BOOTCAMP

Residential Space Conditioning & Water Heating

Day 3!

PRESENTED BY LARRY WATERS

ELECTRIFY MY HOME

ELECTRIFY
MY HOME

BUILDING ENVELOPE 101

- SEGMENT 4 -

Building Enclosure 101

Image courtesy of Judy Rachel

- The primary protection from the outdoor elements – wind, rain, snow, temperature changes and solar radiation
- The enclosure should maximize heat retention in winter and minimize heat gains in summer, thereby reducing heating and cooling needs, and creating the opportunity to provide a comfortable indoor environment

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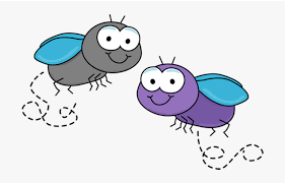
Session Topics

- The 3 elements for an effective building enclosure
- Greatest source of energy loss and comfort issues in homes
- Physics driving building air leakage
- Combustion safety
- Diagnostic tools
- Equipment size reduction due to lowered loads
- Pre-electrification obstacles
- Importance of mechanical ventilation

Terms to Know

Cubic Feet per Minute (CFM): A measure of airflow past a certain point or through a certain structure. Picture a basketball as approximately equivalent to the size of a cubic foot of air.

Pascal (Pa): A metric unit of pressure. 250 Pascal is equal to about one inch of water column. Blower door testing is usually done at -50 Pa. 50 Pa is about one pound per square foot and is about the equivalent of a 20 mph wind on all surfaces of the building.



CFM_{50}: Airflow, in CFM, with a 50 Pascal pressure difference.

ACH: Air Changes per Hour – leakage as compared to volume. The number of times each hour an amount of air equal to the volume of the building leaks out.

ACH_{50}: Air Changes per Hour at an induced pressure of 50 Pa with reference to the outside.

ELA: Equivalent Leakage Area, an estimate in square inches of the cumulative size of the leaks measured by the blower door.

Basic Physics - 2nd Law of Thermodynamics

Energy flows naturally from high to low concentrations

- Pressure flows from **HIGH** to **LOW**
- Heat flows from **WARM** to **COLD**
- Moisture flows from **MORE** to **LESS**
- Energy **In** = Energy **Out**
- 1 CFM **In** = 1 CFM **Out**

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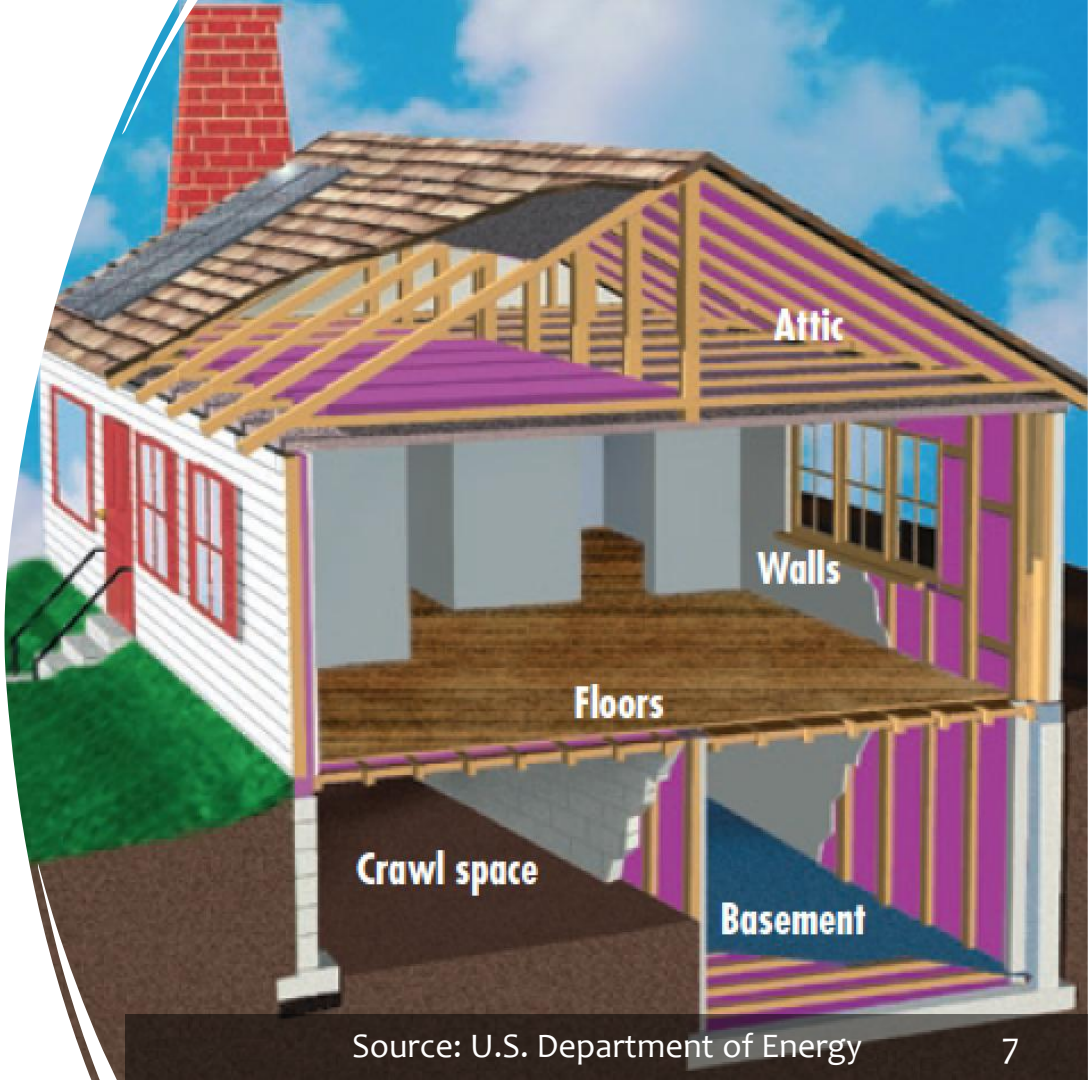
The 3 Critical Elements of the Building Enclosure

- Air Barrier
- Pressure Boundary
- Thermal Boundary



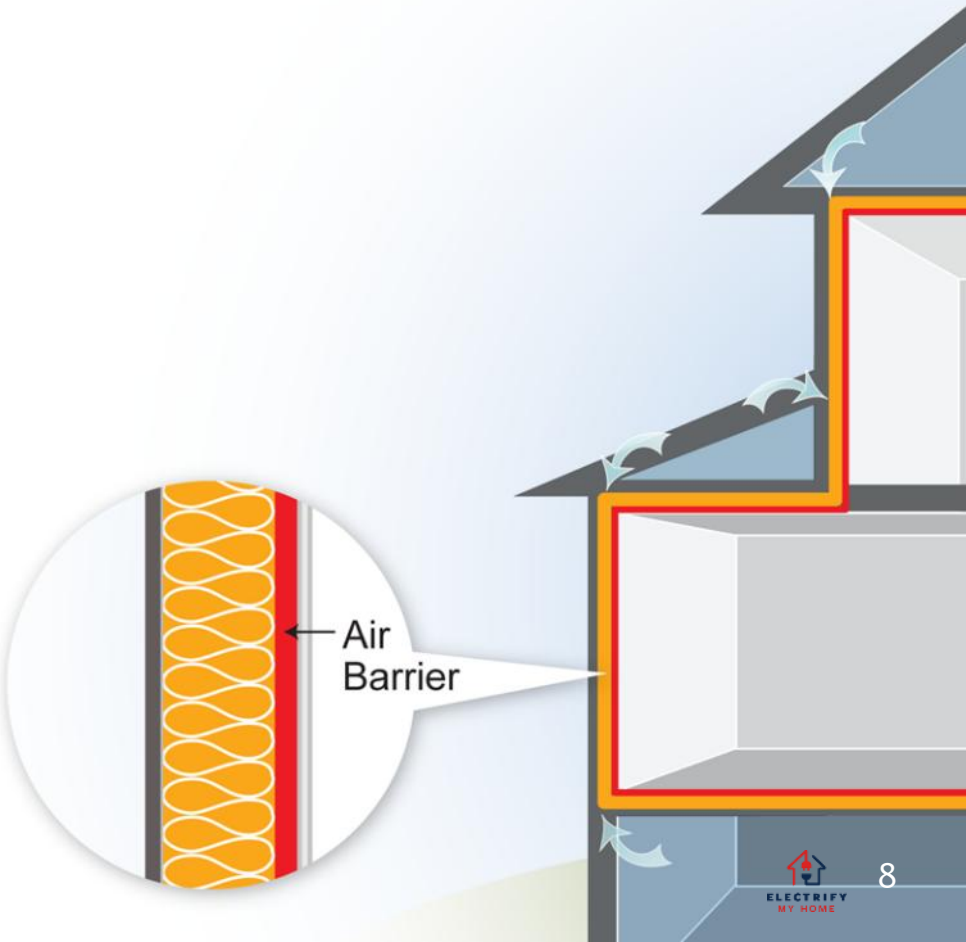
Source: U.S. Department of Energy

Air Barrier

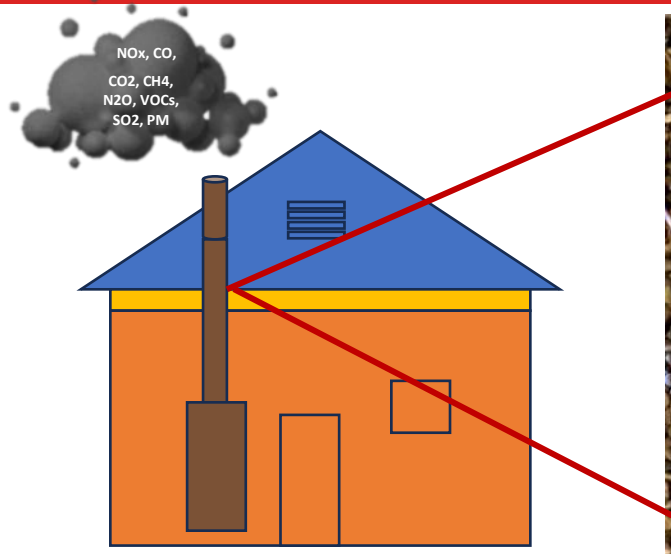
System of materials designed to control airflow between a conditioned space (indoors) and an unconditioned space such as outdoors or a garage.

An effective air barrier must be:

- Impermeable to air flow
- Continuous over the entire building enclosure
- Able to withstand the forces that may act on them during & after construction
- Durable over the expected lifetime of the building
- Define the location of the pressure boundary

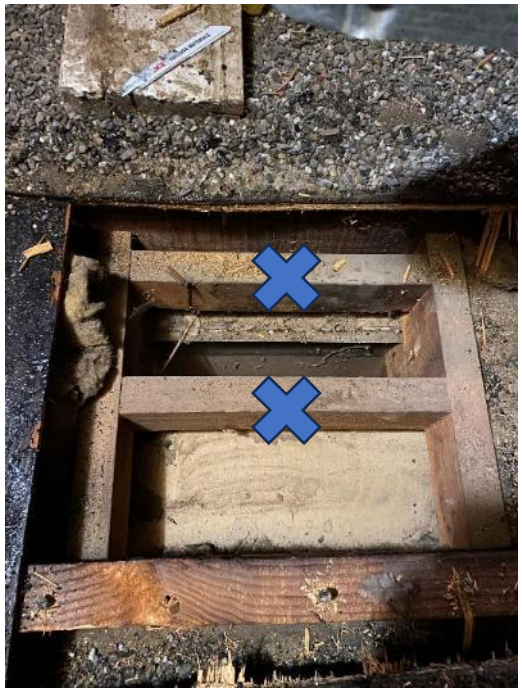


Where's The Air Barrier?



A Closer Look!

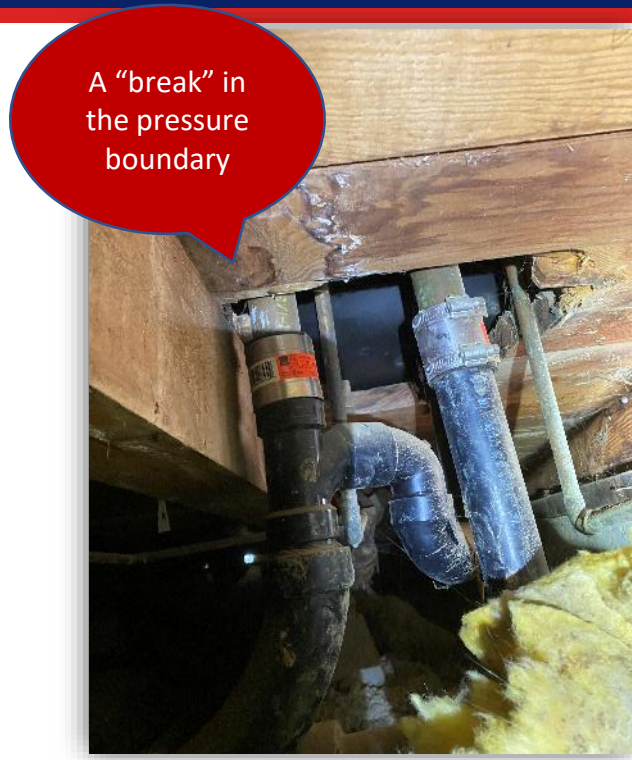
Doing It RIGHT



Pressure Boundary

The boundary point is the point at which inside air and outside air are separated, stopping air and vapor penetration into building cavities

- ✓ The boundary where air sealing should occur
- ✓ Separates garages from conditioned space, making this the “gas barrier”
- ✓ Thermal and pressure boundaries should be aligned



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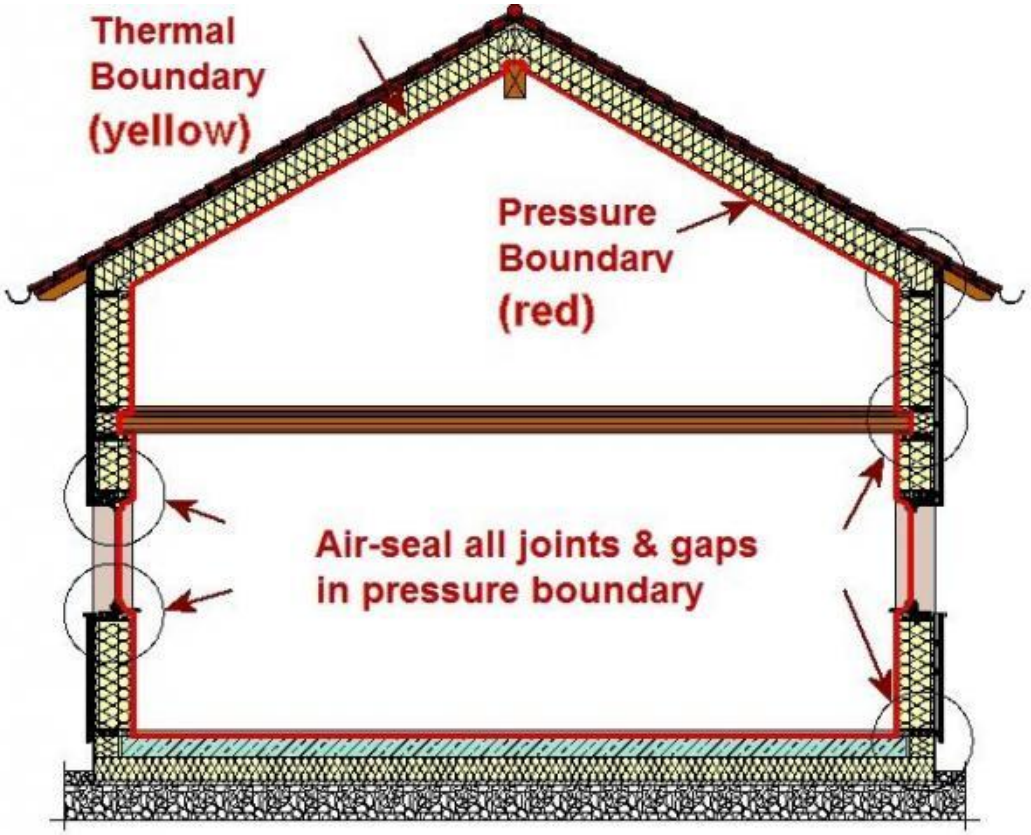
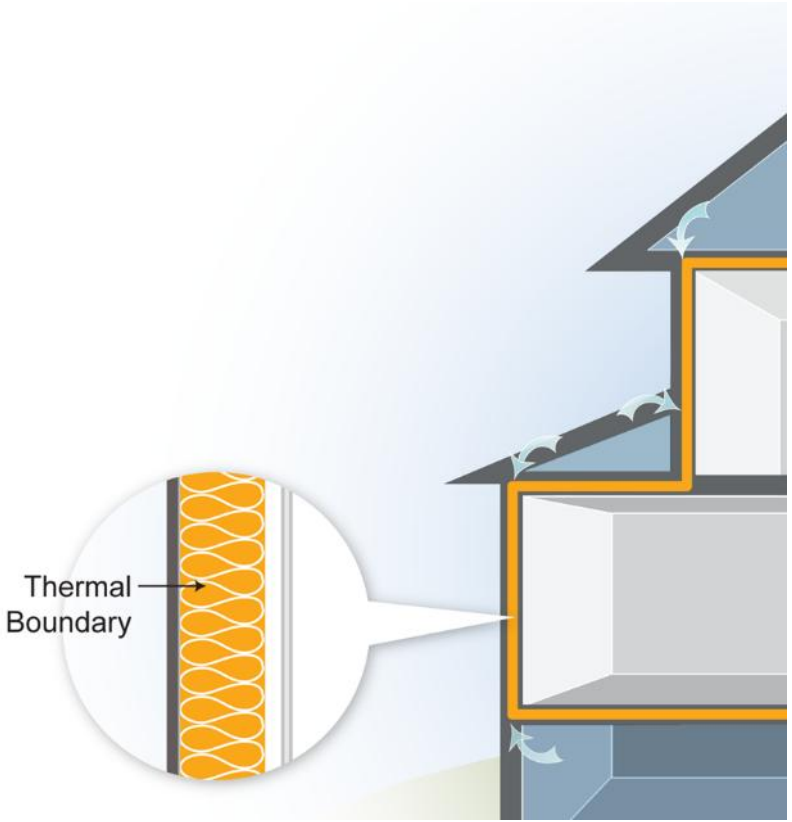


Thermal Boundary

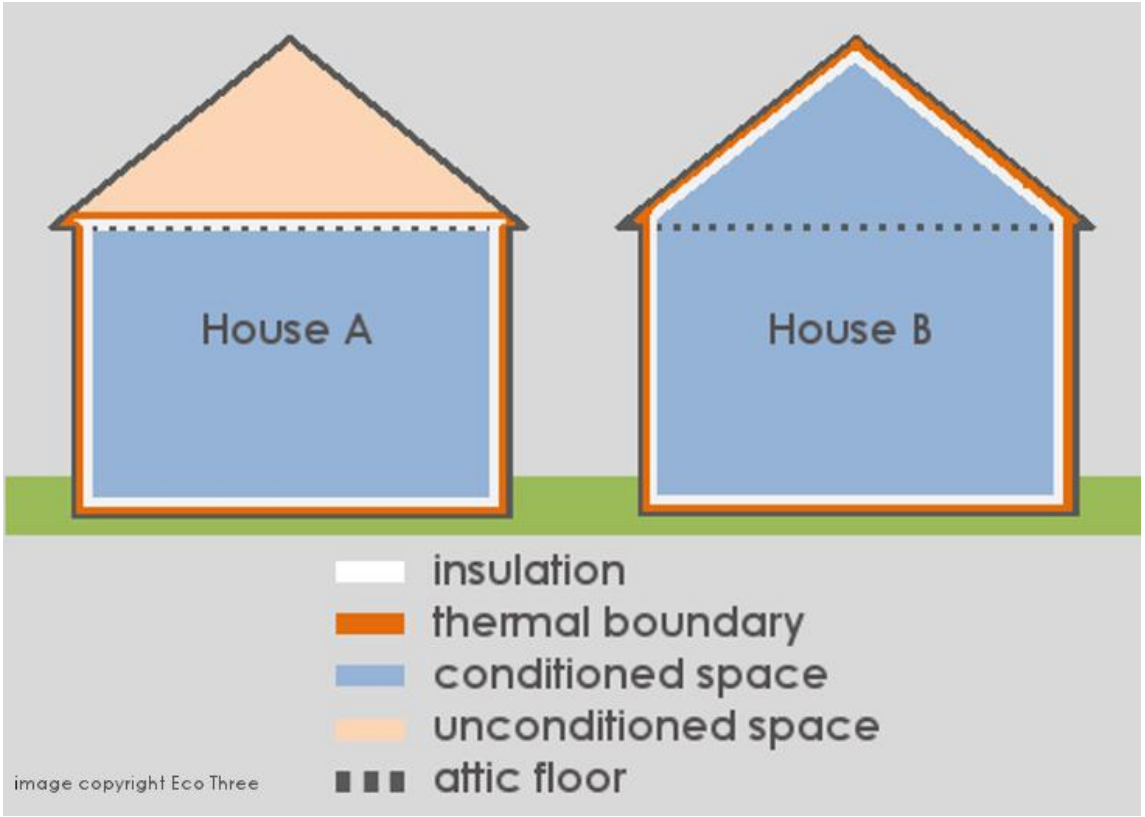
The plane of the building **surrounding the space** that is intentionally heated and cooled. This is where insulation should be located.

- Created by the **presence of insulation** in complete and continuous contact with the air barrier
- Restricts or slows the **heat transmission** through the building enclosure
- Cannot exist without an **air barrier**
- A **necessity** for an energy-efficient building



Thermal Boundary

Thermal boundaries can exist in different spaces, depending where the air barrier is insulated



Without a clearly defined pressure boundary, an aligned air barrier and a true thermal boundary, a building is unable to provide thermal comfort

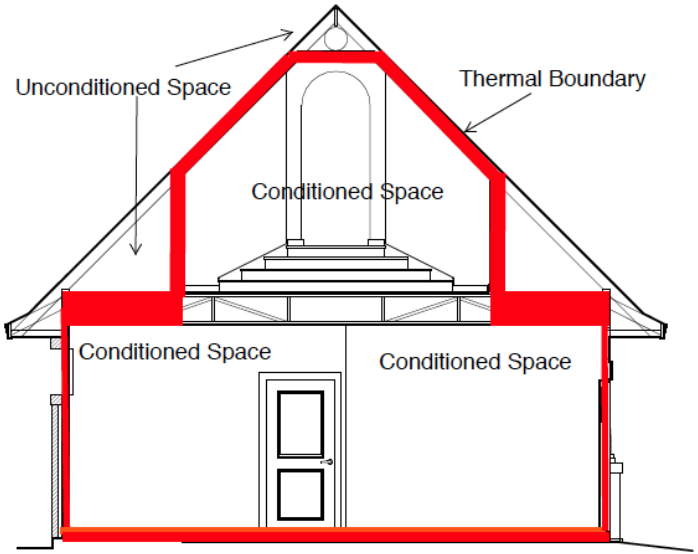


Image courtesy of Judy Rachel

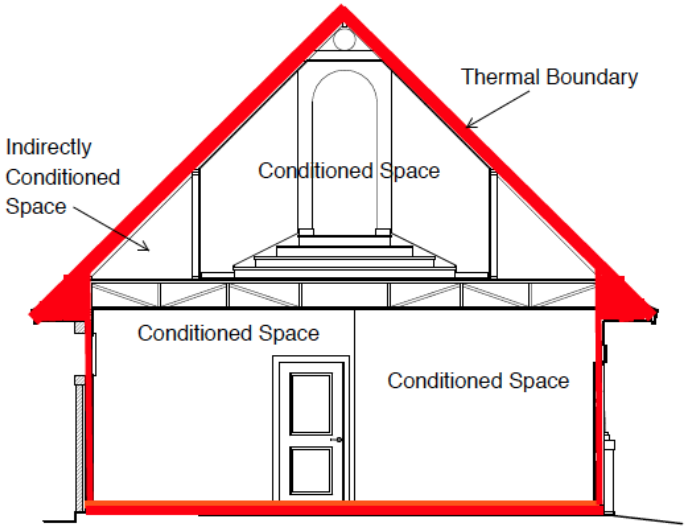


Image courtesy of Judy Rachel

Different ways to define the thermal boundary on the same house

Poor Application of Foam Under Roof in an Attempt to Save Energy

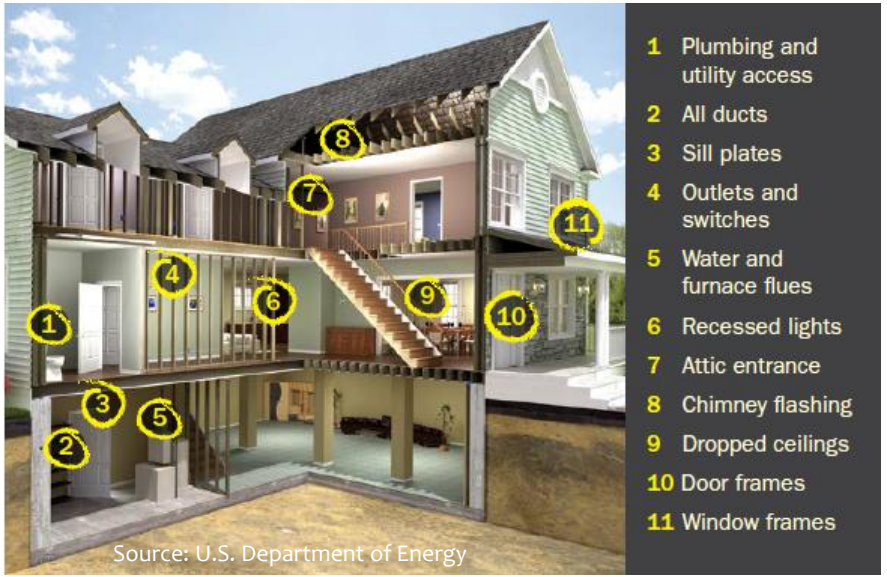
- Foam was applied under the roof
- Existing gable vent was left in place
- This is a misaligned thermal barrier
- Solution: foil back knee-wall insulation installed in proper alignment for thermal barrier

Air leakage
(The Invisible Thief)

Infiltration and Exfiltration

- Air flows into and out of our building enclosures through construction flaws that rob homes of comfort and energy and degrade indoor air quality

- Air leakage in buildings represents 5% to 40% of space-conditioning costs



For typical ducts in attic:

"Supply Leaks SUCK, Return Leaks BLOW"

I.e., Supply leaks lead to infiltration, return leaks cause exfiltration

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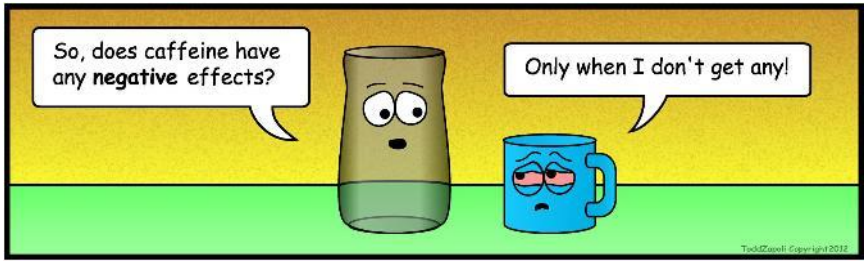
Infiltration Negatively Impacts:

- Indoor air quality
- Comfort
- Energy
- Indoor moisture conditions
- Durability
- Equipment capacity



Typical construction techniques cause loss of energy and comfort, along with building durability problems

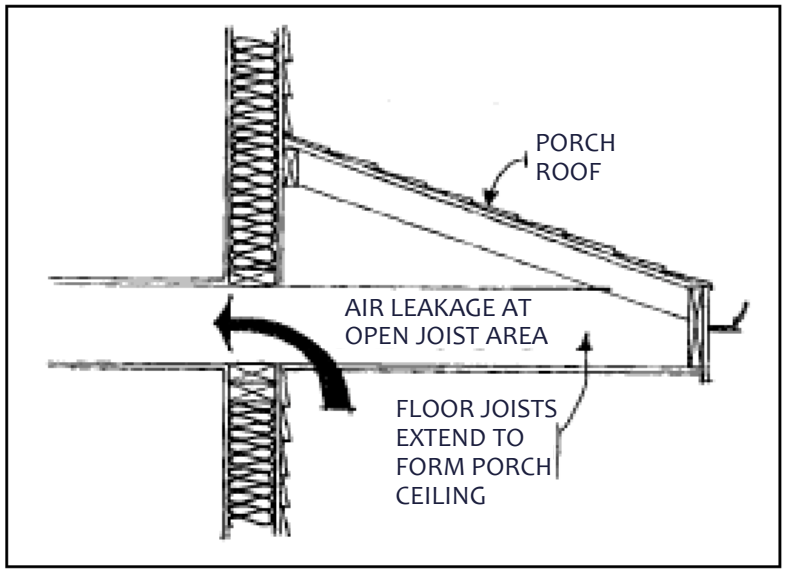
Examples include:

- Balloon framing
- Attached porch
- Unducted returns
- Dropped soffits
- Interstitial cavities/chases
- Stairwells
- Cantilevers
- Knee wall

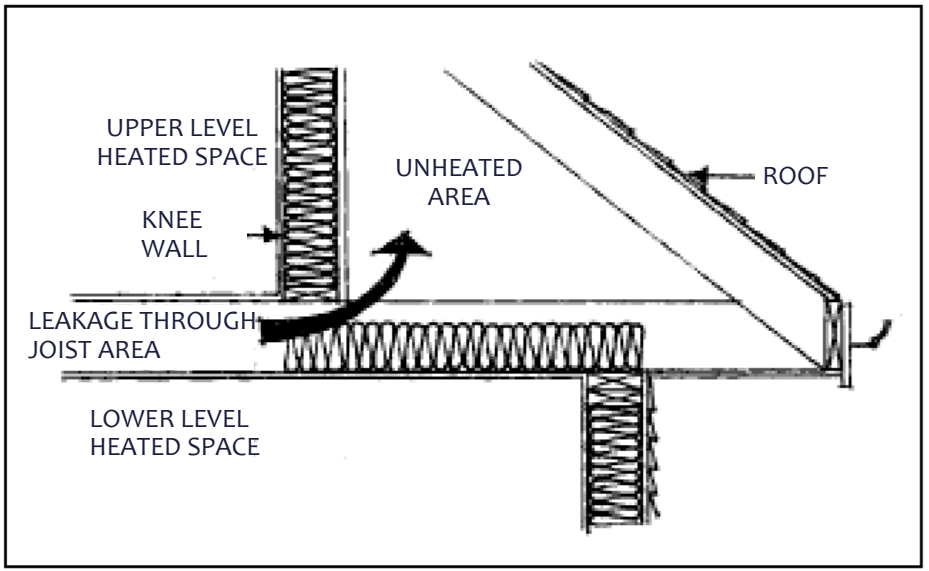
Air Leaks in Assemblies

In the Absence of an Air Barrier, Air Will Find Pathways

Air path from an attached porch



Air path at attic knee-wall



Images courtesy of Minneapolis Blower Door™ Operation Manual for Model 3 and Model 4 Systems pg. 6



Interstitial Cavities

- Found in almost every two-story home with a single HVAC system
- Can increase energy cost by hundreds of dollars every year and create very uncomfortable upper floors
- Allow hot air from the attic space to travel between the floors of two-story homes

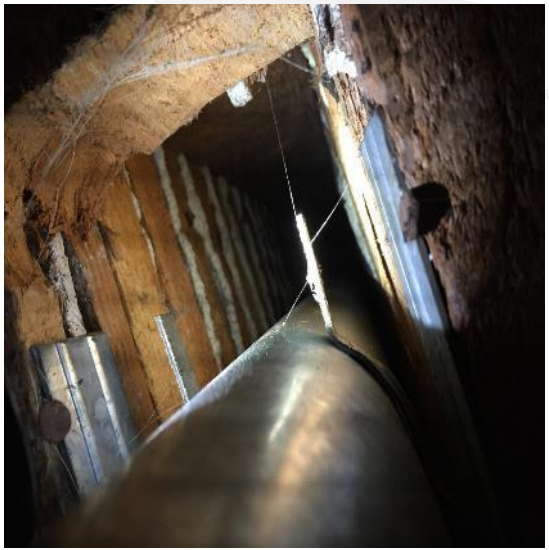
A Building's Horizontal Cavities and Vertical Shafts are Conduits for Air Leakage

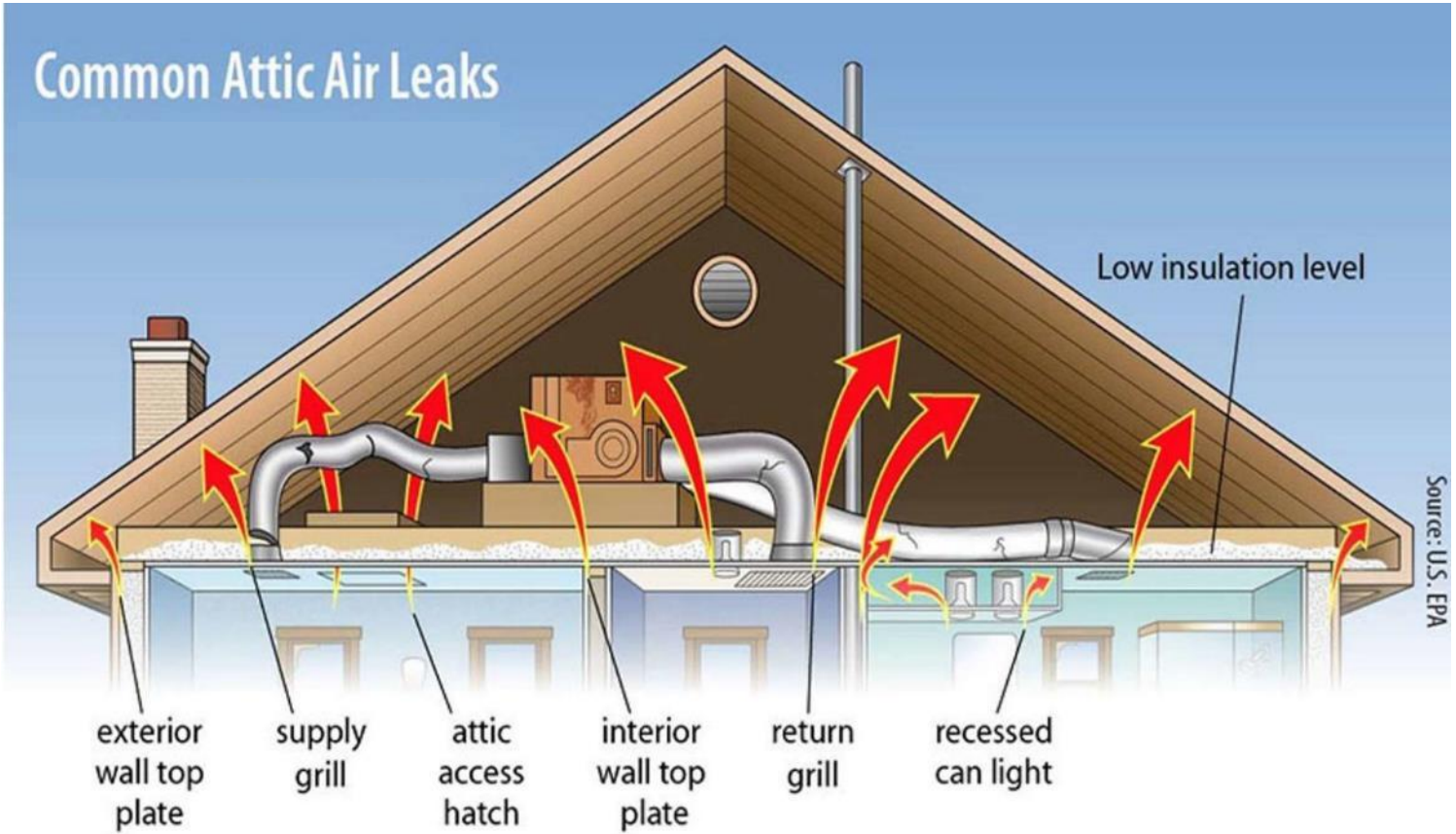
- This interstitial cavity goes from the attic to the home's subfloor
- Rather than attempting to insulate the cavity walls, a better solution for stopping air leakage and thermal comfort issues would be to block and seal this cavity in the attic and then add insulation on top


Photo courtesy of Judy Rachel

Insulation Voids & Air Leaks Must Be Fixed. If Not, Bigger System & Higher Bills

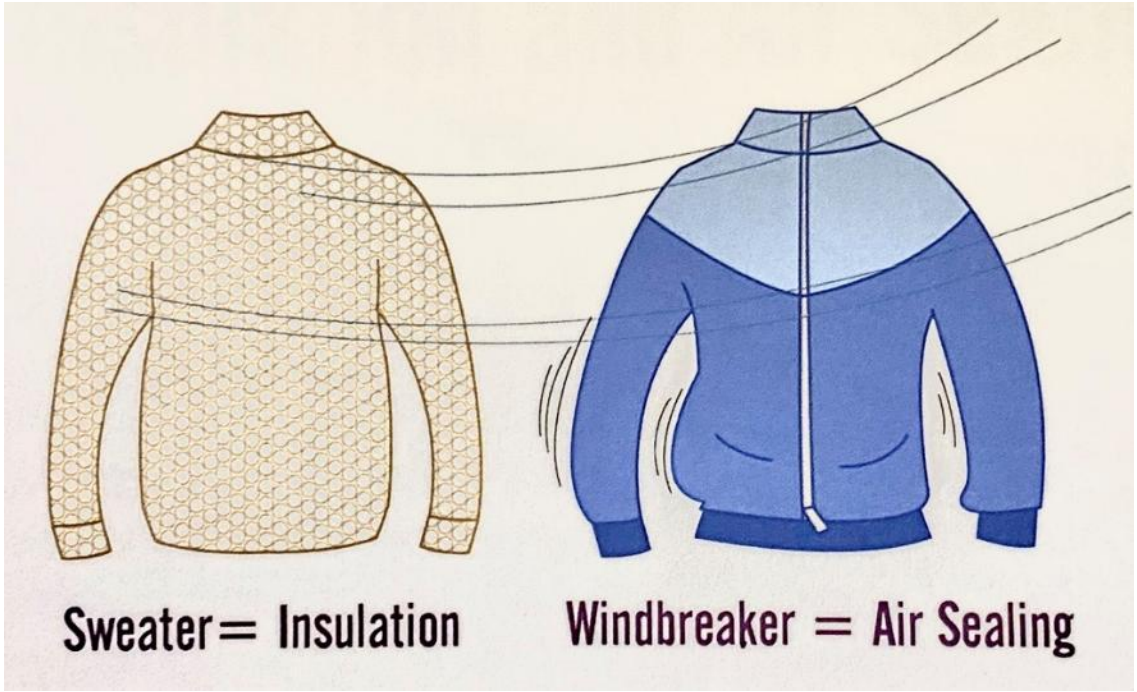
- All of these uninsulated back walls radiate heat in the summer and pull it out of the house in the winter
- These cavities can cause a lot of additional airflow making the house drafty and hard to condition





Source: Energy Star

Fixes – Analogy For Your Customer



Source: The Home Comfort Book, Nate Adams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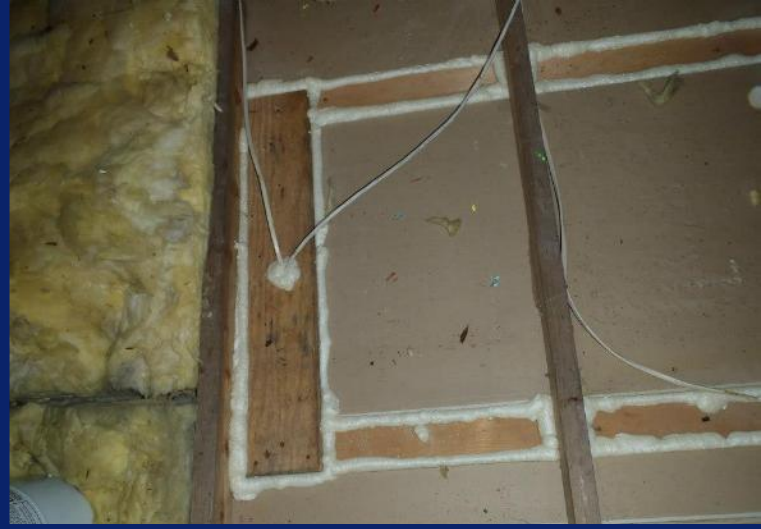


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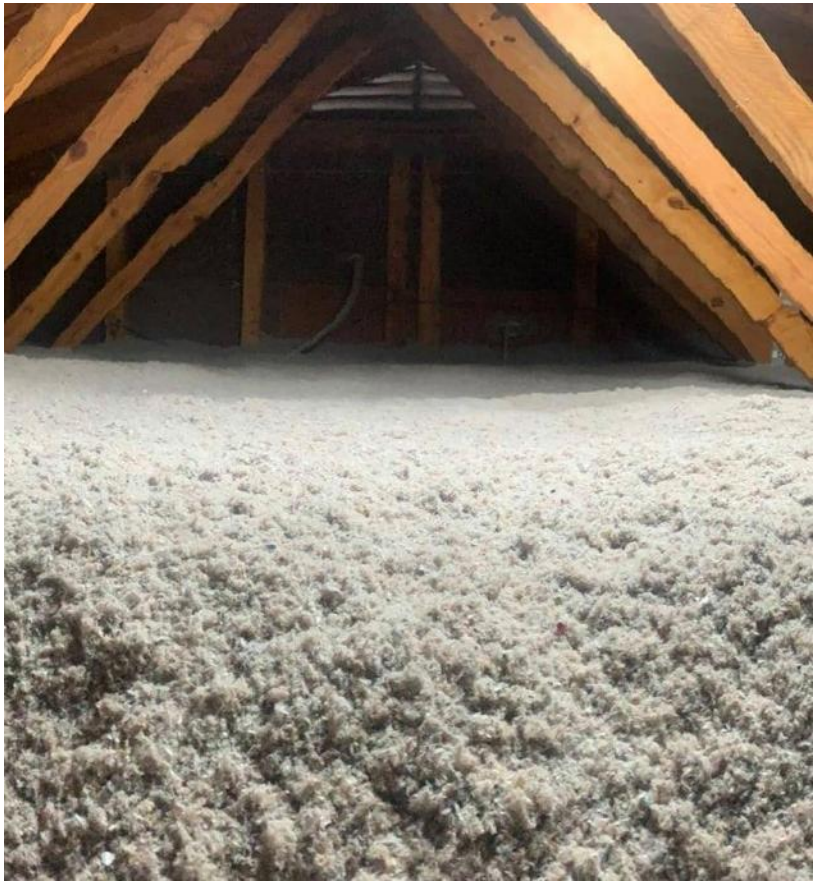
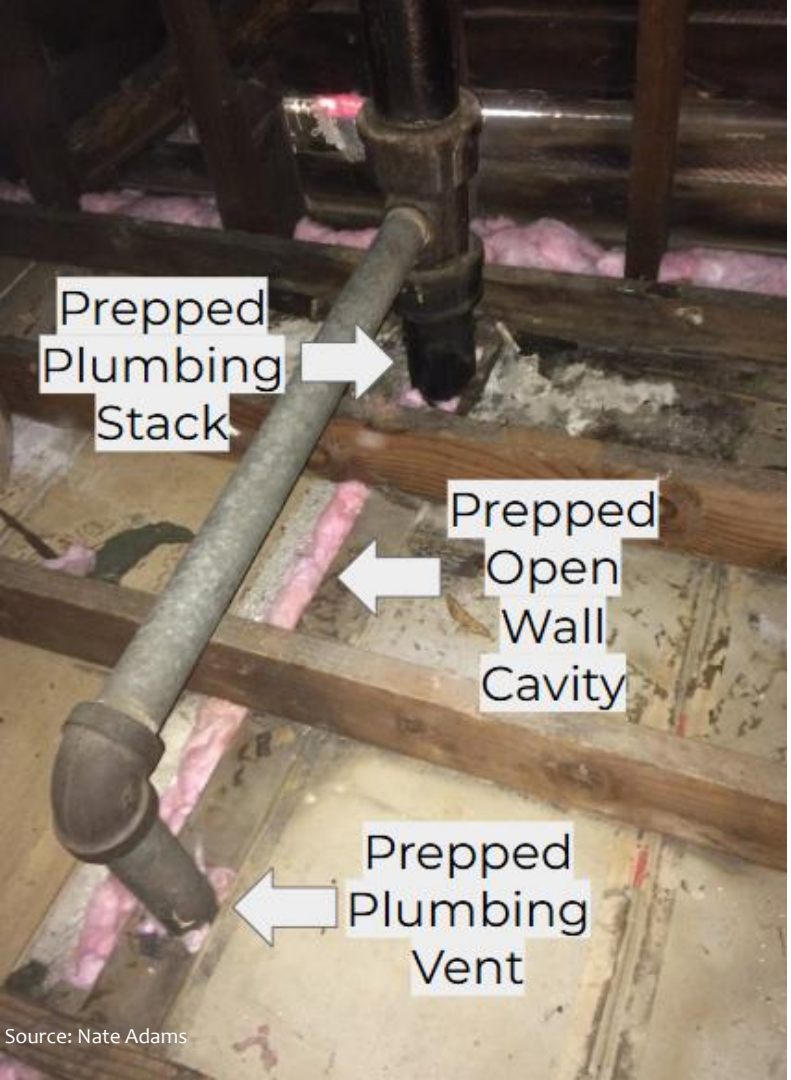


Ineffective Insulation

Air Leakage Before and After

Attic & underfloor <u>can</u> be fixed



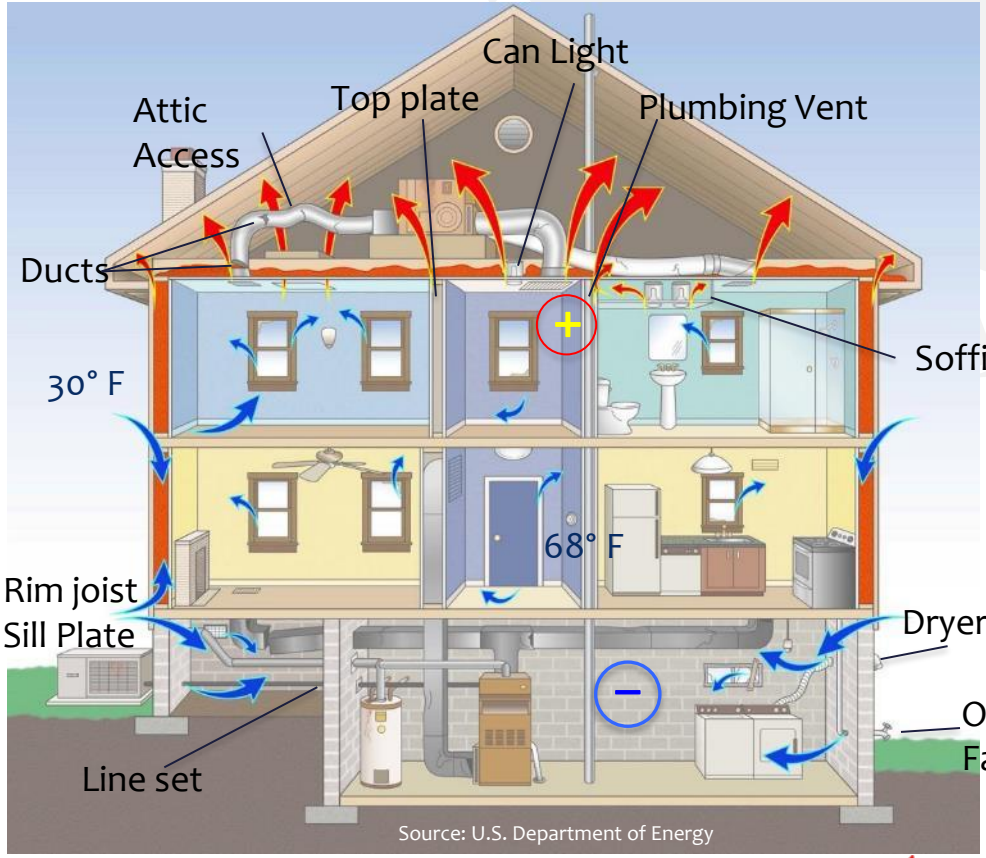
Source: Nate Adams

Wider Gaps?? Stuff w/ Fiberglass Insulation & Then Foam Over

STACK EFFECT

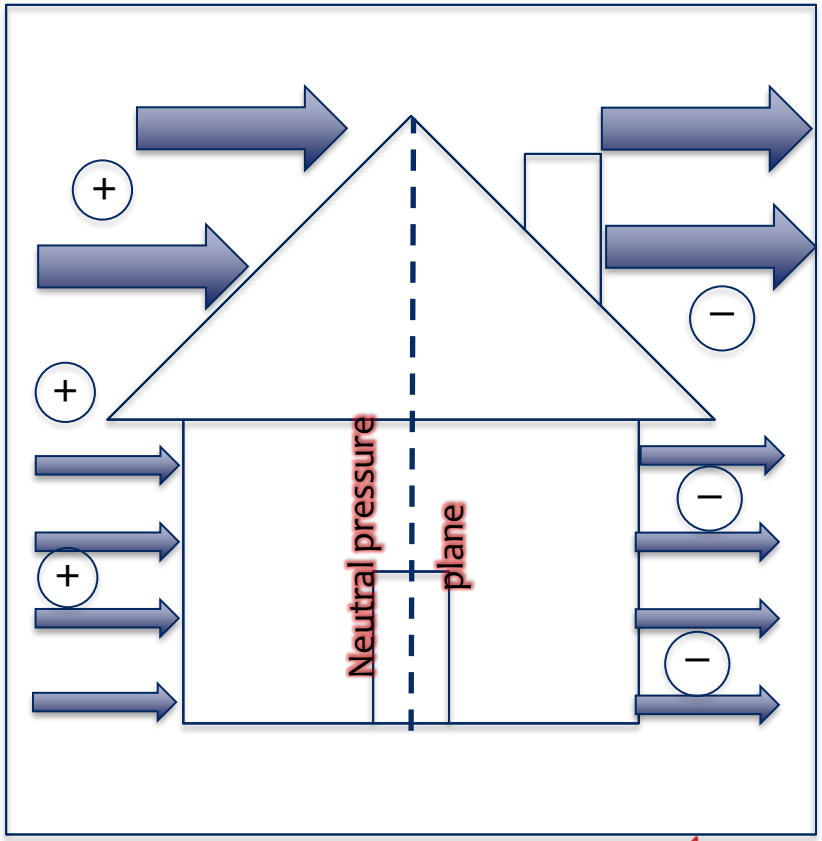
The effect of stratification within a building

- Warm, buoyant air rises and leaks out at the top
- Cold air leaks in from lower in the house (1 cfm in = 1 cfm out)
- The magnitude of this driving force depends upon:
  - The height of the home
  - The difference between the indoor and outdoor temperatures



WIND EFFECT

- Wind blowing against a wall creates a positive pressure area, which drives infiltration
- On the leeward side, negative pressure is created driving exfiltration of interior house air
- The taller the building the greater the wind's force against the home
- Wind speed (force) is affected by trees, fences, nearby buildings or hills



FLUE EFFECT

- Chimneys, vents and flues move air out of buildings, inducing infiltration to make up for that exiting air
- 1 cfm out always equals 1 cfm in

Photo courtesy of Judy Rachel

MECHANICAL EFFECT

- Possibly the largest driving force in a home
- When mechanical fans within a home can cause pressure imbalances to occur
  - Kitchen & bathroom exhaust fans
  - Clothes dryer
  - Whole house vacuum systems
  - Air handler
- These pressures can be large enough to double the home's air leakage rate

Significance of Mechanically-Induced Pressures

- Positive pressure creates **exfiltration** of conditioned air out of the affected zone
- Negative pressure creates **infiltration** of unconditioned air into the affected zone
- Negative pressure can **backdraft** any combustion appliances that are in the zone

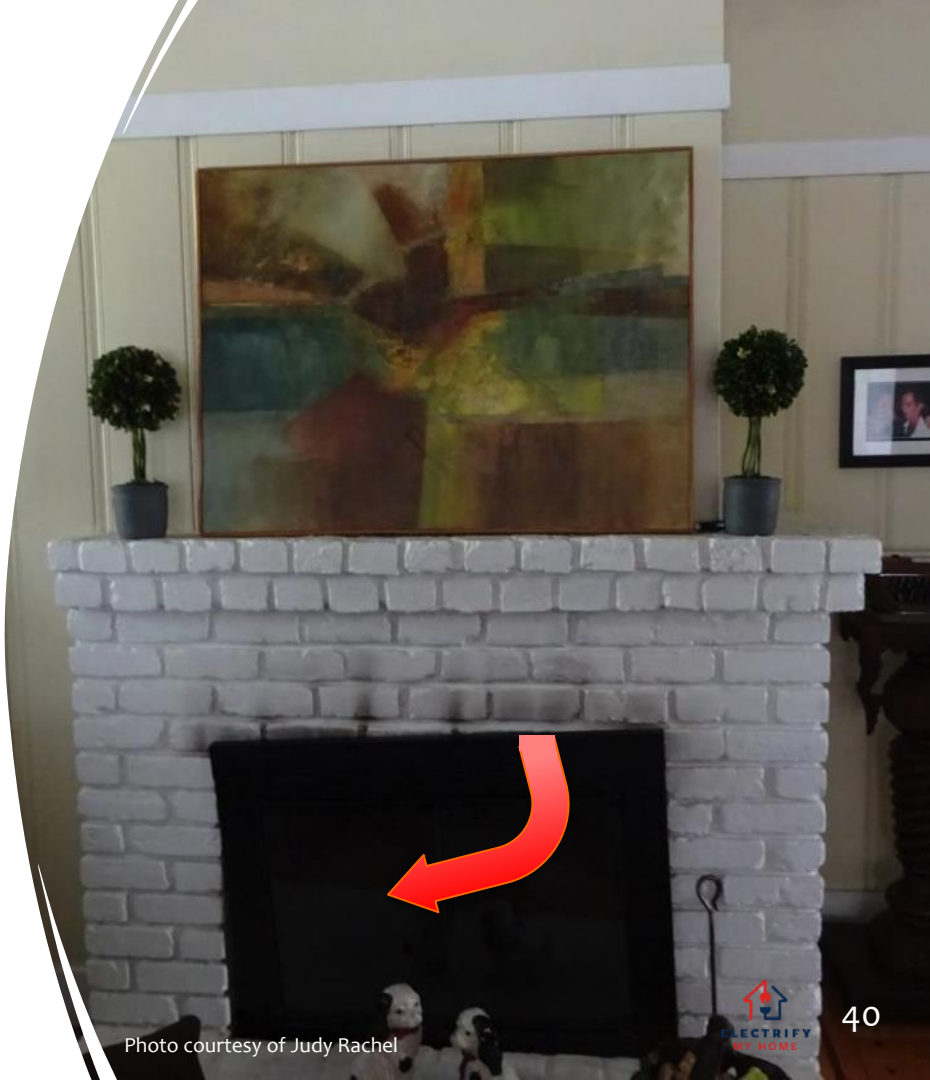


Photo courtesy of Judy Rachel

Doors and Mechanicals Can Create Pressure Imbalances

- Closing doors of rooms with forced air supplies can pressurize the room while depressurizing the neighboring space
- Closed doors can rob combustion appliances (e.g., natural draft water heater) of sufficient make-up or combustion air
    - This can cause spillage, flame roll-out or backdrafting

Driving Forces: Imbalances

Room Pressure Imbalances

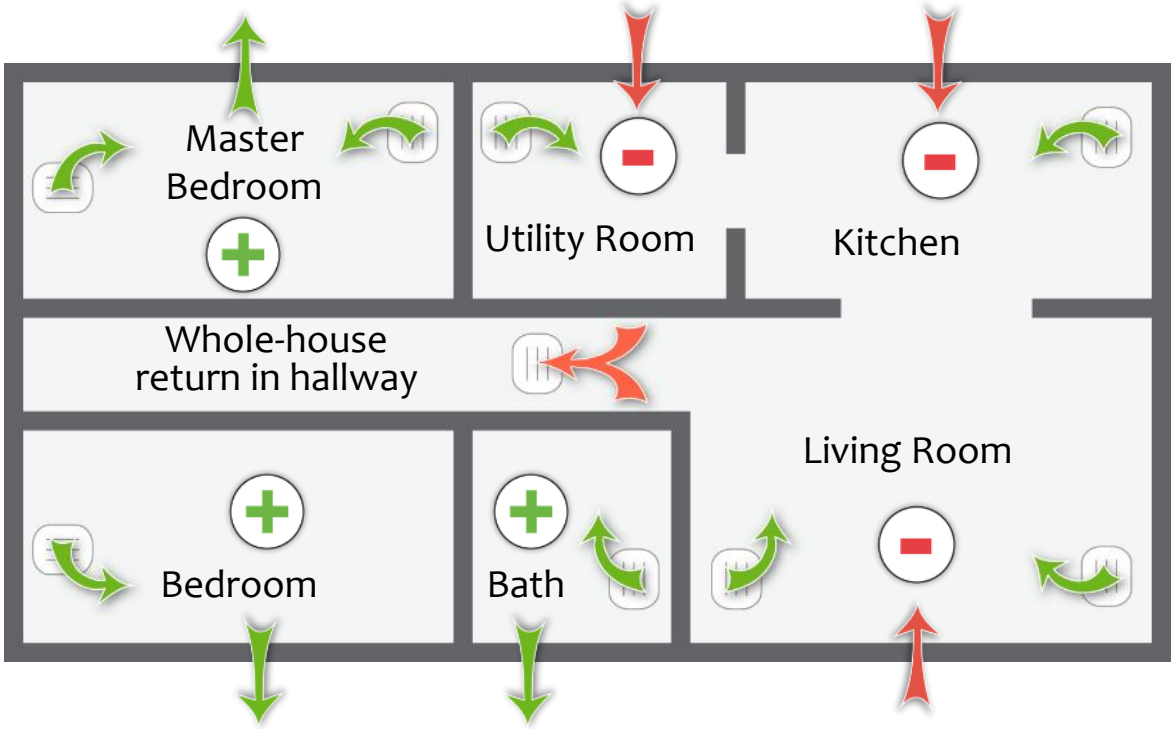


Photo courtesy of Judy Rachel

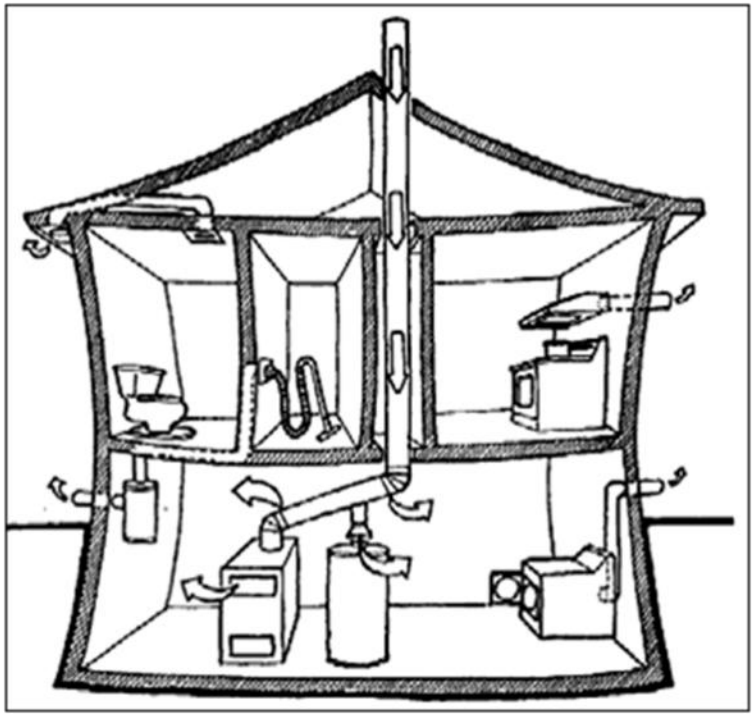
Combustion Appliances & Safety

- Most homes still have combustion appliances for heating, water heating, cooking or drying clothes
- The by-products of combustion can cause serious health problems and even death

Flue pipe condensation can be a sign of serious problems

Combustion Safety Overview

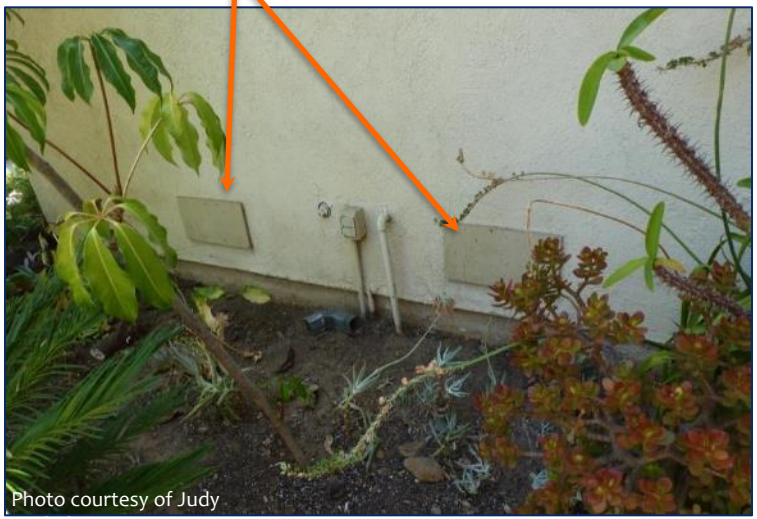
- Must properly vent appliances to outside
- Must provide adequate air to sustain draft
- Competition for air can cause combustion appliances to:
  - Spill their vent gasses back into the home
  - Cause flame roll-out
  - Extinguish pilot lights, causing natural gas to build up in the area around the appliance
- Tightly sealed houses mean even greater vigilance to ensure proper venting



Intentional Combustion Openings

- Never seal combustion air openings!

Look for this when you inspect the home



Large commercial range/oven with commercial range hood against this wall

Contractor blew insulation over combustion air inlets

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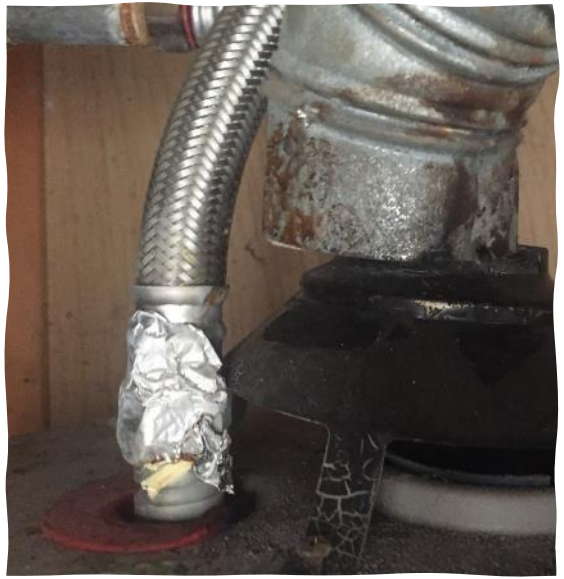
Check EVERY Water Heater at Every Job

- Many are spilling exhaust into the occupied space
- Ceiling interstitial wall cavities can make this worse
- Ensure you have enough combustion air

More Examples of Spillage



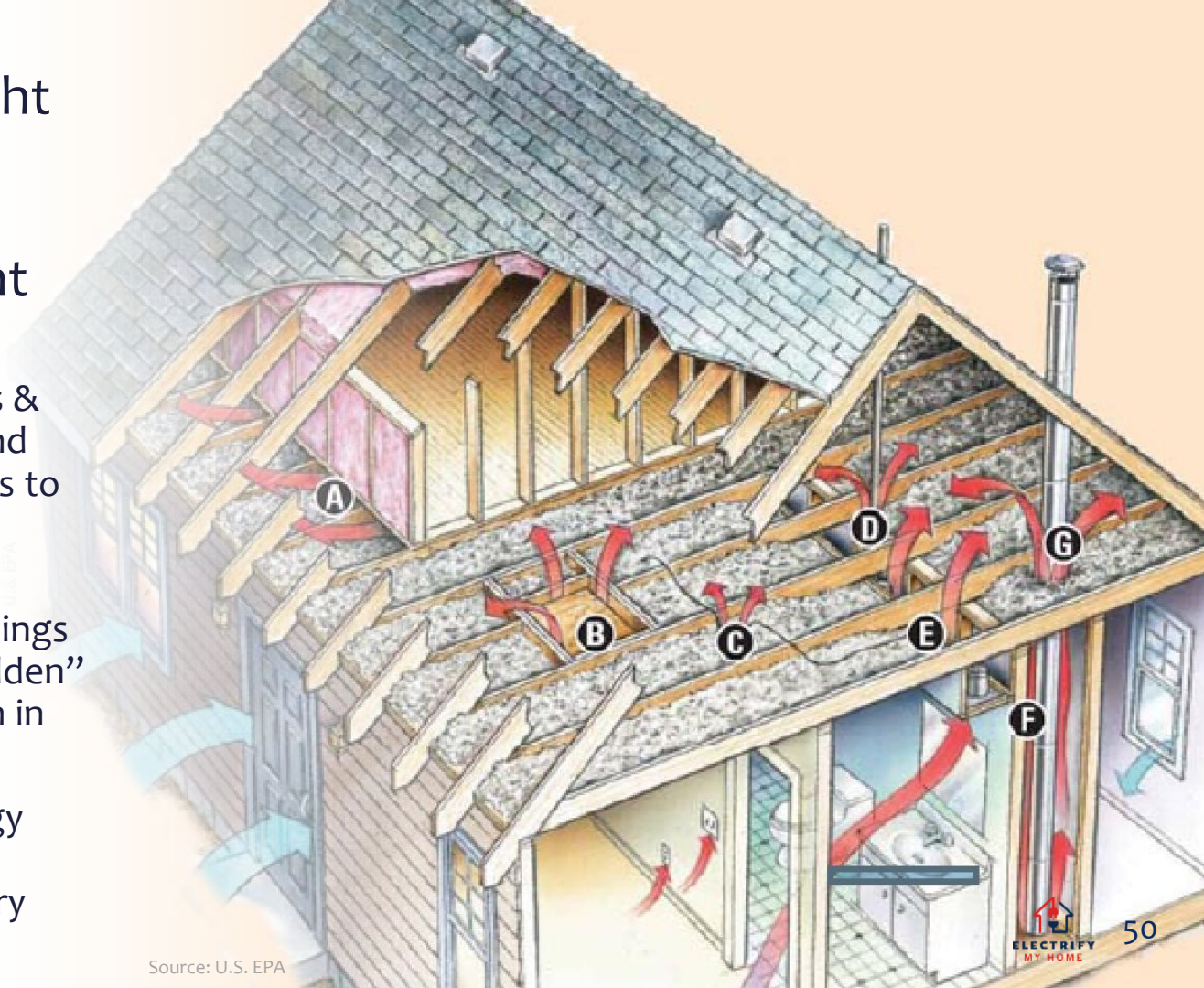

the Building Performance Workshop
IS YOUR WATER HEATER POISONING YOUR HOME?

DIAGNOSTIC TOOLS

How we measure condition and efficiency

Traditional Thought Has Been That Buildings Are Relatively Air Tight

- From 1975-1985 scientists & technicians developed and implemented instruments to assess air leakage
- The ability to evaluate performance of our buildings has shown there are “hidden” leaks from top to bottom in most homes
- Title 24, our state’s energy code, is requiring more performance testing every code cycle

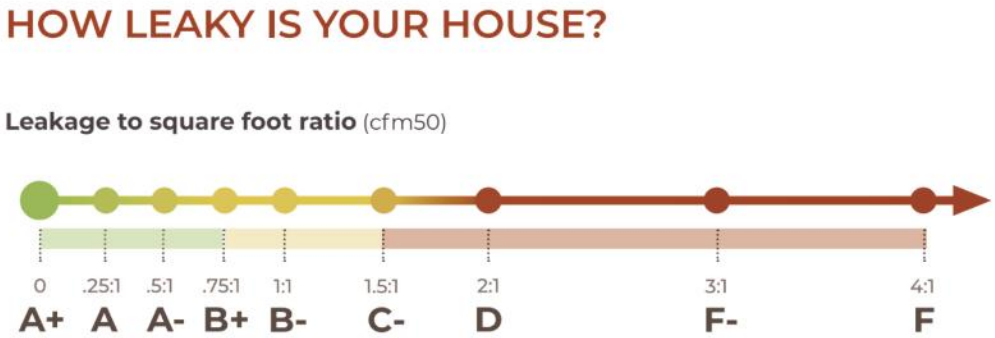


Source: U.S. EPA

Blower Door

Energy Conservatory Blower Door

- Quantifies air leakage
- Helps locate air leaks
- Measures the effectiveness of air sealing efforts
- Enhances infrared camera diagnostics
- Necessary part of duct leakage to the outside test



Source: Nate Adams

The Two Primary Blower Door Manufacturers

Energy Conservatory

Photos courtesy of Judy Rachel

T·E·C

Retrotec

retrotec

Manometer

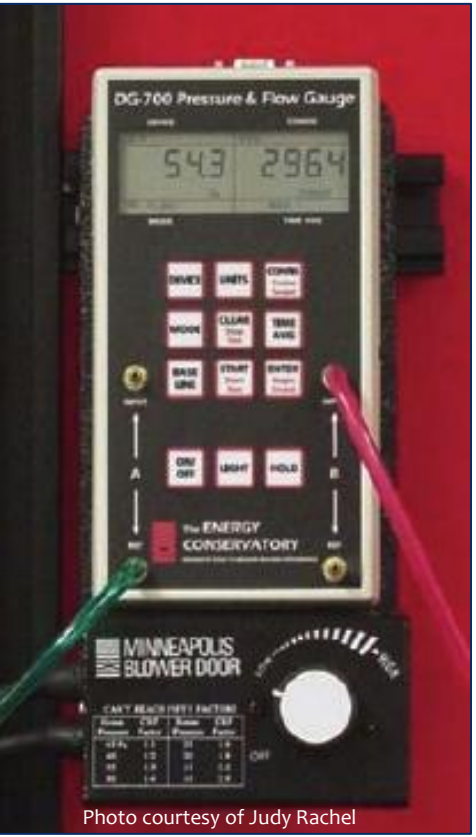


Photo courtesy of Judy Rachel

DG-700

- A multi-functional differential pressure gauge
- Provides high resolution pressure measurements. These all have 2 independent measurement channels.
- Accurately calculates air flow

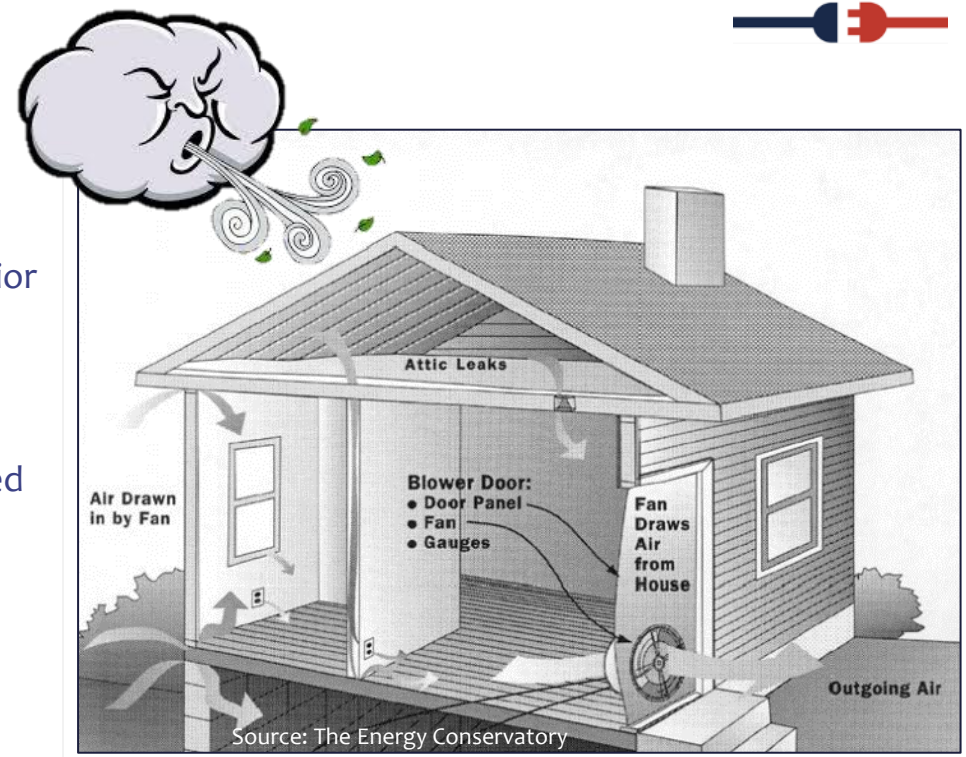
DM-2

DM32

DG-1000

Blower Door Test Set-Up

- Temporarily seal blower door system into an exterior doorway
- All exterior doors and windows of the house are closed
- All combustion appliances are turned off or disabled
- 2 hoses are attached to the manometer
  - 1 hose terminates outside the house
  - 1 hose connects to the blower door pressure sensor
- The fan blows air into or out of the house to create a 50 Pa pressure difference between inside and outside
- The manometer converts the air flow through the fan to CFM_{50} or ELA



Blower Door Depressurization Test

How A Blower Door Works

Remember the variables necessary for air flow to occur:

1. A hole (of a known size)
2. A pressure across the hole (Pascals)
3. Creates air flow (CFM)

(If you know any two, you can calculate the third)

The manometer measures the pressure past the fan's pressure sensor and converts the pressure reading to air flow in CFM_{50}

Using the controller, the fan is turned up until a 50 Pa pressure difference is created between the house and outside

Hoses connected to the manometer measure pressure difference across fan and from inside to outside

Hole of a known size

Duct Testing Equipment

A calibrated air flow measurement system designed to test and document the air tightness of forced air duct systems

- Estimate HVAC losses from duct leakage
- Diagnose duct leakage locations
- Measure quality of duct system installation
- Document and certify duct leakage compliance for building code

Retrotec DucTester System

Energy Conservatory Minneapolis Duct Blaster

Duct Blaster

Can be used to accurately measure total air flow through the air handler using the plenum pressure matching procedure

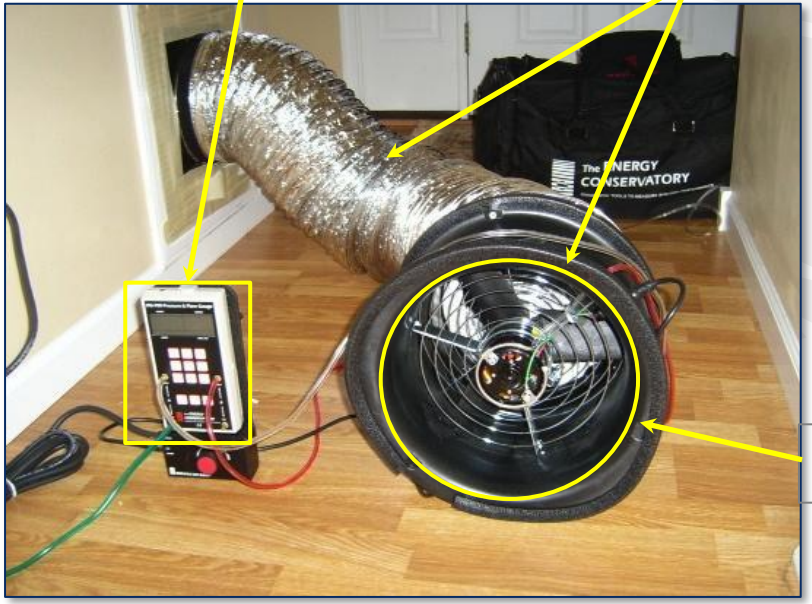
- Used as a powered flow hood to accurately measure total air flow through supply and return registers, exhaust fans and other air flow devices
- Can be used as a small Blower Door to test the airtightness of small or tightly built houses

Duct Leakage Testing

- Duct air-tightness determined by measuring duct system at a uniform test pressure with the duct blaster fan
- The duct tester is connected to the return intake
- The duct system is temporarily sealed off and pressurized to 25 Pa

The manometer converts the pressure reading to CFM_{25}

With the fan a 25 Pa pressure difference is created between the house/outside and the duct system



Hole of a known size

Infrared Inspection

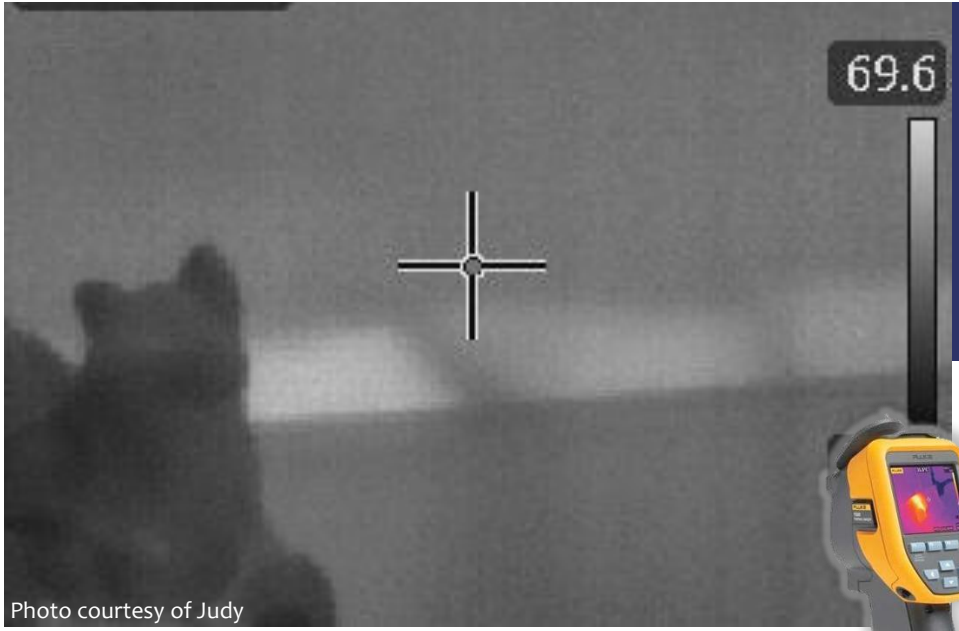


Photo courtesy of Judy

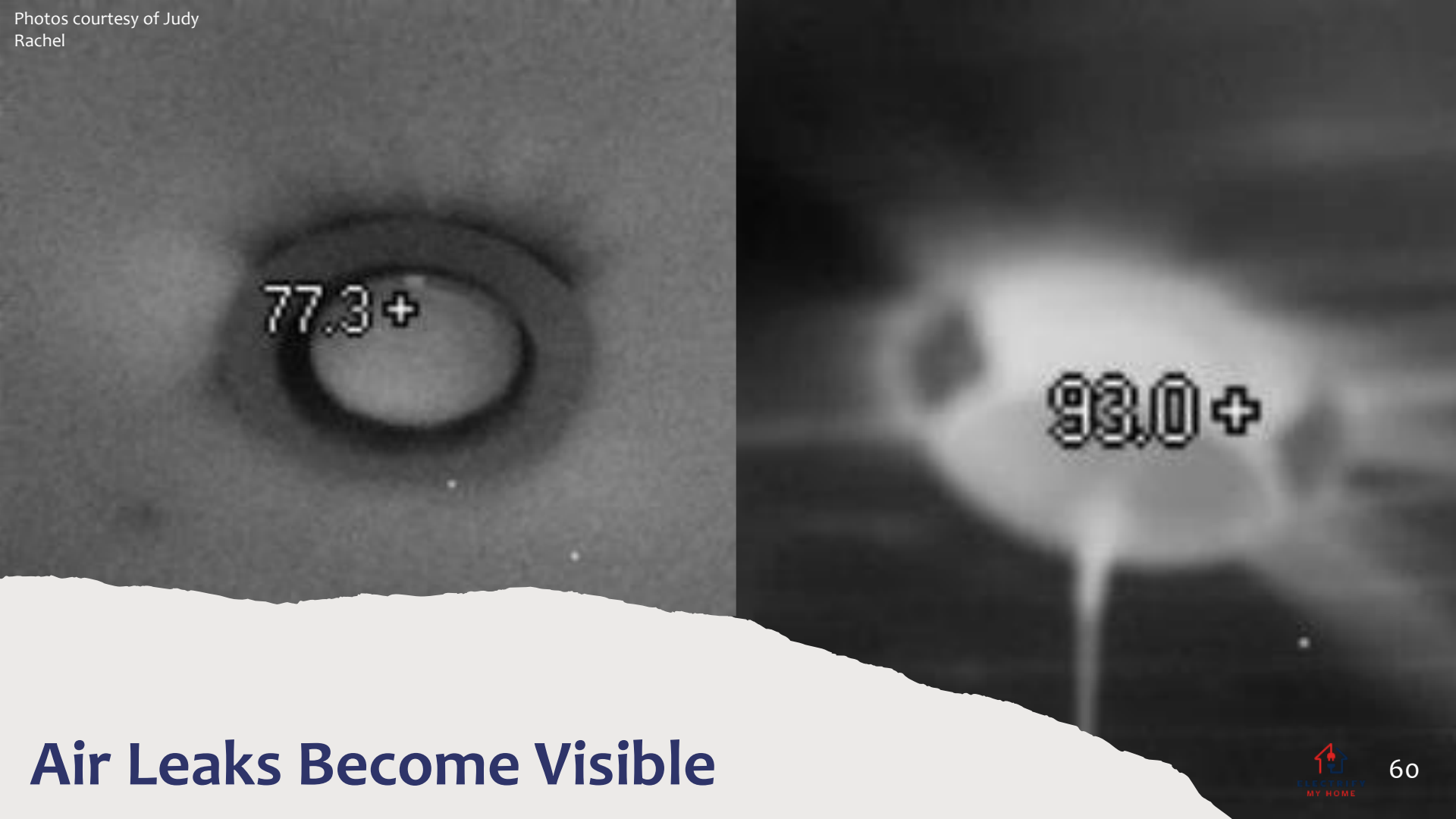
Provides the ability to locate:

- Air leaks
- Thermal bridging
- Missing or poorly performing insulation

Fluke

Flir

Photos courtesy of Judy Rachel



Air Leaks Become Visible

Photo courtesy of Judy Rachel

Air Leaks Become Visible

Air Leaks Become Visible

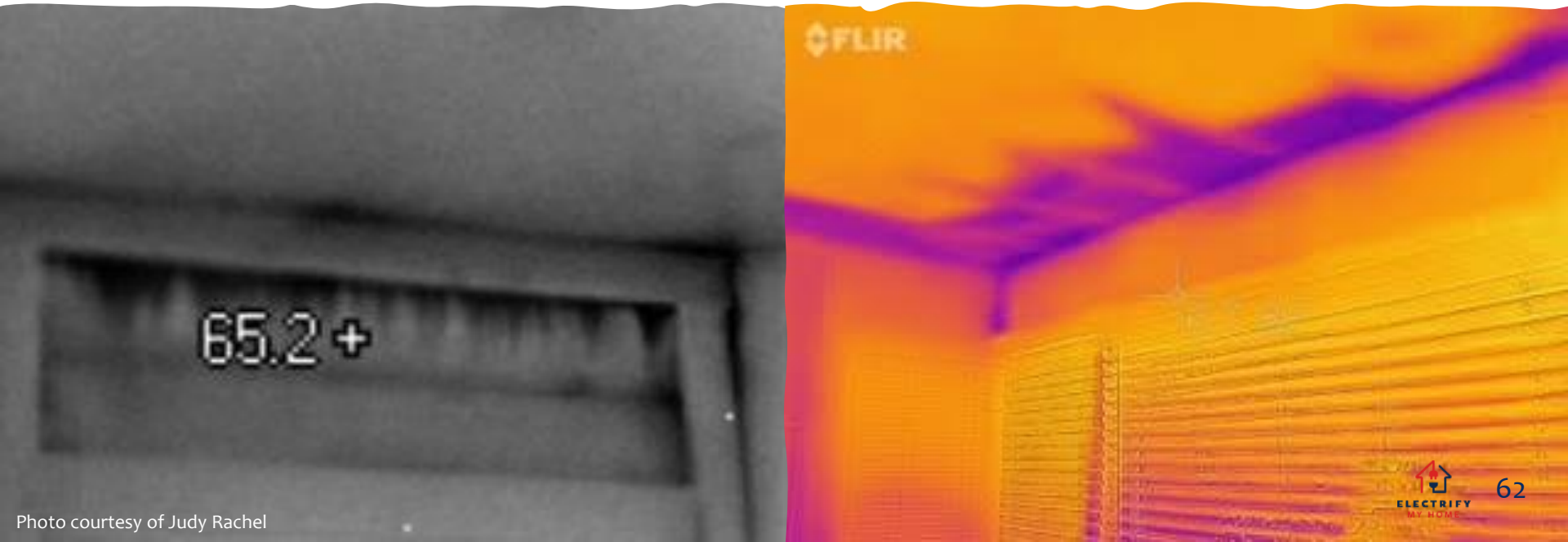
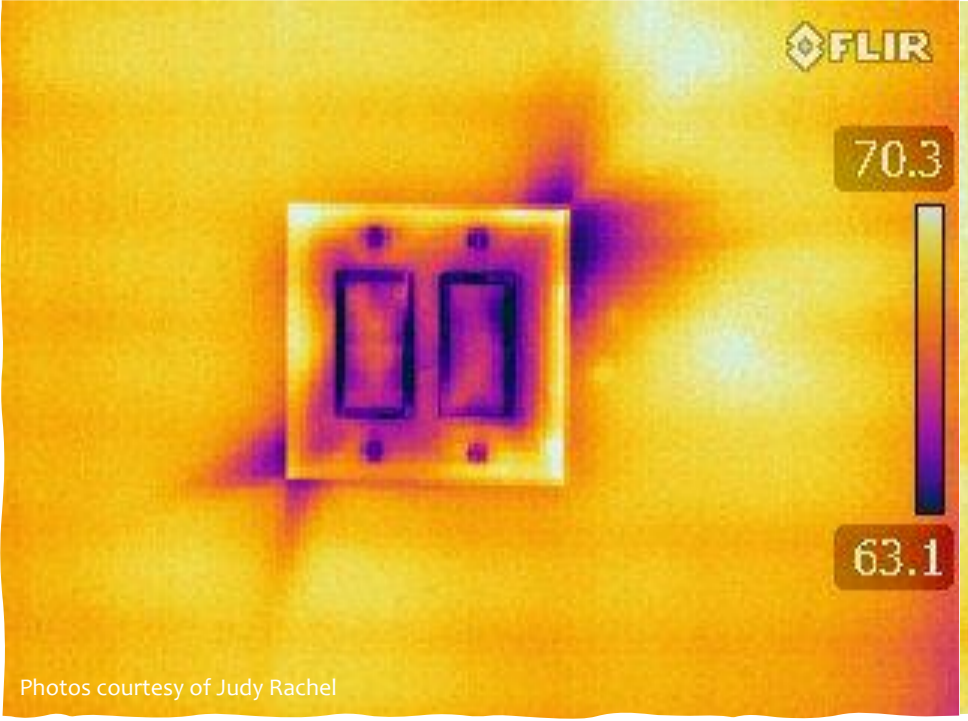
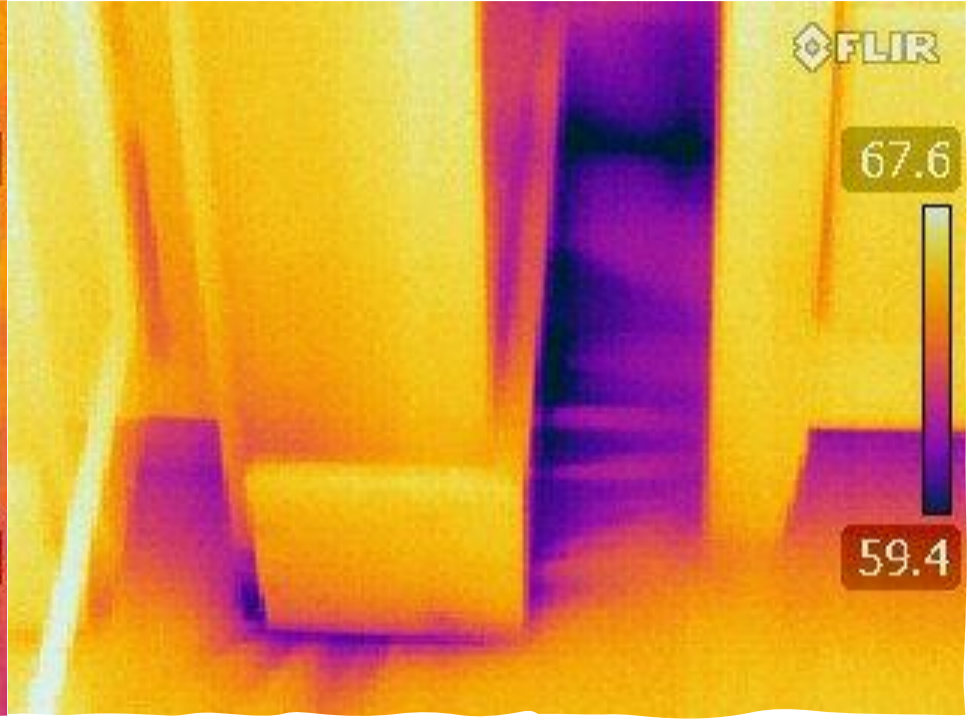


Photo courtesy of Judy Rachel

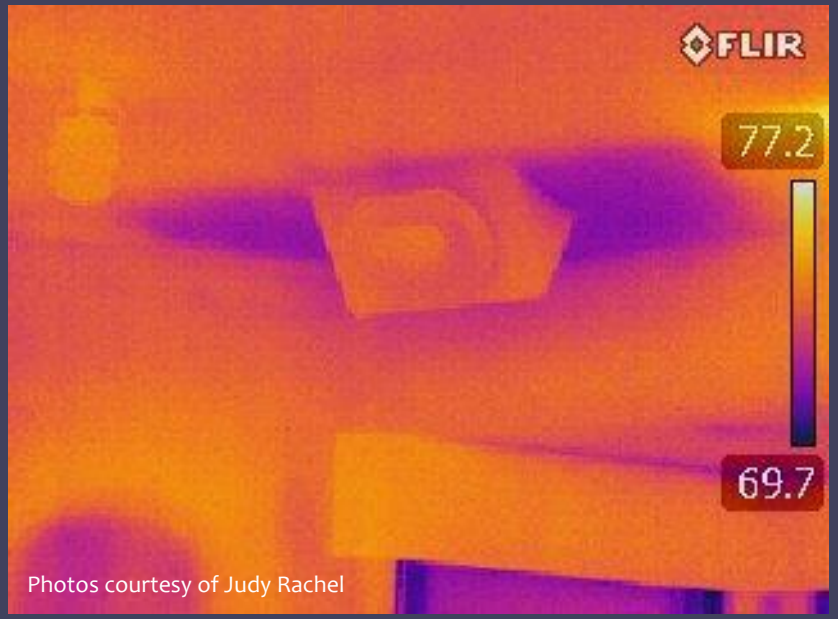




Photos courtesy of Judy Rachel

Air Leaks Become Visible

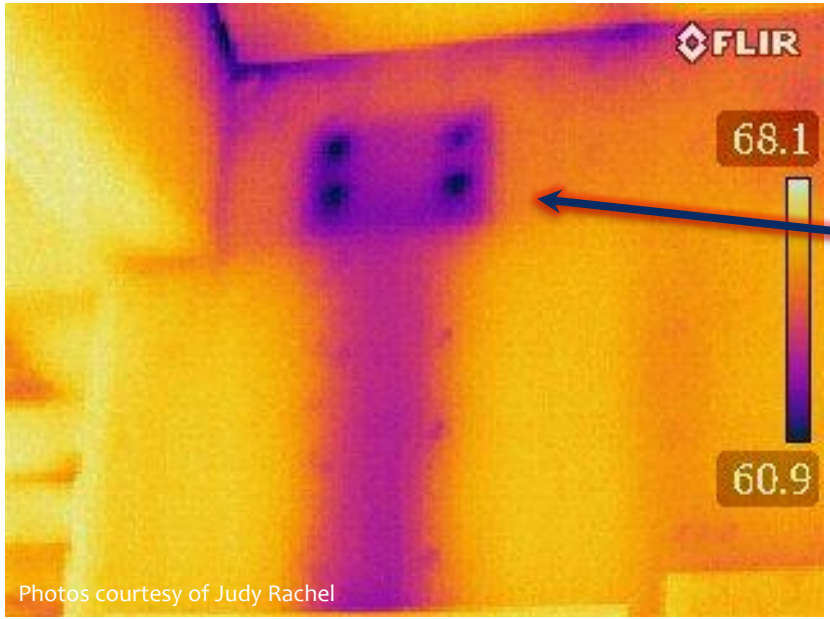
Insulation Flaws Become Visible



Photos courtesy of Judy Rachel

Insulation Flaws Become Visible

Photos courtesy of Judy Rachel



Photos courtesy of Judy Rachel

Conduction Issues Become Visible

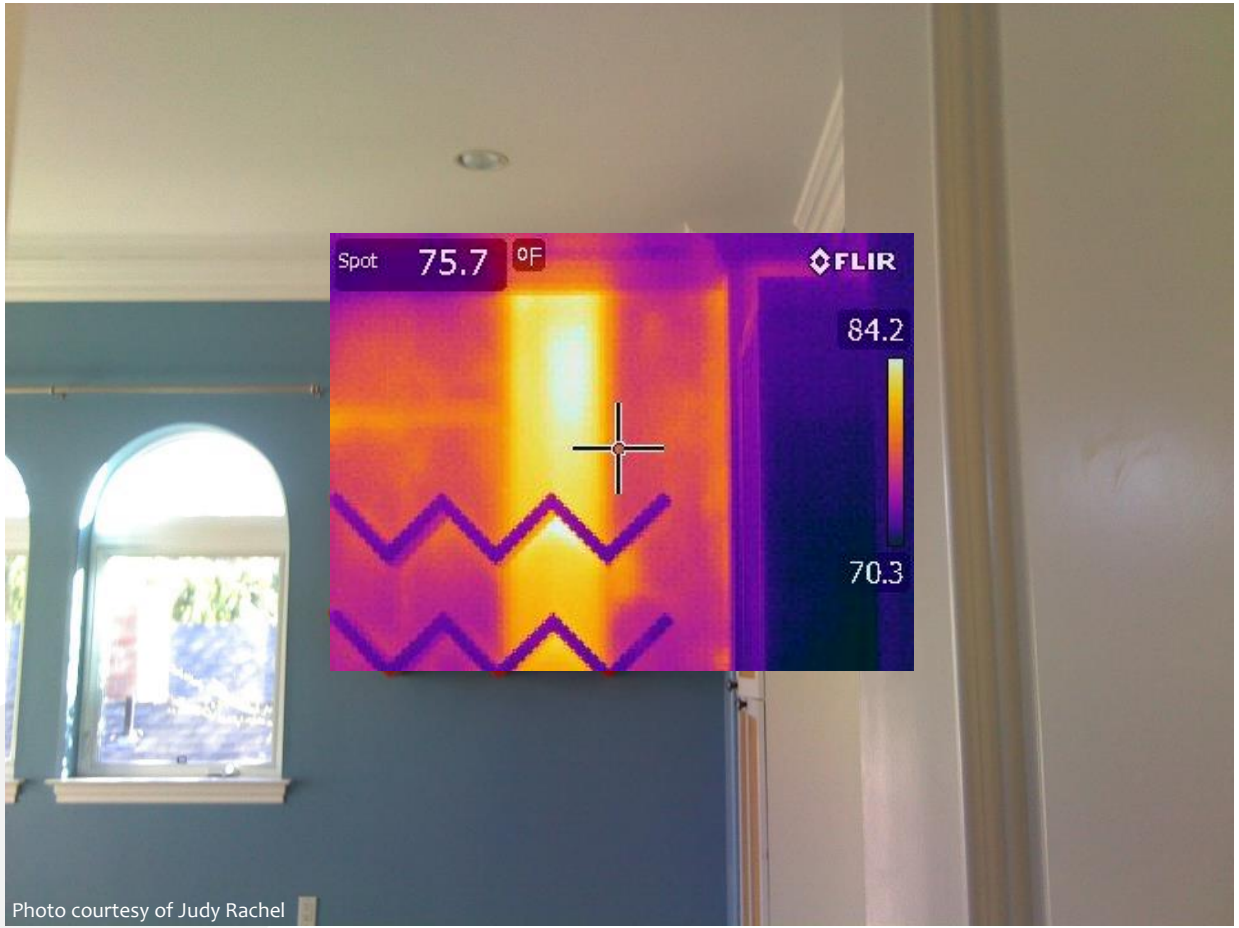


Photo courtesy of Judy Rachel

Hidden Chases Become Visible

Air Sealing & Improving the Building Enclosure Reduces Heating and Cooling Loads

Blocking and sealing this interior chase removes what was an "exterior" space in the middle of the home.

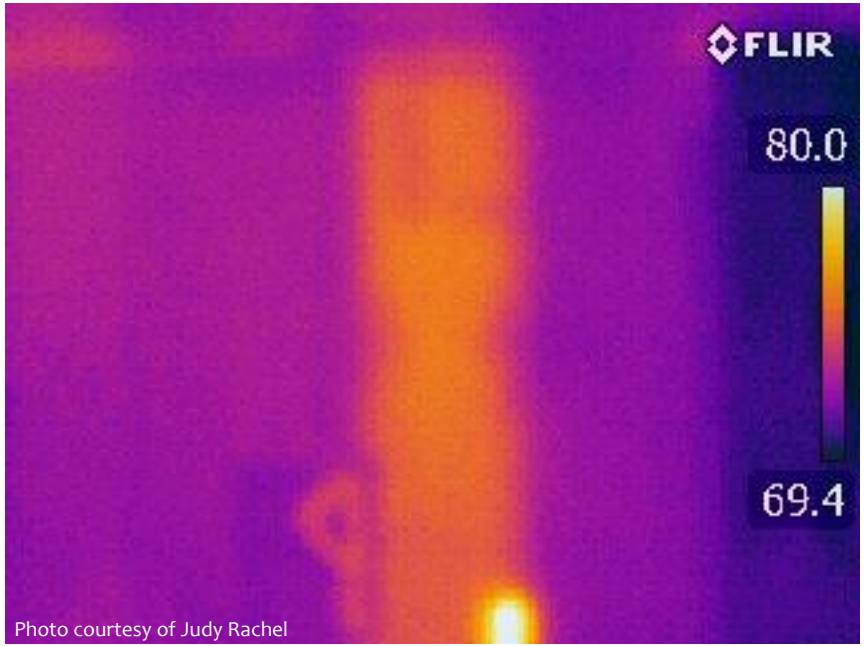


Photo courtesy of Judy Rachel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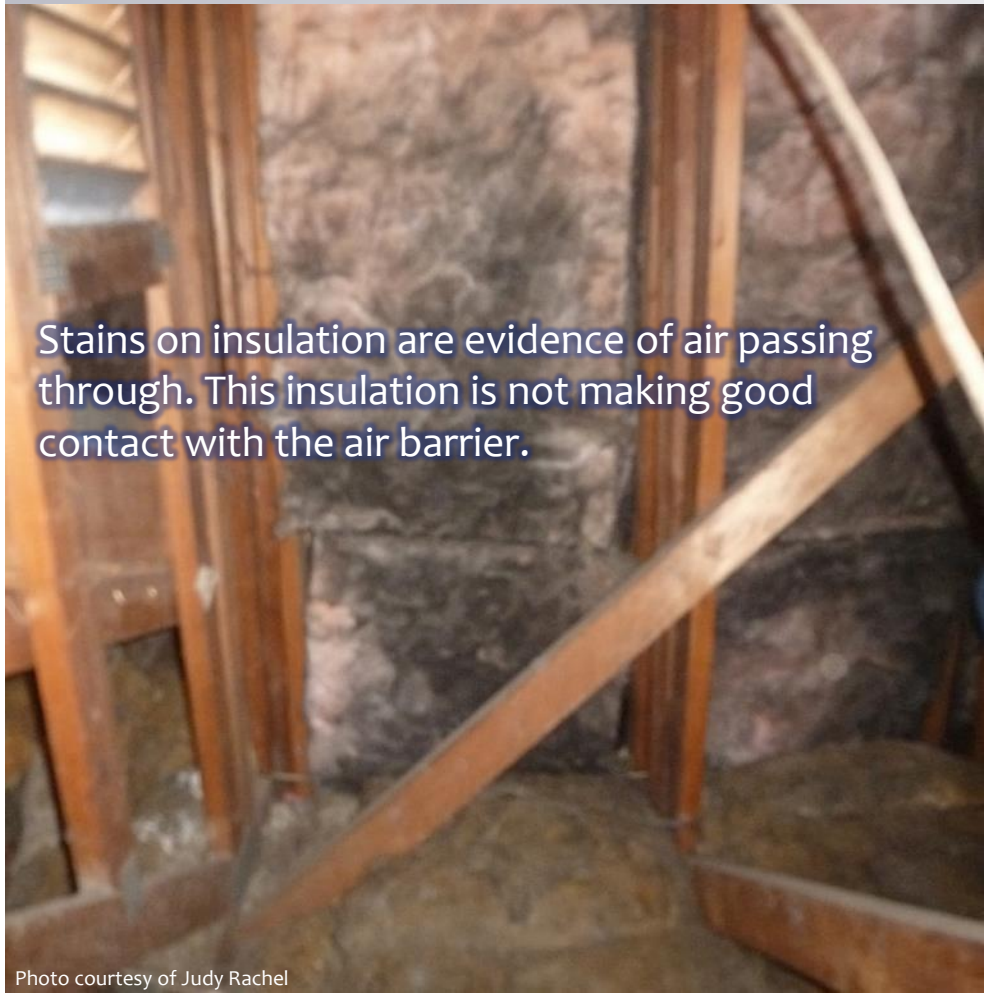

Insulation Performance Factors

- No gaps or voids
- No compression

- In continuous contact with an air barrier

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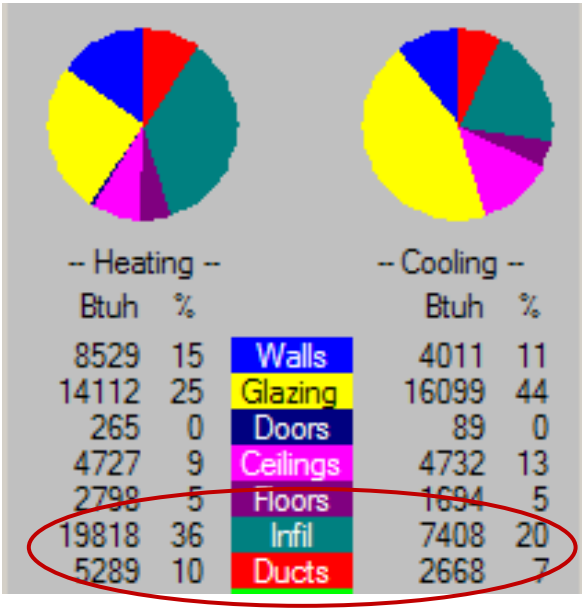
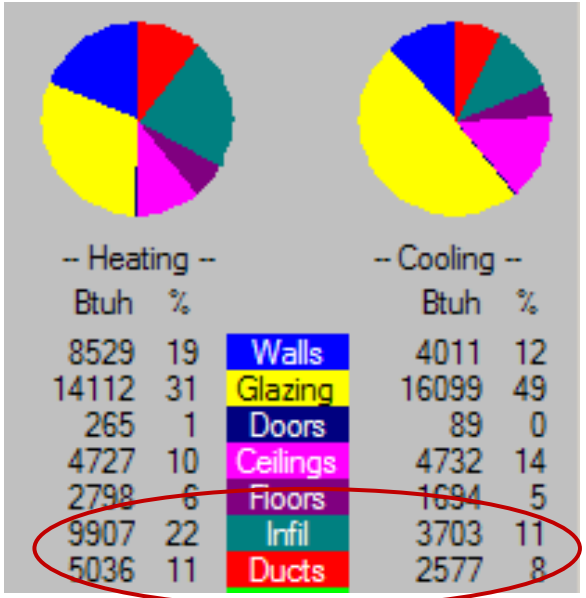
Infiltration is a Significant Portion of the Heating and Cooling Loads

Reducing loads = Smaller equipment

Existing Home:
5145 cfm_{50} = 12.4 ACH_{50}



50% reduction
2572 cfm_{50} = 6.2 ACH_{50}



Benefits of air sealing missed by load calculations

- Increased effectiveness of insulation
- Reducing "exterior" surface area by sealing interstitial cavities, chases and dropped soffits

Photo courtesy of Judy Rachel

Deferred Maintenance

Pre-Electrification Obstacles

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Photo courtesy of Judy Rachel


Photo courtesy of Judy Rachel

Fix Electrical Hazards

Any electrical work that cannot or should not be buried in the insulation should be ***moved above the insulation level***

Photo courtesy of Judy Rachel

Photo courtesy of Judy Rachel

Upgrade Electrical Hazards

...for example, Knob and Tube Wiring

Pre-Electrification Obstacles

Photos courtesy of Judy Rachel

Identify Non-IC Versus ICAT Recessed Lights

- Replace Non-IC rated fixtures with ICAT fixtures. There must be 3” of clearance on all sides of a non-IC rated fixture. This can significantly reduce the overall effective R-value of the insulation on the attic floor.


Photo courtesy of Judy Rachel

Non-insulation contact: Not intended for insulation contact. Do not install insulation within 76 mm (3 in) of any part of the luminaire.


Photo courtesy of Judy Rachel

Insulation contact: Intended for insulation contact The luminaire may be in direct contact with combustible materials and insulation.

Combustion Hazards

- Clearance must be maintained around chimneys and flues of any still-existing combustion appliances

Stand-offs Need to be Built Around Combustion Vents


Photo courtesy of Judy Rachel

Taller than insulation level will be with 1” clearance all the way around vent

Not tall enough for what insulation level should be. Needs high temperature sealant.


Photo courtesy of Judy Rachel

Moisture Hazards

Identify and repair plumbing leaks

Moisture laden air from bathroom & laundry room exhaust fans must be vented completely to the outside

Fire Sprinklers

Photo courtesy of Judy Rachel

Photo courtesy of Judy Rachel

Rodent Entry and Contaminants

Rats used line set penetration as access into an attic

Are Exhaust Fans Functioning?

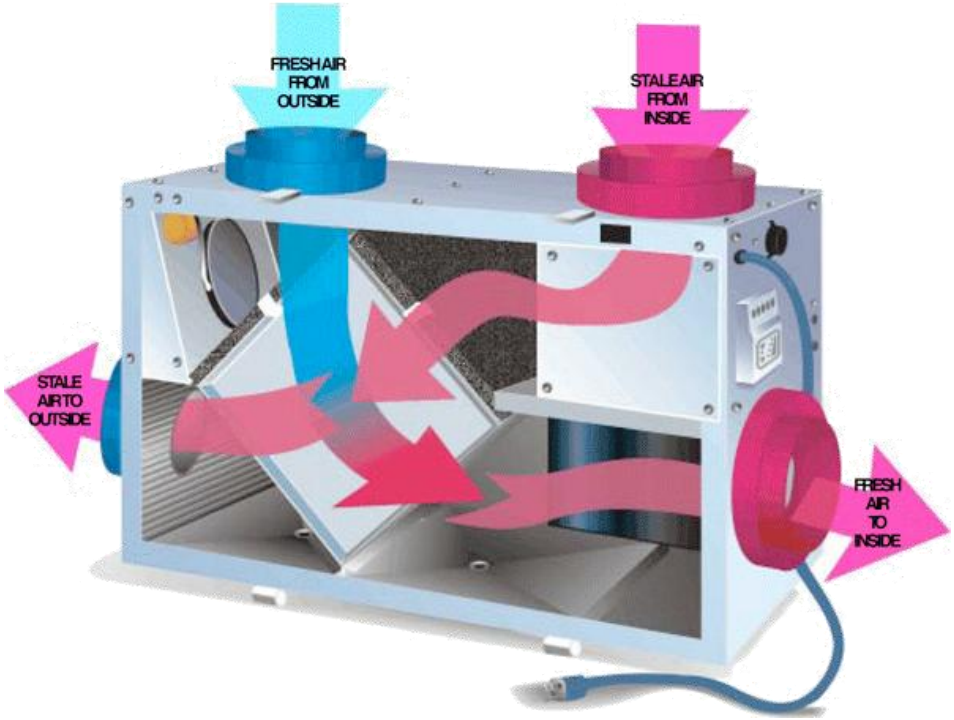
Photo courtesy of Judy Rachel


Photo courtesy of Judy Rachel

The “V” in HVAC

The Most Ignored Opportunity

Ventilation



Ventilation systems, when well designed, installed, operated and maintained, are preferable for meeting the ventilation requirements of buildings and provide opportunities to control the energy impacts and to recover some of the associated heat (cool) from the outgoing air. (Persily and Emmerich, 2012)

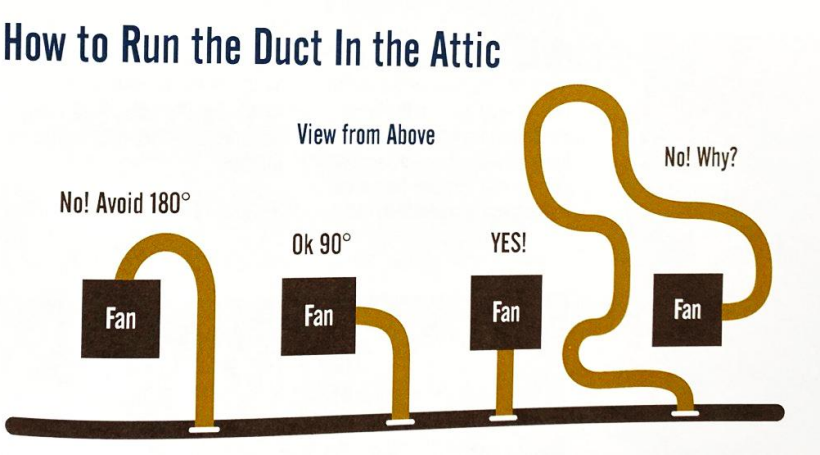
Bath Fans = Vent & Run Them Right!

Yes!
Roof

Yes!
Out the Wall

No!
Avoid Soffits

Into the attic?
Oh, the horror



Sources: The Home Comfort Book, Nate Adams

Indoor Air Quality

- Indoor air is a dominant pathway for exposure to airborne contaminants
- People spend the majority of their time (90%+) indoors
- Indoor air commonly contains numerous contaminants originating from both indoor and outdoor sources
- Concentrations of many contaminants are higher indoors than outdoors
- The health and economic benefits of improved IAQ are far greater than the costs of implementing these improvements

Air Leakage Versus Mechanical Ventilation

Infiltration is not a good way to ventilate a building since the rates are not controlled, nor is the air distribution within the building. (Persily and Emmerich, 2012)

Air Leakage	Mechanical Ventilation
Brings pollutants in	Dilutes & removes indoor pollutants
Uncontrolled entry of air through unintentional openings	Controlled amount of air through intentional openings
No control over source of air	Filtered air from clean, dry source
Moves randomly through building	Flows through building per design
Significant, wasteful portion of heating and cooling load	Small, integral portion of the heating and cooling load
Detracts from a healthy indoor environment	Contributes to a healthy indoor environment

Be Aware of Interactions

- **Exhaust Only Ventilation** can be detrimental to indoor air quality because we have no way to control the path the make up air takes through the building.
- **Exhaust Ventilation** can cause back-drafting of combustion equipment.
- **Supply Only Ventilation** can drive moisture into the building enclosure at high flow rates.
- **Supply and Exhaust Ventilation** without heat recovery has consequences for conditioning costs as it brings in unconditioned air from outside.

Ventilation Choices

- Spot or Local Ventilation
  - Kitchen exhaust - **Essential**
  - Bathroom exhaust
    - Can be integrated as part of the balanced ventilation system

- Whole House Ventilation
  - Exhaust
  - Supply - **Separate from HAC system**
  - Balanced
    - HRV – Heat Recovery - **Good choice for Dry Climates**
    - ERV – Moisture and Heat Recovery

HRV - Balanced Ventilation with Heat Recovery

...a Good Choice for Homes in Dry Climates

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Part 3, Quiz 1: Building Enclosures

TRUE OR FALSE:

____ 1) The pressure boundary separates the conditioned space from the outside and is the point that should be insulated.

____ 2) The thermal boundary is where insulation makes contact with the air barrier.

____3) It is important to seal all interstitial wall cavities connected to the attic space.

____ 4) Every home needs to be completely sealed in order for a heat pump to work

____ 5) Turning on a ceiling fan (not a bath fan) can cause exfiltration.

____ 6) Water heater spillage into the conditioned space is very common.

11) What Is the purpose of the air barrier?
A) Control air flow inside to out
B) Stop wind from getting in the house
C) Perform as one portion of a thermal barrier
D) All of the above

12) A leaky return located in the attic can cause:
A) Exfiltration
B) Infiltration into the building envelope

13) A thermal imaging camera is especially good for what use?
A) Spotting voids in the insulation
B) Visualizing air leakage during a blower door
C) Determining duct leakage points
D) All of these

Part 3, Quiz 2: Comfort, Sizing, Airflow, Ducts

1) Name three common comfort problems in a home

_____
_____
_____

2) Supply grilles should be sized to provide velocities in which range?

A. 100 – 300 FPM
B. 300 – 500 FPM
C. 500 – 700 FPM
D. 700 – 800 FPM

2) Which of the following is NOT a step in proper air balancing?

A. Install diffusing grilles
B. ACCA Manual J
C. Air supply to the unoccupied portion of the room to avoid drafts
D. Room air flows adjusted to within 10% of room loads

3) What should you do at the thermostat in every home?

A. Place it 3-4 feet from the ground
B. Caulk the wire hole behind the t-stat
C. Locate it in an area most utilized by occupants
D. B & C
E. All of the above

4) Which of the following devices can be used to measure air flow?

A. Duct blaster
B. TrueFlow Grid
C. Capture hood/balometer
D. All of the above

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Questions?

Turn it on. Relax. We've got you covered.

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