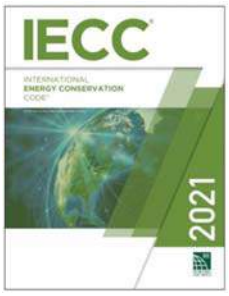
Applying Energy Codes & Upgrades to Existing Homes

Improving Efficiency, Comfort, and Health

Mike Barcik
Technical Principal, Southface
mikeb@southface.org
www.southface.org



Matt Belcher
MO Energy Code Support
Matt@moenergycodesupport.org

Energy Code Resources

https://codes.iccsafe.org/content/IECC2021P2

Technical assistance or training requests:

Matt Belcher, Energy Code Consultant
Matt@moenergycodesupport.org
314.749.4189

Energy Code Resources

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

www.southface.org

mikeb@southface.org

Southface MEEA

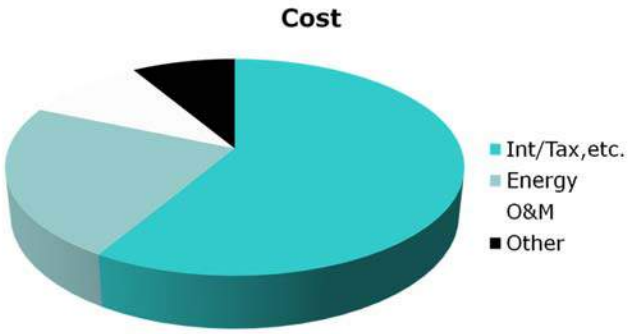
Learning Objectives

- Software – home assessment discussion
- Easy Things You Should Do
- Quick Building Science review (Heat, Air, Moisture)
- Safety issues:
  Asbestos, Lead, Mold & Moisture, Combustion Safety, Radon
- Applying the Code:
  - Correctly Air Sealing and Insulating the house
  - Ductwork & Mechanicals
  - Lighting
- Typical Scope of Work (SOW) for existing home weatherization

Southface MEEA

Equity!

- **Analyzing the Monthly Payment:**
  - Largest % Is Cost of Home
  - Next largest are Cost of Utilities + Cost of Maintenance
- **Utility and Maintenance costs** decrease with increase in Quality and Efficiency
- **Result is Added Value and more Equity!!**



Southface MEEA

Easy Things You Should Do

1. Don't use incandescent or halogen bulbs – replace these now with LED (don't wait for them to burn out)
2. Only buy LED bulbs from now on (use existing CFL's and properly dispose of them when they burn out since they contain mercury)

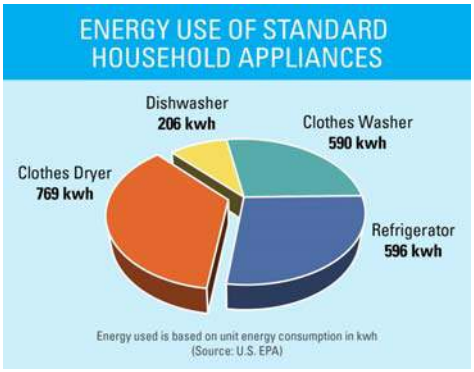
***CFL** uses 1/4 of the energy of an incandescent*
***LED** uses 1/6 of the energy of an incandescent*

Turn off lights (and fans and appliances, etc.) when no one is in the room!

Southface MEEA

More Things You Should Do

3. Use ENERGY STAR appliances – "*ES: The Most Efficient list*"
   - Dishwasher – common
   - Refrigerator / freezer (don't keep old ones in garage)
   - Washers and now Clothes Dryers – clothes lines are free!
   - Bath exhaust fans – install pre-set timer controls



More Things You Should Know


Wellton 54 in LED Espresso Bronze DC Motor Ceiling Fan with Light

4. Kitchen hoods – use them; preference for the back burners
5. For cooling, use (DC motor!) ceiling fans only when people are in that room
   - Larger, aerodynamic blades are more efficient than paddles – low speed!
6. Close up the house when heating or cooling the inside
   - Or, shut system off and open windows when conditions are good
7. Replace / upgrade HVAC filter

Use Better Filters

Why?

A 1" filter is mainly there to protect the mechanical equipment. It isn't really there for human health.

Even higher quality 1" filters can't do much better. As filters load up, they actually work better, however they greatly impact air flow and strain the HVAC system.

Outcome:

If you want to catch particles that affect human health (~2.5 microns), use a thicker (deeper) pleated filter.

Deep, pleated filters

Utilize deep filters as when fully disassembled, our media allows for 27 sq. ft. of surface area. This allows for deep loading not surface loading which allows maximum air flow over a longer period of time while maintaining very good pressure drops.

PRESSURE DROP OVER TIME

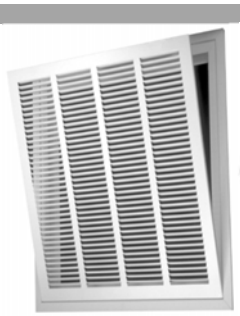
(3-TON SYSTEM)

Aprilaire filters, with over nine times the surface area of a 1" filter, have extremely low initial resistance and high dust holding capacity, allowing them to work for 12 months without being overly restrictive. This helps maintain proper airflow, reducing potential call backs.

Filters

- Change every leap year?
- El Cheapo vs. HEPA filters
- Want thicker, pleated filters
- Don't accept installs that prohibit easy filter access
- Seal filter access covers

"Filter Lock" uses magnets to seal access



Practical Pleat

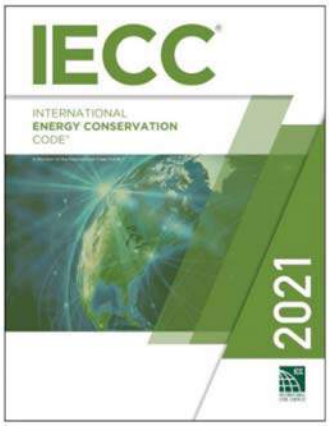
www.filtrationmfg.com

www.anykindoffilter.com

"AKF003" is discount code

Importance of Energy Codes

- **Save energy** - Buildings consume 40% of energy in U.S.
- **Save money** - Energy costs continue to escalate, and energy codes help keep money within local economy
- **Additional benefits:**
  - Increases comfort, health and durability of homes
  - Increases value of homes in local community
  - Reduces liability for builders and subcontractors



Southface MEEA

Scope of Residential Energy Code

- Focus is on building thermal envelope
  - Ceilings, walls, windows, floors, and foundations
  - Sets insulation & fenestration U-factors, and solar heat gain coefficients
  - Infiltration control – caulk and seal to prevent air leaks, and test
- Ducts, air handlers, filter boxes – seal, insulate, and test
- Limited space heating, air conditioning, and water heating requirements
- Federal law sets most mechanical equipment efficiency levels, not the I-codes (similar for appliances)
- Lighting equipment – 90% of lamps to be high-efficacy lamps or 90% of lighting fixtures to have only high-efficacy lamps

Southface MEEA

Residential Buildings

- New construction
- 1 and 2 family (R3)
- Multi-family, 3 stories and less (R2 and R4) – IECC 2015
- Additions, Alterations, Repairs

ALTERATION. Any construction, retrofit or renovation to an existing structure other than *repair* or *addition*. Also, a change in a building, electrical, gas, mechanical or plumbing system that involves an extension, addition or change to the arrangement, type or purpose of the original installation.

Exempt Buildings
- Low energy < 1 w/sq.ft.
- No conditioning
- Historic buildings (501.6)
- Log homes – ICC400

CONDITIONED SPACE. An area, room or space that is enclosed within the *building thermal envelope* and that is directly or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

Southface MEEA

Building Science

Improving Efficiency, Comfort, and Health in Existing Homes

Southface MEEA

The house as a system

- A house is a system made up of interrelated parts:
  - Building thermal envelope
  - Space conditioning
  - Ventilation
  - Water heating & distribution
  - Lighting & appliances
- Building science represents a holistic view of a house and applies an understanding of the flow of: **Heat, Air, and Moisture**

Southface MEEA

Section R402 – Building Thermal Envelope

- The building thermal envelope is the barrier that separates conditioned space from unconditioned space
- The envelope should consist of a **continuous** thermal boundary (insulation) and a **continuous** air barrier that are in complete contact

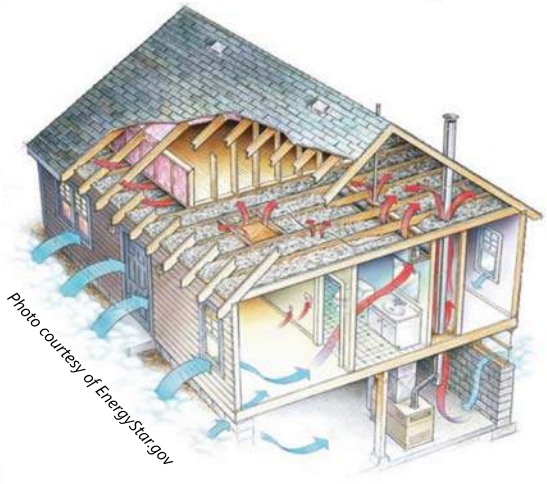
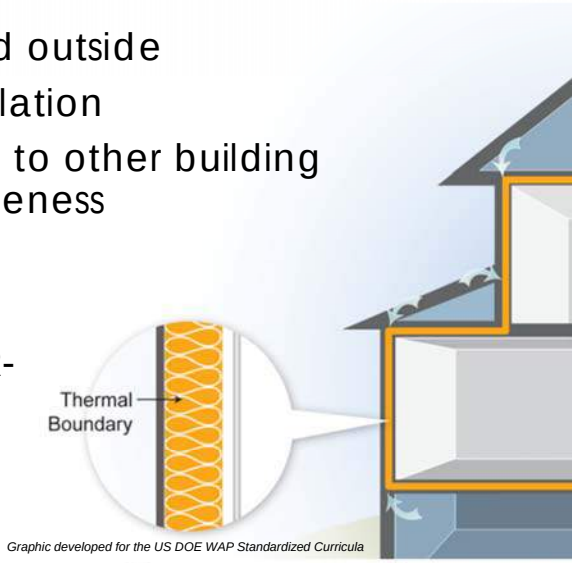


Photo courtesy of EnergyStar.gov

Southface MEEA

Thermal Boundary (Insulation)

- Limits heat flow between inside and outside
- Easy to identify by presence of insulation
- The location of insulation in relation to other building components is critical to its effectiveness
- Even small areas of missing insulation are critical
- Voids of 7% can reduce effective R-value by 50%

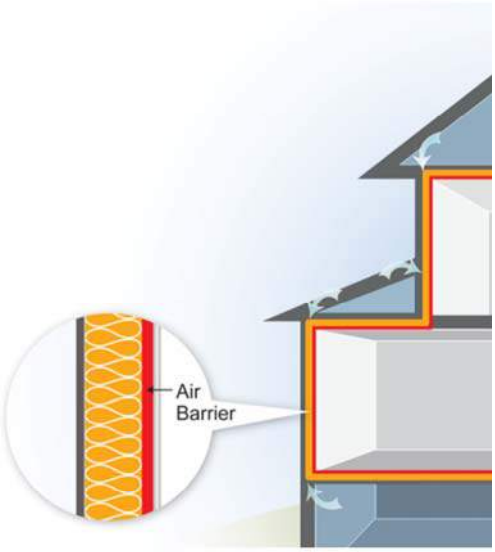


Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Air Barrier

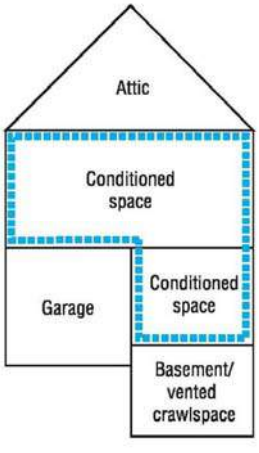
- Limits airflow between inside and outside
- More difficult to identify
- Not always where you think it is
- Must be co-located with the thermal boundary
- Must be continuous
- Blower door is used to locate & verify air barrier

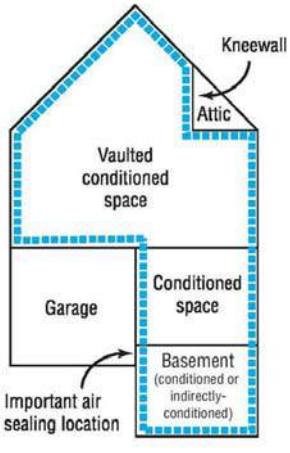


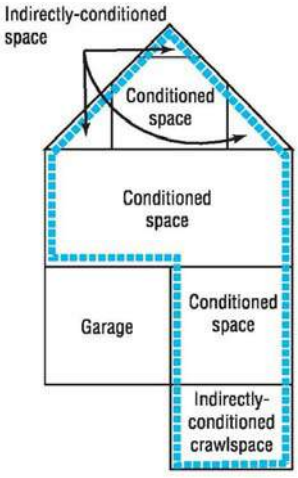
Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Thermal Envelope Example





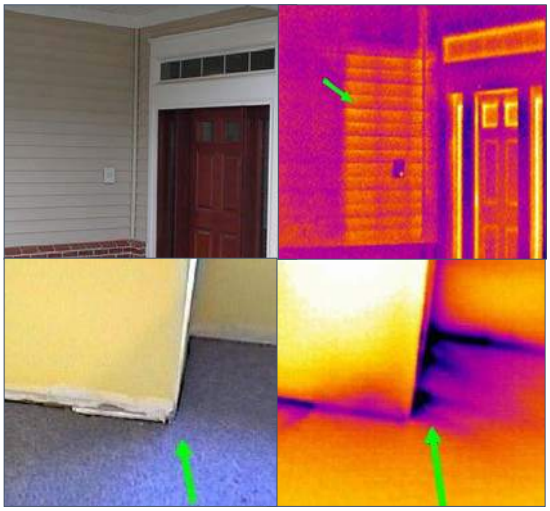


*Although these three homes look identical from the outside, each has defined the building thermal envelope differently

Southface MEEA

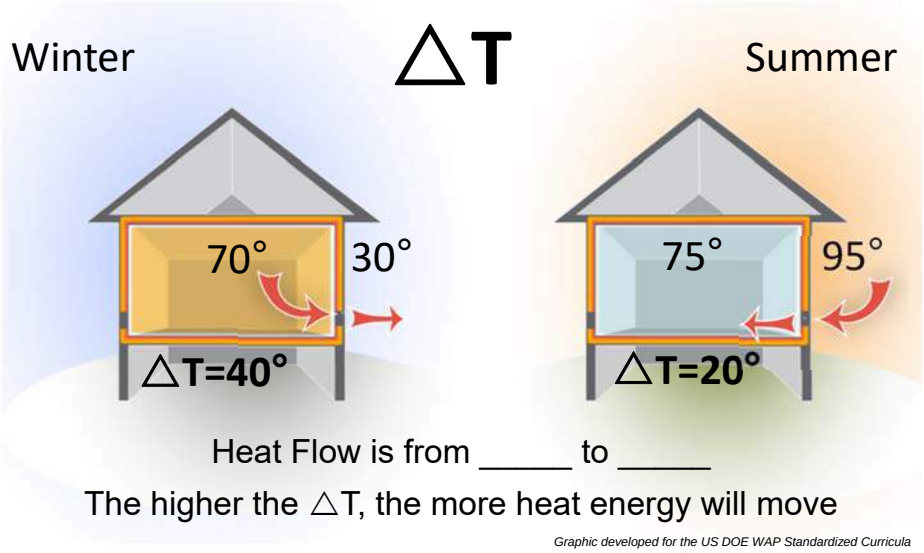
Heat Transfer

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



Southface MEEA

Heat Flow: Temperature Difference



Heat Flow is from _____ to _____

The higher the △T, the more heat energy will move

Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Radiation

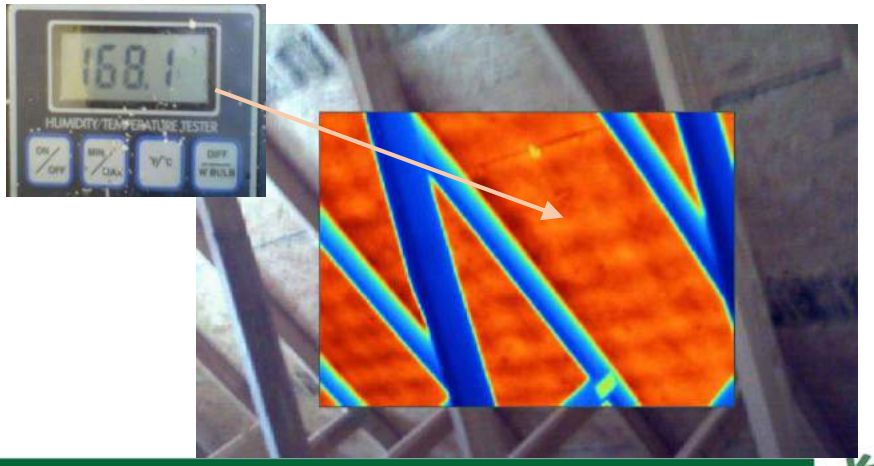
Radiation is the movement of heat from a hot surface to a cold surface with nothing solid or opaque in between (low-emitting surfaces slow radiation)



Southface MEEA

Heat transfer: Radiation

- Low-emitting surfaces slow radiation




Southface MEEA

- Attic radiant barrier retrofit

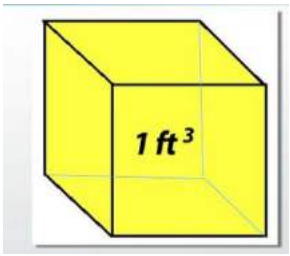
Conduction

- Heat moves through a material
- Insulation can slow down conduction
  - How well a material slows conduction is called resistance
  - Resistance is measure of R-value, inverse is U-value

Convection

- Outdoor air of different temperature replacing indoor air
- Air moves from areas of higher pressure to areas of lower pressure
- Natural and man-made forces that can create pressure differences cause air to flow
- Whenever air moves out of a home, an equal amount of air enters the home

Air Leakage

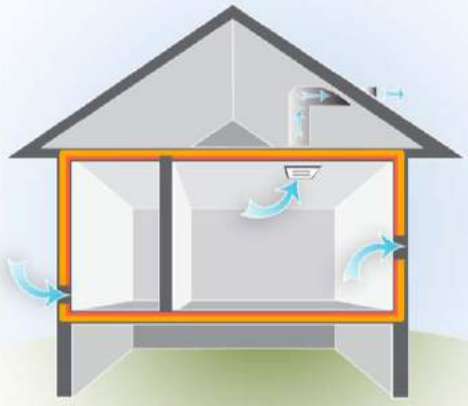


- Airflow is measured in cubic feet per minute, also written as ft^3/min, or CFM
- 1 CFM out = 1 CFM in
- Airflow takes the path of least resistance
- Air moves from high to low pressure areas
- Air usually moves from high to low temperature areas

Air Leakage

Ventilation = Controlled air leakage

Infiltration =
Air leaking in



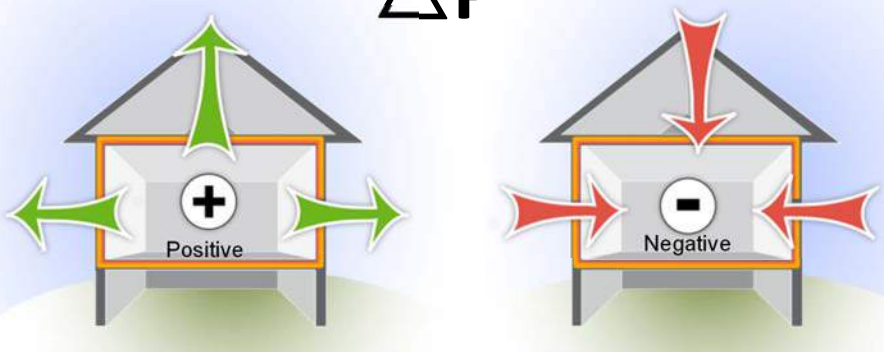
Exfiltration =
Air leaking out

Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Air Leakage: Pressure Difference

△P



Air Flow is from _____ to _____

Flow takes the path of least resistance

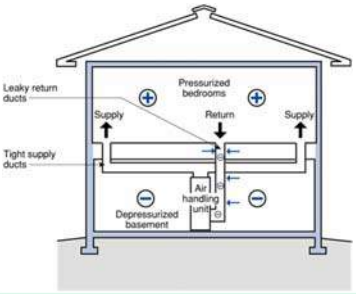
Graphic developed for the US DOE WAP Standardized Curricula

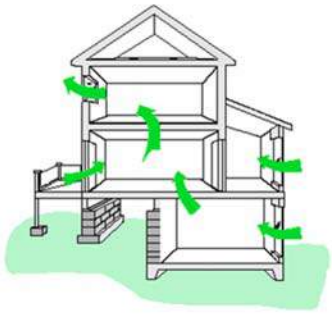
Southface MEEA

Air Leakage: Driving Forces

Three forces create pressure differences in a home:

- Wind
- Stack Effect
- Mechanical Fans

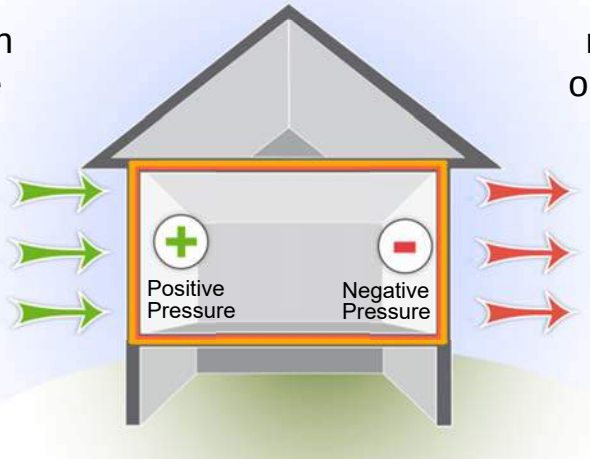




Southface MEEA

Driving Forces: Wind Effect

Wind creates a positive pressure on the windward side of the building



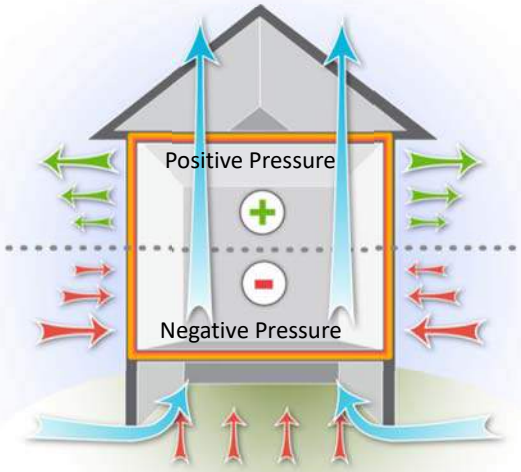
Which creates a negative pressure on the leeward side of the house

Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Driving Forces: Stack Effect

- Warmer air rises and escapes out of the top of the house
- This creates a suction that pulls in outside air at the bottom of the house

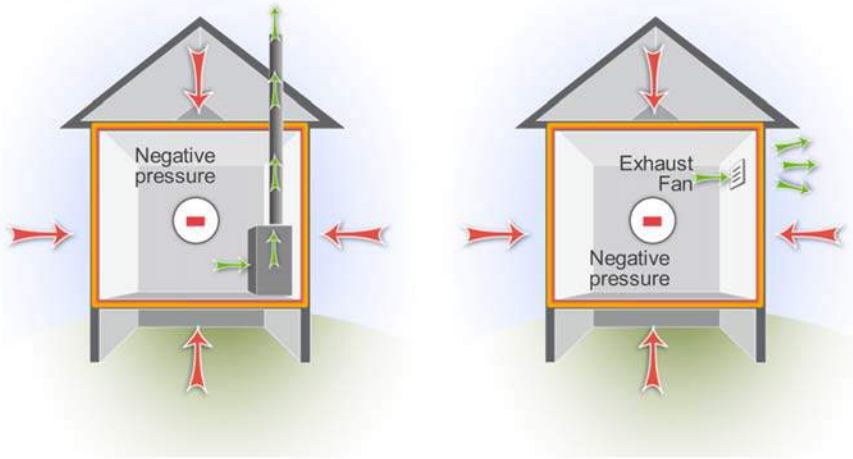


Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Driving Forces: Mechanical Effect

Combustion Equipment & Exhaust Fans



Graphic developed for the US DOE WAP Standardized Curricula

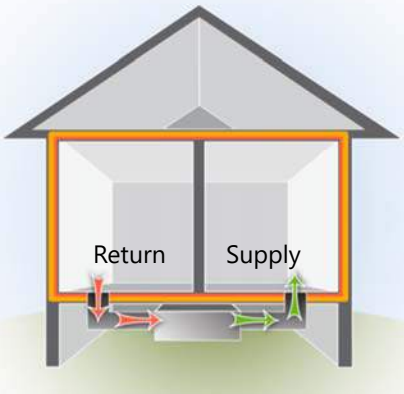
Southface MEEA

Driving Forces: Mechanical Effect

Duct Leakage

Duct leakage can create positive and negative pressures in different areas of the house

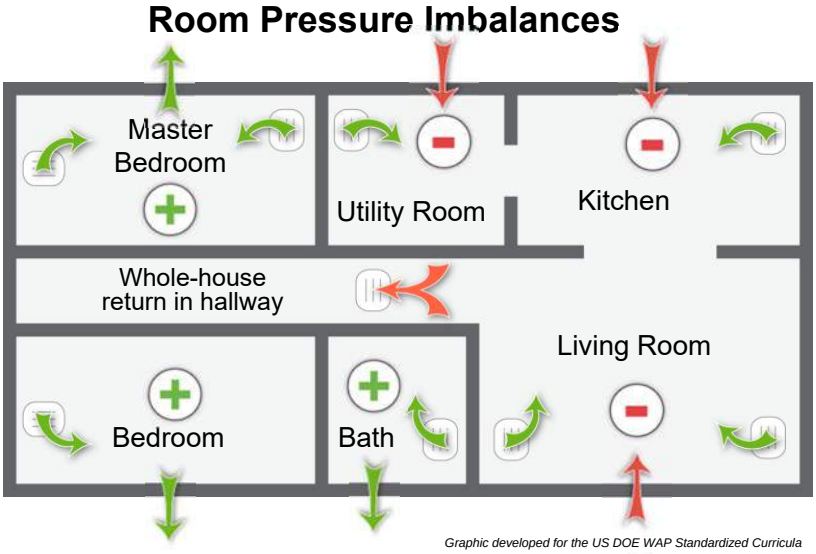
The pressures associated with duct leaks can be larger and more significant because the driving force is stronger



Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

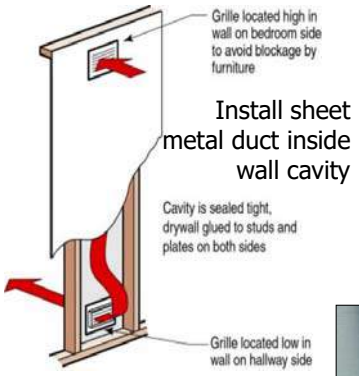
Driving Forces: Mechanical effect

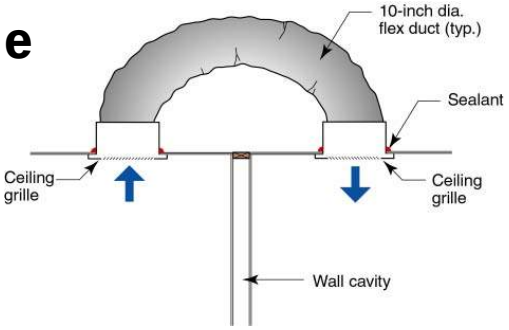


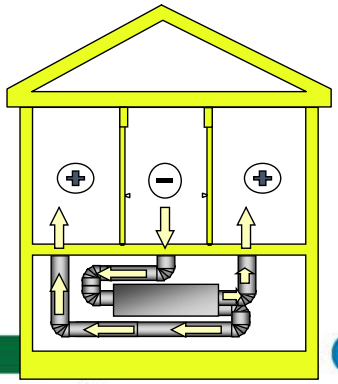
Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

Correcting Pressure Imbalance with a Proper Return Path





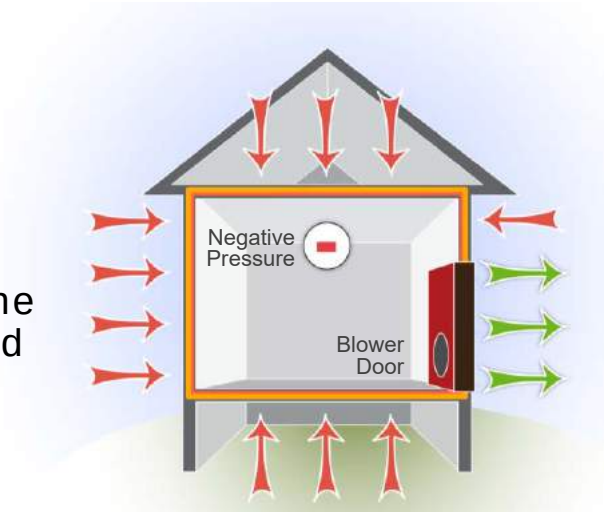


MEEA

Driving Forces: Mechanical Effect

Use a Blower Door as a Controlled Driving Force

Using the blower door depressurizes the house, drawing air through all the holes between inside and outside



Graphic developed for the US DOE WAP Standardized Curricula

Southface MEEA

MOISTURE TRANSPORT

Moisture moves…

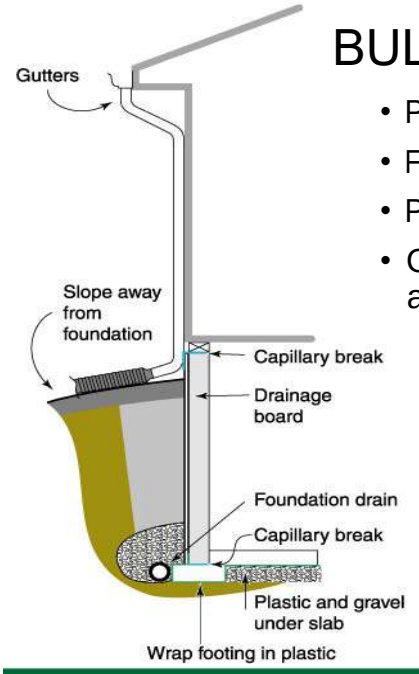
…from wet to dry

- **Liquid** Water
  - Bulk (rain/drainage, plumbing)
  - Capillarity (wicking)
- Water **Vapor**
  - Diffusion (molecular)
  - Air Leakage (infiltration)

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

Appropriate measures for moisture control are essential!

Southface MEEA



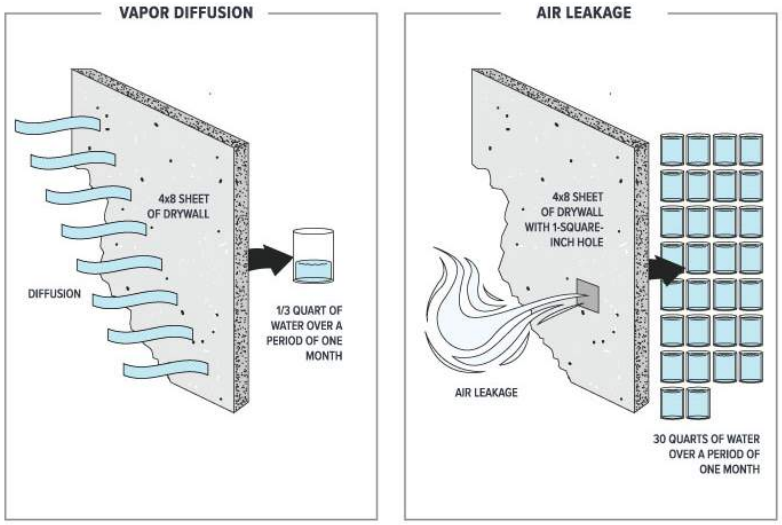
BULK MOISTURE CONTROL

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

Southface MEEA

Moisture Vapor

- Another reason to limit air flow in a home is to reduce moisture intrusion
- Even a small hole can allow a large amount of water into the building



Southface MEEA

Safety

Improving Efficiency, Comfort, and Health in Existing Homes

Southface MEEA

Asbestos

Asbestos can be located in:

- Siding, walls, ceilings, etc.
- Vermiculite insulation
- On pipes, furnaces, and other small covered surfaces

This scanning electron micrograph of asbestos shows the tiny, glass-like fibers that make asbestos so dangerous. These miniscule fibers become lodged in the lungs and can cause mesothelioma or other cancers.

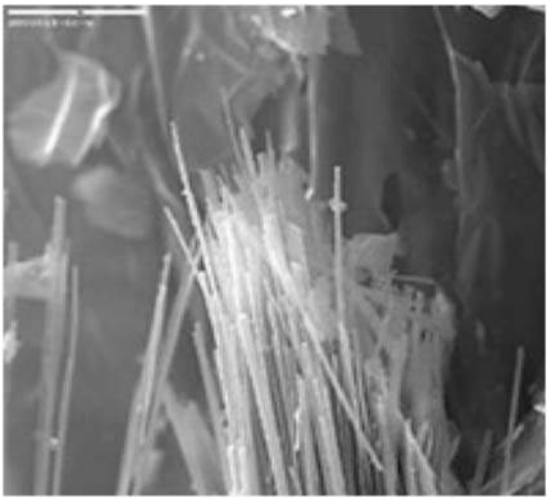


Photo courtesy of U.S. EPA

Southface MEEA

Asbestos

Southface MEEA

Lead-Based Paint

- Assume presence of lead in pre-1978 housing stock
- Lead-based paint is the primary source of lead-contaminated dust in housing
- Lead dust can harm everyone
  The most vulnerable are:
  - Babies/Children
  - Pregnant women
  - You!

Southface MEEA

Renovation, Repair and Painting (RRP)

- ALL paid contractors who work in pre-1978 housing where there's a risk that lead-based paint will be disturbed, or lead-based paint dust will be created, must comply with the EPA's Renovation, Repair and Painting (RRP) Rule or HUD's Lead Safe Housing Rule
- Consult your state environmental protection office or local jurisdiction for info on training requirements. Initial trainings are usually required with refreshers every 3-5 years

Southface MEEA

Mold and Moisture

- Moisture problems generally occur in bathrooms, kitchens, crawlspaces, and basements
- Always treat the source of the problem first!
- Installing a bath fan or range hood can mitigate moisture problems – consider push button pre-set timer controls

Southface MEEA

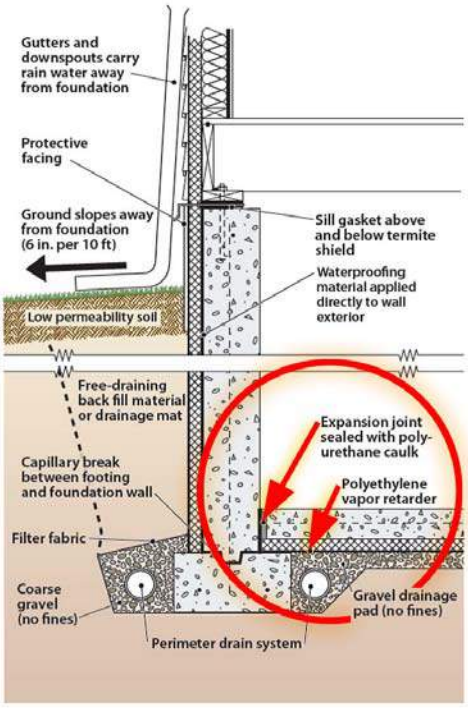
Mold and Moisture

Do not use a plastic moisture barrier in basement walls!

Southface MEEA

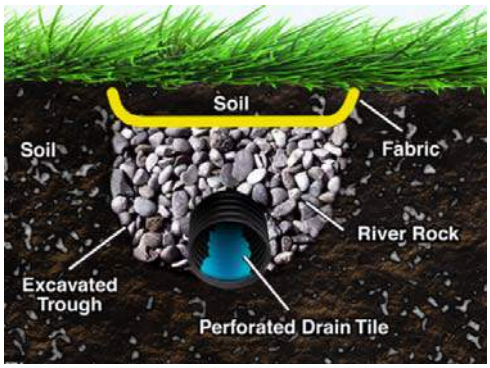
Mold and Moisture

- Some details might be harder (more expensive) to correct in existing homes
- Some techniques to consider:
  - Regrade the site to direct water away from home
  - Install footing or French drains
  - Use dimpled plastic moisture barrier on exterior surfaces of below grade walls
  - Utilize pervious surfaces to allow water to drain properly



Bulk Moisture Control & Correction

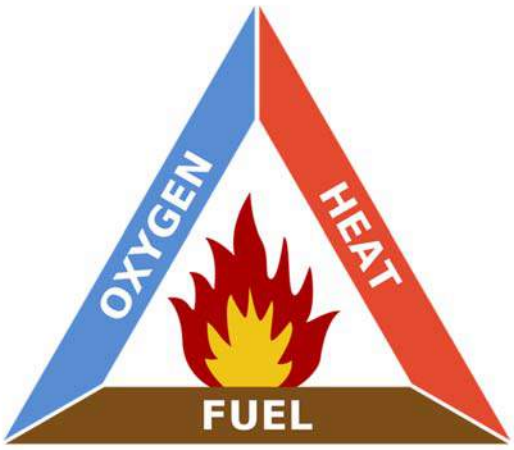
- Proper site drainage
  - Grading with positive slope
  - Swales
  - French drains



Southface MEEA

Combustion Safety

- Carbon Monoxide **CO** is a byproduct of incomplete combustion
- Improperly vented appliances and negative pressures in the home can magnify the problem
- Air sealing a house saves energy but means the oxygen available for appliances is reduced –
  Provide fresh air for the occupants and upgrade the appliances to have their own separate combustion air



Southface MEEA

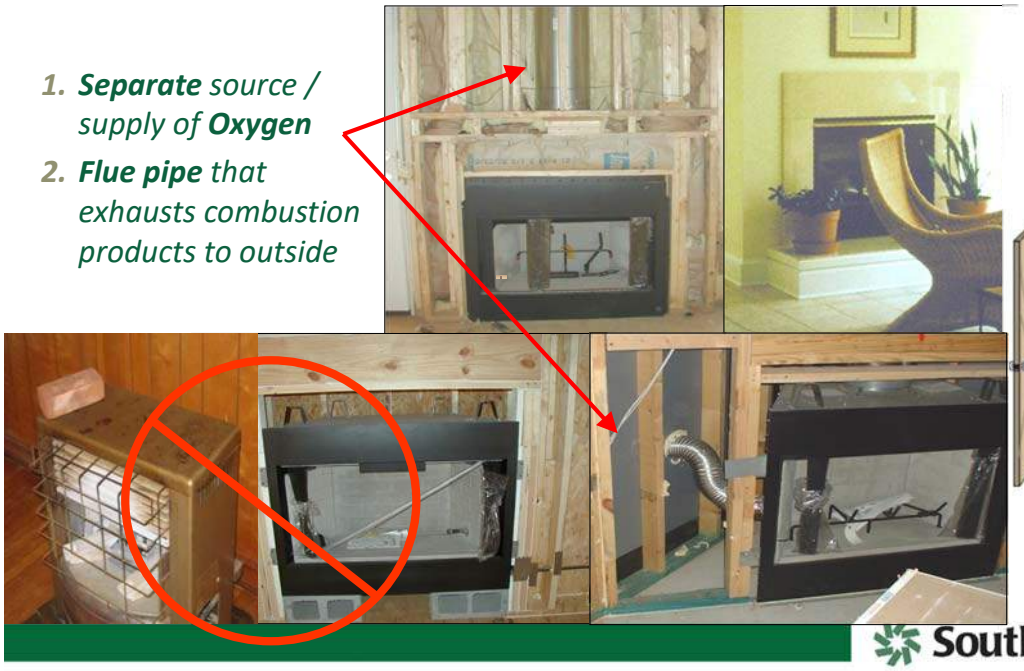
Combustion Safety

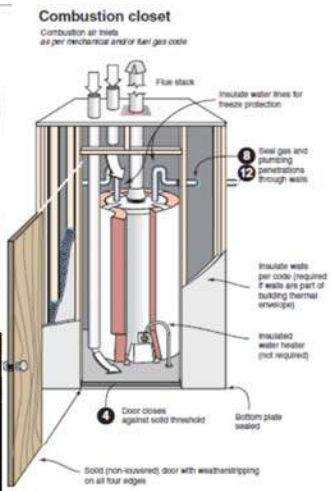
- **Proper air sealing with ventilation from a known source is key**
- **Making the house tighter without proper ventilation could:**
  1. Make existing problems worse
  2. Create new problems
- **These existing and new problems could be lethal**
  1. Carbon monoxide, Gas leaks, Back-drafting, Moisture (and mold)
- **Energy efficiency should not be a health hazard!**

Southface MEEA

Two Essentials for Safe Combustion

1. ***Separate*** *source / supply of* ***Oxygen***
2. ***Flue pipe*** *that exhausts combustion products to outside*





Southface MEEA

Sealed Combustion Furnaces/Boilers

- Safer because they use combustion air coming from exterior (if vented properly)
- More efficient because a secondary heat exchanger extracts more heat before venting
- Produces condensation and must be drained

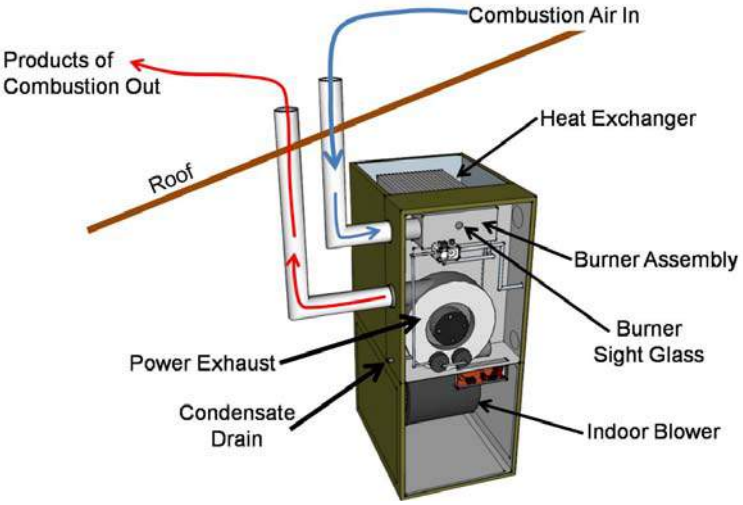
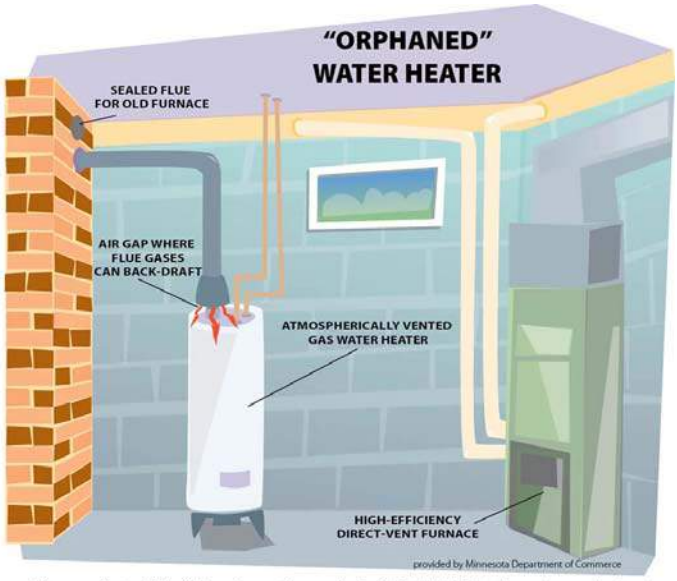


Diagram courtesy of Building America

Southface MEEA



After upgrading to a high efficiency furnace, there may be insufficient "draft" in the chimney to properly exhaust the flue gasses from an atmospherically vented gas water heater. Under certain conditions this can lead to **dangerous levels** of carbon monoxide and other pollutants. Solutions include adding a power vent to the existing water heater or replacing with a new direct vent water heater.

Photo courtesy of InterNACHI

Southface MEEA

Direct Vent Water Heater

- For new construction & retrofit replacement of electric water heaters
- Requires no electric power
- Uses double wall vent pipe
- All air for combustion is taken from outside. No chimney to install
- Can be side vented

Southface MEEA

Power Vented Water Heater

- Uses 3” PVC or CPVC or ABS vent piping
- Vents horizontally or vertically
- High efficiency- up to 11% more than a standard EF water heater
- Electronic ignition (eliminates pilot)
- Pressure switch reduces backdraft risk

Southface MEEA

Tankless Water Heaters

- Only heats water when it is being used
- Eliminates standby energy losses associated with storage water heaters
- Can use multiple units in parallel for larger heating loads or in combination with traditional units
- Retrofits have “hidden cost” of running larger gas lines

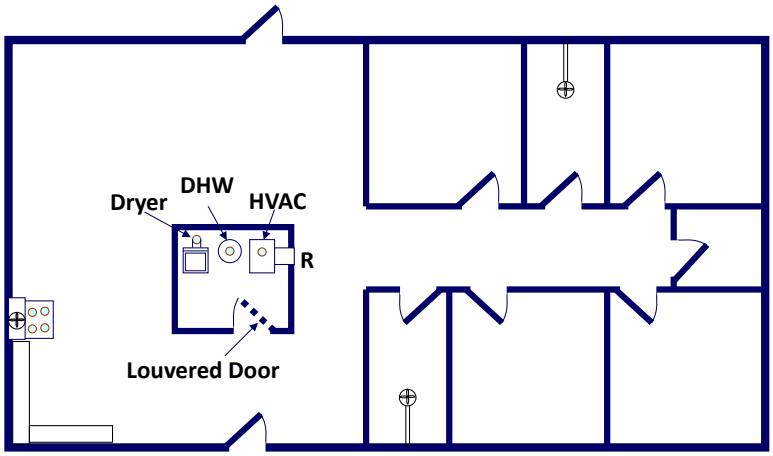
Southface MEEA

Unvented Appliances

- *All* gas appliances can produce CO
- Fireplaces & other combustion equipment should be equipped with (a) flue pipe and (b) outside combustion air supply
- **Don't use unvented gas appliances!**

Southface MEEA

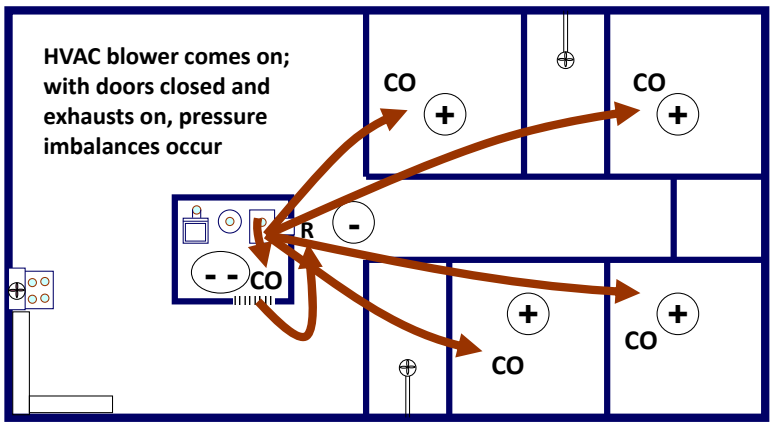
House as a System Problem



In this configuration, all equipment operated properly.

Southface MEEA

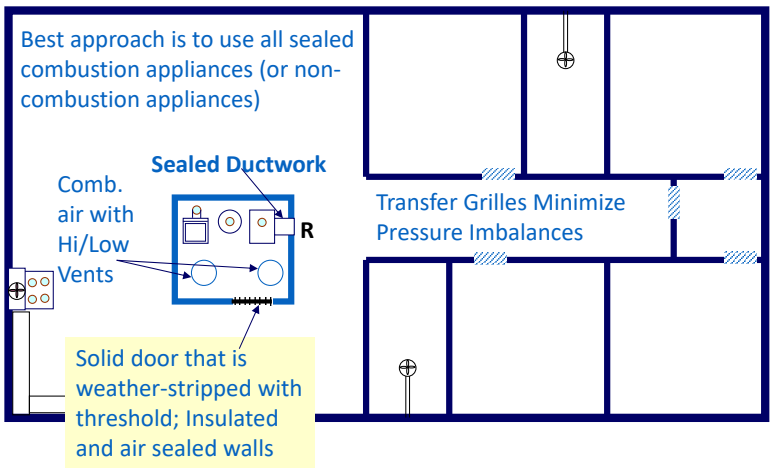
Negative Pressures



In this configuration, negative pressures caused backdrafting, which produced CO!

Southface MEEA

"House As A System" Approach



There are numerous ways to solve/prevent this problem!

Southface MEEA

Southface ACBI –
Small Commercial Building Assessment Combustion Toolkit

		(4) If CAZ alone is confined and combustion air is provided via connection with the indoor space,
y	y / n	- are **Both** connections to indoor space made within 1' of ceiling **and** 1' of floor?
		typically, this is rectangular with a grill
18.00	in	- width of opening of each connecting duct
8.00	in	- length of opening of each connecting duct
0.75		- Net free area multiplier for *rectangular* duct (between 0 and 1)
108.00	in^2	TOTAL cross sectional area of each duct connection
100.00	in^2	CALCULATED cross sectional net free area required for each duct
Adequate		Adequate or Undersized? Is the duct cross sectional area greater or less than the net free area required by code?

Net Free Area Required by Code:
- interior ducts: 1 in^2 for 1 kBtu/hr (but not less than 100 in^2)
- minimum opening dimension is 3"

- 3" round – 7 square inches
- 4" round – 12.5 square inches
- 5" round – 19.6 square inches
- 6" round – 28.3 square inches
- 7" round – 38.5 square inches
- 8" round – 50.3 square inches
- 10" round – 78.5 square inches
- 12" round – 113 square inches

- Guidelines with lots of pictures and case studies
- Spreadsheet / Workbook that checks combustion air compliancea

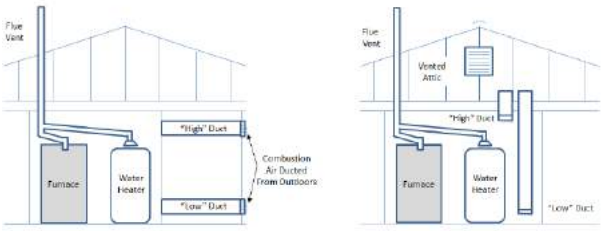
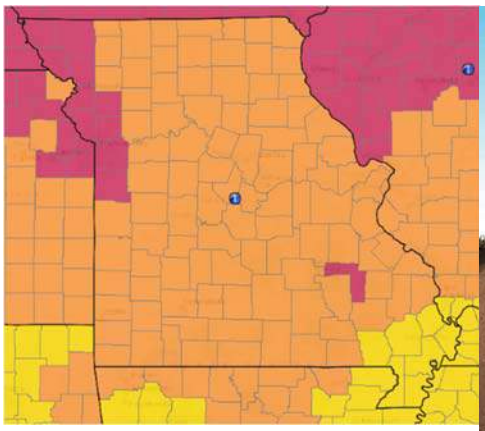


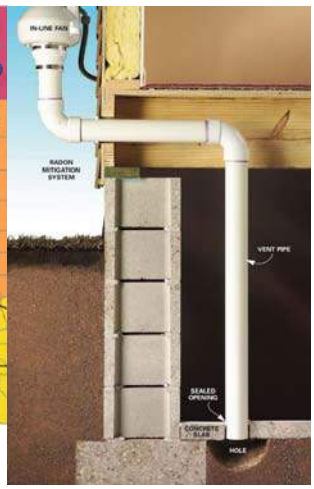
Figure 18: Safe! – Source combustion air via "High-Low" vents directly from the exterior (left) or from spaces connected to outdoors (e.g., a ventilated attic, right). (Barcik)

Southface MEEA

Radon

- Radon is the second leading cause of lung cancer and the number one cause of lung cancer among non-smokers, according to EPA estimates
- Must test to know if radon is a problem and requires remediation
- Test after upgrades





Invisible killer: Spreading the word about radon cancer risk

FEATURE · December 16, 2019 · Georgia Health News · 0

Southface MEEA

Thermal Boundary

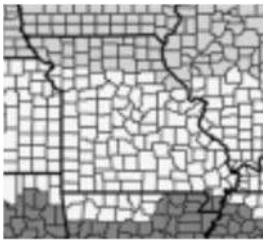
Improving Efficiency, Comfort, and Health in Existing Homes

Southface MEEA

Energy Codes

2021 IECC

- Buchanon, Caldwell, Chariton, Clinton, are now CZ 4A
- Dunklin & Pemiscot, are now CZ 3A



- One prescriptive "answer" for how to build per climate zone (now CZ: 3, 4, 5)

TABLE R402.1.3 INSULATION MINIMUM *R*-VALUES AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

2021

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b, i]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b, e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE[g]	MASS WALL *R*-VALUE[h]	FLOOR *R*-VALUE	BASEMENT[c, g] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c, g] WALL *R*-VALUE
3	.30	0.55	0.25	49	20 or 13& 5ci[h] or 0& 15ci[h]	8/13	19	5ci or 13[f]	10ci, 2 ft	5ci or 13[f]
4 except Marine	.30	0.55	0.40	60	30 or 20&5ci[h] or 13& 10ci[h] or 0&20ci[h]	8/13	19	10ci or 13	10ci, 4 ft	10ci or 13
5 and Marine 4	0.30[f]	0.55	0.40	60	30 or 20&5ci[h] or 13& 10ci[h] or 0&20ci[h]	13/17	30	15ci or 19 or 13& 5ci	10ci, 4 ft	15ci or 19 or 13& 5ci
6	0.30[f]	0.55	NR	60	30 or 20&5ci[h] or 13& 10ci[h] or 0&20ci[h]	15/20	30	15ci or 19 or 13& 5ci	10ci, 4 ft	15ci or 19 or 13& 5ci

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

Southface MEEA

IECC Code Differences – ’18 to ’21

- Redefined CZ’s for 6 counties in MO
- Window Ufactors dropped (more stringent)
- Wall and ceiling R-values increased
- Attic pull-down stairs details – R-13 okay for CZ1-4
- Floor insulation options
- Basement options
- Sunrooms and heated garage separation
- Ducts in conditioned space
  - Must now be tested < 8% Total Leakage
  - Ducts outside, still tested < 4% Total Leakage
- Ventilation fans (kitchen, bath, whole house) have airflow verified to meet minimum required by IMC
- 100% efficient lighting and controls (dimmer, occupant sensors, with exceptions; exterior)
- Additional Efficiency Package - required

Southface MEEA

IECC Code’21

- Section 408 Additional Efficiency Package – 1 required

SECTION R408
ADDITIONAL EFFICIENCY PACKAGE OPTIONS

R408.1 Scope.
This section establishes additional efficiency package options to achieve additional energy efficiency in accordance with Section R401.2.5.

R408.2 Additional efficiency package options.
Additional efficiency package options for compliance with Section R401.2.1 are set forth in Sections R408.2.1 through R408.2.5.

R408.2.1 Enhanced envelope performance option.
The total *building thermal envelope* UA, the sum of *U*-factor times assembly area, shall be less than or equal to 95 percent of the total UA resulting from multiplying the *U*-factors in Table R402.1.2 by the same assembly area as in the proposed building. The UA calculation shall be performed in accordance with Section R402.1.5. The area-weighted average SHGC of all glazed fenestration shall be less than or equal to 95 percent of the maximum glazed fenestration SHGC in Table R402.1.2.

R408.2.2 More efficient HVAC equipment performance option.
Heating and cooling *equipment* shall meet one of the following efficiencies:

1. Greater than or equal to 95 AFUE natural gas furnace and 16 SEER air conditioner.
2. Greater than or equal to 10 HSPF/16 SEER air source heat pump.
3. Greater than or equal to 3.5 COP ground source heat pump.

For multiple cooling systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the cooling design load. For multiple heating systems, all systems shall meet or exceed the minimum efficiency requirements in this section and shall be sized to serve 100 percent of the heating design load.

- Envelope is 5% better
- HVAC efficiency

Southface MEEA

IECC Code'21

- 408 Additional Efficiency Package (cont.) – 1 required

R408.2.3 Reduced energy use in service water-heating option.

The hot water system shall meet one of the following efficiencies:

1. Greater than or equal to 0.82 EF fossil fuel service water-heating system.
2. Greater than or equal to 2.0 EF electric service water-heating system.
3. Greater than or equal to 0.4 solar fraction solar water-heating system.

- Water heater efficiency

R408.2.4 More efficient duct thermal distribution system option.

The thermal distribution system shall meet one of the following efficiencies:

1. 100 percent of ducts and air handlers located entirely within the *building thermal envelope*.
2. 100 percent of ductless thermal distribution system or hydronic thermal distribution system located completely inside the *building thermal envelope*.
3. 100 percent of duct thermal distribution system located in *conditioned space* as defined by Section R403.3.2.

- Ducts inside envelope

R408.2.5 Improved air sealing and efficient ventilation system option.

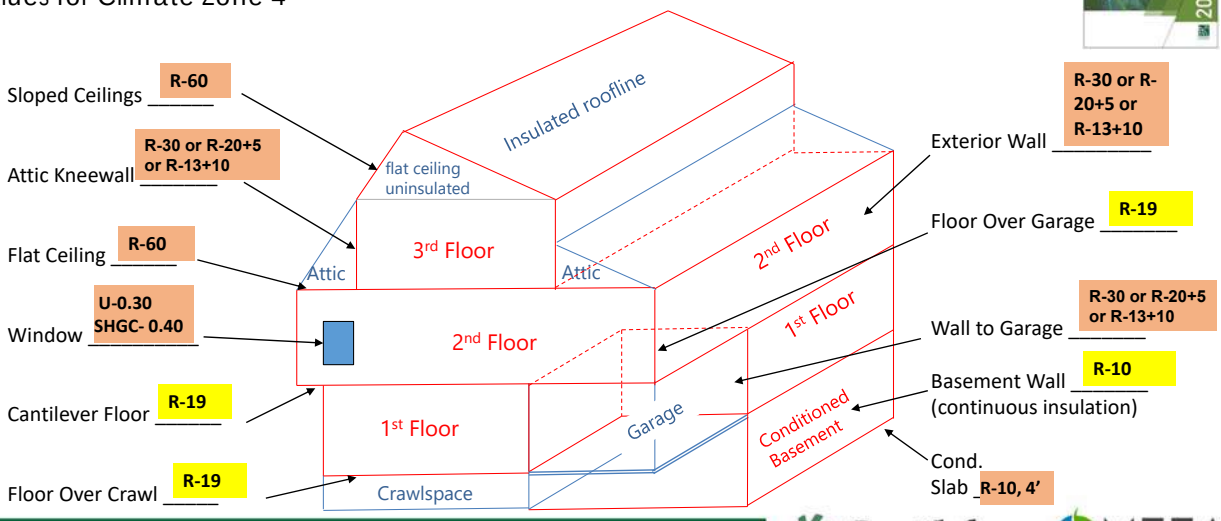
The measured air leakage rate shall be less than or equal to 3.0 ACH50, with either an Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV) installed. Minimum HRV and ERV requirements, measured at the lowest tested net supply airflow, shall be greater than or equal to 75 percent Sensible Recovery Efficiency (SRE), less than or equal to 1.1 cubic feet per minute per watt (0.03 m^3/min/watt) and shall not use recirculation as a defrost strategy. In addition, the ERV shall be greater than or equal to 50 percent Latent Recovery/Moisture Transfer (LRMT).

- Tight home with ERV/HRV

Energy Codes

2021 IECC/IRC Prescriptive Code R-Values

Values for Climate Zone 4



Section 402.2: Insulation Requirements

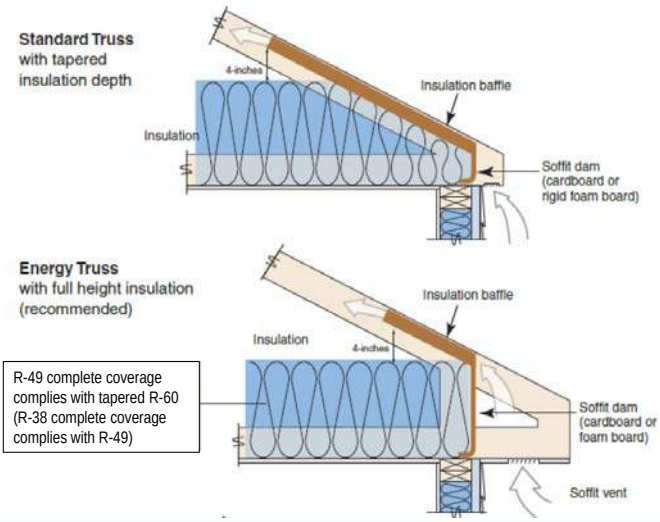
- Details for insulating various aspects of the building envelope:
  - **Ceilings with Attic – 402.2.1**
  - **Ceilings w/out Attic – 402.2.2**
  - **Eave baffles – 402.2.3**
  - **Access hatches and doors– 402.2.4**
  - Mass Walls – 402.2.5
  - Steel Framing – 402.2.6
  - **Floors – 402.2.7**
  - **Basement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

402.2.1 - Ceilings with Attics

- R-49 (CZ3) and R-60 (CZ4-5) is prescriptive requirement
- Rulers required every 300 s.f.

Insulation Requirements

402.2.1 Ceilings with Attics

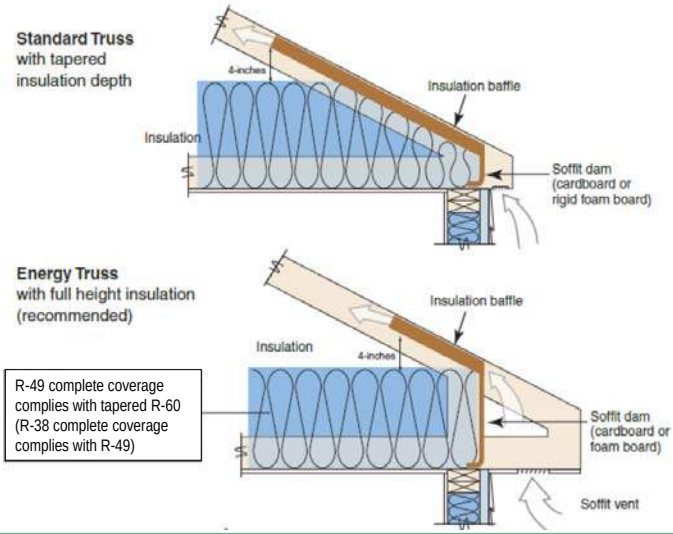


R402.2.1 Ceilings with attics.

Where Section R402.1.3 requires R-49 insulation in the ceiling or attic, installing R-38 over 100 percent of the ceiling or attic area requiring insulation shall satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. Where Section R402.1.3 requires R-60 insulation in the ceiling or attic, installing R-49 over 100 percent of the ceiling or attic area requiring insulation shall satisfy the requirement for R-60 insulation wherever the full height of uncompressed R-49 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the insulation and fenestration criteria in Section R402.1.2 and the Total UA alternative in Section R402.1.5.

Southface MEEA

402.2.3 Eave Baffles

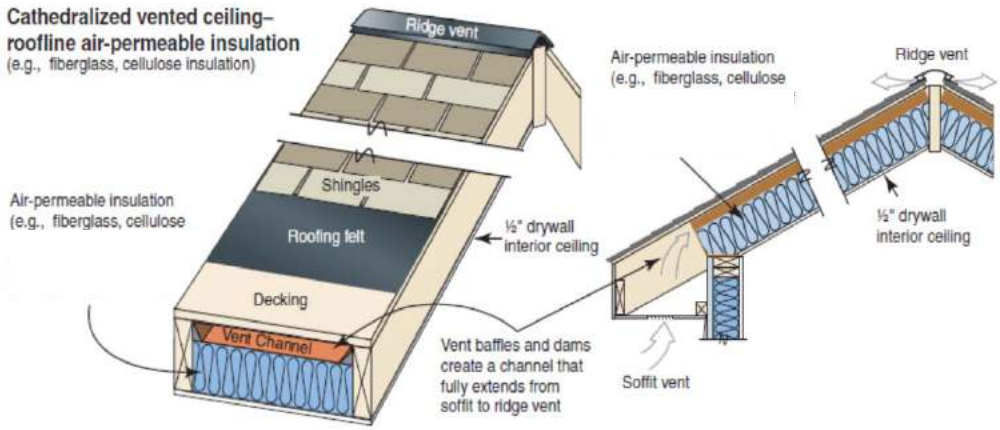


R402.2.3 Eave baffle. P

For air-permeable insulation in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain a net free area opening equal to or greater than the size of the vent. The baffle shall extend over the top of the attic insulation. The baffle shall be permitted to be any solid material. The baffle shall be installed to the outer edge of the *exterior wall* top plate so as to provide maximum space for attic insulation coverage over the top plate. Where soffit venting is not continuous, baffles shall be installed continuously to prevent ventilation air in the eave soffit from bypassing the baffle.

402.2.2 - Ceilings without Attics

- Old school approach



402.2.2 - Ceilings without Attics

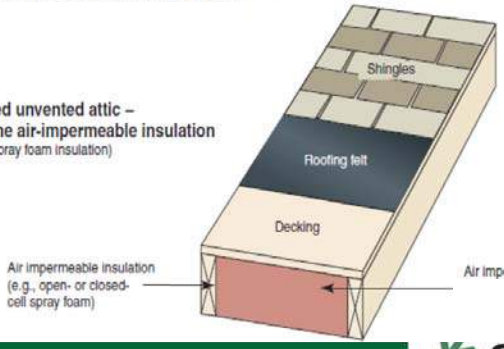
- R-30 for 20% (up to 500 s.f.) acceptable for CZ4&5
- Vaulted ceilings and foam sprayed rooflines will need to perform an R-value trade-off

Roofline Installed Insulation Options

R402.2.2 Ceilings without attics.

Where Section R402.1.3 requires insulation *R*-values greater than R-30 in the interstitial space above a ceiling and below the structural roof deck, and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation *R*-value for such roof/ceiling assemblies shall be R-30. Insulation shall extend over the top of the wall plate to the outer edge of such plate and shall not be compressed. This reduction of insulation from the requirements of Section R402.1.3 shall be limited to 500 square feet (46 m^2) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the Total UA alternative in Section R402.1.5.

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

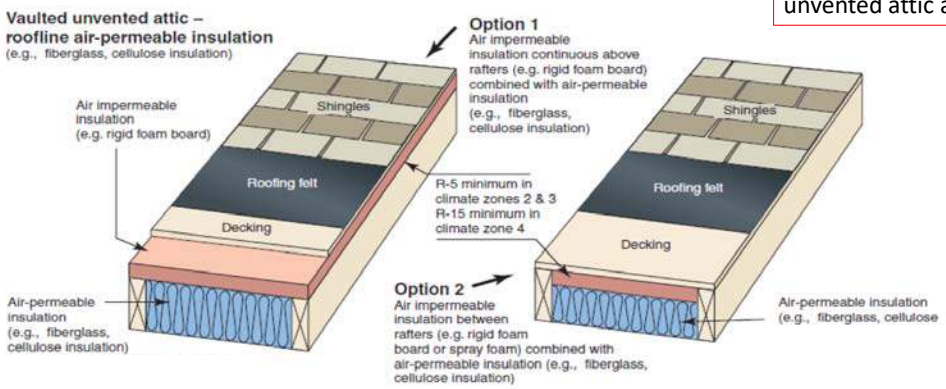


Hybrid Insulation Approaches

402.2.2 - Ceilings without Attics

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

Reference IRC Section 806.5 unvented attic assemblies



IRC 806.5 Unvented Roof Assemblies

- To reduce risk of condensation, install a certain amount of "air-impermeable" insulation before using an "air-permeable" product in an unvented roof assembly
- Provides Thermal break and also "Condensation break"

TABLE R806.5
INSULATION FOR CONDENSATION CONTROL

CLIMATE ZONE	MINIMUM RIGID BOARD ON AIR-IMPERMEABLE INSULATION *R*-VALUE[a, b]
2B and 3B tile roof only	0 (none required)
1, 2A, 2B, 3A, 3B, 3C	R-5
4C	R-10
4A, 4B	R-15
5	R-20
6	R-25
7	R-30
8	R-35

a. Contributes to but does not supersede the requirements in Section N1102.

b. Alternatively, sufficient continuous insulation shall be installed directly above the structural roof sheathing to maintain the monthly average temperature of the underside of the structural roof sheathing above 45°F (7°C). For calculation purposes, an interior air temperature of 68°F (20°C) is assumed and the exterior air temperature is assumed to be the monthly average outside air temperature of the three coldest months.

Southface MEEA

- Dams and baffles at eaves
- Electrical okay
- Air sealing performed
- Bath fans ducted to outdoors
- Decking/ catwalk elevated
- Rulers

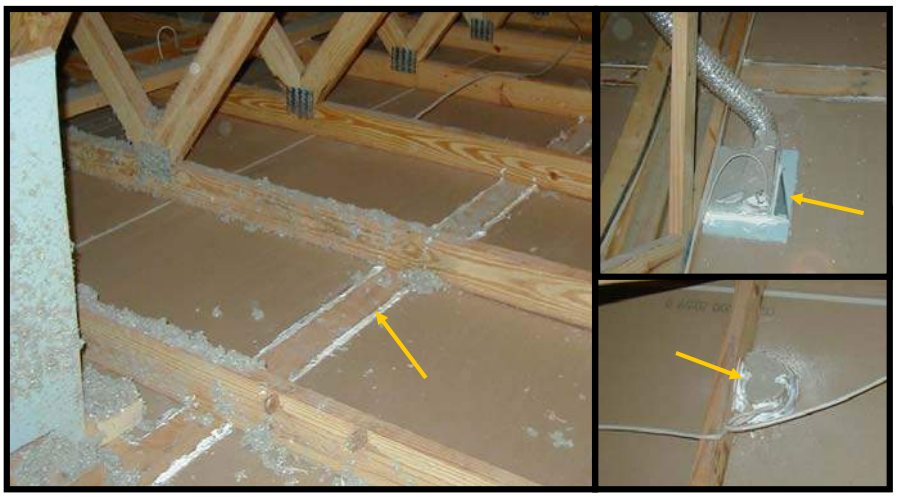
Southface MEEA

- Dams and baffles at eaves
- Electrical okay
- Air sealing performed
- Bath fans ducted to outdoors
- Decking/ catwalk elevated
- Rulers

Southface MEEA

Attic Air Sealing Before Insulation

- Top plate to drywall (interior wall cavities often connect to attic)
- Duct and electrical penetrations

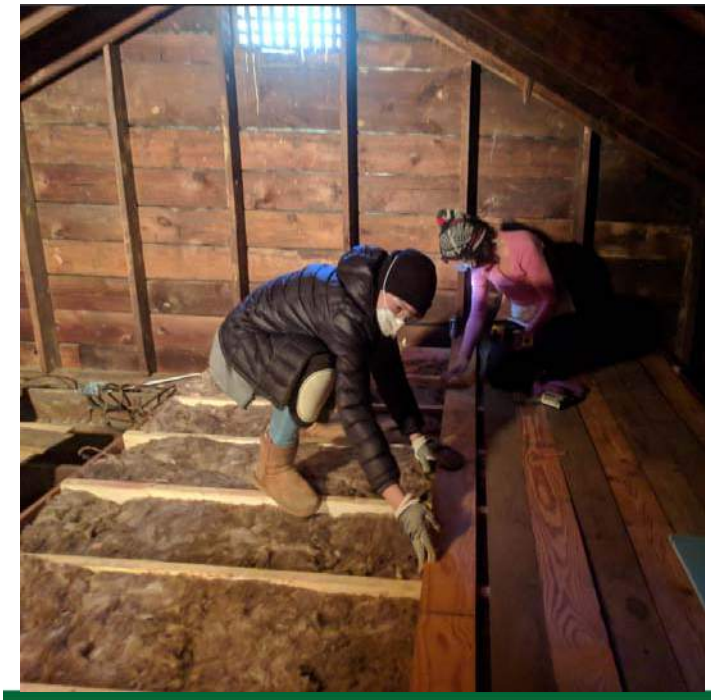


Southface MEEA

Attic Air Sealing Before Insulation

- Seal plumbing, HVAC, and electrical penetrations

Southface MEEA

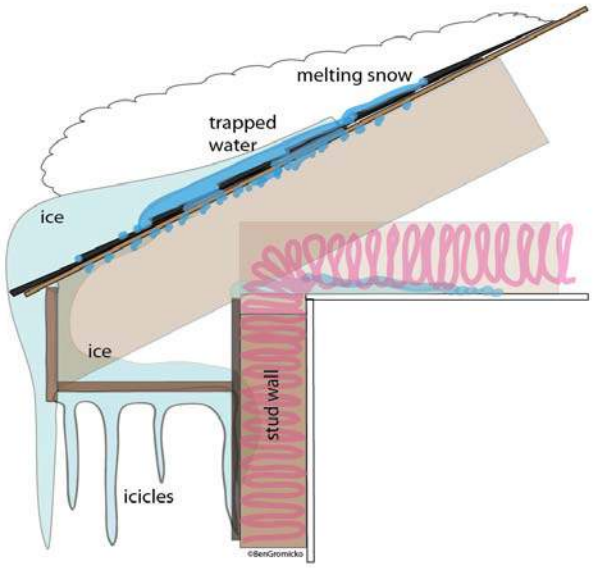


- Dams and baffles at eaves
- Electrical okay
- Air sealing performed
- Bath fans ducted to outdoors
- Decking/ catwalk elevated
- Rulers

Southface MEEA

Ice Damming

- If there are air leaks or the insulation is not continuous (e.g., does not cover the top plate), heat from the interior will transfer through the compromised insulation to the roof, causing snow to melt on the roof and cause ice damming



Southface MEEA

Insulation Requirements

402.2.4 Access Hatches & Doors

- Attic access at same R-value as wall/ceiling
- Exception for pull-down stairs CZ 0-4

- Nominal R-13

R402.2.4 Access hatches and doors.

Access hatches and doors from conditioned to unconditioned spaces such as attics and crawl spaces shall be insulated to the same *R*-value required by Table R402.1.3 for the wall or ceiling in which they are installed.

Exceptions:

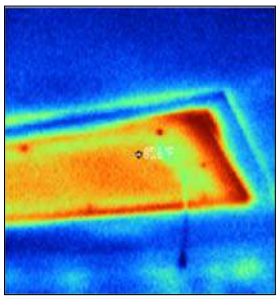
1. Vertical doors providing access from conditioned spaces to unconditioned spaces that comply with the fenestration requirements of Table R402.1.3 based on the applicable climate zone specified in Chapter 3.
2. Horizontal pull-down, stair-type access hatches in ceiling assemblies that provide access from conditioned to unconditioned spaces in Climate Zones 0 through 4 shall not be required to comply with the insulation level of the surrounding surfaces provided the hatch meets all of the following:
   - 2.1. The average *U*-factor of the hatch shall be less than or equal to U-0.10 or have an average insulation *R*-value of R-10 or greater.
   - 2.2. Not less than 75 percent of the panel area shall have an insulation *R*-value of R-13 or greater.
   - 2.3. The net area of the framed opening shall be less than or equal to 13.5 square feet (1.25 m^2).
   - 2.4. The perimeter of the hatch edge shall be weatherstripped.

Southface MEEA

402.2.4 Access Hatches and Doors

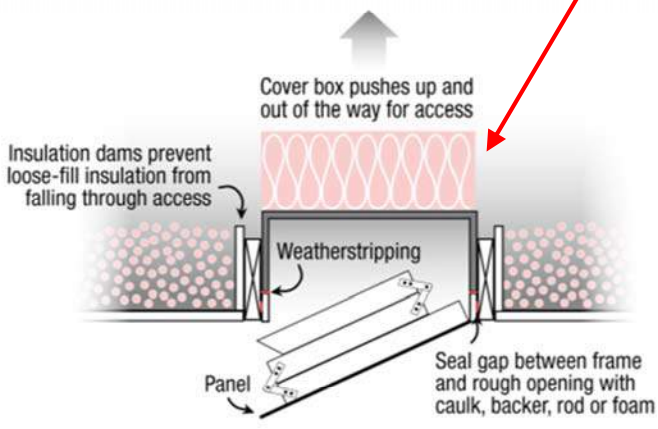
- Attic access cover at same R-value as ceiling

- If an attic has 990 s.f. at R-49, and 10 s.f. at R-1, Effective R-value =
- R-33!



Southface MEEA

Attic Stairs



Graphic courtesy of http://www.energysavers.gov

Foam board stairs cover (assembled with mastic and nails, batt glued to top)

Insulation in stairs door

Southface MEEA

Attic Access Options

Southface MEEA

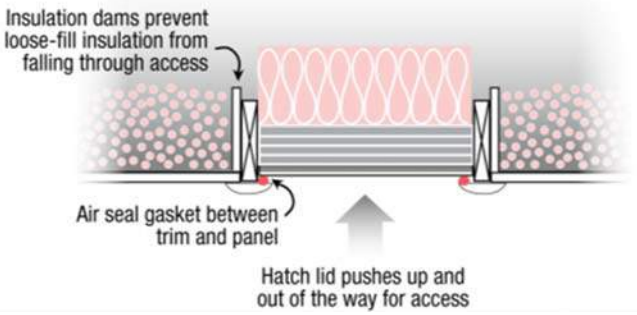
- Attic pull-down stairs efficiency retrofit

MEEA

Attic Access Details

Southface MEEA

Attic Hatches



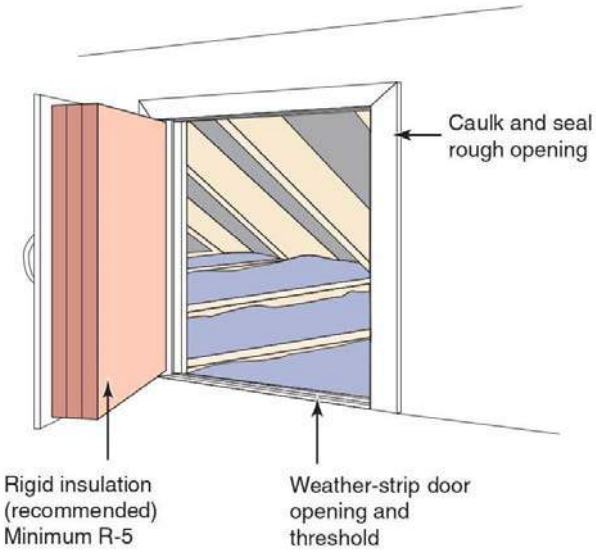
Graphic courtesy of http://www.energysavers.gov

Southface MEEA

Attic Doors

Vertical doors should have a minimum of R-5 and must be weather-stripped for air sealing.

Ideally, should have same R-value as knee wall (R-20)



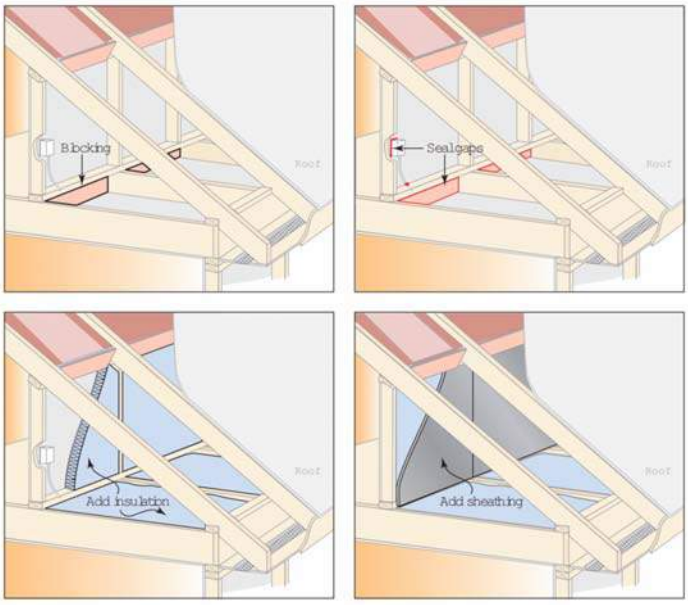
Southface MEEA

Knee Walls

Southface MEEA

Knee Walls

- Add Blocking
- Air Seal
- Insulate
- Sheathe



Southface MEEA

Insulation Requirements

402.2.8 Floors

- Insulation should maintain ***continuous permanent*** contact against subfloor

R402.2.7 Floors.

Floor *cavity insulation* shall comply with one of the following:

1. Installation shall be installed to maintain permanent contact with the underside of the subfloor decking in accordance with manufacturer instructions to maintain required *R*-value or readily fill the available cavity space.
2. Floor framing cavity insulation shall be permitted to be in contact with the top side of sheathing separating the cavity and the unconditioned space below. Insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed.
3. A combination of cavity and continuous insulation shall be installed so that the cavity insulation is in contact with the top side of the continuous insulation that is installed on the underside of the floor framing separating the cavity and the unconditioned space below. The combined *R*-value of the cavity and continuous insulation shall equal the required *R*-value for floors. Insulation shall extend from the bottom to the top of all perimeter floor framing members and the framing members shall be air sealed.

Southface MEEA

R402.2.8 Floors

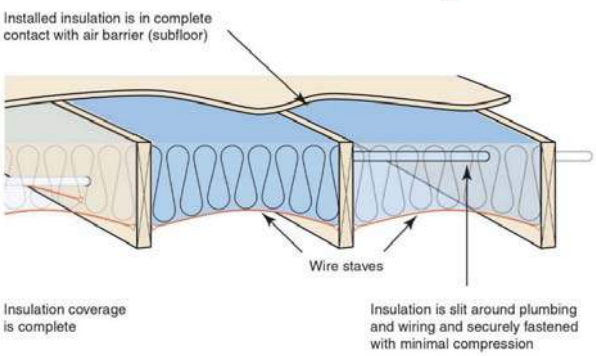
- Floor insulation must maintain **permanent** contact with the subfloor

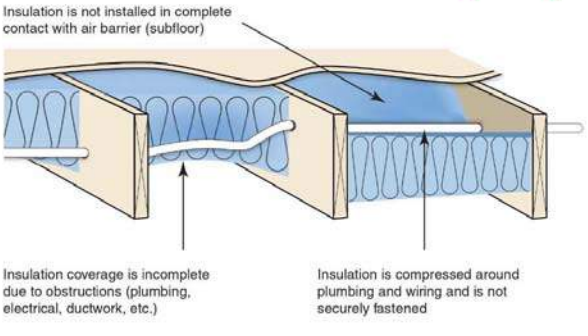
Southface MEEA

Floor Insulation

GOOD!

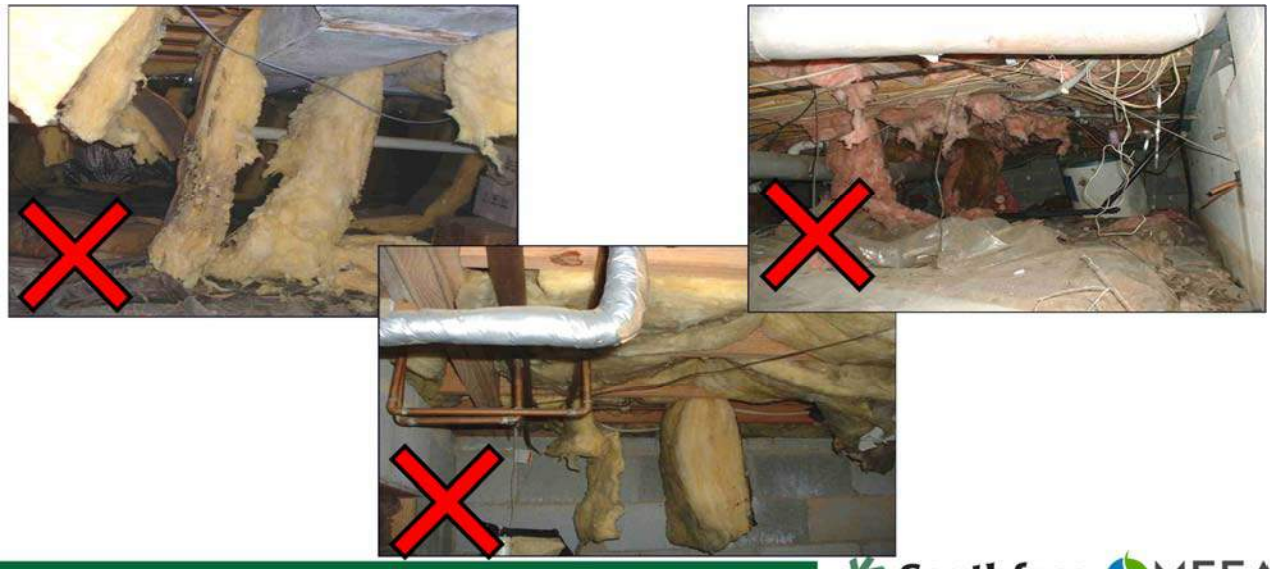
BAD!





Southface MEEA

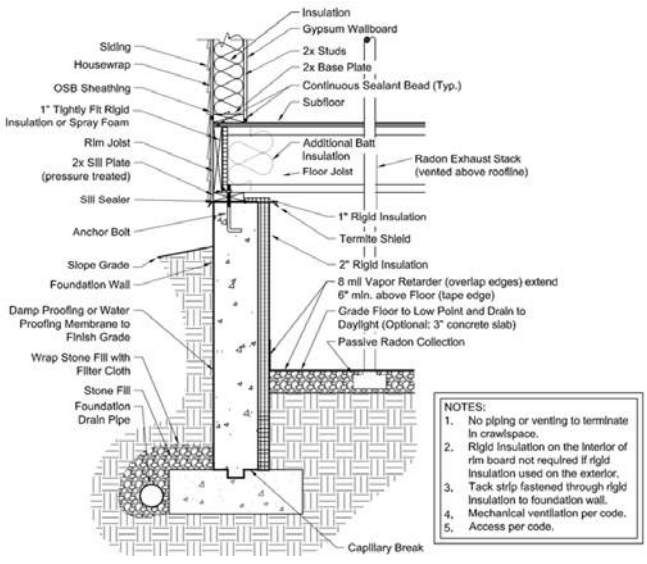
Problems with Floor Insulation



Southface MEEA

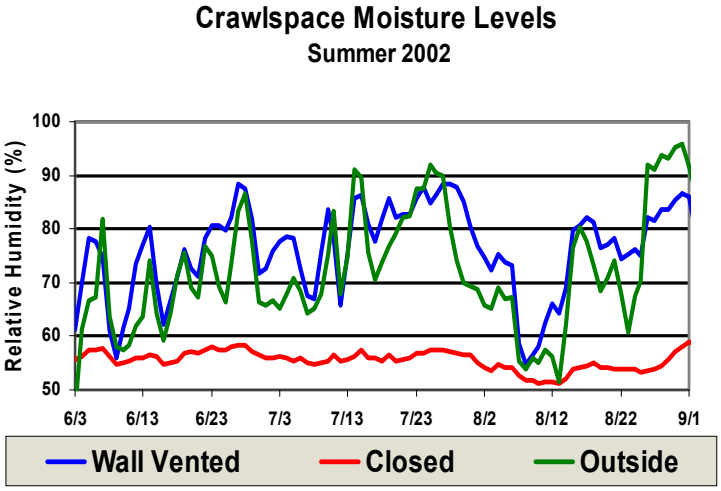
Closed Crawlspaces

- In mixed-humid climates, crawlspace encapsulation is an excellent option
- A properly sealed, moisture-protected, and insulated crawlspace will:
  - increase comfort,
  - save on energy costs
  - improve the durability homes
  - reduce moisture intrusion
  - reduce pest entry



Southface MEEA

Closed Crawlspace Case Study



- If crawlspace is vented, the humidity levels will often be at least as high as the ambient air

www.crawlspaces.org

Southface MEEA

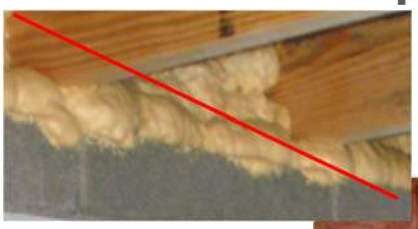
R402.2.11 Crawlspace Walls

- Air seal & insulate band area
- Insulation must be permanently fastened and extend at least to the finished interior grade
- Pest control inspection strips required in some areas
- Complete plastic sealed to walls at least 6 inches up the stem wall
- Overlap seams by 6 inches

Southface MEEA

Insulation techniques – Crawl Walls

Insulation techniques – Band area



Open/ Closed Cell Foam

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

Caulk and Fiberglass Batt

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

Blown Bag / Pillow

The band joist area can be a challenge to insulate correctly.
For installers working with blown fiberglass or cellulose, a fire-rated bag can be filled with blown insulation on site, then friction fit between joists.

Crawlspace Walls

- Seal ground with minimum 6 mil plastic (6" up walls, 6" overlaps)
- Eliminate all vents and leaks (access doors sealed and insulated)
- Insulate all walls to R-10 continuous
- Use a sealed combustion/direct vent furnace or install a heat pump
- Condition crawlspace
  - Supply air
  - Dedicated dehumidifier (Best!)
- Install moisture sensor and alarm

Southface MEEA

Atmospherically Vented Appliances

- Do **not** use atmospherically vented appliances in closed crawlspaces or attics (install 2-pipe condensing furnace)

Southface MEEA

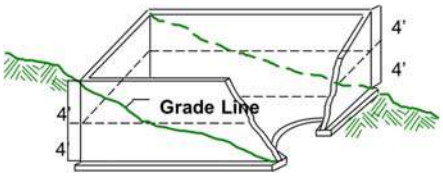
Systems Approach to Basements

Advantages to insulating *all* basement walls:

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

Southface MEEA

Basement Walls



- Basement Wall – Average gross wall must be > 50% below grade and enclosed conditioned space
- CZ4: R-10 continuous or R-13 cavity
- CZ5: R-15 continuous or R-19 cavity

Try to avoid cavity insulation; continuous insulation performs better

Southface MEEA

Basement Insulation Strategies

Cellulose batt

https://www.youtube.com/watch?v=la0ihgfqRDw

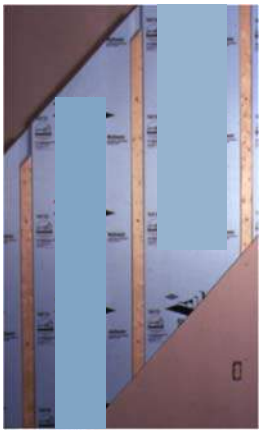
Fiberglass batts with vinyl backing

Foil-faced rigid foam board

Southface MEEA

Basement Insulation Strategies

Rigid foam board



Foam board on concrete

Spray Polyurethane foam

Southface MEEA

Interior Insulation Strategies

Southface MEEA

Choose the Right Insulation

- Select the right Insulation for the application(s)

Top Left to Right

Kraft faced batt to reduce moisture vapor transfer

Unfaced batt for total enclosure (encapsulation)

Plastic Encapsulated Batts for ready made moisture/air control (e.g.; basement finishes)

Southface MEEA

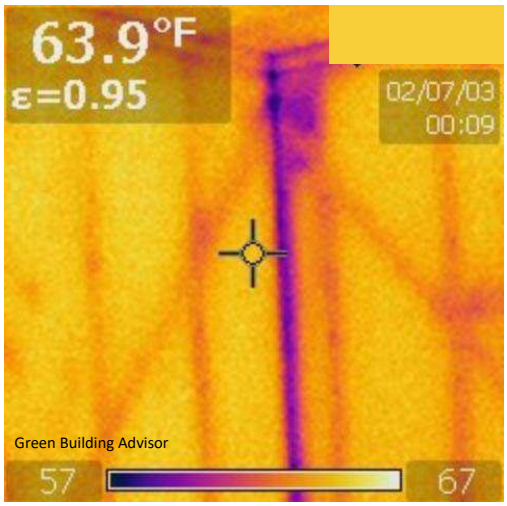
Exterior Wall Insulation

- Insulation must be applied to wood-frame, steel-frame, and mass walls that are above grade and associated with the building thermal envelope
- R20 or R13+5 c.i. is current IECC
- Continuous insulation is desirable because it prevents thermal bridging and is more effective overall

Southface MEEA

Thermal Bridging

- Studs conduct heat better than insulation, so each stud acts as a thermal bridge
- Continuous insulation creates a thermal break, which slows down conduction considerably
- Consider continuous insulation when renovating exterior walls. It can be installed on the interior or exterior (preferred) depending on the scope of the remodel



Southface MEEA

Insulating Exterior Walls

Southface MEEA

Insulating Exterior Walls

Southface MEEA

Insulating Exterior Walls

Southface MEEA

Insulating Exterior Walls: from inside – drill holes and patch

Southface MEEA

Siding Drainage Plane Retrofit – Interior Wall Stripped to Studs

- Install vertical spacer strips into sides of cavity
- Install ½" foam board piece (~14.25" width) against strips
- Seal edges with caulk or foam
- Slightly compress batt into cavity against foam board

Southface MEEA

Siding Remains: Drainage Plane Retrofit – Interior Stripped to Studs

Wall and Ceiling Vapor Retarders

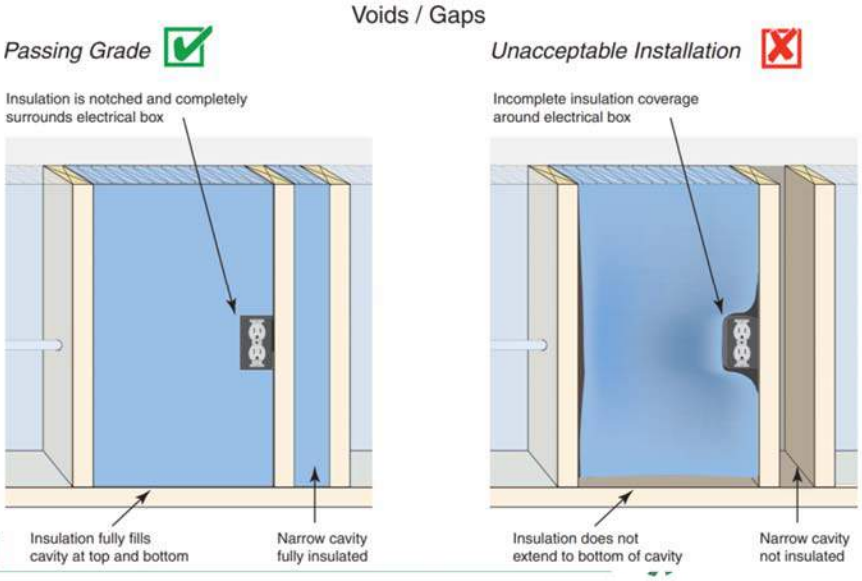
Not required in CZ 1-4

Class 1 or 2 vapor retarder is required on the interior side of frame walls per IRC in zone 5. Except for:

1. Basement walls.
2. Below-grade portion of any wall.
3. Construction where moisture or its freezing will not damage the materials

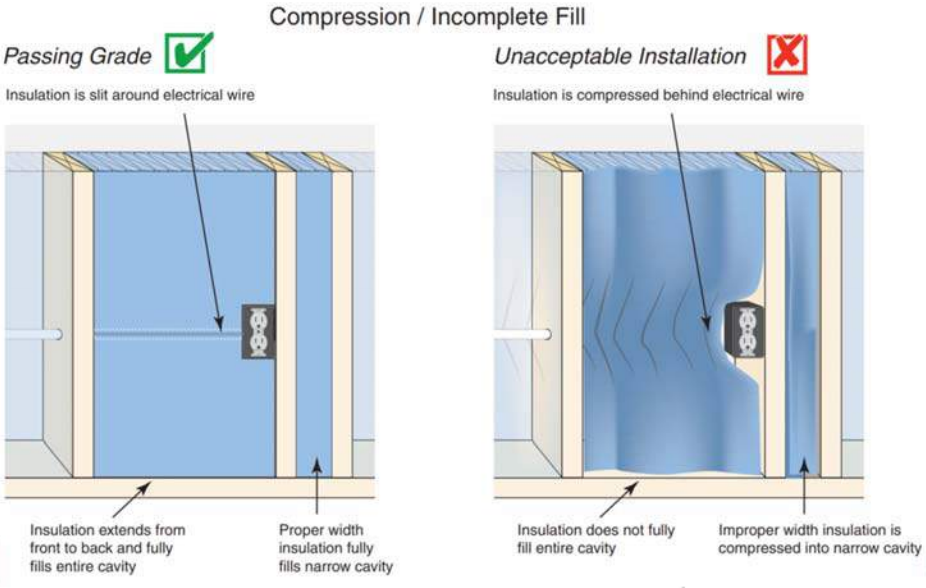
Southface MEEA

Wall Insulation Details



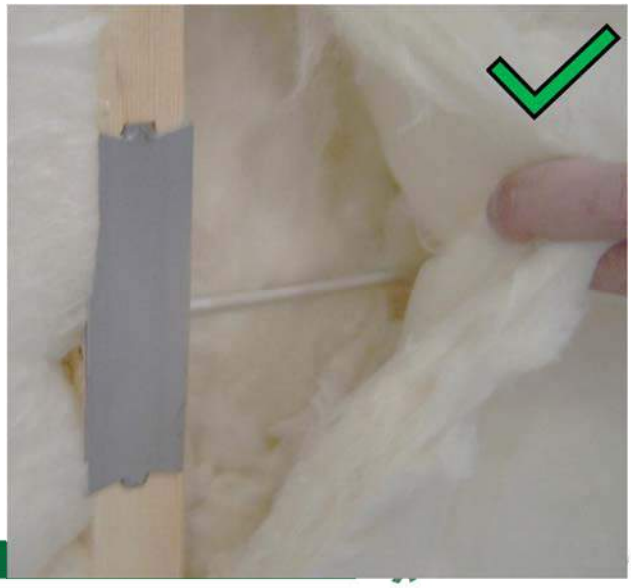
MEEA

Wall Insulation Details



Wall Insulation Details

- Batt is split to allow the wire to bisect the cavity

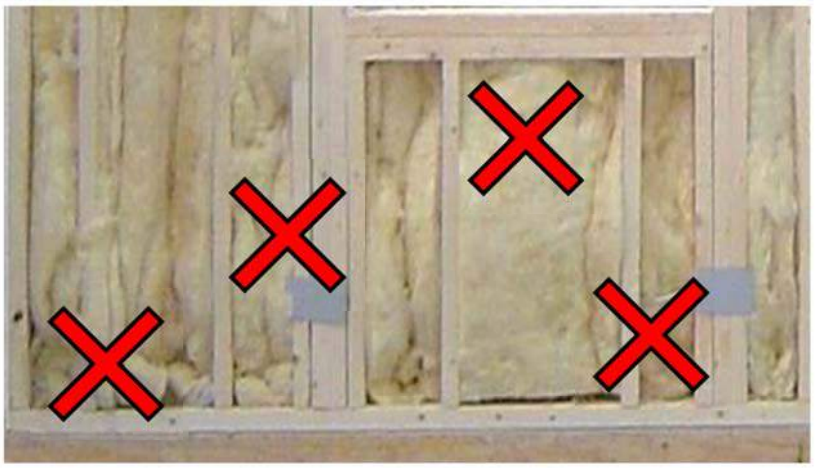


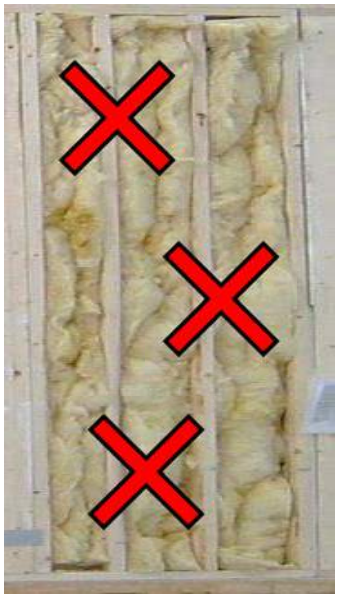
Wall Insulation Details

- Wire is compressing the insulation
- Voids around electrical outlet
- Missed a whole cavity

Southface MEEA

Wall Insulation Details





Southface MEEA

Wall Insulation Details

- Complete fill
- Goes behind tub
- Plumbing penetrations are neat

Southface MEEA

Wall Insulation Details

- Spray Polyurethane Foam is great for retrofits, if installed properly

Southface MEEA

Air Barrier Installation

Improving Efficiency, Comfort, and Health in Existing Homes

Southface MEEA

Use Proper Air Sealing Materials

Fiberglass and cellulose insulation do not stop air flow!

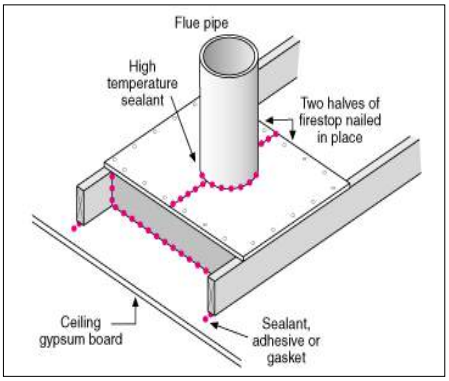
Southface MEEA

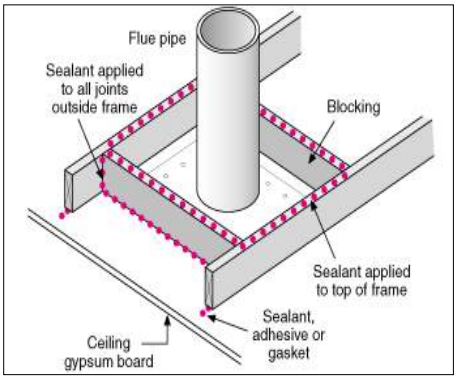
Water Heater/Furnace Flue Pipes

This chase should be capped and then insulated!

Southface MEEA

Cap and Seal Chases





- Chases around flues and chimneys must be sealed with fire-safe materials

Southface MEEA

Top Plates

Southface MEEA

Wire Penetrations

Southface MEEA

Cap and Seal Chases

Southface MEEA

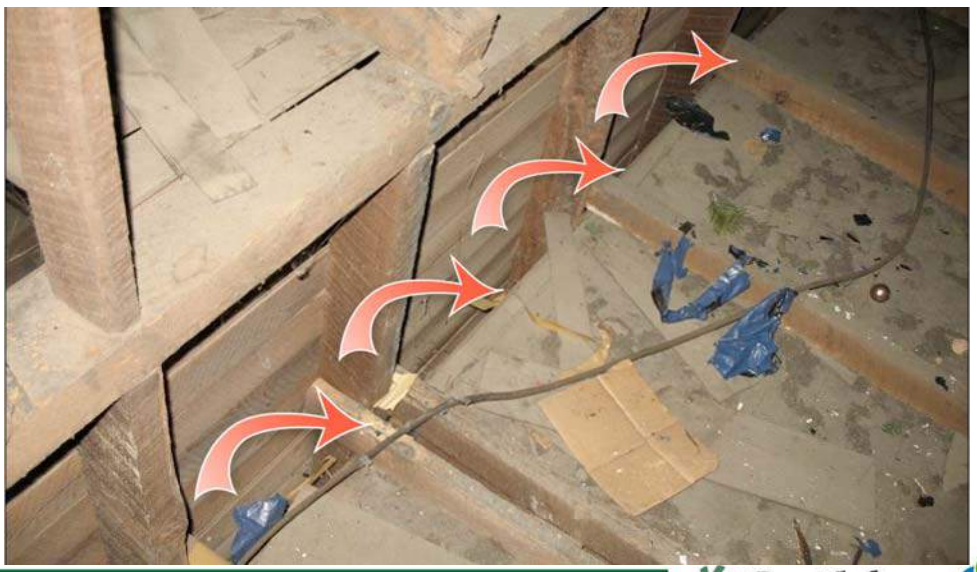
Seal first, then Insulate

Southface MEEA

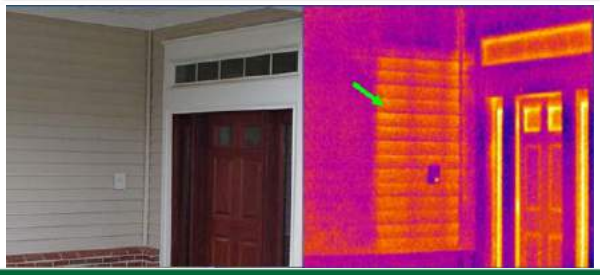
Dropped Soffits

Southface MEEA

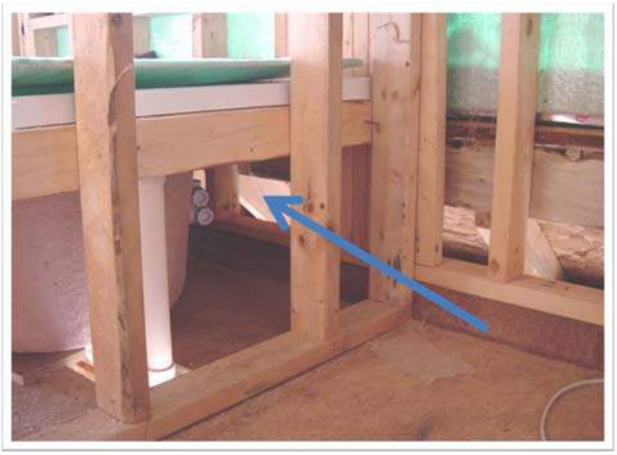
Changes in Ceiling Height



Southface MEEA



Shower/Tub on Exterior Wall



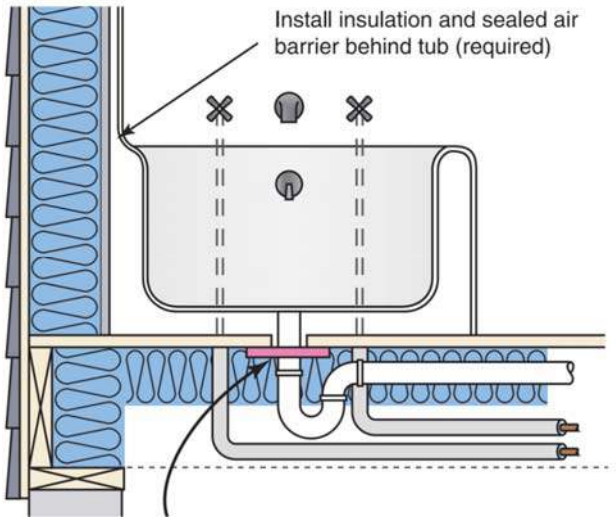
Southface MEEA

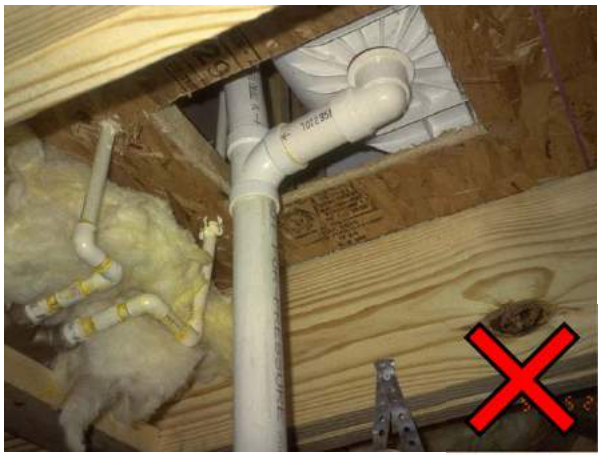
Shower/Tub on Exterior Wall

- Coordinate with your subcontractors so that insulation and air sealing details are not missed before it is too late!

Southface MEEA

Plumbing and wiring





Southface MEEA

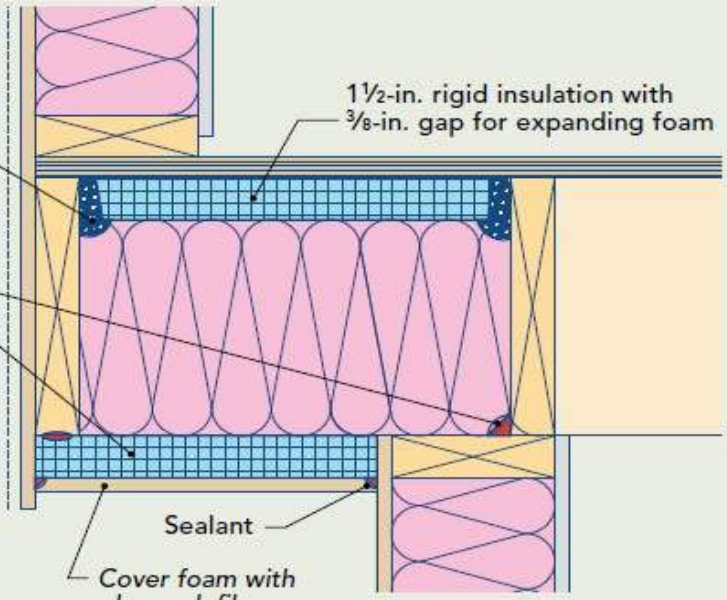
Air Sealing
Tub Drains

Southface MEEA

Cantilevered floor

Southface MEEA

Diagram courtesy of Green Building Advisor



Cantilevered floor

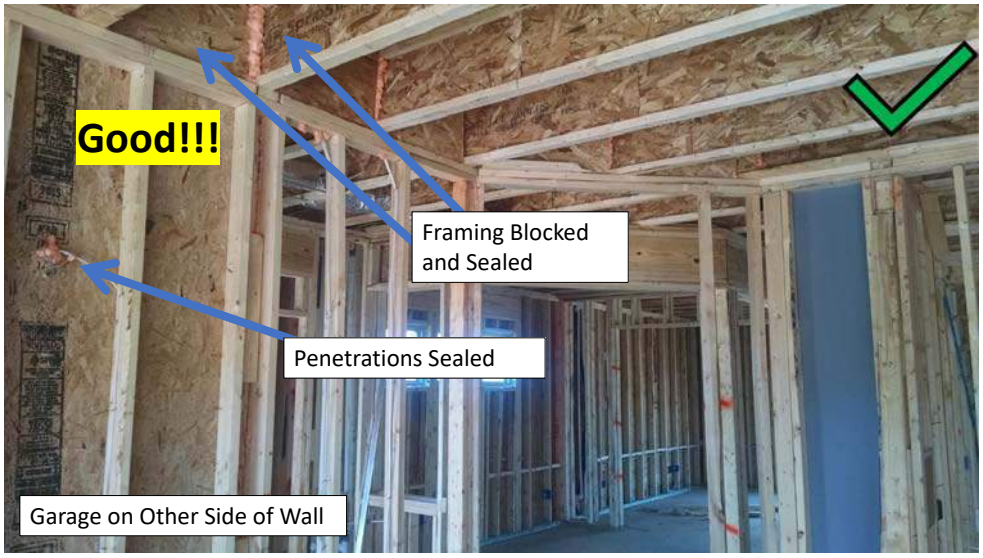
The blocking above the bearing wall helps to define the home's air barrier, so each piece of blocking needs to be sealed at the perimeter with caulk or canned spray foam. As long as both layers of rigid foam are installed with attention to airtightness, this type of cantilevered floor performs well.

EEA

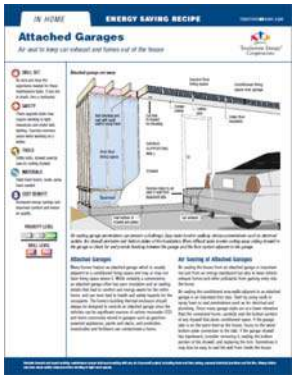
Garage Separation

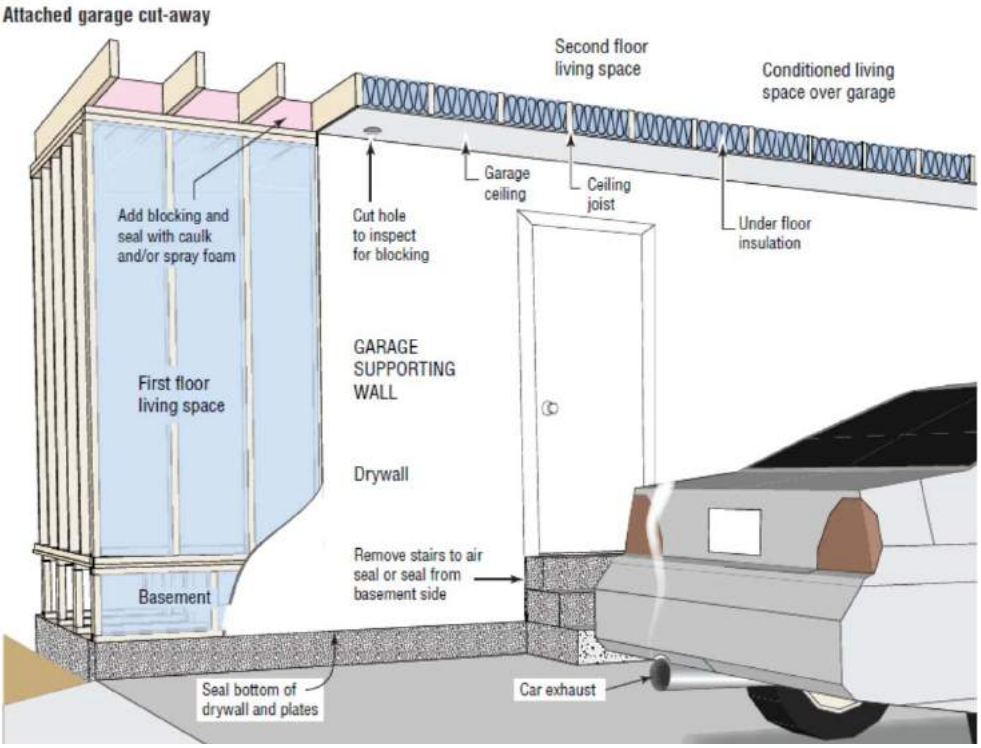
Southface MEEA

Garage Separation



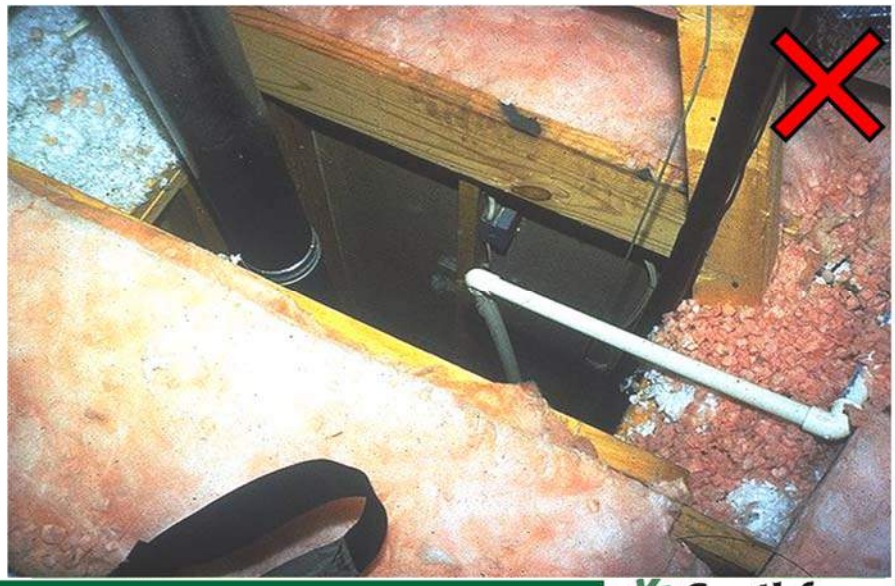
- Air leaks from attached garages does not equal healthy house…





Chases are BIG Holes in the Envelope!

- First, cover with sheet material and seal
- Install insulation dams against “hot pipes”
- Install insulation



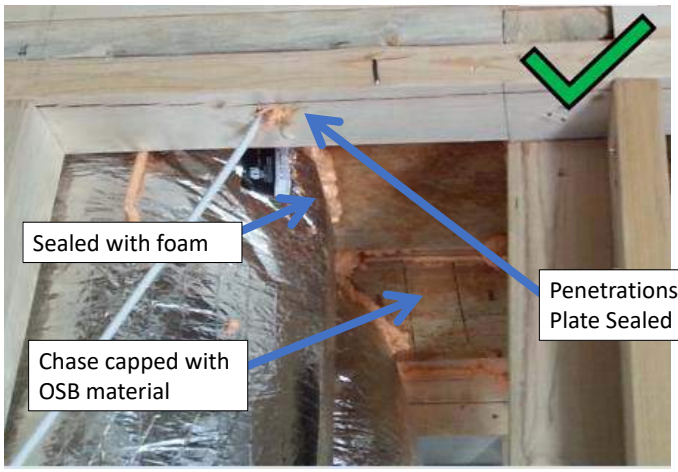
Southface MEEA

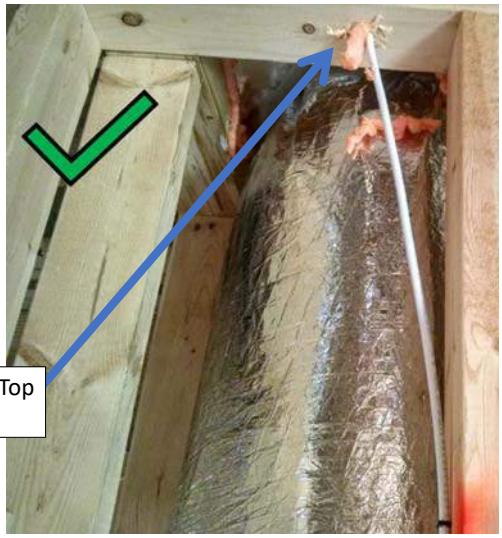
Duct Shafts

Cap chases with rigid material and seal tight around ducts or flue pipes

Southface MEEA

Duct Shafts

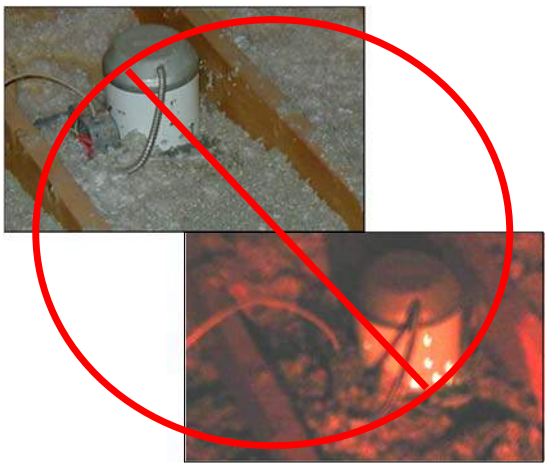




Southface MEEA

402.4.5 Recessed Lights

- Standard Can Light



Airtight and IC Rated

- All recessed luminaires shall be labeled as having an air leakage rate not more than 2.0 cfm tested at 75 pa
- All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering

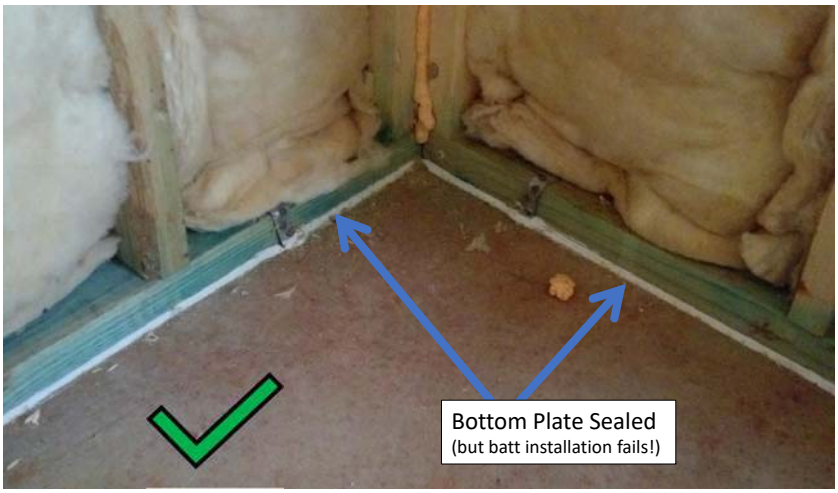
Southface MEEA

Recessed Lights

- Standard Can Light

Southface MEEA

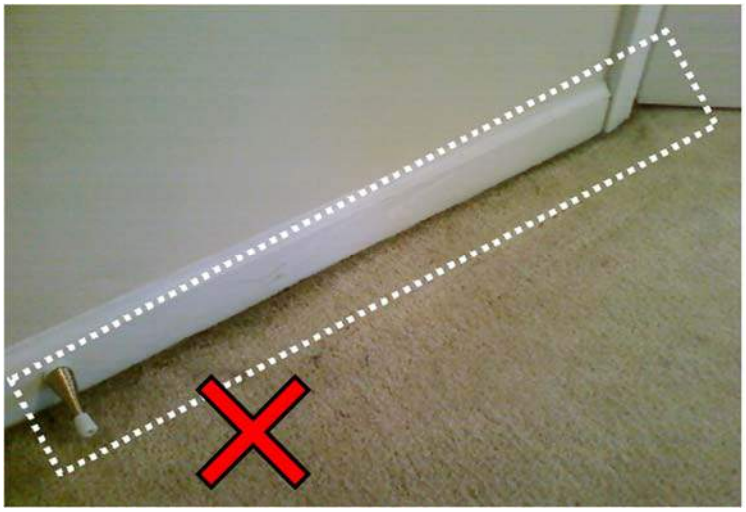
Sill (bottom) plate



Southface MEEA

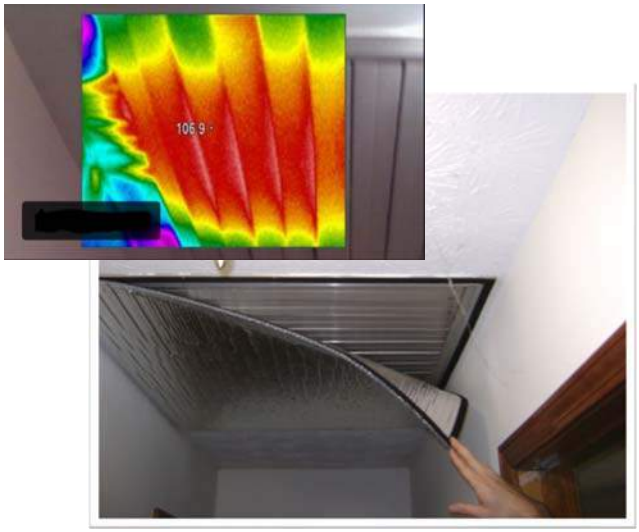
Dirty Carpet?!

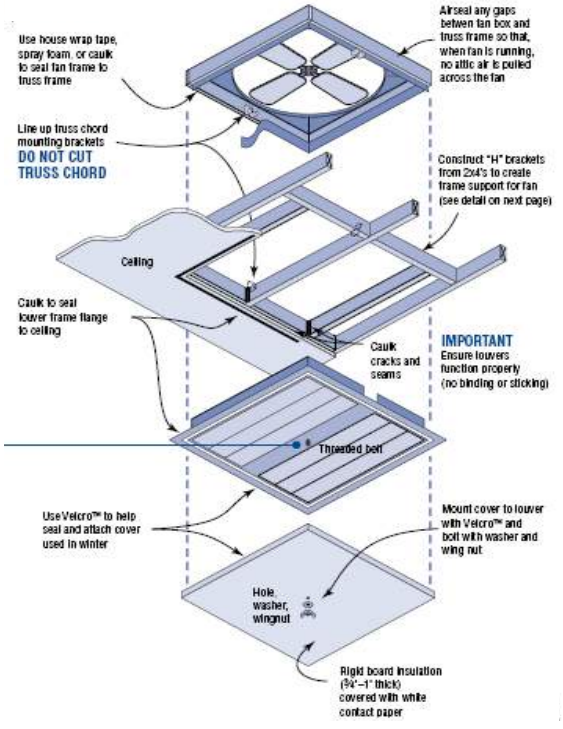
- Dirty carpet on **exterior** wall indicates leak at wall sill plate
- On **interior** wall indicates wall leaking to and from attic



Southface MEEA

Whole House Fans





Whole House Fan

Southface MEEA

Whole House Fans

Southface MEEA

Unused Fireplace

- First, close flue damper
- Then use mastic and foam board to glue a ledger
- When dry, seal foam board to ledger with mastic & fasteners

Southface MEEA

Ducts

Improving Efficiency, Comfort, and Health in Existing Homes

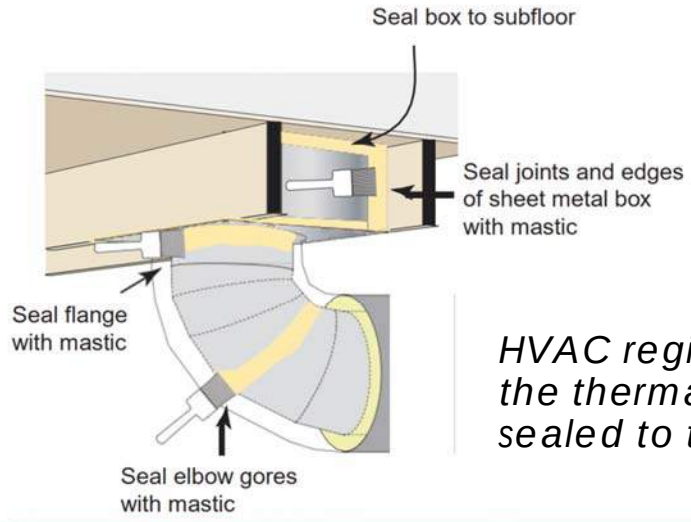
Southface MEEA

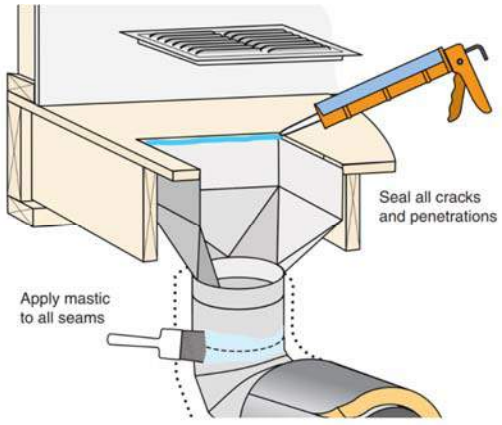
Duct Sealing

- All duct connections must be mechanically fastened
- **Regardless of duct location**, the joints and seams of all ducts, air handlers, and filter boxes should be sealed with mastic or mastic tape that is at least 2 mm in thickness (0.08 inch), approximately the thickness of a nickel
- Mastic shall be installed at the inner liner of rigid metal and flexible duct (not the outer insulation jacket).

Southface MEEA

HVAC Register Boots





HVAC register boots that penetrate the thermal envelope must be sealed to the subfloor or drywall.

Southface MEEA

- Remove registers
- Vacuum duct
- Seal with mastic – start as far in as you can reach and work your way out
- Finish by sealing boot to floor/ceiling

Southface MEEA

- Remove registers
- Vacuum duct
- Seal with mastic – start as far in as you can reach and work your way out
- Finish by sealing boot to floor/ceiling

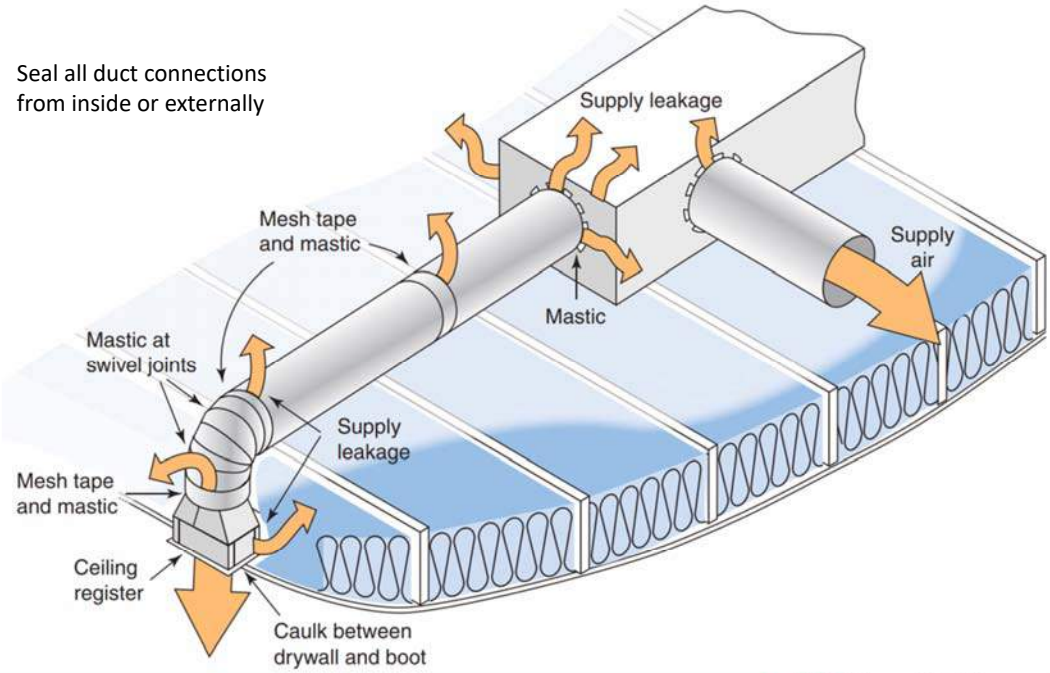
Southface MEEA

Pan Returns

- Unlined building cavities should not be used as ducts, returns, or plenums!

Southface MEEA

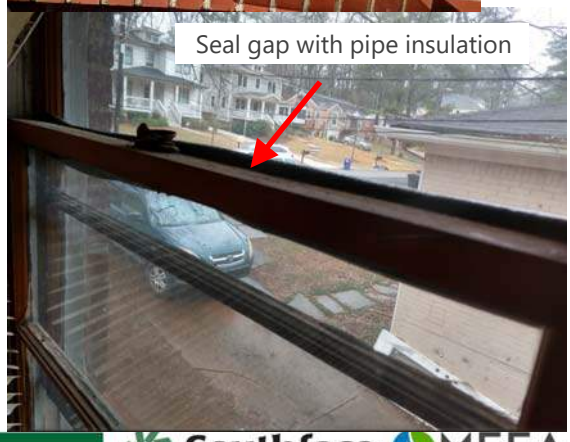
Seal all duct connections
from inside or externally



Southface MEEA

Sealing window unit AC's

Sealed for winter; cut top and two sides for summer operation. Tape 3 sides for winter



Seal gap with pipe insulation

Southface MEEA

Heat Pump Water Heaters

- About 3x efficiency of electric resistance
- Ideal for basements

Southface MEEA

Lighting

Improving Efficiency, Comfort, and Health in Existing Homes

Southface MEEA

R503.1.4 Lighting

New lighting systems that are part of the alteration shall comply with Section R404.1

Exception: Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.

Southface MEEA

R404.1 Lighting Equipment

- This requirement is **mandatory**
- 100 percent of the permanently installed lighting fixtures shall contain only high-efficacy lamps
- High efficacy lamps include
  - Compact fluorescents
  - T8 or T5 fluorescent bulb
  - **LEDs**
- Exception – low voltage lighting

Southface MEEA

Benefits of LED Lighting

- LEDs boast a 25,000-hour average life, which means less maintenance for your clients
- LEDs use 6 times less energy than comparable incandescent bulbs
- Upgrade all bulbs to LED
- Look for the ENERGY STAR® label

Southface MEEA

Economics of Incandescent Lighting

9 bulbs x 60 watts each = 540 w

540 w x 4 hours a day = 2160 wh

2160 wh x 365 days = 788,400 wh a year

788,400 / 1000 = 788.4 kWh

788.4 kWh x $.127 = **$100.13** per year

Southface MEEA

Economics of LED Lighting

9 bulbs x **9 watts** each = 81 w

81 w x 4 hours a day = 324 wh

324 wh x 365 days = 118,260 wh a year

118,260 / 1000 = 118.3 kWh

118.3 kWh x $.127 = **$15.02 per year**

Southface MEEA

Color Temperature

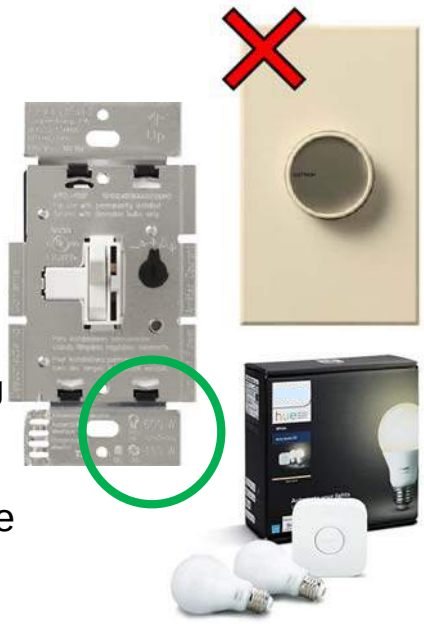
- LEDs are available in a wide range of color temperatures
- Some smart bulbs have color temperature ranges from 2000K-6500K + 16 million colors

westinghouselighting.com

Southface MEEA

LED Retrofit Issues

- "Dimmable" LEDs might not be compatible with all existing dimmer switches
  - LED bulbs may flicker, blink, hum or buzz
  - Problems are more prevalent in track lighting fixtures or other fixtures with multiple bulbs
- Recommendation – Replace dimmers with standard switches or LED compatible dimmers
- Smart bulbs offer dimming capability



Southface MEEA

Summary of Typical Weatherization – SOW

Scope of Work for Appropriate Upgrades

- Air seal walls, floors, ceilings and fireplaces
- Attic prep & baffles for insulation, raised attic walkway
- Vacuum and seal ducts with mastic
- Dryer vent cleaning and proper ducting
- Plastic vapor barrier on crawlspace ground
- Whole house fan & attic access insulated covers
- Exterior site drainage corrections – swales & grading
- Light bulb replacement with LED's
- Light globe and ceiling fan blade cleaning & repair
- Blown in attic insulation, dense-pack walls.
- Hot water pipe insulation + window unit AC Wx
- Combustion safety improvements
- Mechanical ventilation
- Dehumidification
- Upgrade equipment and appliances
- Window enhancements

Southface MEEA

Questions / Thoughts?

- When does code apply to additions and alterations (the short answer: **pretty much always**...the question is, how can you do it cost effectively)
- Historic preservation
- Mass wall improvements?

Southface MEEA

Southface MEEA
MIDWEST ENERGY EFFICIENCY ALLIANCE