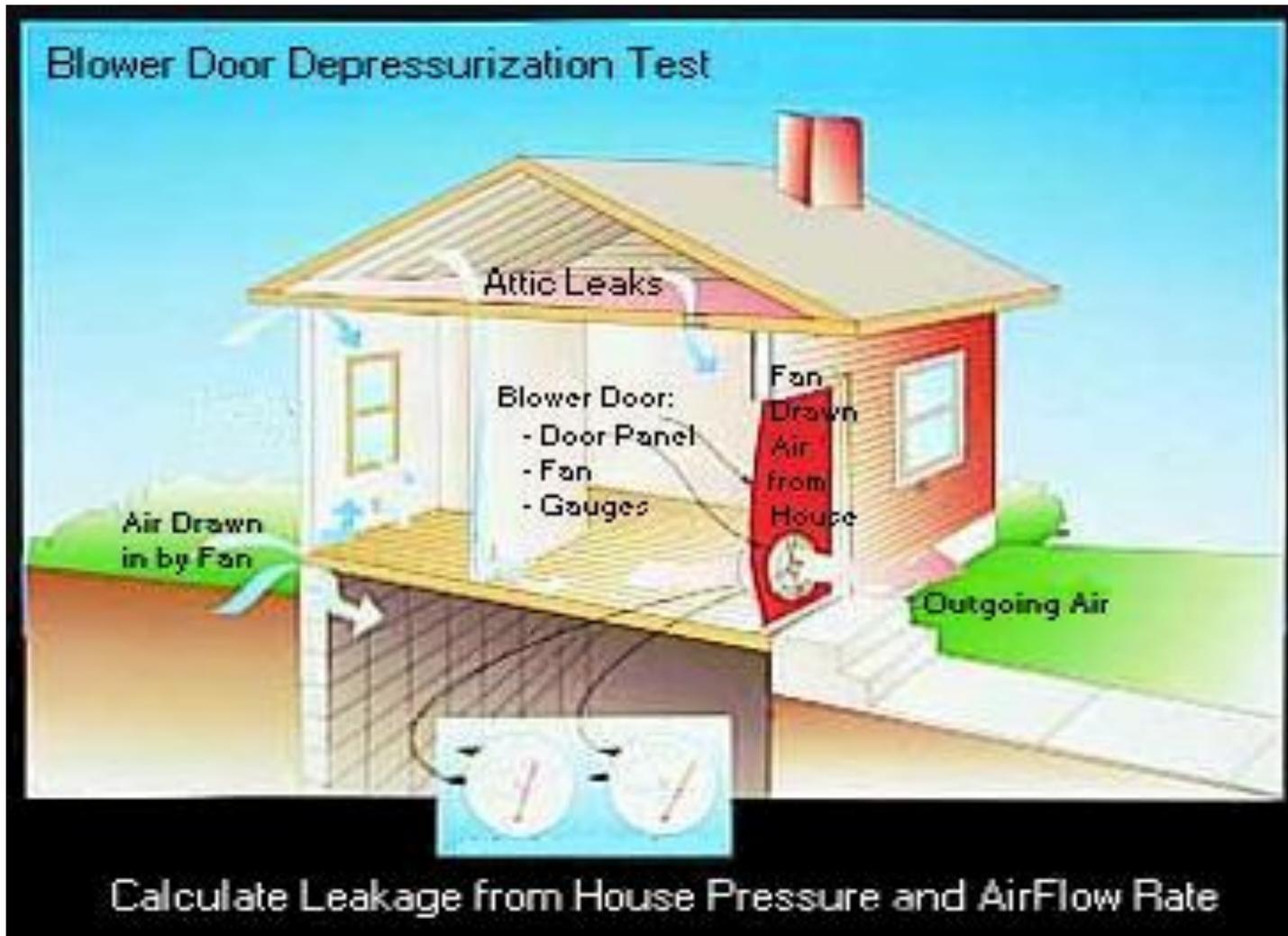
BLOWER DOOR TESTING



- One of the options allowed by code to verify air sealing
- Provides a measurement of the actual infiltration rate
- Code requires $< 7 \text{ ACH}_{50}$
- The BD also helps identify leak paths



BLOWER DOOR OPERATION



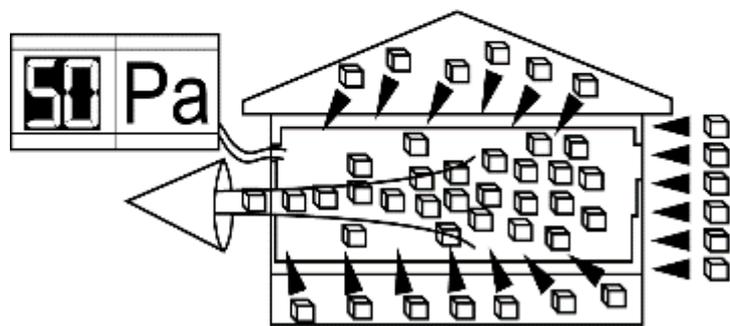
DEPRESSURIZING HOUSE



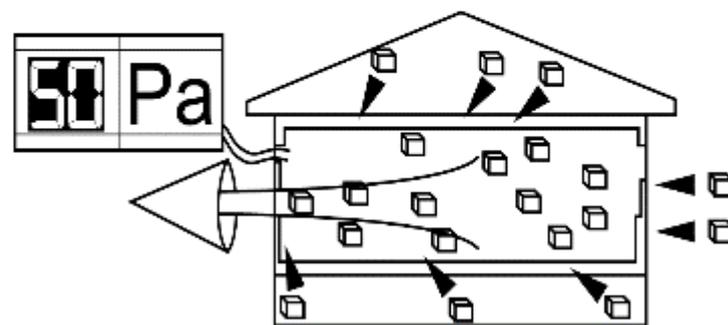
- CFM = Cubic Feet of air per Minute
- 1 CFM out = 1 CFM in
- $1000 \text{ CFM}_{50} = 1 \text{ s.f. hole in envelope}$

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

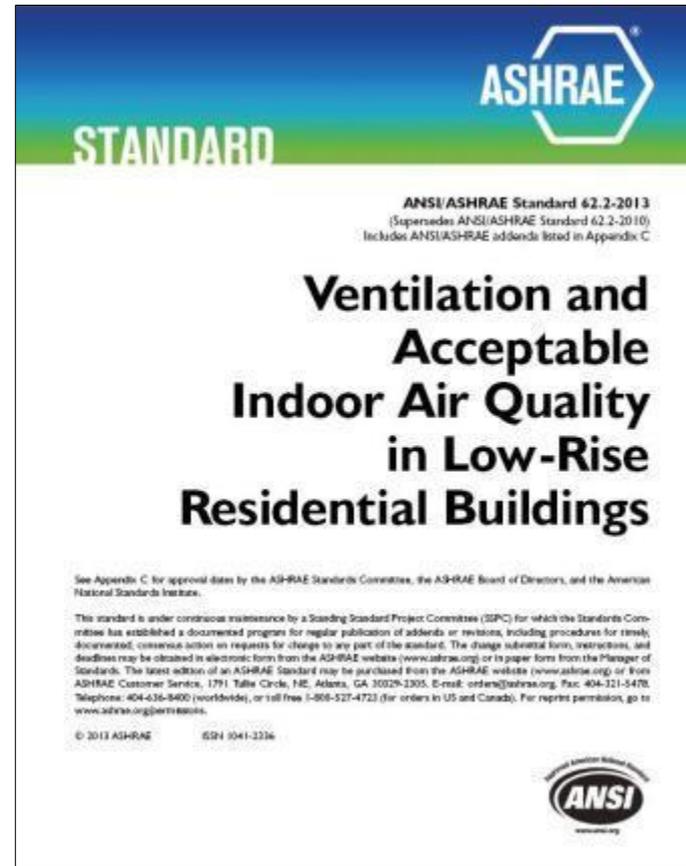
**Build tight,
Ventilate right**

ASHRAE STANDARD 62.2

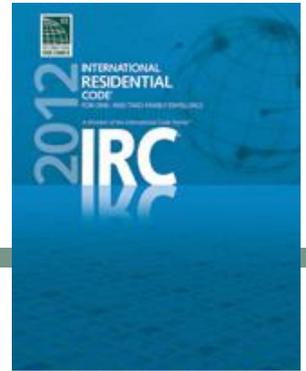


ASHRAE 62.2-2013

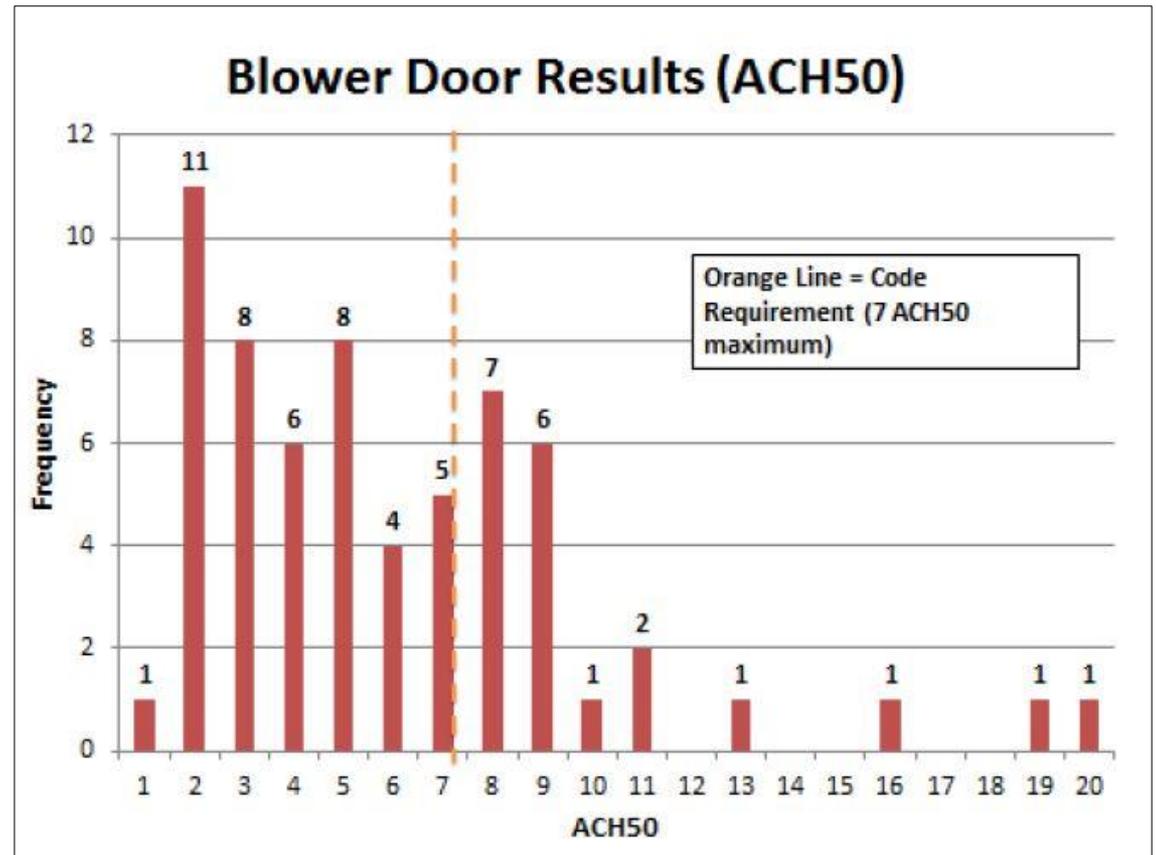
7.5 cfm/person + 3 cfm / 100 s.f.



VENTILATION CODE REQUIREMENTS



- Whole house ventilation is not just a good idea, it may be required by code!
- 2012 IRC requires homes with $< 5 \text{ ACH}_{50}$ 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



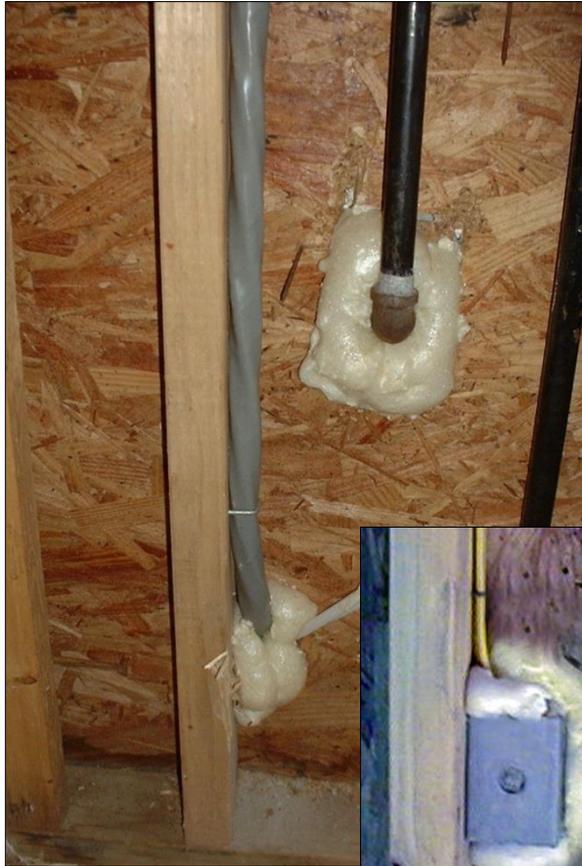
TOP FIVE AIR SEALING CHALLENGES

**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. |

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

AIR SEALING & INSULATION

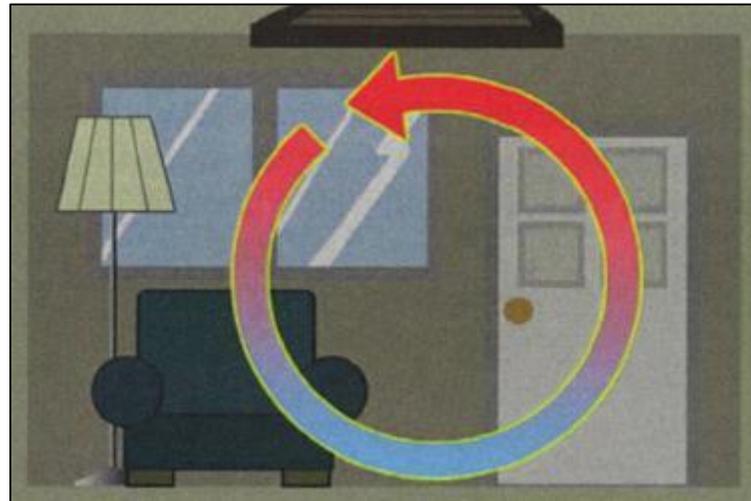
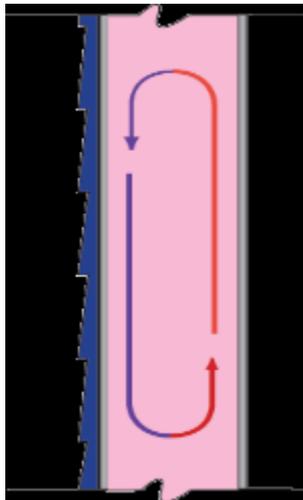


- Air sealing & insulation go hand in hand
- Both are necessary for an effective building envelope



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)



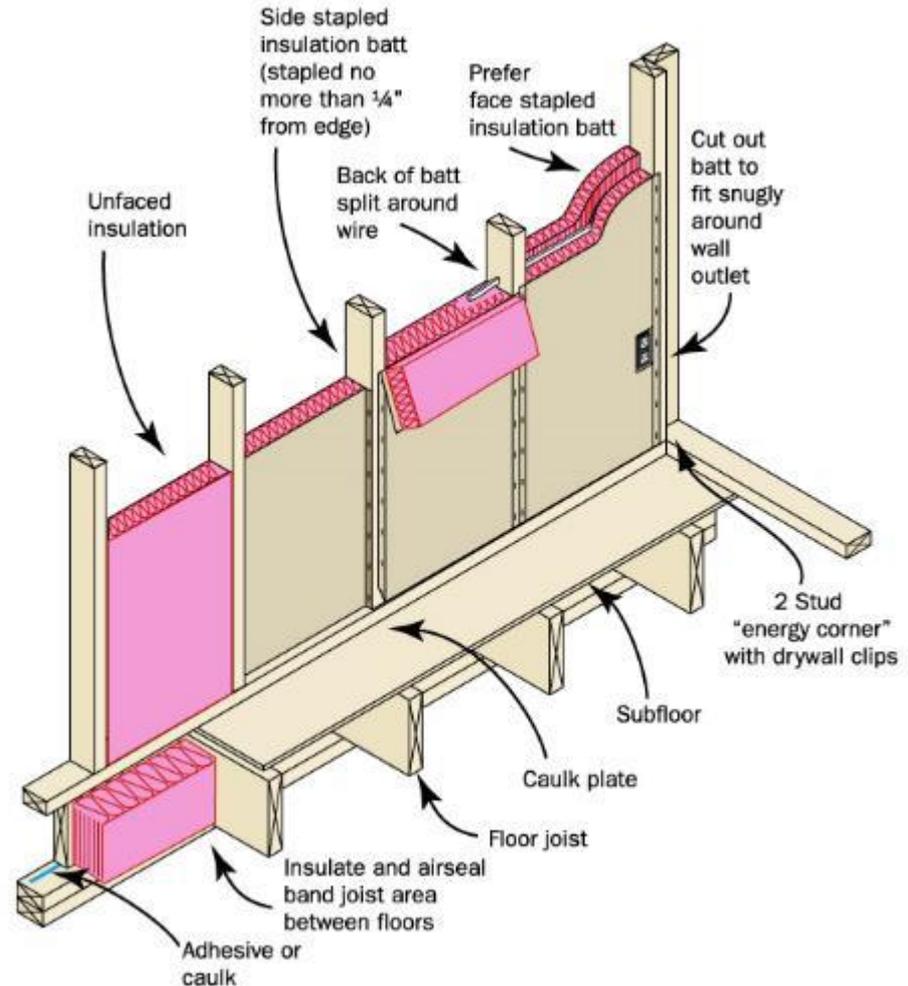
THE IMPORTANCE OF INSULATION

- Energy efficiency
- Comfort
- Durability
- Noise reduction

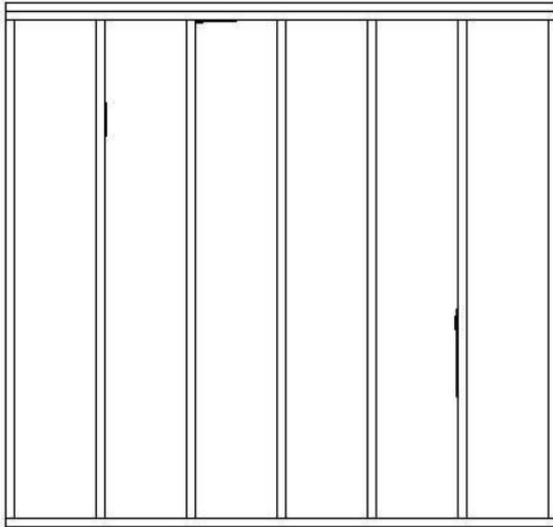


INSTALL INSULATION CORRECTLY

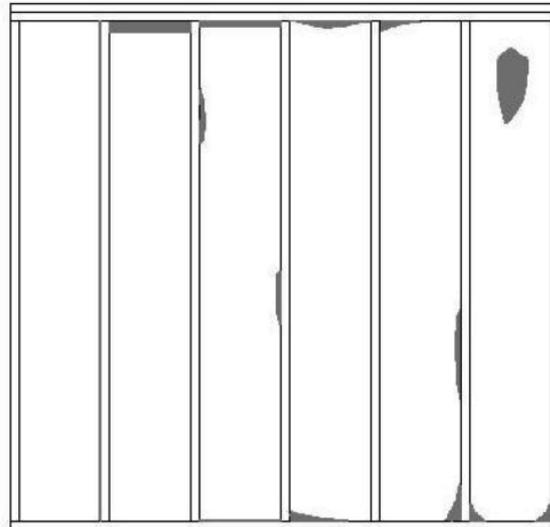
- No gaps
- Cut around plumbing, electrical wiring and outlets
- Compressed insulation reduces R-Value



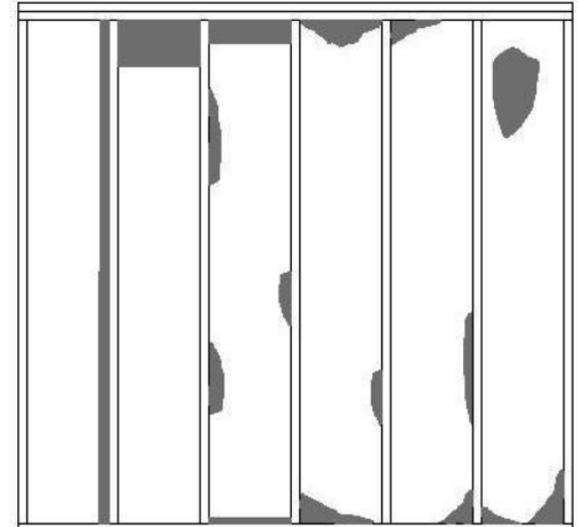
INSPECTION



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



Spray foam insulation is applied directly at the roof deck (plywood), **NOT** at the attic floor. It completely seals the building envelope!

YES

NO

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) |

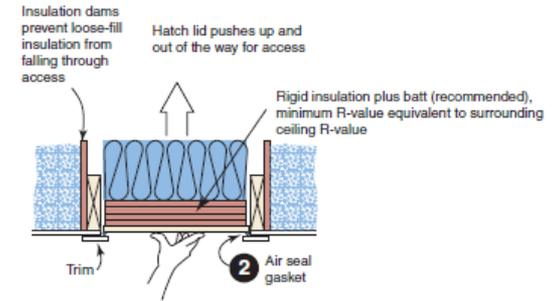
FOCUS: ATTICS



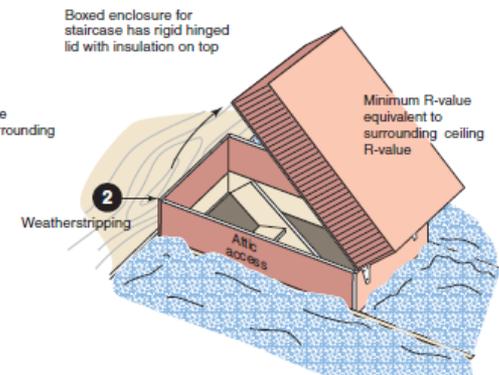
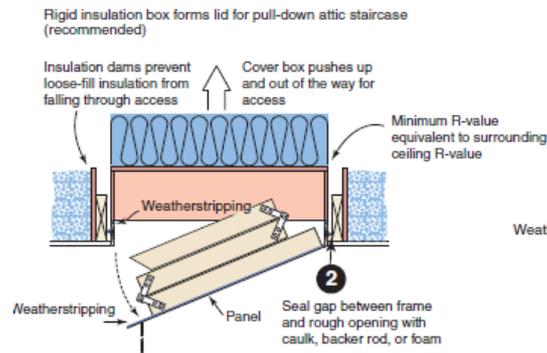
AIR SEALING ATTIC ACCESS



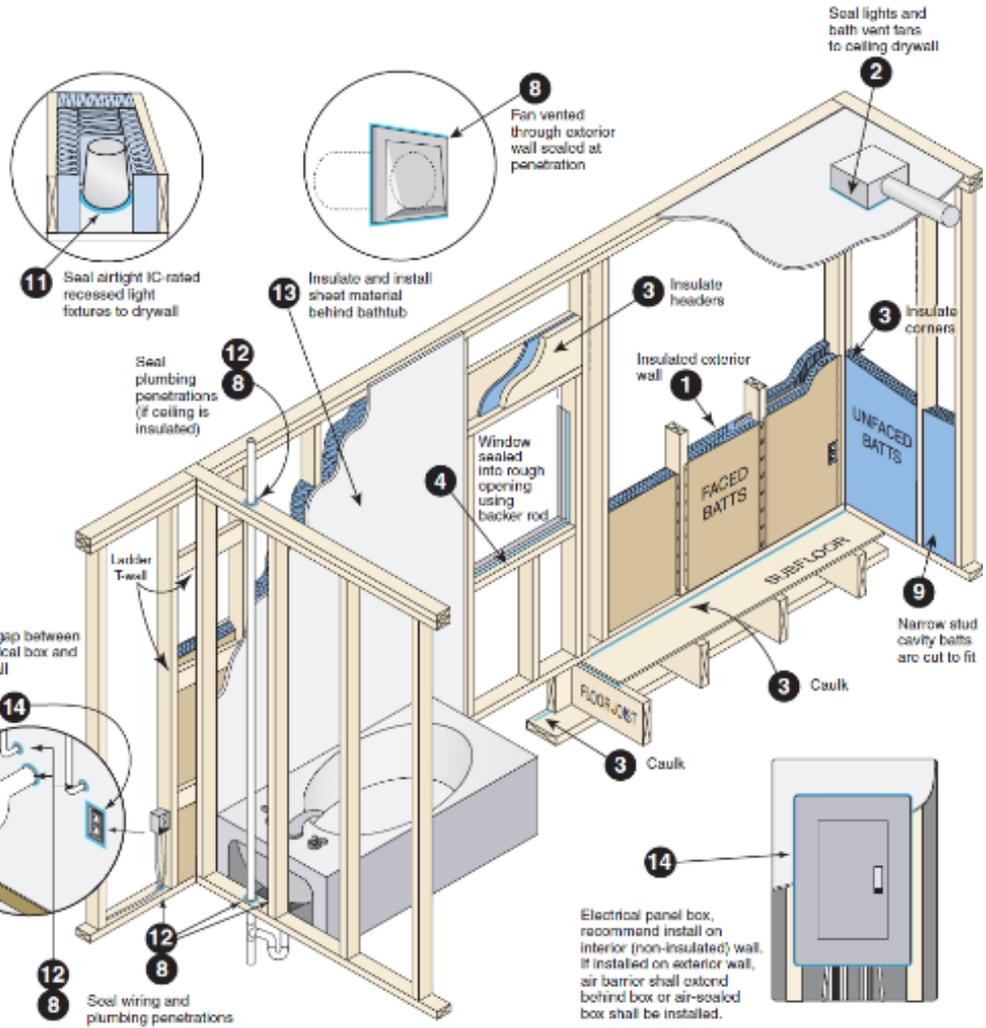
Attic scuttle



Attic pull-down stairs

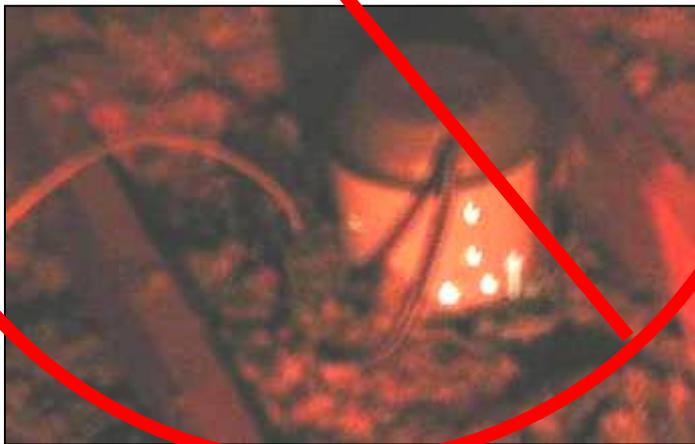


AIR SEALING



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

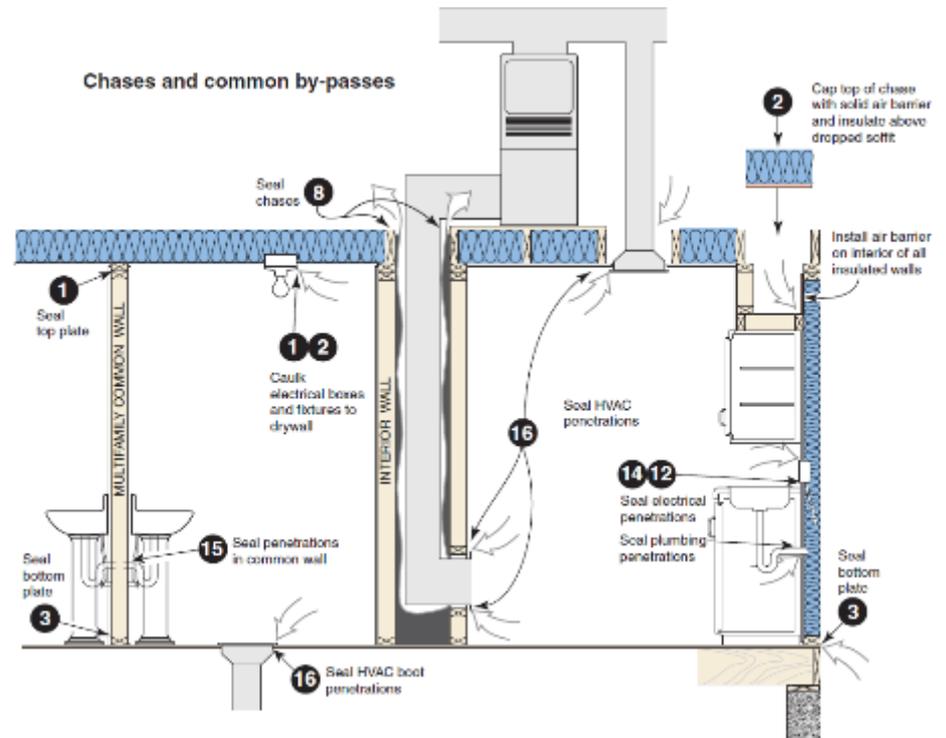


A home performance crew moved the attic insulation aside to access the gaps at the **top plates**

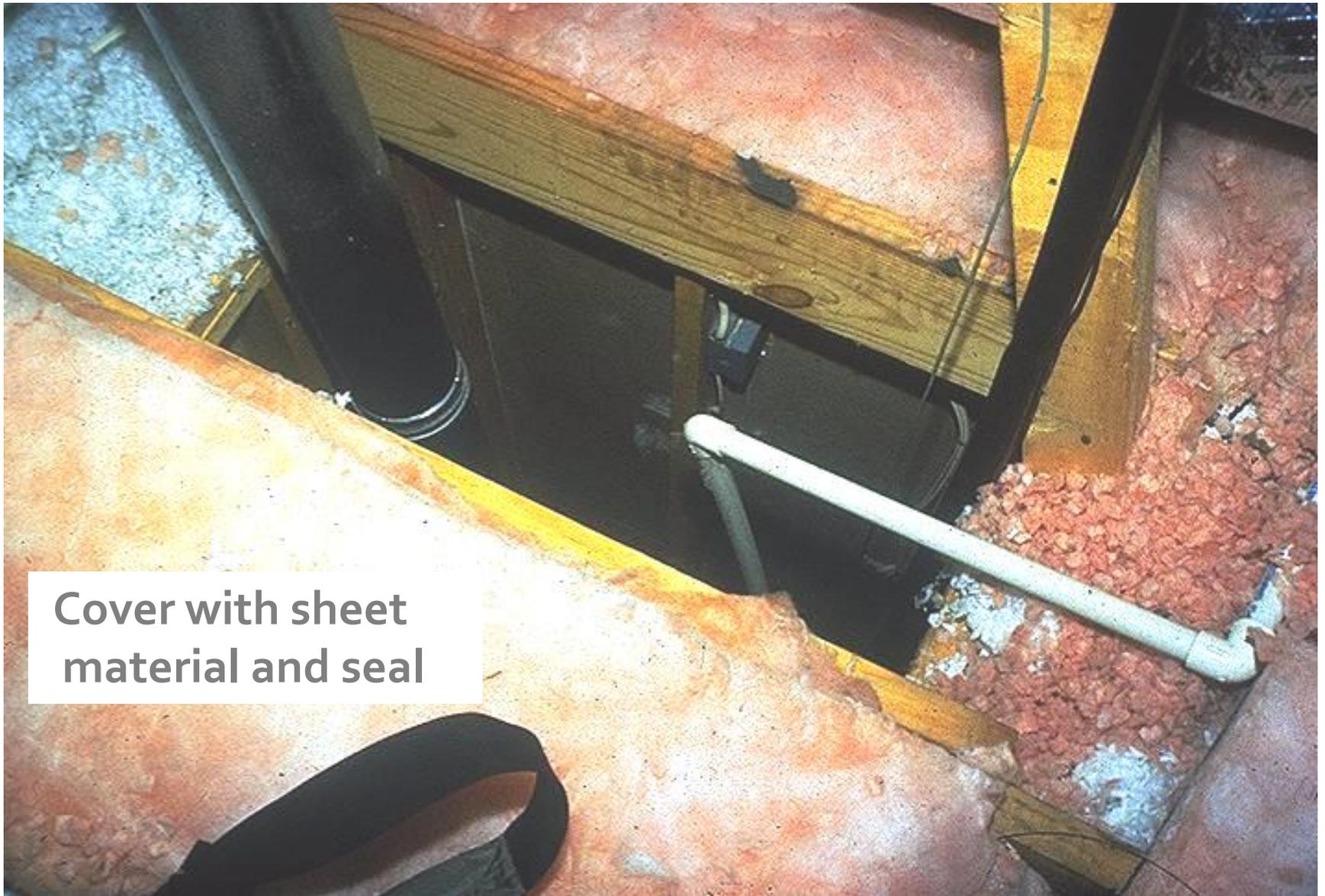


The crew sealed the gaps with **one part foam** and will install insulation on top of the sealed pressure boundary

AIR SEALING



PRACTICAL AIR SEALING - EXAMPLE



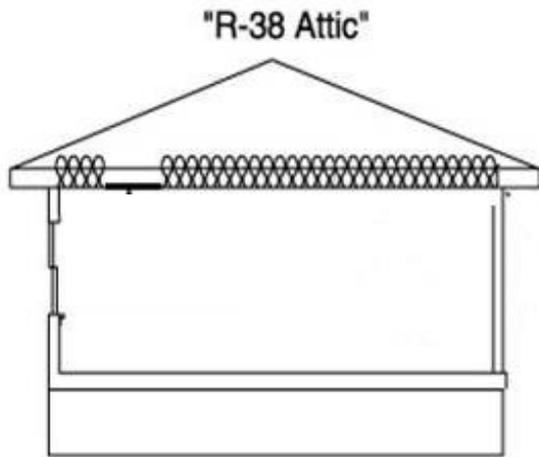
CEILING INSULATION



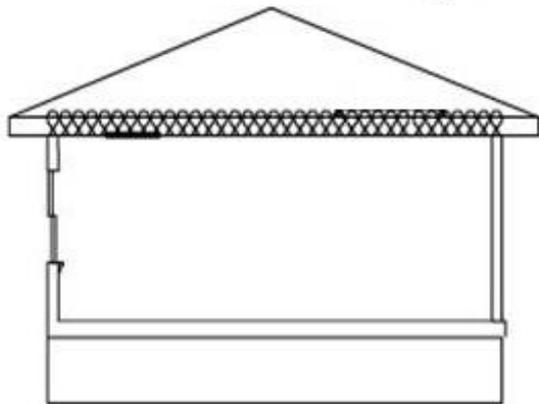
- Rulers and attic card in each attic space
- Blown insulation should not block soffit vents – use baffles



ATTIC DECKING - COVERAGE IS KEY!



R-28 – Full Coverage



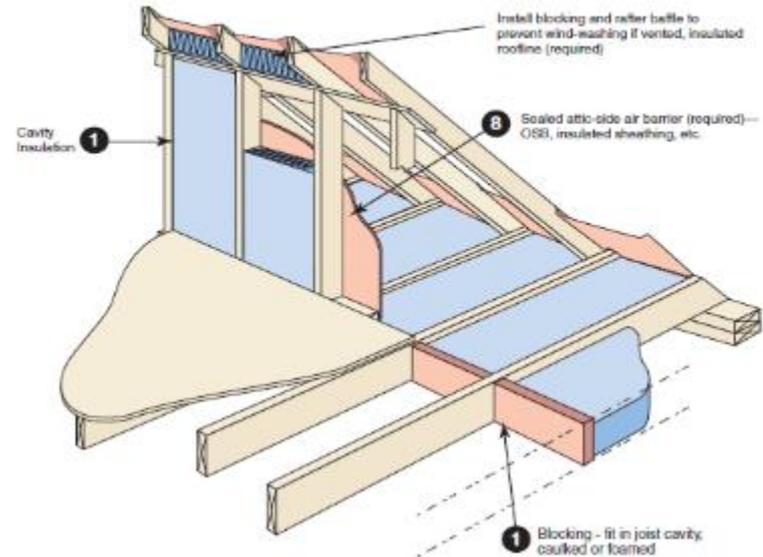
$$U_{\text{avg}} = \frac{U_1 \times A_1 + U_2 \times A_2}{A_{\text{Total}}}$$

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

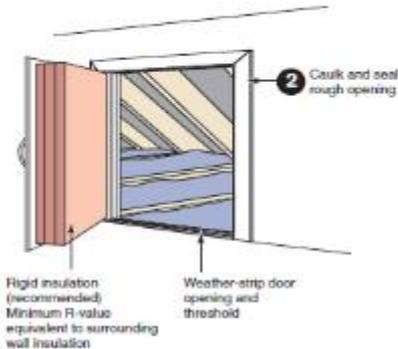


An attic has a total area of 1000 ft². If 990 ft² is installed with R-38 while 10 ft² is an uninsulated area underneath attic decking (R-1), the average R-value of the entire attic is reduced to R-27!

AIR SEALING KNEEWALLS



Attic knee-walls



Two-level attic

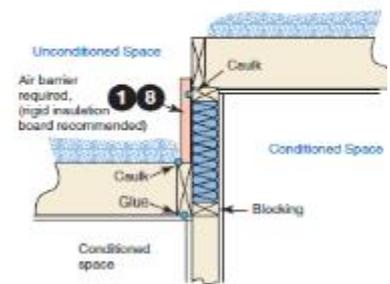
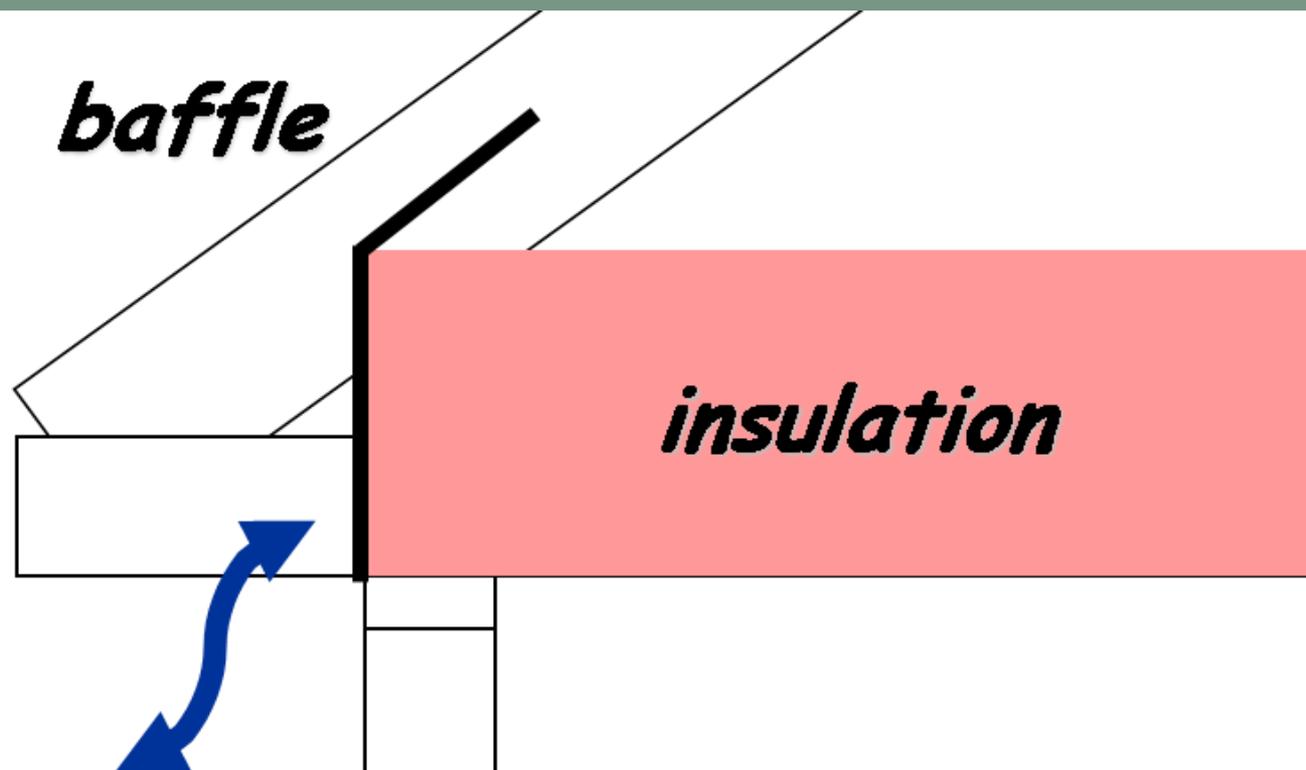


Illustration
The McGraw-Hill Companies

PROPER INSULATION INSTALLATION?



INSULATION: BAFFLES



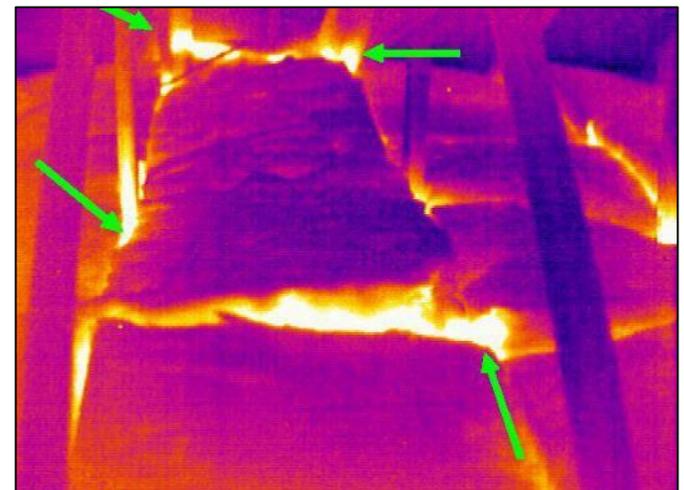
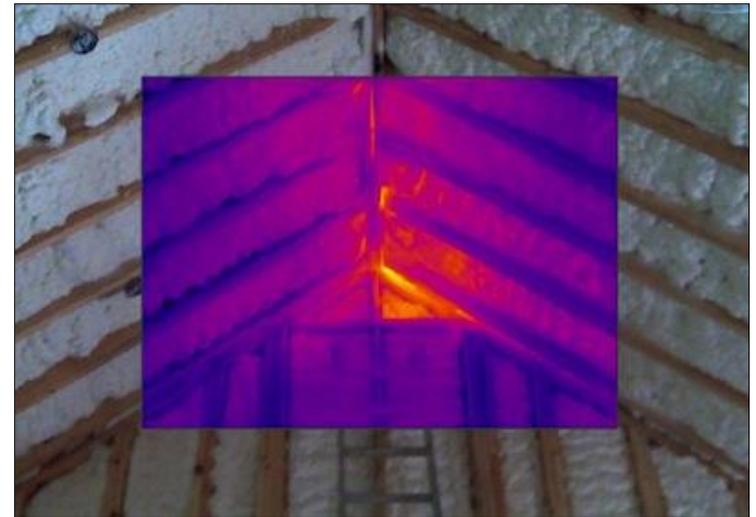
- Protects insulation from wind-wash
- Ensures proper ventilation by preventing insulation from blocking soffit vent

INSULATING THE ROOFLINE



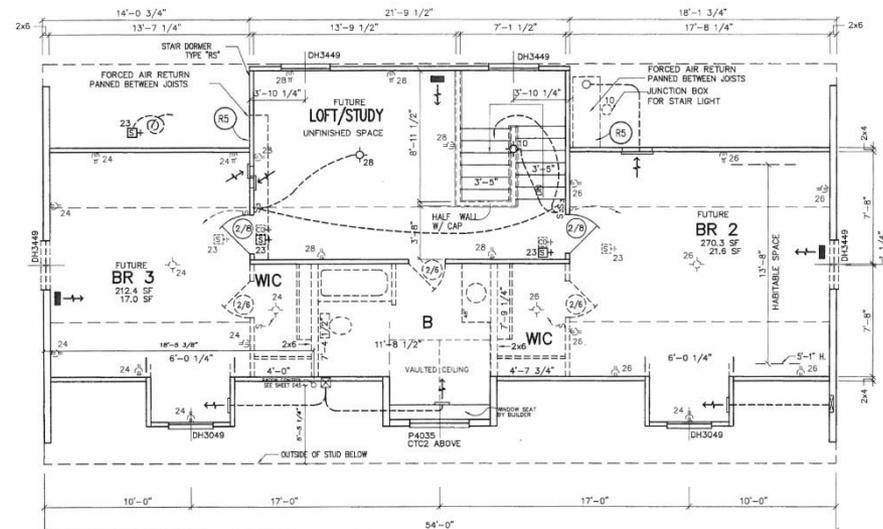
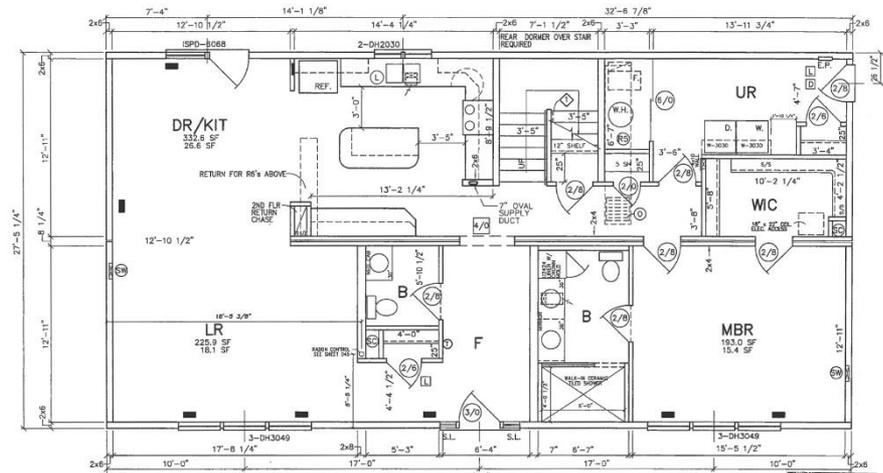
INSTALLATION

- 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

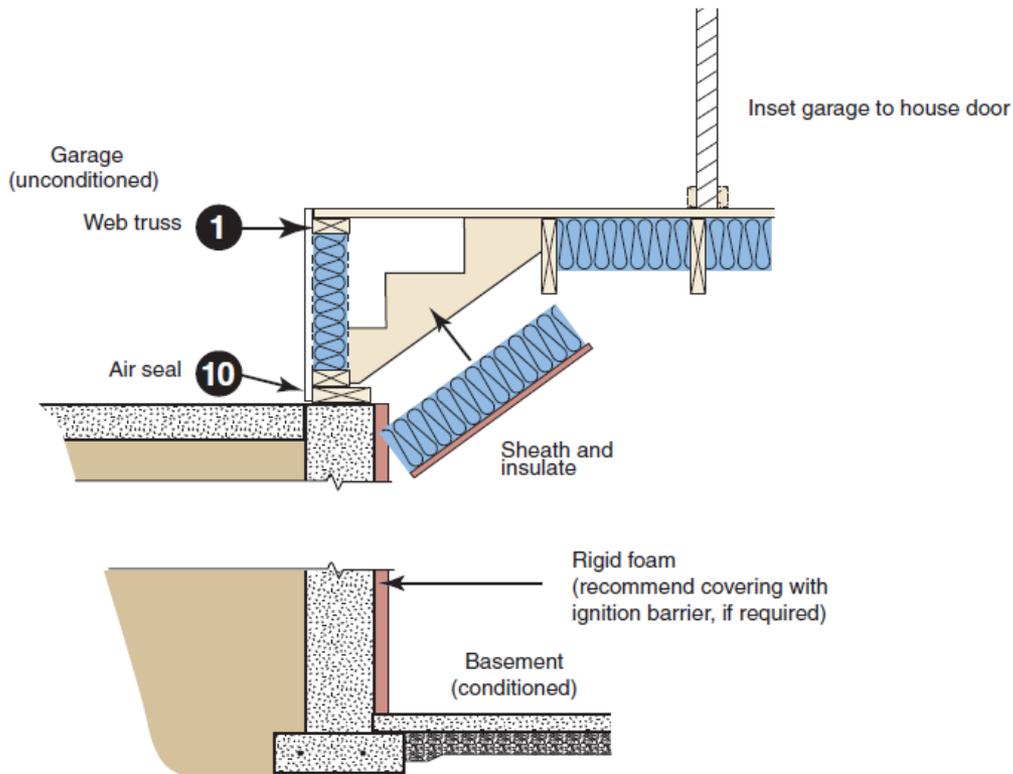
- Identify the attic kneewalls on the handout
- Describe the air sealing and insulation code requirements for kneewalls
- Are there alternative ways to define the building envelope that do not create kneewalls?



FOCUS: CRAWLSPACE/BASEMENT



AIR SEALING



INSULATING IN CRAWLSPACES

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



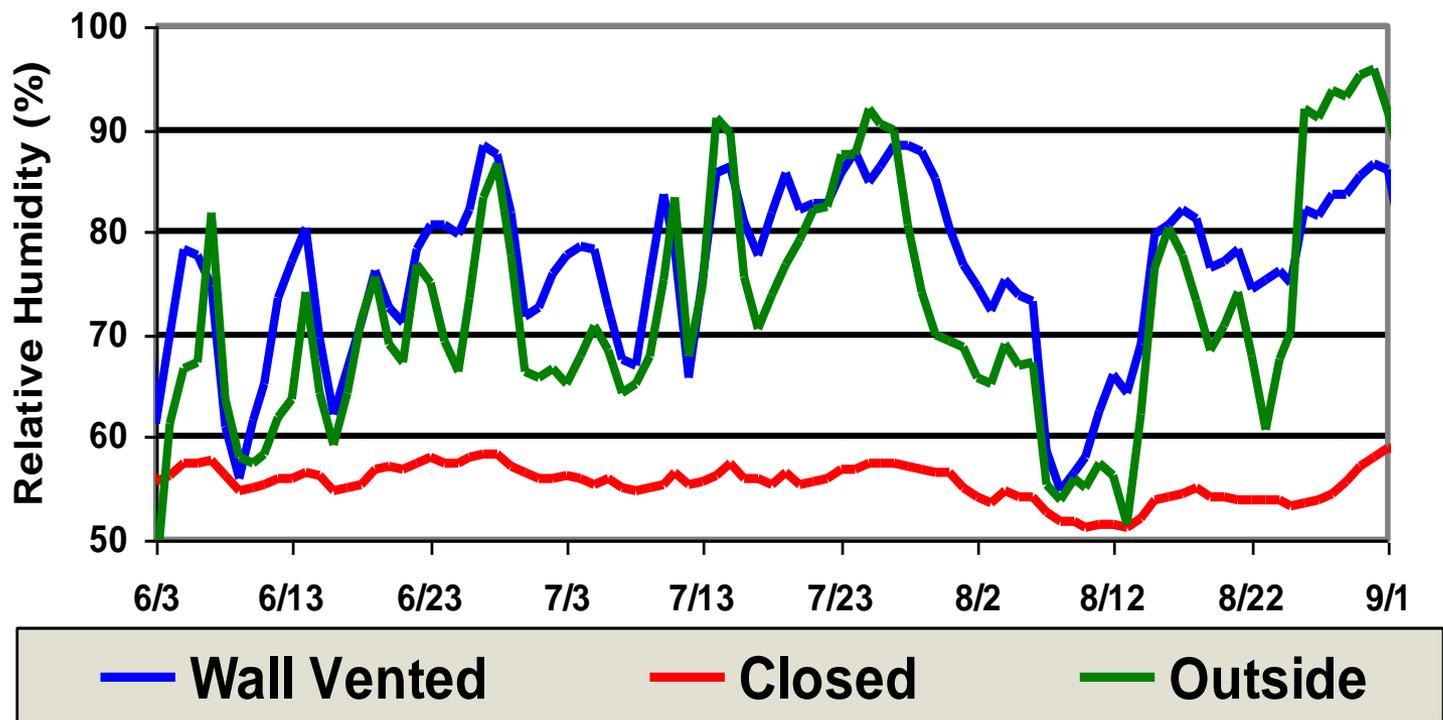
Closed (encapsulated) crawlspace:
Insulate & air seal crawlspace **walls**



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

SEALED CRAWLSPACE STUDY

Crawlspace Moisture Levels Summer 2002



Advanced Energy - crawlspace.org

CODE SAYS TO VENT, BUT OFFERS AN EXCEPTION...

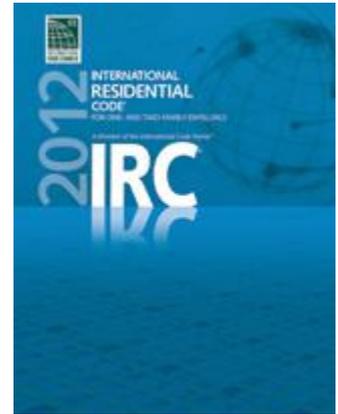
SECTION R408 UNDER-FLOOR SPACE

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 m²) for each 150 square feet (14 m²) 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 m²) for each 1,500 square feet (140 m²) 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 m²) for each 150 square feet (14 m²) 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.

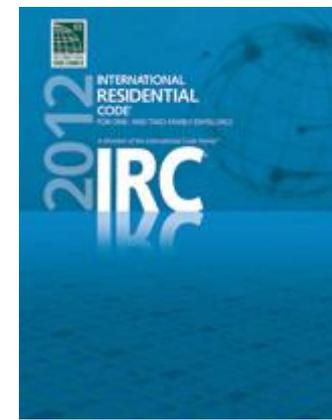
- 1:150 s.f. just vents
- 1:1500 s.f. with Class 1 vapor retarder installed (e.g., 6 mil poly)



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:

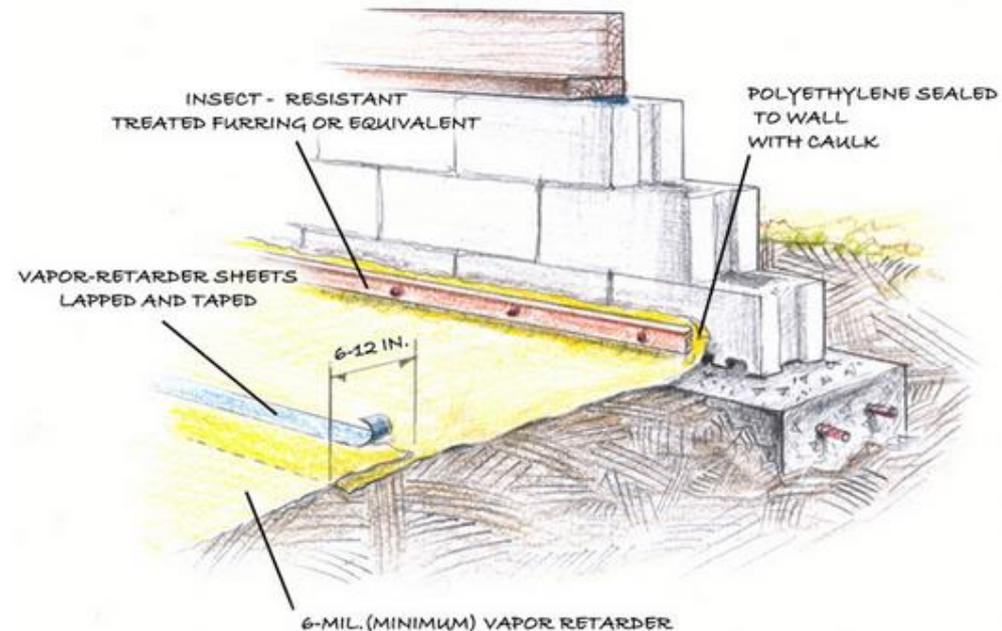
1. Exposed earth is covered with a continuous Class I vapor retarder. Joints of the vapor retarder shall overlap by 6 inches (152 mm) and shall be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (152 mm) up the stem wall and shall be attached and sealed to the stem wall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



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

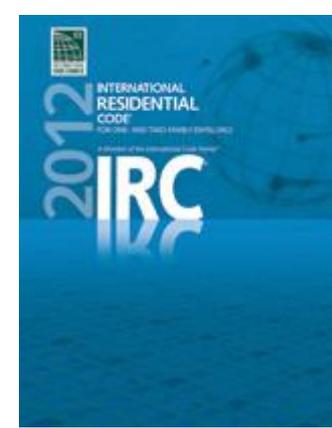


Photo thanks to Donnie Holmes



CRAWL SPACE - VAPOR RETARDER OVER SOIL

UNVENTED EXCEPTION, PART 2.1

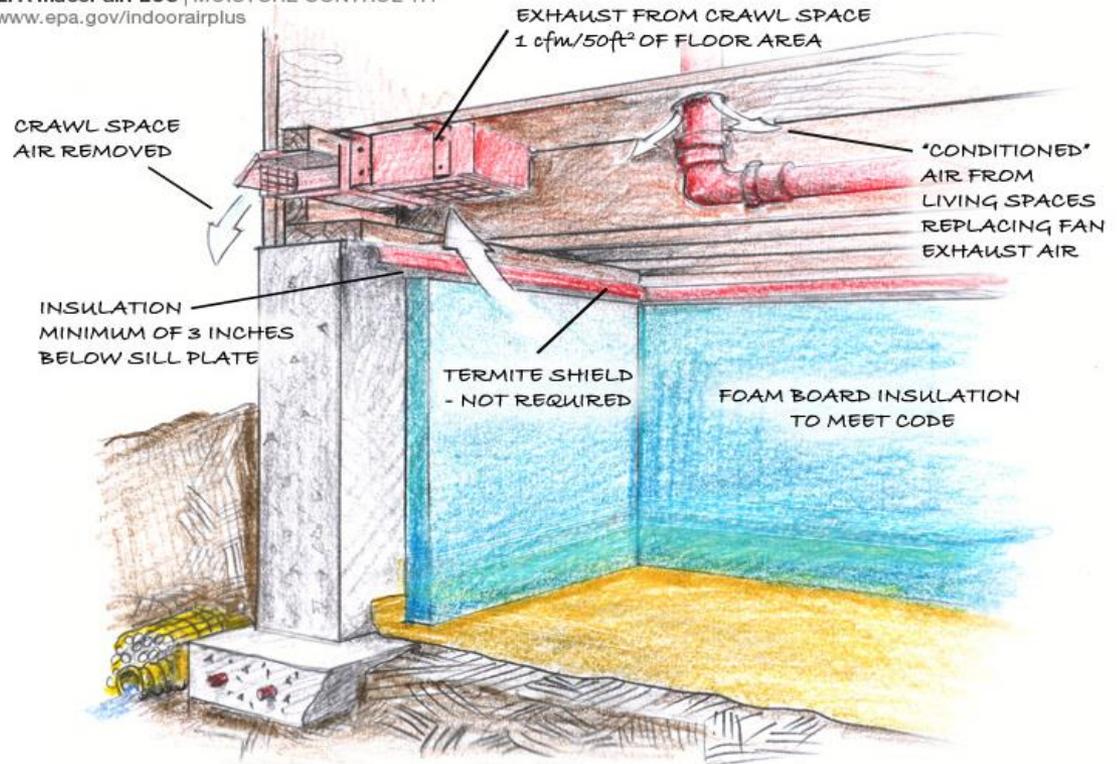


2. One of the following is provided for the under-floor space:

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 (4.7m²) 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;

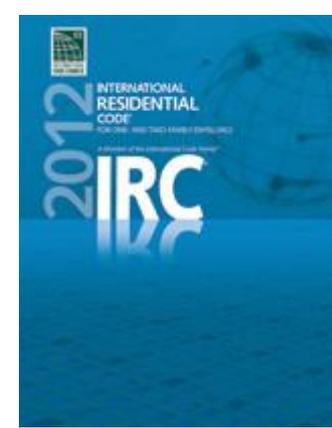
- Arguably, an active radon remediation system could be deemed continuously operated mechanical exhaust ventilation

EPA Indoor airPLUS | MOISTURE CONTROL 1.4
www.epa.gov/indoorairplus



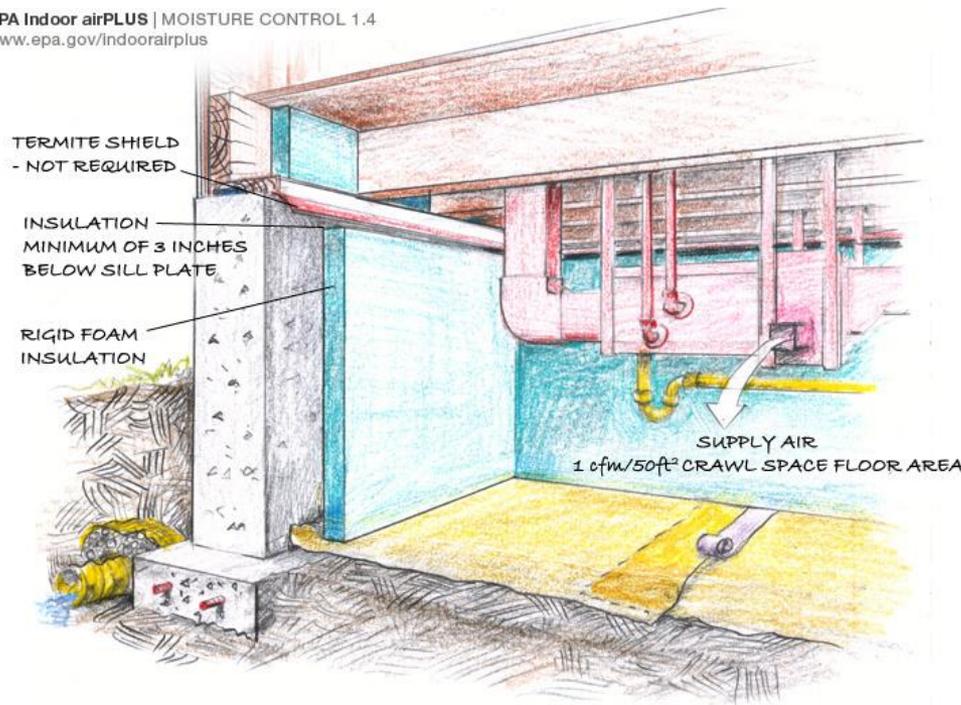
EXHAUST FAN FOR SEALED CRAWL SPACE

UNVENTED EXCEPTION, PART 2.2



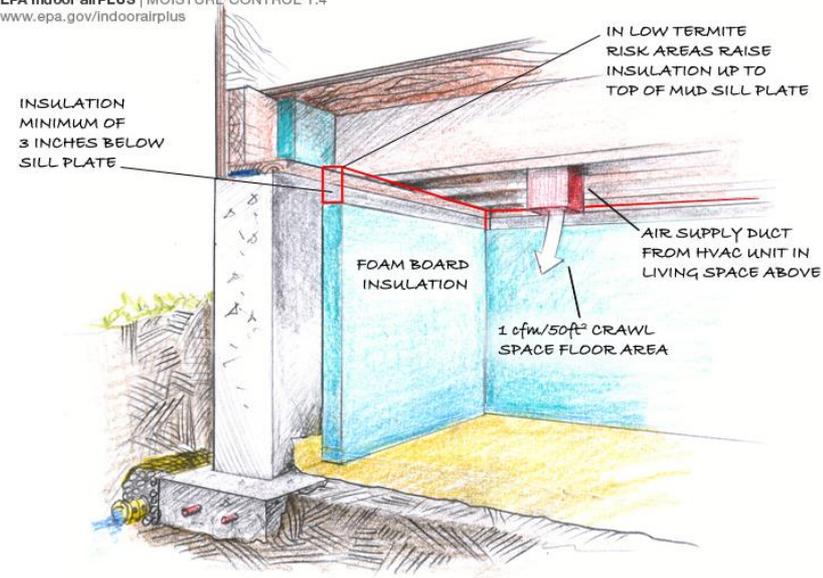
2.2. *Conditioned air supply sized to deliver at a rate equal to 1 cubic foot per minute (0.47 L/s) for each 50 square feet (4.7 m²) of under-floor area, including a return air pathway to the common area (such as a duct or transfer grille), and perimeter walls insulated in accordance with Section N1102.2 of this code;*

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www.epa.gov/indoorairplus



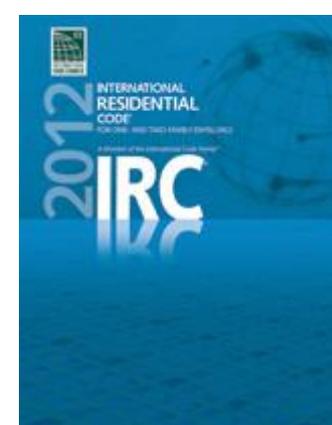
CONDITIONED AIR SUPPLY TO SEALED CRAWL SPACE

EPA Indoor airPLUS | MOISTURE CONTROL 1.4
www.epa.gov/indoorairplus



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 m²) 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.



**DON'T
DO
IT**



DON'T DO IT.

TO CLOSE UP OR NOT?



- Drainage problems
- Combustion safety
- Pest control

Is it practical to close all
crawlspace?

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

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



Closed cell



High-borate cellulose

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 insulate 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



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

Photos thanks to Donnie Holmes

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



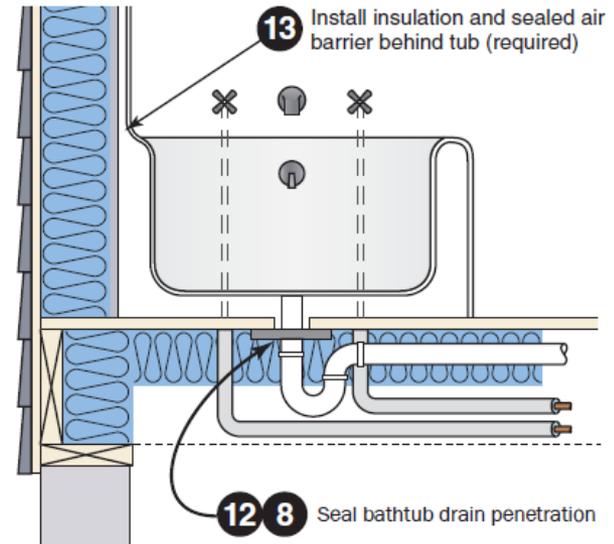
ECOCELL blankets - 3.7 R-value per inch

FOCUS: THE SHELL



AIR SEALING BLOCKING & SHEATHING

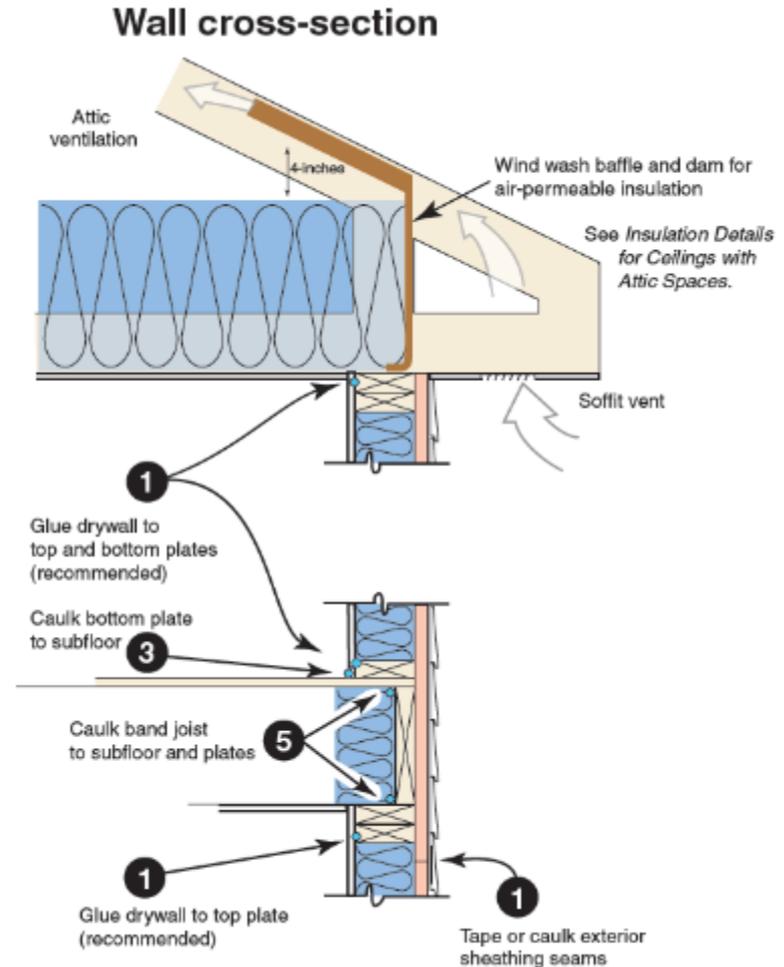
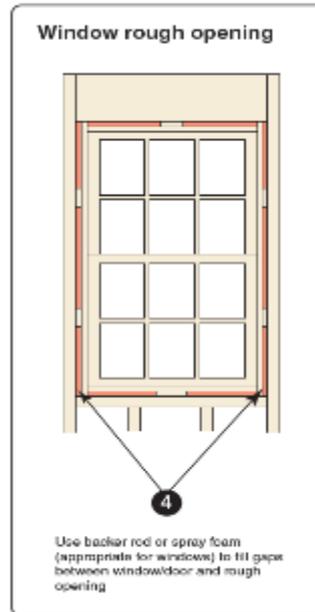
Solid sheet behind tubs & showers on insulated walls



Call back waiting to occur
Call back prevention

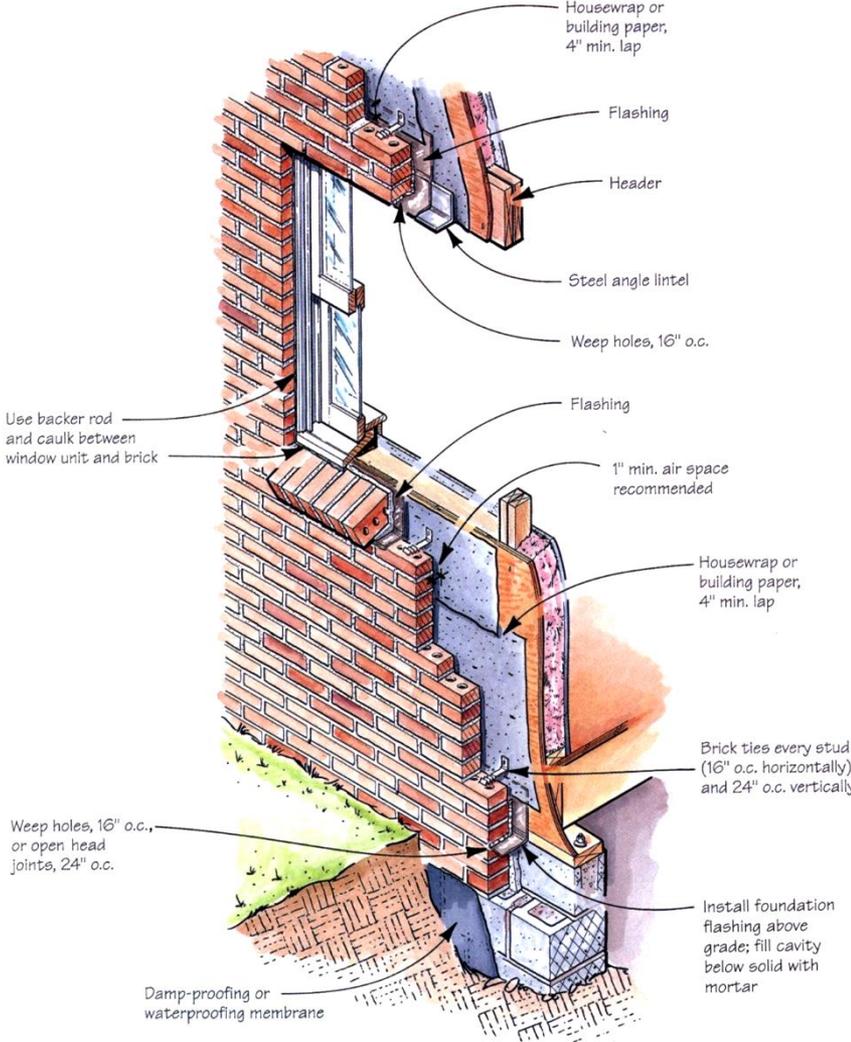


AIR SEALING WINDOWS & WALLS



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



ANATOMY 1

Since the 1950s, no which require a drainage cavity to avoid water damage.

Wood sheathing

Two layers #15 built

Brick ties anchor b wall framing.

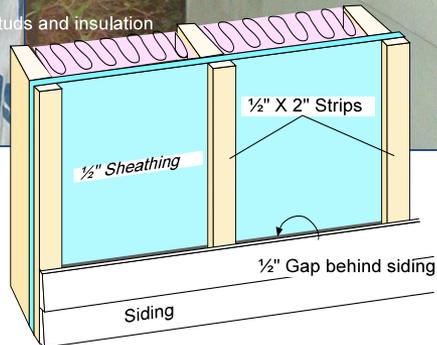
Concave or V-shap joints shed water.

A 2-in. drainage cavity allows water to flow down the back of bricks.

RAIN SCREEN / DRAINAGE PLANE



Studs and insulation



HOUSEWRAP: DETAILS ARE CRITICAL

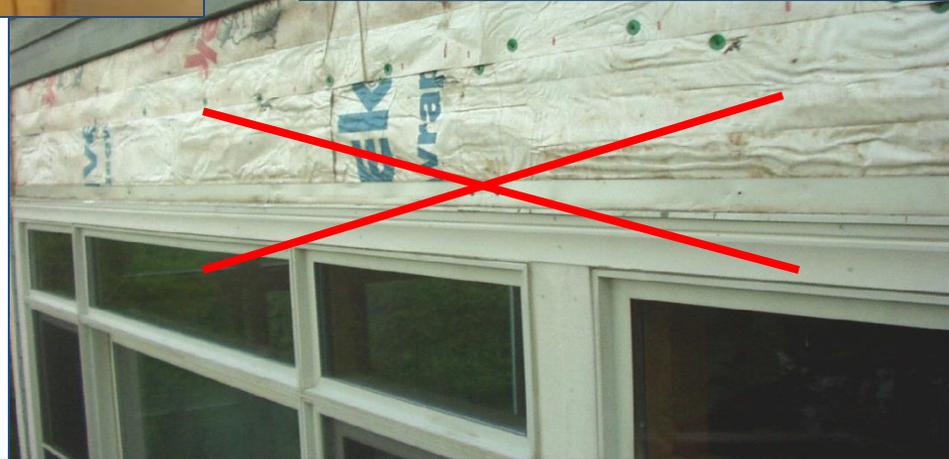
Top Sash after trim removed



Rotten Header



*Windows
(incorrectly)
have flange over
housewrap*



HOUSEWRAP AS A WEATHER BARRIER

Technology Fact Sheet

WEATHER-RESISTIVE BARRIERS

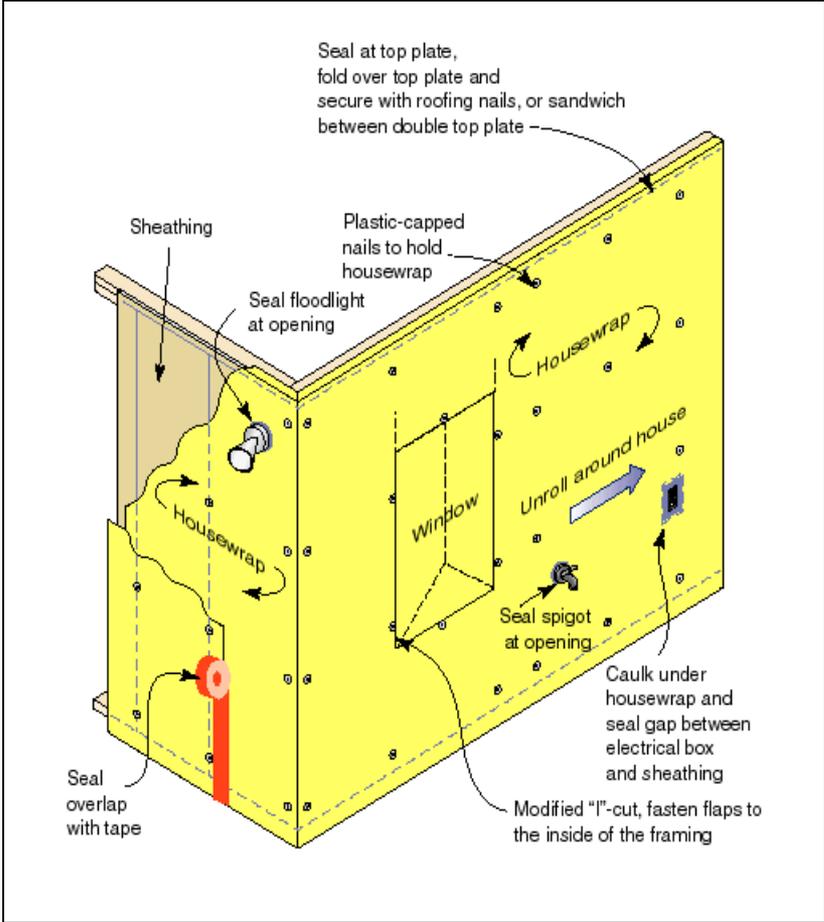
How to select and install housewrap and other types of weather-resistive barriers



Buildings for the 21st Century

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 are 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)

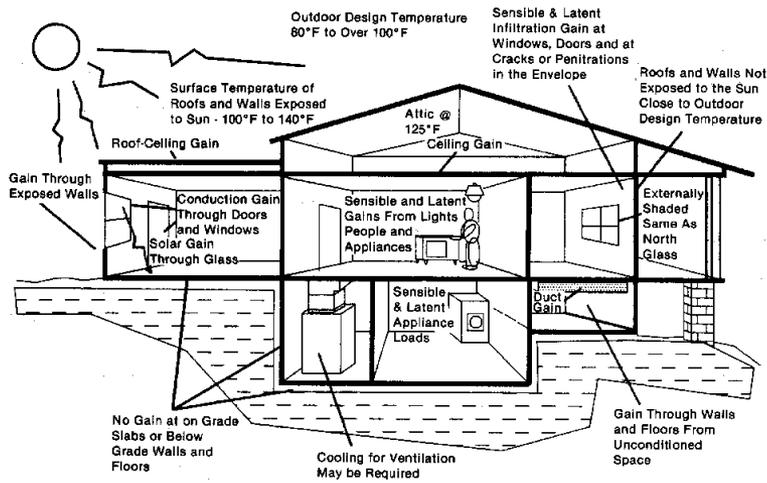
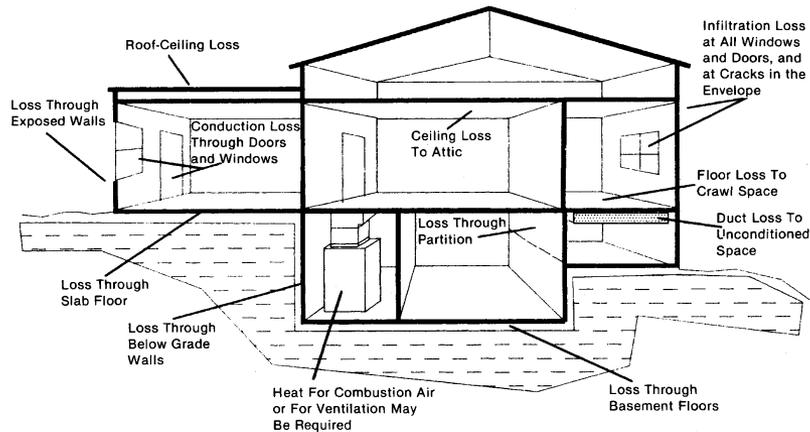


HOW AIR CONDITIONING REMOVES MOISTURE



- 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



- 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)

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

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:

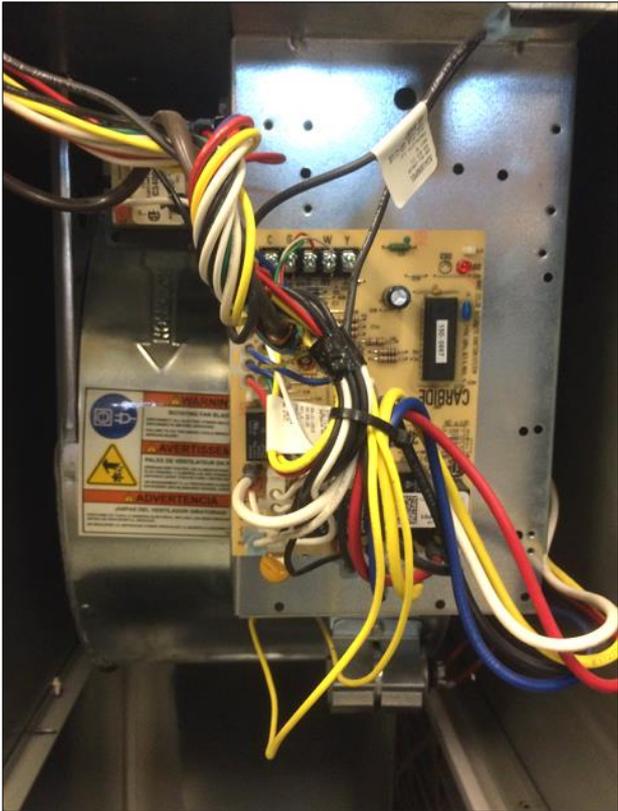
- Ineffective moisture removal
- Poor comfort
- IAQ concerns
- Durability issues



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

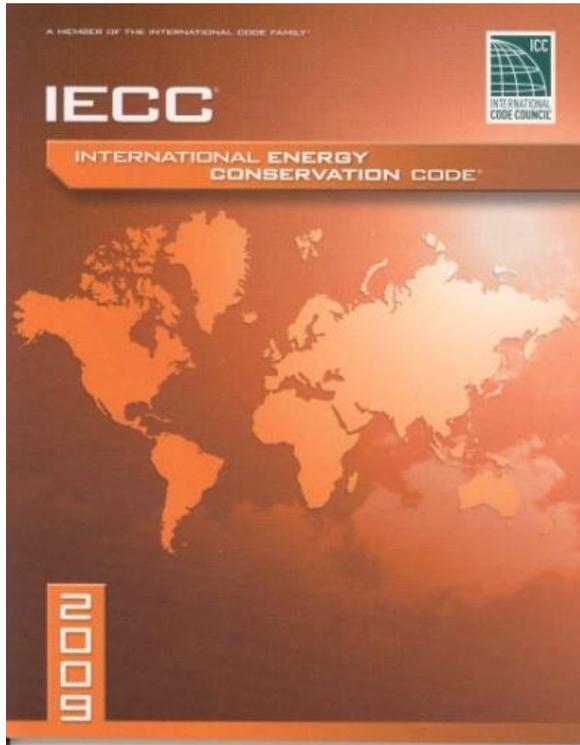


DUCT SEALING IS CRITICAL!

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



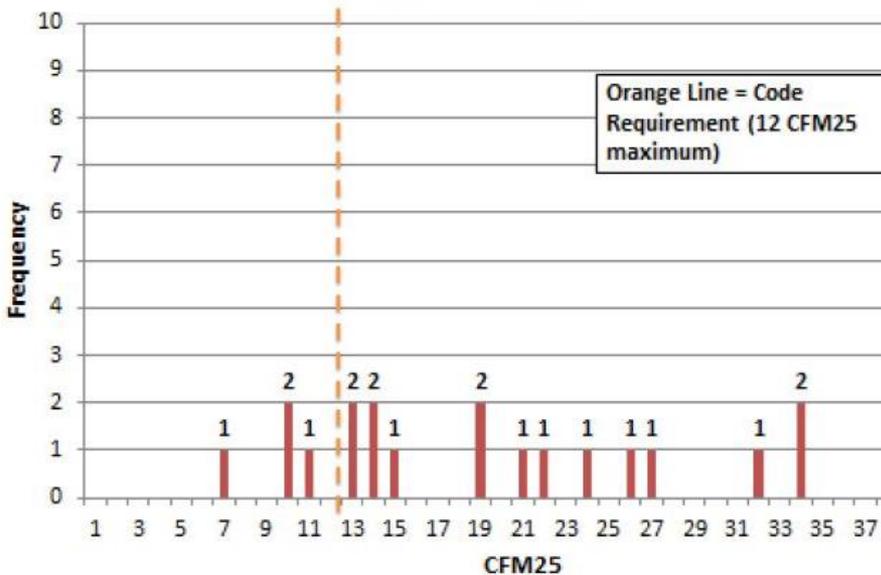
DUCT TESTING REQUIREMENTS



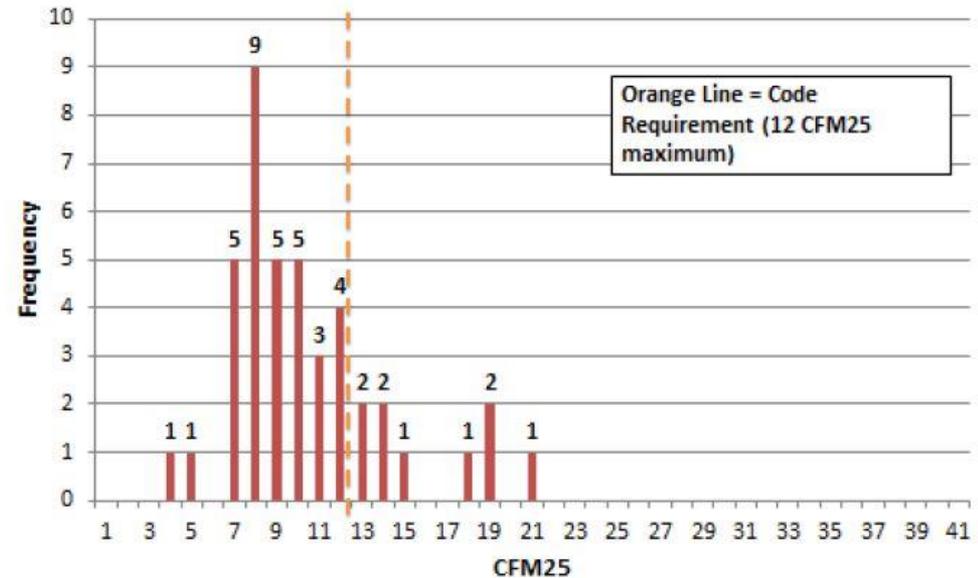
- Kentucky code requires leakage testing of ducts (unless located within conditioned space)
- Even if ductwork is exempt from testing, it still must be sealed

ROOM FOR IMPROVEMENT!

Duct Leakage - Conditioned Space (CFM25)



Duct Leakage - Unconditioned Space (CFM25)

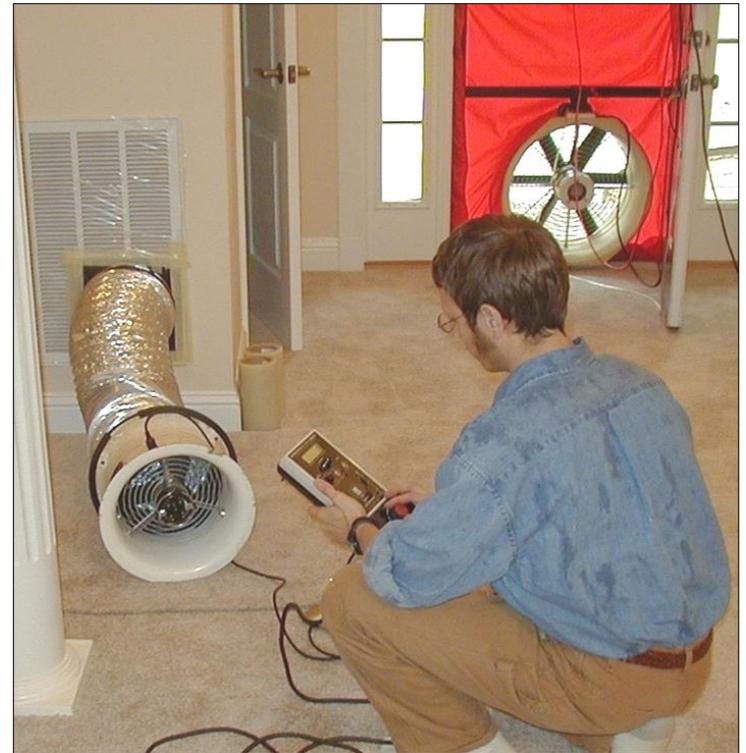


Kentucky code requires leakage testing of ducts (unless located within conditioned space)

DUCT TESTING REQUIREMENTS

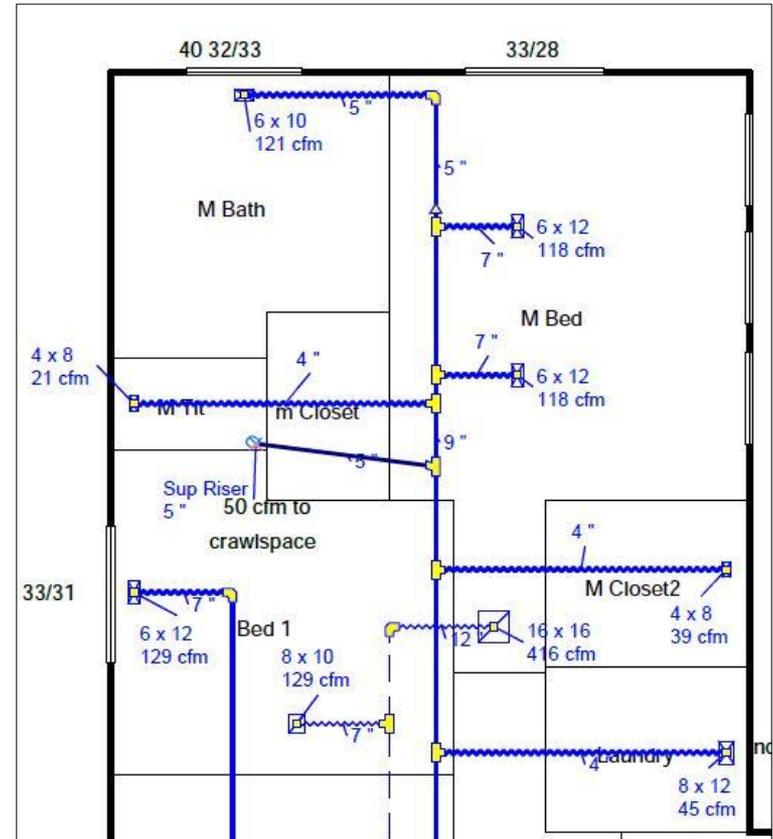
Duct leakage must meet one of the following:

- 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

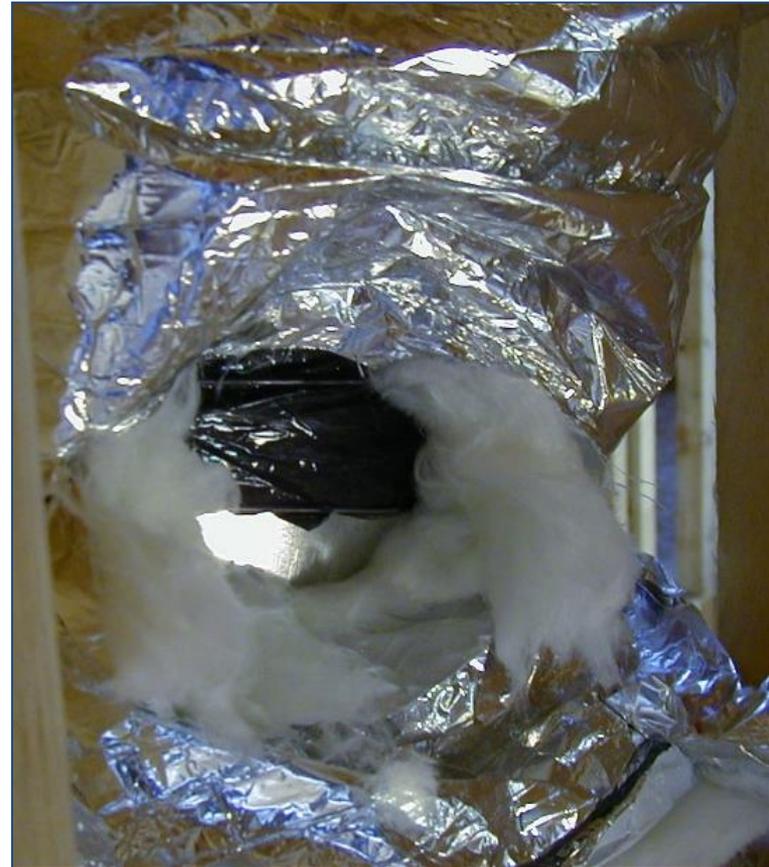


DUCT INSTALLATION

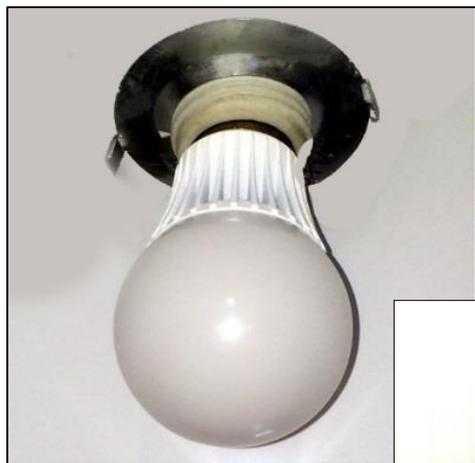
- ACCA Manual D should be used for duct design
- Ducts should be properly sized
- Ducts should be short, straight, and well supported



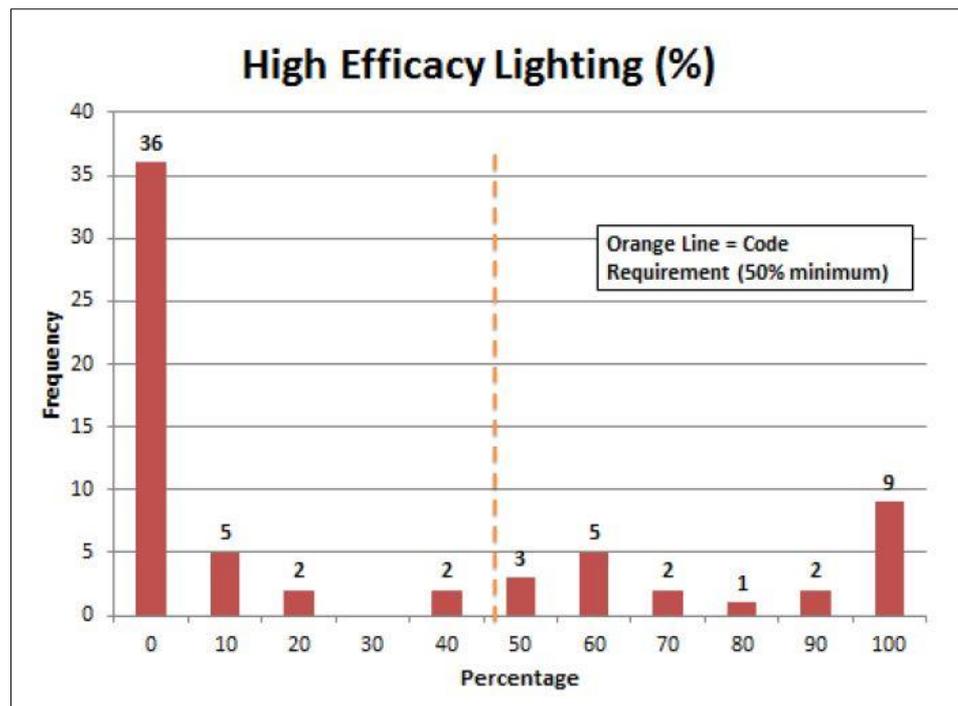
DUCT INSTALLATION



FOCUS: LIGHTING



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



Compliance is low in KY – why?

INCANDESCENT VS. CFL VS. LED



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



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



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

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 $\$0.10 / \text{kwh}$, how long will it take an LED light bulb to pay for itself?

Bulb cost = **\$5.00**

Energy cost =

$32.9 \text{ kwh/yr} \times \$0.10 / \text{kwh} = \mathbf{\$3.29/\text{year}}$

Energy cost for Incandescent =

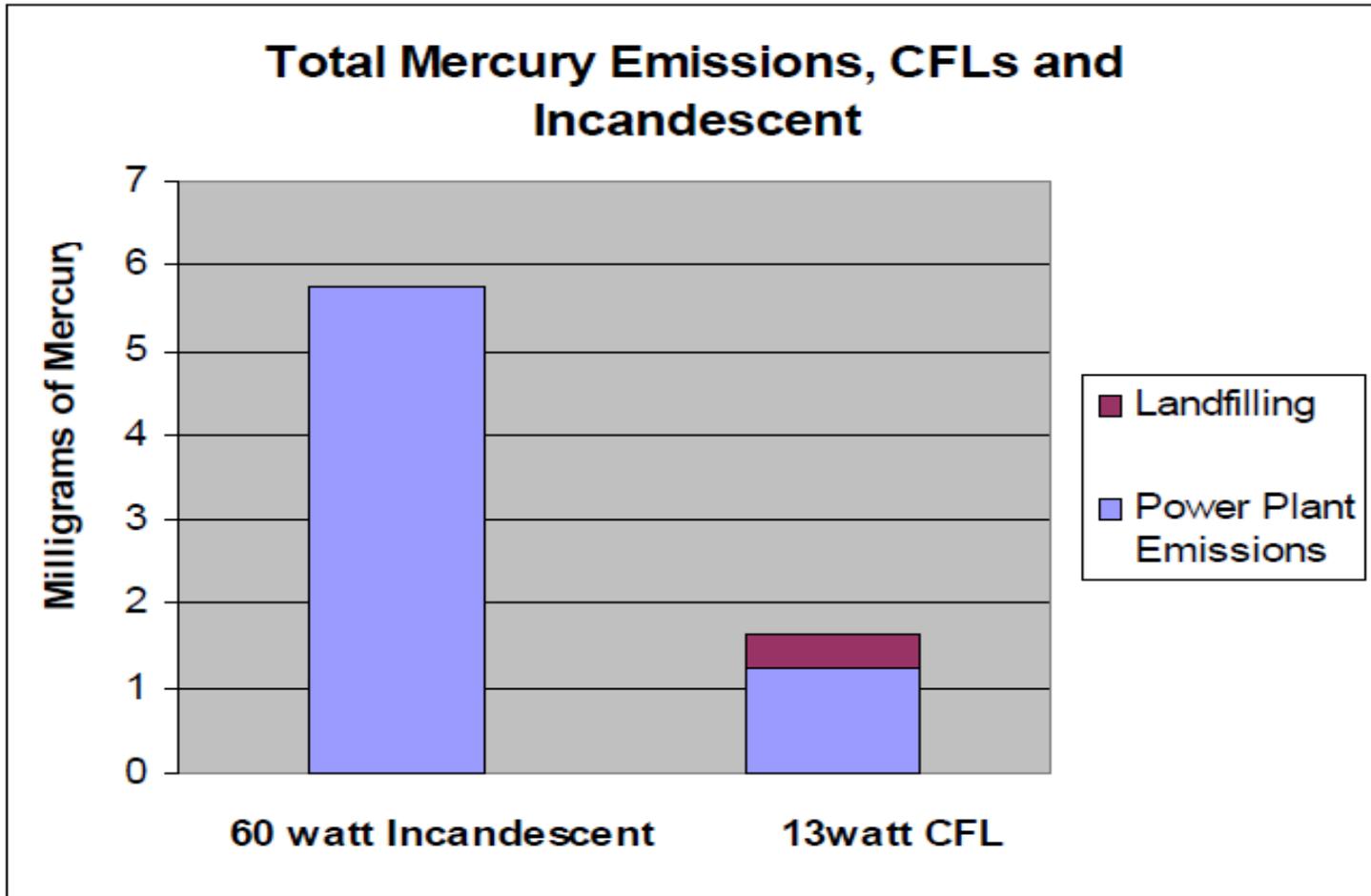
$219 \text{ kwh/yr} \times \$0.10 / \text{kwh} = \mathbf{\$21.90/\text{year}}$

Annual savings for LED: **\$18.61**

Simple Payback = Cost/Savings

$\$5.00 / \$18.61 = 0.27 \text{ years} = \mathbf{14 \text{ weeks}}$

CFL MERCURY CONCERNS



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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?

