Fundamentals of Building Science: Air Movement

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Energy Code Resources

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Energy Code Resources

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

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

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Who are you?

A. Weatherization
B. HERS Rater
C. Code official
D. Designer/Engineer
E. Contractor/Builder/Sub
F. Utility
G. Manufacturer/Product Rep
H. Policy / Government
I. Facilities
J. Home Inspector

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Why building science?

- Employ scientific principles from a variety of fields that govern building performance
- Optimize building performance and understand, prevent and correct building failures
- Systems approach to houses
- Physics of Heat, Air & Moisture

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The house as a system

- A house is a system made up of interrelated parts:
- The building thermal envelope
- Space conditioning
- Ventilation
- Water heating & distribution
- Lighting & appliances

The human factor

- It’s not just about energy efficiency
- Many efficiency measures also improve comfort, health and reduce maintenance
- All efficiency measures should take occupants into account (e.g. air sealing & ventilation)

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Building Science: Heat transfer

- Heat is a form of energy
- Heat moves from hot to cold
- 3 methods of heat transfer:
  - **Radiation:**
    Heat emits from a hot surface or hot object, e.g., hot coals
  - **Conduction:**
    Heat moves through a material by contact, e.g., the grill grates
  - **Convection:**
    Heat energy carried by a fluid, e.g. the air inside the covered grill

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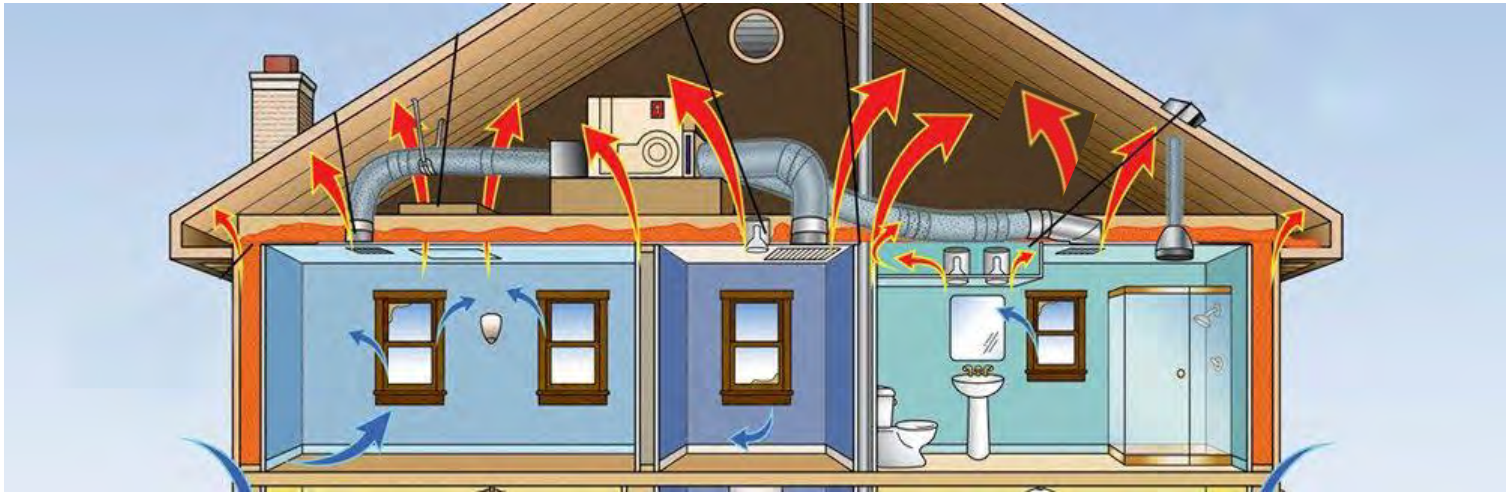
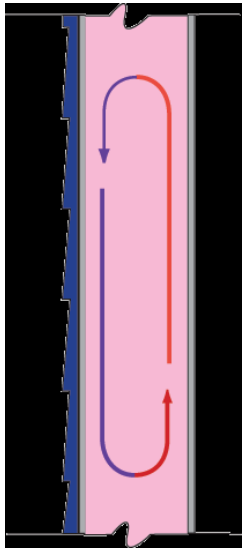
Heat transfer: Convection

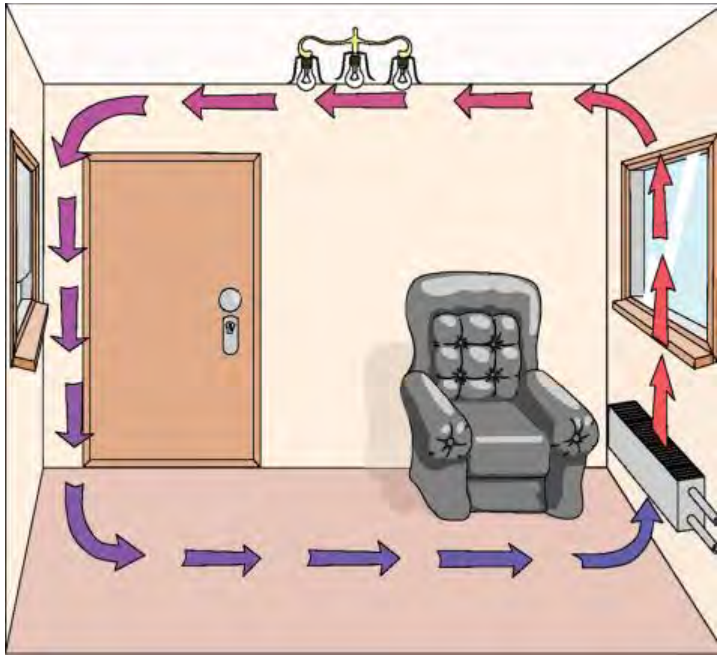
Convection is the transfer of heat caused by the movement of a fluid, like water or air (air barriers slow convection)



Convective Loop



- Air movement due to temperature and pressure gradients
- 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!)
- Increases heat flow and can reduce insulation effectiveness



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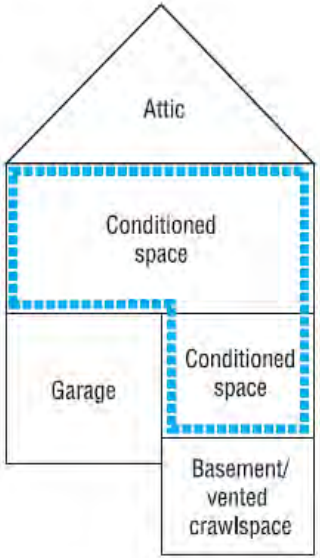
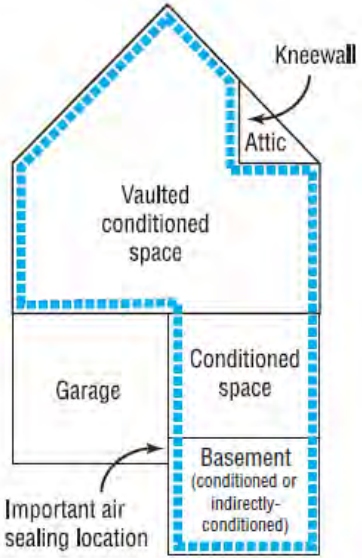
Building Thermal envelope

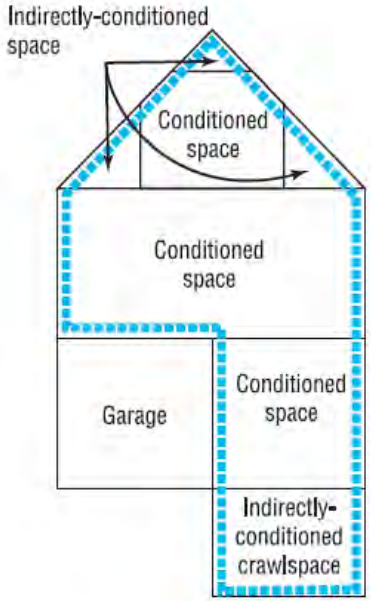
Example 1



Example 2



Example 3



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

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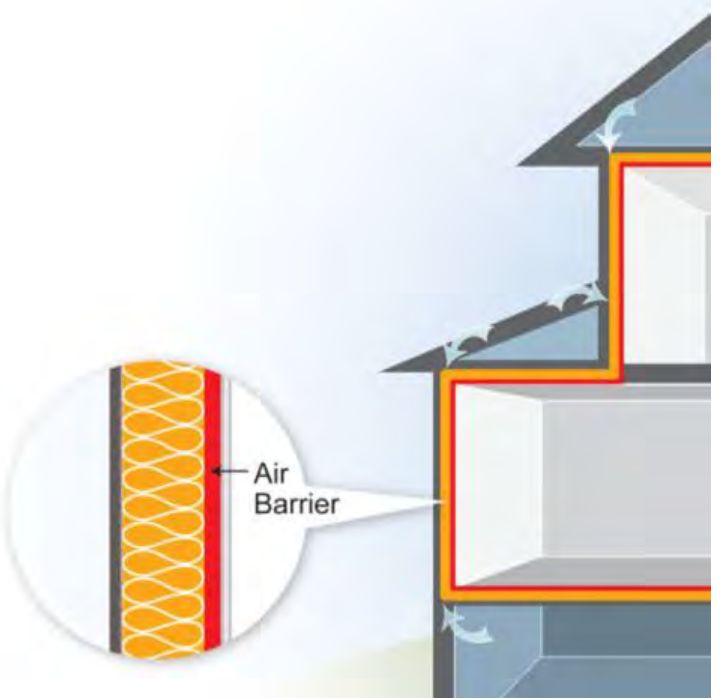
Air barrier

- Limits airflow between inside and outside.
- The IECC defines the air barrier as materials assembled and joined together to limit air leakage.
- Should be collocated with the thermal boundary
- New homes – wall sheathing
  Old homes – wall interior finish



Graphic developed for the US DOE WAP Standardized Curricula

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Air Leakage

Air leakage

- **Air leakage requires two things:**
- A hole.
- Pressure difference across that hole.
  - The bigger the hole or higher the pressure difference, the more airflow.
  - To reduce airflow, we could lower the pressure difference or reduce the size of the hole.

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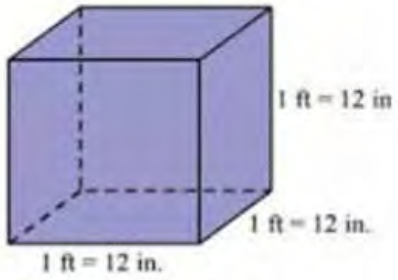
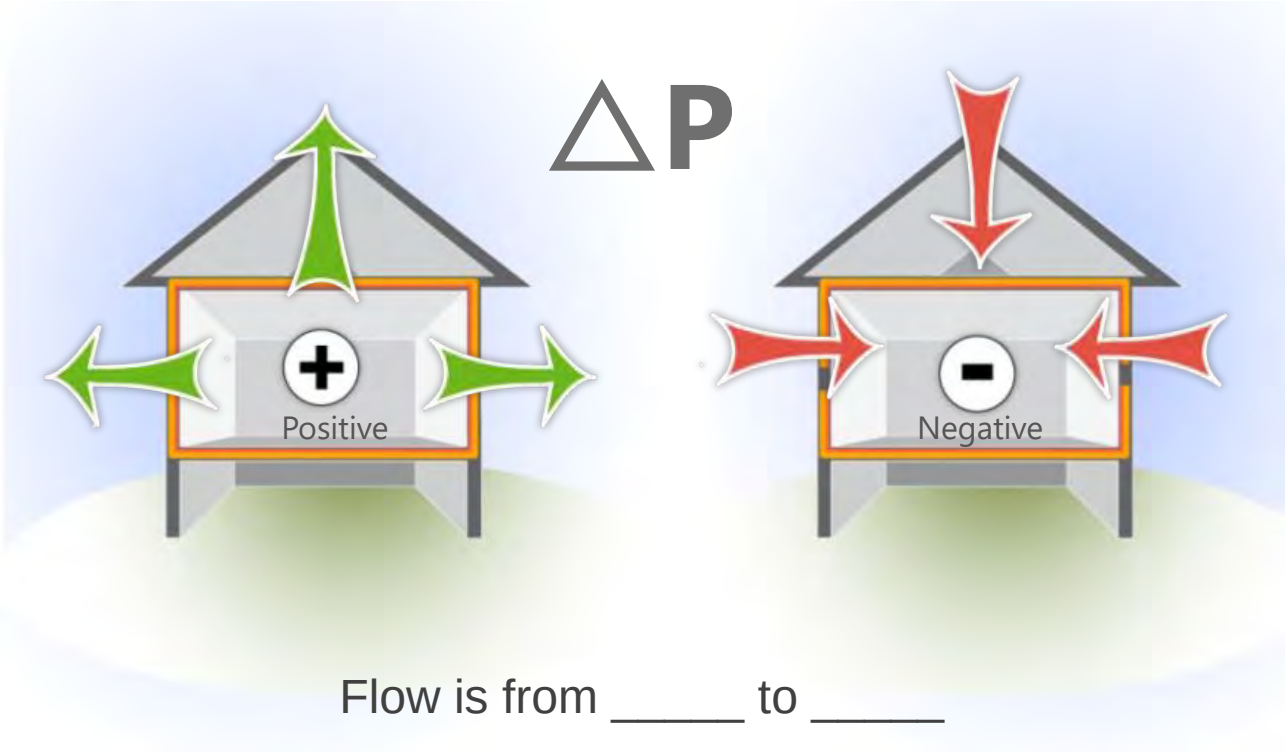
Air Leakage

- 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.
- Warm air rises, cool air sinks.



1 Cubic foot

Air Leakage: Pressure



Flow is from _____ to _____

Flow takes the path of least resistance

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Air Leakage

Ventilation = Controlled air exchange

Infiltration =
Air leaking in

Exfiltration =
Air leaking out

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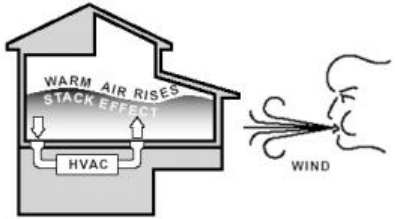
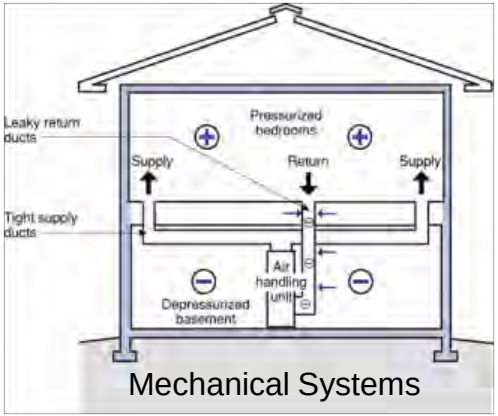
Air Leakage: Driving Forces

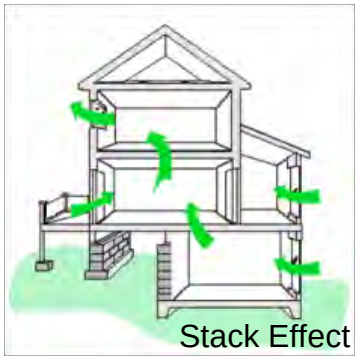
- **Three forces create pressure differences in a home:**
- Wind
- Stack Effect
- Mechanical Fans





Mechanical Systems

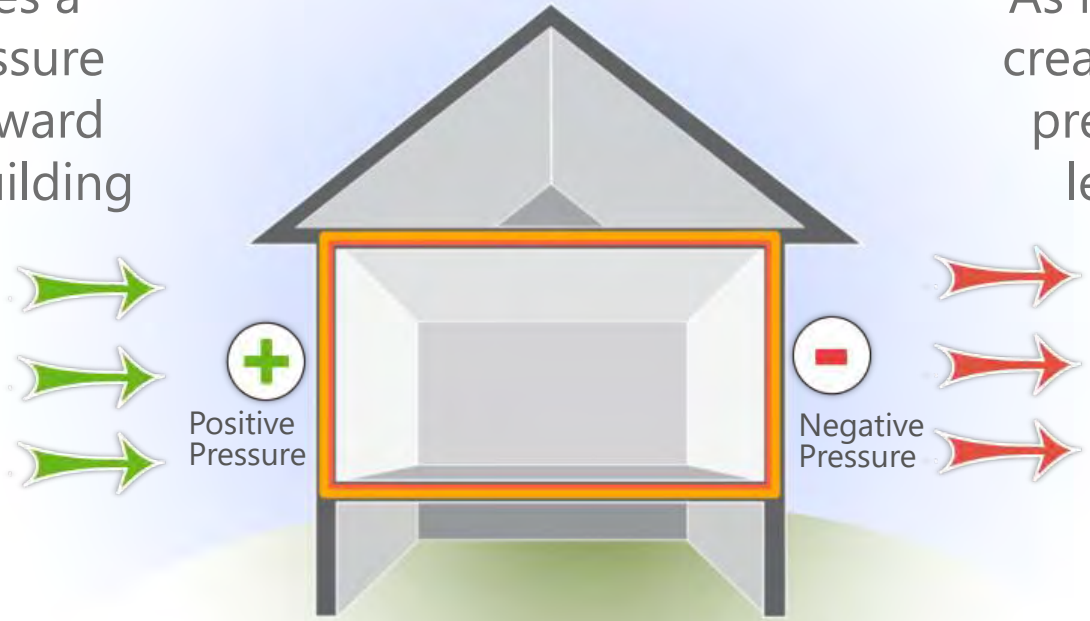

Wind


Stack Effect

Driving Forces: Wind Effect

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

As it flows past, it creates a negative pressure on the leeward side

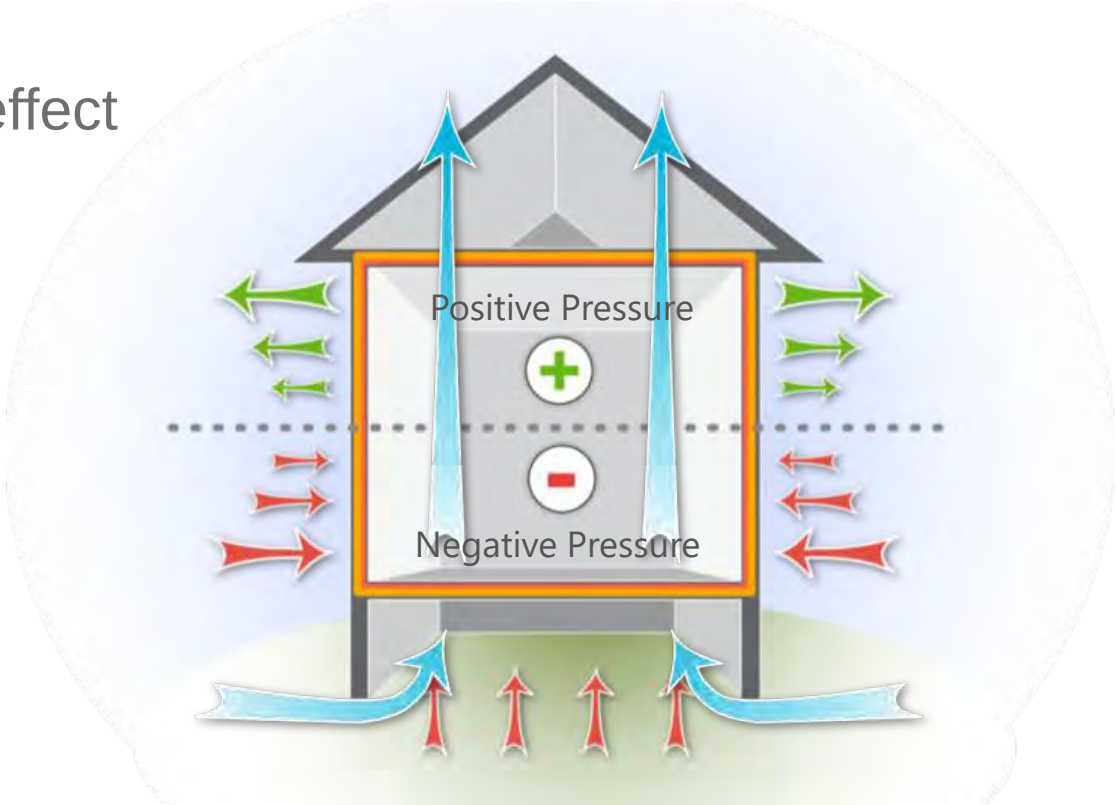


Graphic developed for the US DOE WAP Standardized Curricula

Driving Forces: Stack effect

Warmer air rises and escapes out of the top of the house…

…which creates a suction that pulls in outside air at the bottom of the house.



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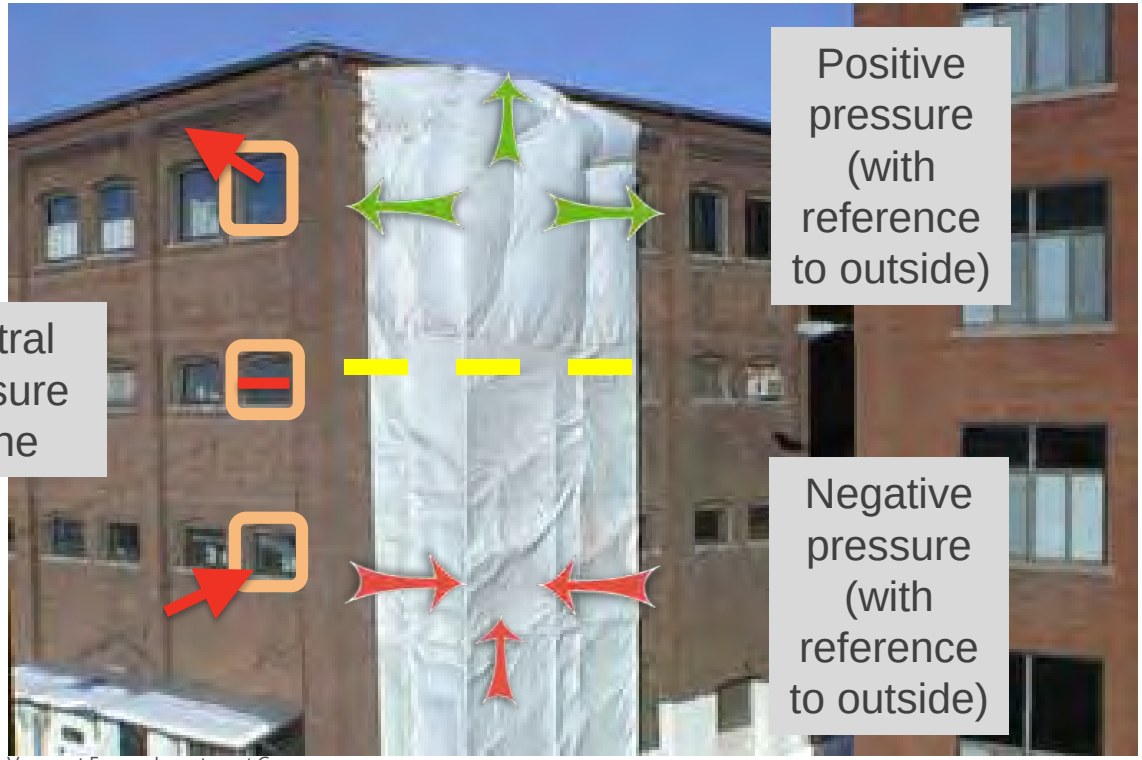
Stack effect

- Function of
  - Building Height
  - Temperature difference

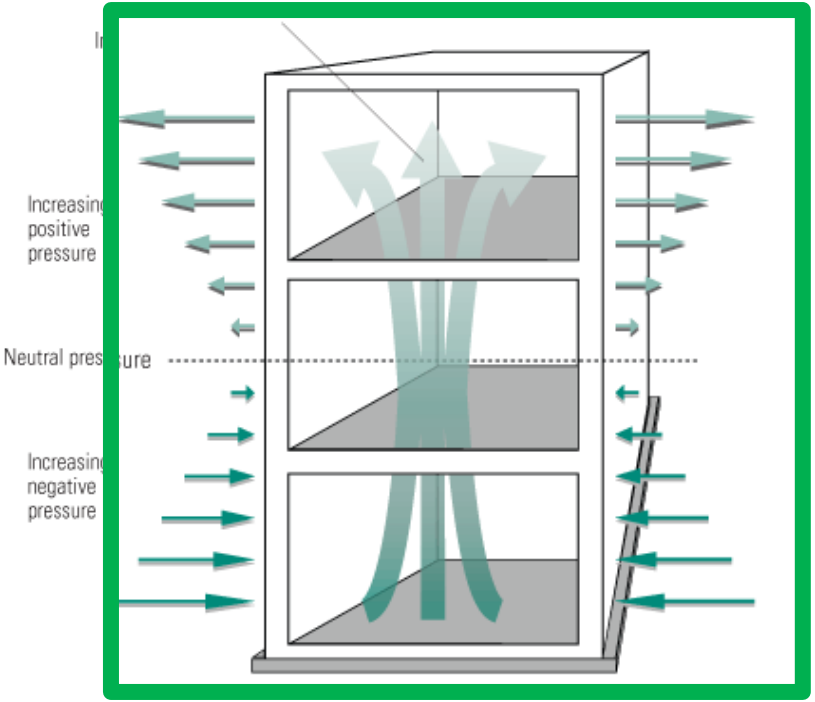


Vermont Energy Investment Corp.

Pressures / Driving Forces

Stack Effect (Chimney Effect)

- The stack effect causes air movement due to the buoyancy of heated air
- The greater the thermal difference and the height of the structure, the greater the buoyancy force



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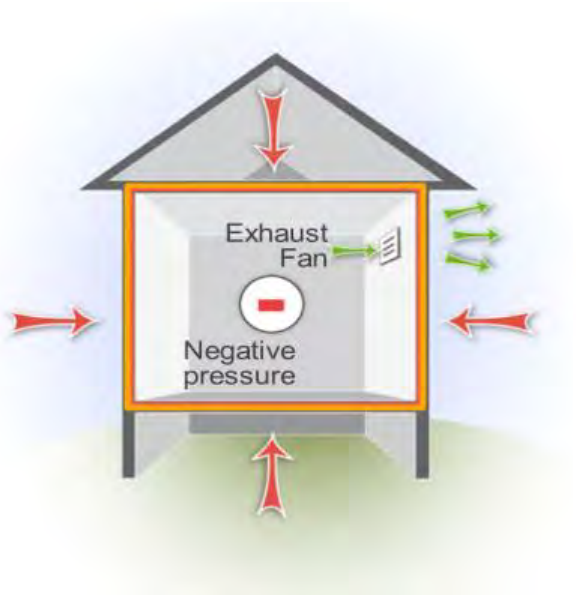
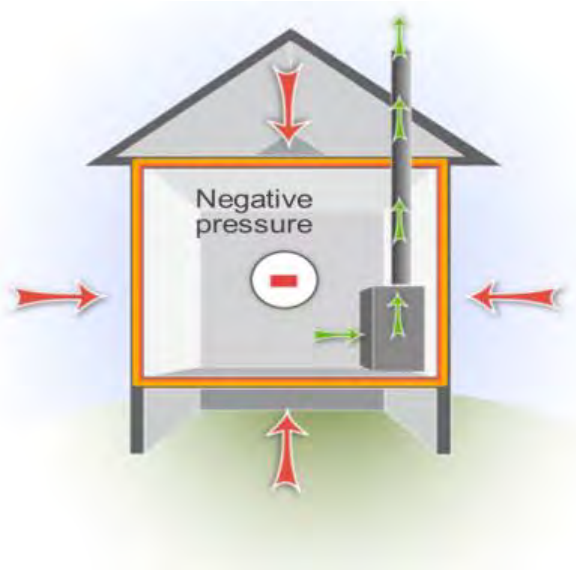
Driving Forces: Mechanical effect

Combustion Equipment & Exhaust Fans





Graphic developed for the US DOE WAP Standardized Curricula

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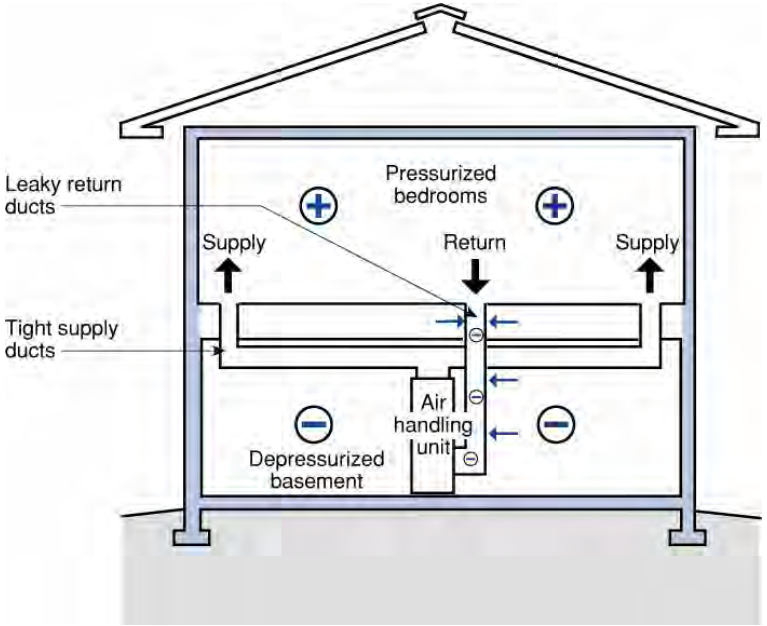
Fans—Driving Forces for Infiltration

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



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Make up air for large kitchen hoods

Details

- Motorized damper for make up air (not shown)
- Wire damper to open when fan operates

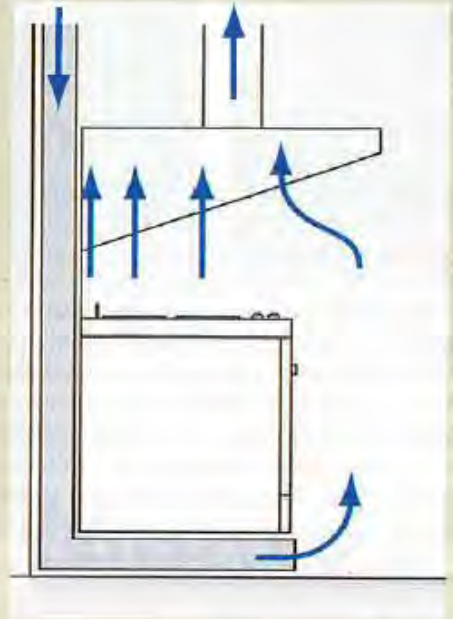

Figure 2: Capture the Effluent. The first thing we make sure is that the exhaust hood actually works to capture the effluent. The hood must overhang the cooking surface big-time. The absolute best approach is to use a backshelf hood with side panels and large overhangs on both sides and the front. Backshelf hoods can typically use 30% less exhaust to capture bad stuff compared to other hoods. Side panels can get you another 30% improvement. Note the direct makeup air using a modified backwall approach such that this makeup air is introduced at floor level. This direct makeup air introduced at floor level should never provide more than 60% to 70% of the hood exhaust. Why? Ah, we need a zone of negative pressure around the cooking surface. You don't want to push the bad stuff; you want to pull the bad stuff.

www.buildingscience.com

http://www.youtube.com/watch?v=NsSvMB9bJeE

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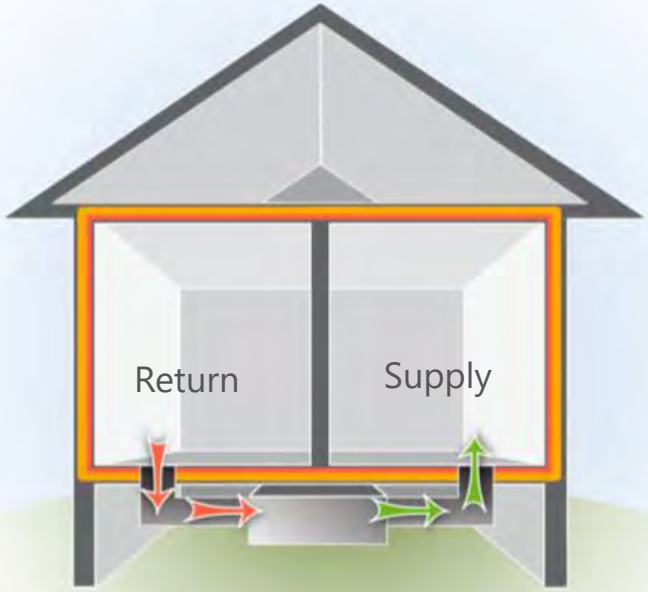
Driving Forces: mechanical effect

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.



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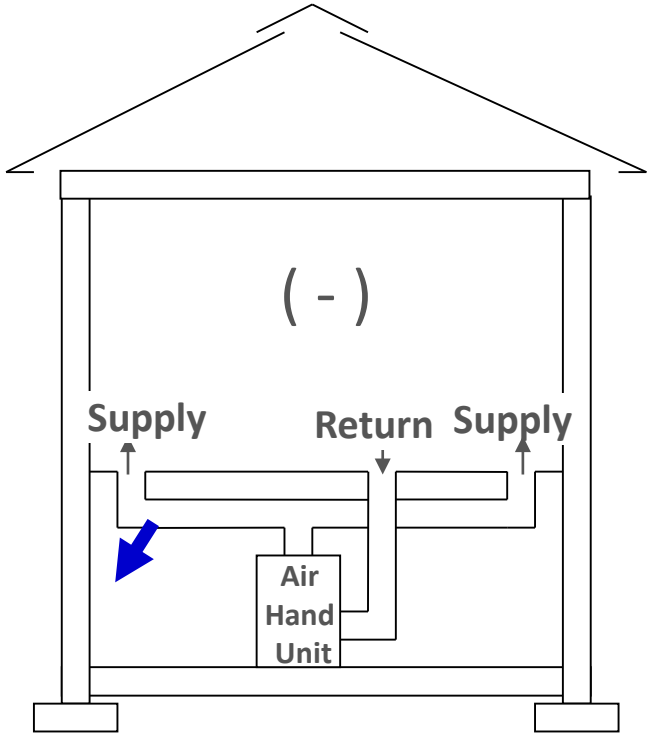
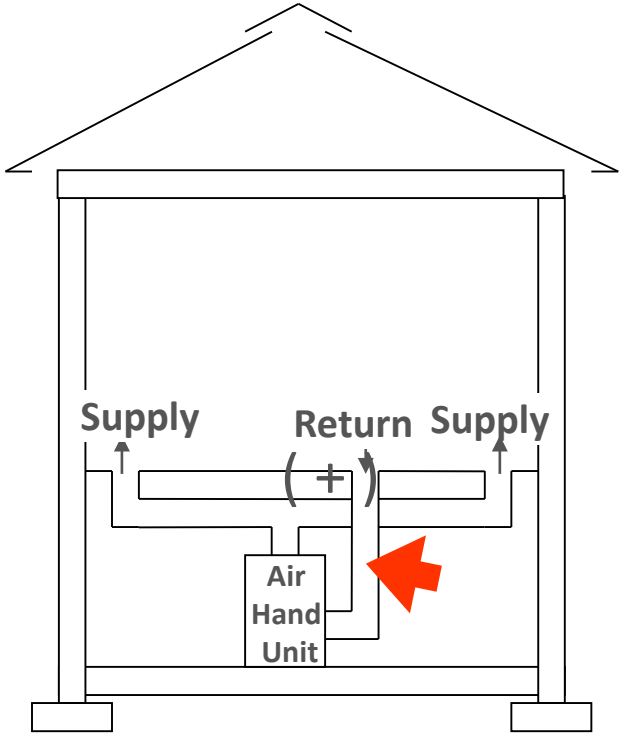
Driving Forces: mechanical effect

Duct Leakage

Duct leakage can create positive and negative pressures in a house.



Leakage in supply side of duct system



Leakage in return side of duct system

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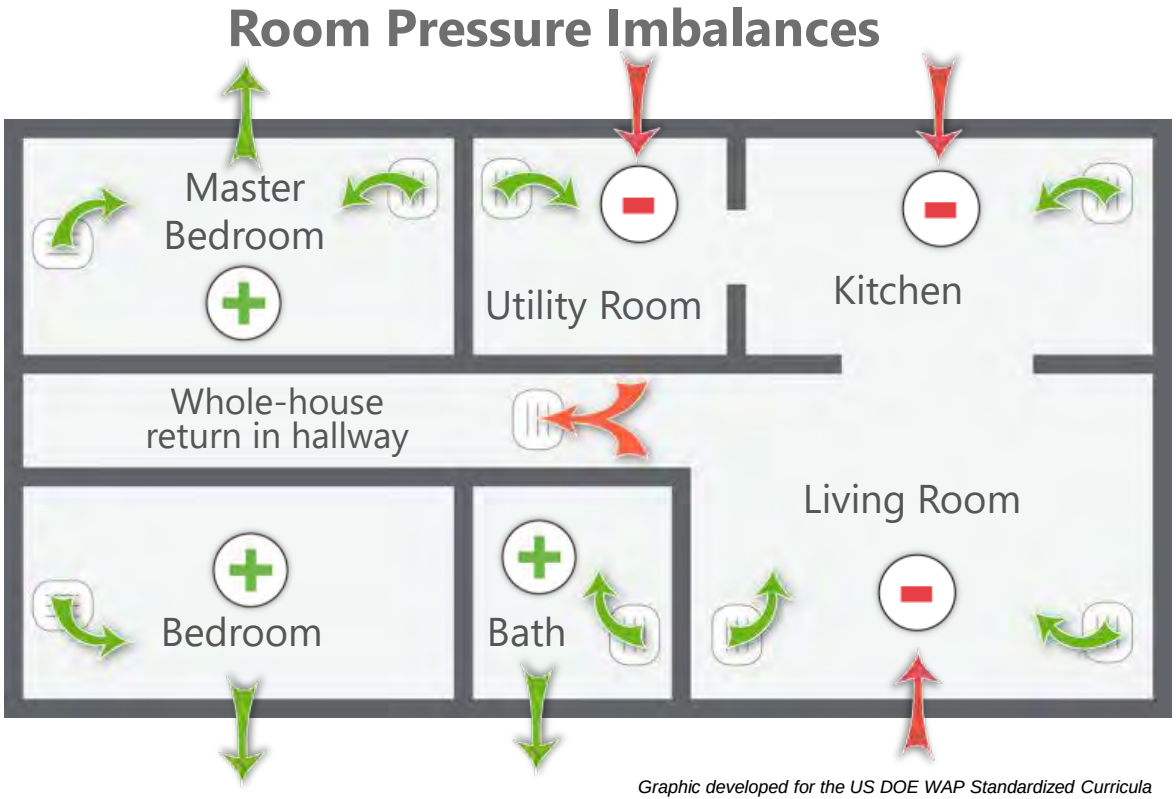
Driving Forces: mechanical effect



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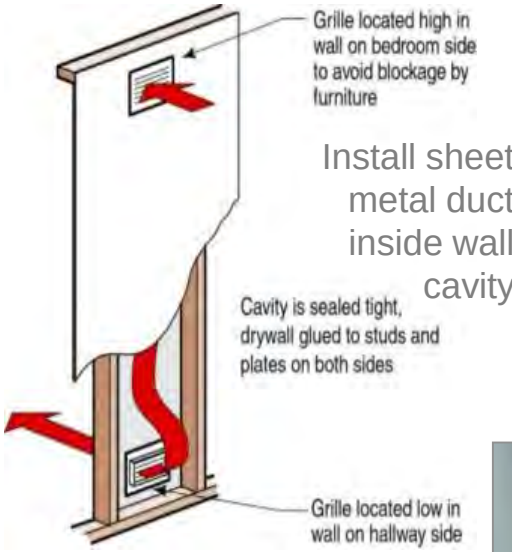
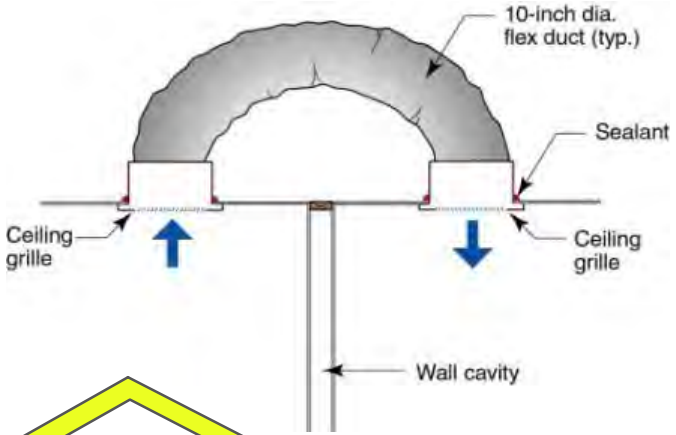
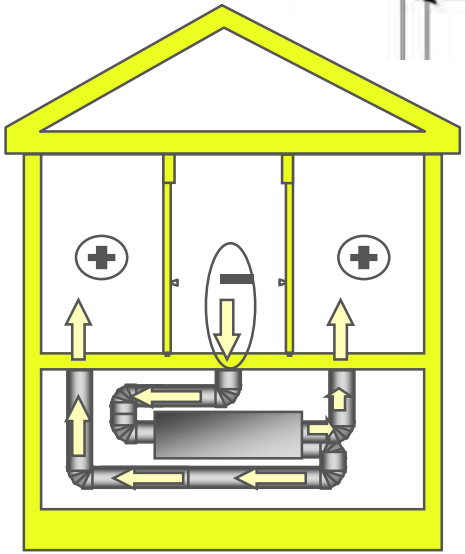
Driving Forces: mechanical effect

DESIGN FOR PROPER RETURN PATH



Install sheet metal duct inside wall cavity





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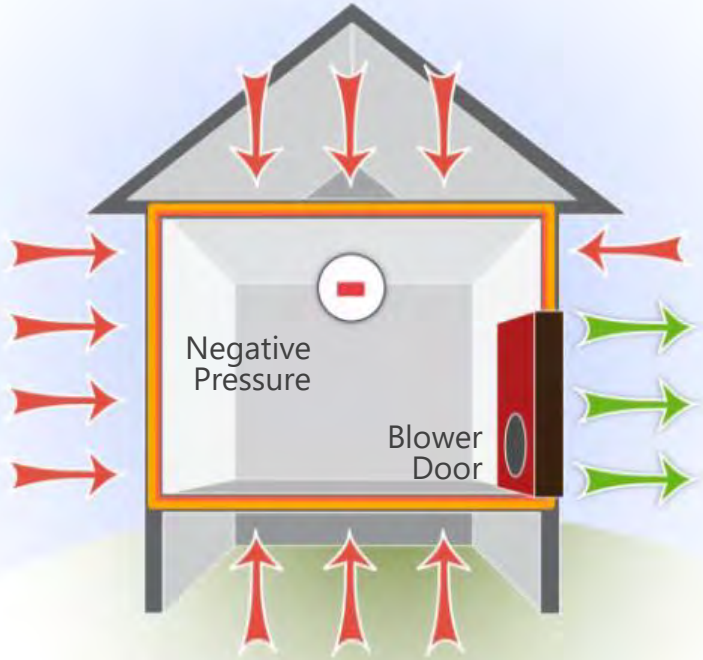
Driving Forces: Mechanical Fans

- **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.
- To achieve a 50 Pascal pressure difference across the envelope, there is one unique answer for how much CFM is required for any given home (CFM_{50})



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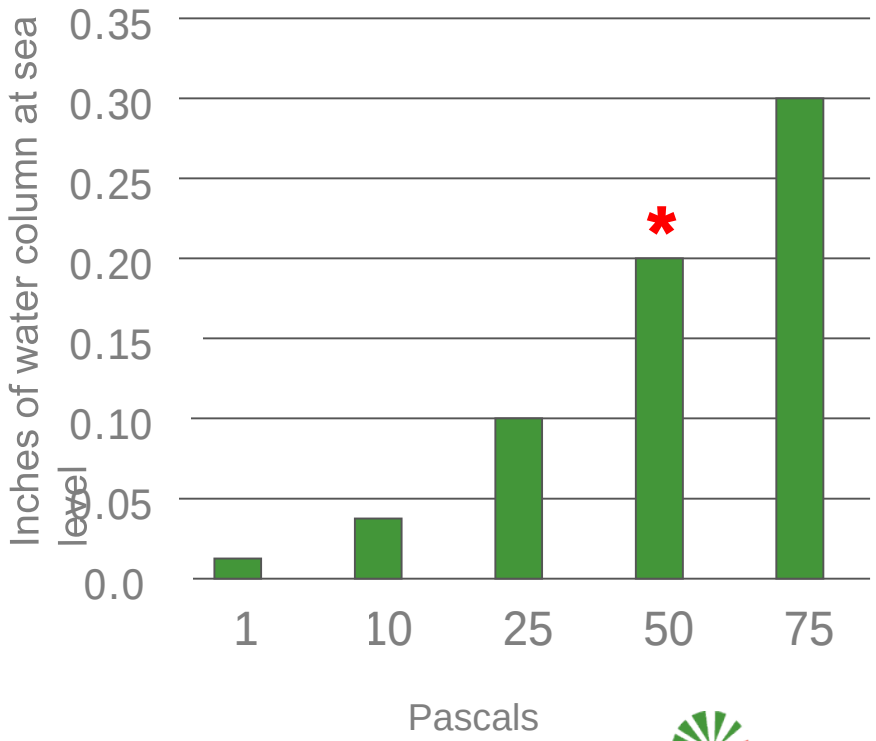
What is a Pascal?

A Pascal is the unit of pressure in the International System of Units. Named after French scientist Blaise Pascal (1623-1662), it is abbreviated Pa.

1 Pa = 1 Newton of force applied over 1 square meter.

50 Pascals (0.2” w.c.) is approximately the same as a 20 mph wind blowing on all six surfaces of a house



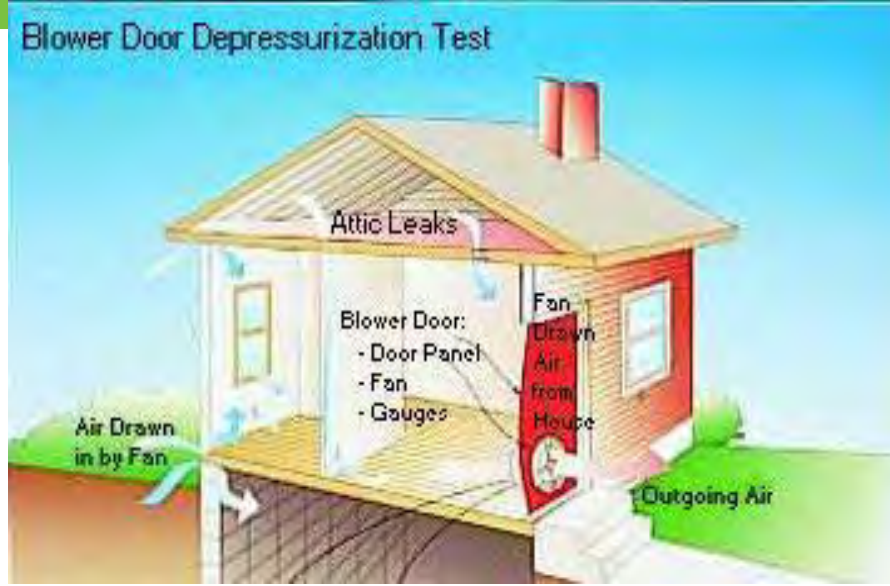
1 inch of water column = 248 Pascals

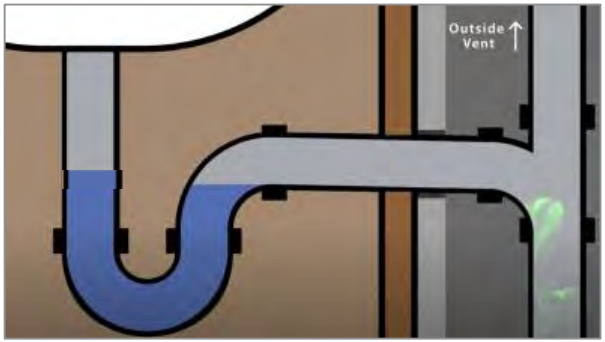
Blower Door Question

A blower door is used to depressurize a house to -50 Pa.

While the fan is running, the water in a sink's P-trap will…

a. Be pushed downward by 0.2”
b. Stay the same – it wouldn't move
c. Rise up (towards the house) by 0.2”
d. Rise up (towards the house) by 1”





ANSWER: c. Water in trap will rise up 0.2” towards the house

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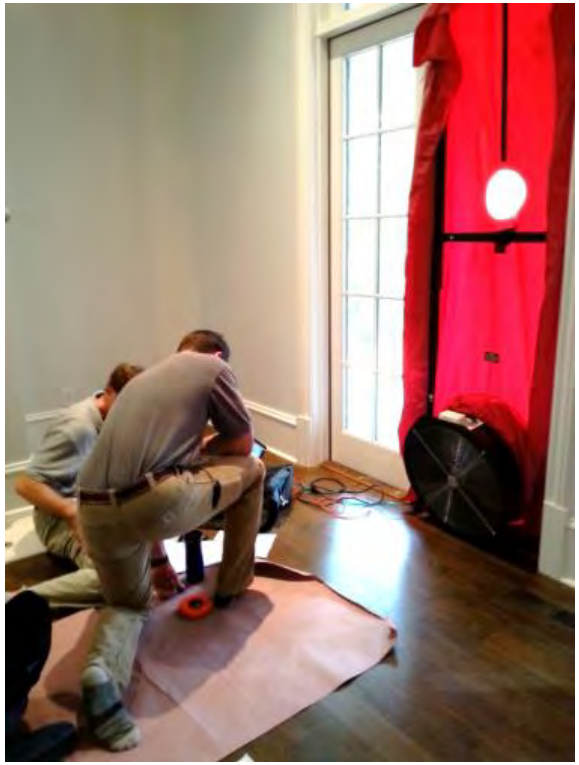
Residential Blower door testing

- Optional in 2009 IECC (<7 ACH_{50}), Required by 2012 and later versions
  - CZ 1-2 < 5 ACH_{50}
  - CZ 3-8 < 3 ACH_{50}

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

- Quantifies the amount of leakage across the home's thermal boundary
- Several states - Test performed by a certified professional (DET Verifier, HERS Rater, BPI, etc.)
- Reported to builder and code official via certificate



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Residential Blower Door Testing

- Optional in 2009 IECC (<7 ACH_{50}), Required by 2012 and later versions
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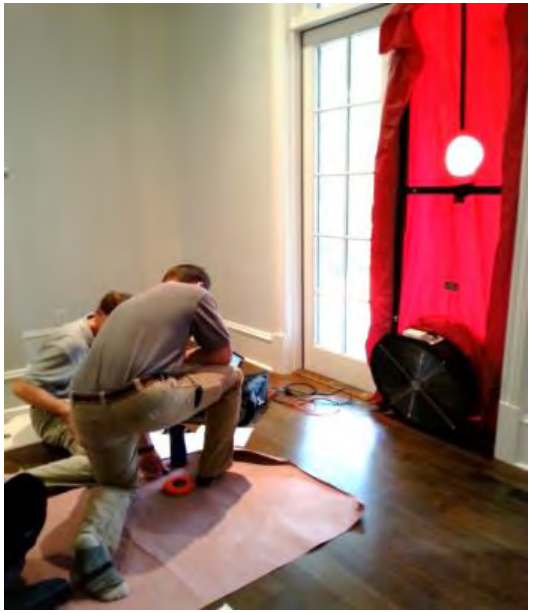
  - CZ 3-8 < 3 ACH_{50}
- Quantifies the amount of leakage across the home's thermal boundary
- Several states - Test performed by a certified professional (DET Verifier, HERS Rater, BPI, etc.)
- Reported to builder and code official via Energy Code Certificate (usually on electrical panel box)



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Major Air Leakage Locations - Residential

TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION[a]

COMPONENT	AIR BARRIER CRITERIA	INSULATION INSTALLATION CRITERIA
General requirements	A continuous air barrier shall be installed in the building envelope. The exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed.	Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling or soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed. Access openings, drop down stairs or knee wall doors to unconditioned attic spaces shall be sealed.	The insulation in any dropped ceiling/soffit shall be aligned with the air barrier.
Walls	The junction of the foundation and sill plate shall be sealed. The junction of the top plate and the top of exterior walls shall be sealed. Knee walls shall be sealed.	Cavities within corners and headers of frame walls shall be insulated by completely filling the cavity with a material having a thermal resistance, *R*-value, of not less than R-3 per inch. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
Windows, skylights and doors	The space between framing and skylights, and the jambs of windows and doors, shall be sealed.	—
Rim joists	Rim joists shall include the air barrier.	Rim joists shall be insulated.
Floors, including cantilevered floors and floors above garages	The air barrier shall be installed at any exposed edge of insulation.	Floor framing cavity insulation shall be installed to maintain permanent contact with the underside of subfloor decking. Alternatively, floor framing cavity insulation shall be in contact with the top side of sheathing, or continuous insulation installed on the underside of floor framing; and shall extend from the bottom to the top of all perimeter floor framing members.

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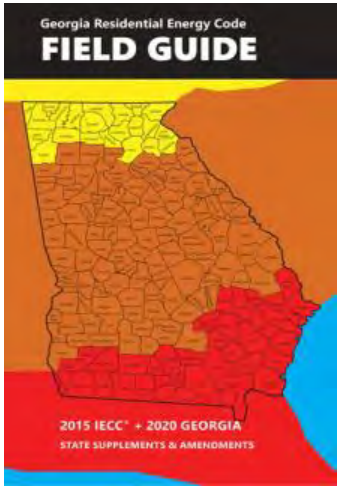
Major Air Leakage Locations - Residential



Crawl space walls	Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.	Crawl space insulation, where provided instead of floor insulation, shall be permanently attached to the walls.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.	—
Narrow cavities	—	Batts to be installed in narrow cavities shall be cut to fit or narrow cavities shall be filled with insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.	—
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be sealed to the finished surface.	Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated.
Plumbing and wiring	—	In exterior walls, batt insulation shall be cut neatly to fit around wiring and plumbing, or insulation, that on installation readily conforms to available space, shall extend behind piping and wiring.
Shower/tub on exterior wall	The air barrier installed at exterior walls adjacent to showers and tubs shall separate the wall from the shower or tub.	Exterior walls adjacent to showers and tubs shall be insulated.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical and communication boxes. Alternatively, air-sealed boxes shall be installed.	—
HVAC register boots	HVAC supply and return register boots that penetrate building thermal envelope shall be sealed to the subfloor, wall covering or ceiling penetrated by the boot.	—
Concealed sprinklers	Where required to be sealed, concealed fire sprinklers shall only be sealed in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.	—

a. Inspection of log walls shall be in accordance with the provisions of ICC 400.

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Managing Water 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 vapor into the building.