



MAD-AIR 2015

Mechanical Air Distribution and Interacting Relationships

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1988 Original Paper

Google search: Mechanical Air Distribution
and Interacting Relationships

<http://repository.tamu.edu/bitstream/handle/1969.1/6566/ESL-HH-89-10-05.pdf?sequence=3>

MAD-AIR Agenda

- System thinking
- A few air flow fundamentals
- 26 house study of pressure differences
- Soil depressurization study
- % of house air originating from the garage
- % of house air originating from the crawl space
- Code changes that effect MAD-AIR
- Real world effects

Dealing With Houses Requires System Thinking

House

A system is a whole that derives its characteristics (good or bad) from the interactions of its essential parts.....and none taken separately.





The essential parts to make an Oak tree

The essential parts to make an Oak tree



The essential parts to make an Oak tree



+



The essential parts to make an Oak tree



+



+



The essential parts to make an Oak tree



+



+



+



The essential parts to make an Oak tree



+



+



+



All are Essential - None are Sufficient

The essential parts to make an Oak tree



+



+



+



All are Essential - None are Sufficient

Taken separately none will produce a healthy oak tree.

A House Is a System



All are essential, none are sufficient

No part of the house is a house; only the whole is

System Thinking

Characteristics

- The defining behavior of a high performance home
 1. Healthy and safe
 2. Durable
 3. Comfortable
 4. Energy efficient
 5. Environmentally responsible





A system is a whole that derives its characteristics from the interactions of it's essential parts....and none taken separately

MAD-AIR Demands Homes Be Viewed As A System

- ▶ A **HOME** is a whole that derives its characteristics or behavior from the interactions of its essential parts.....and no part taken separately.



Change has either a.....



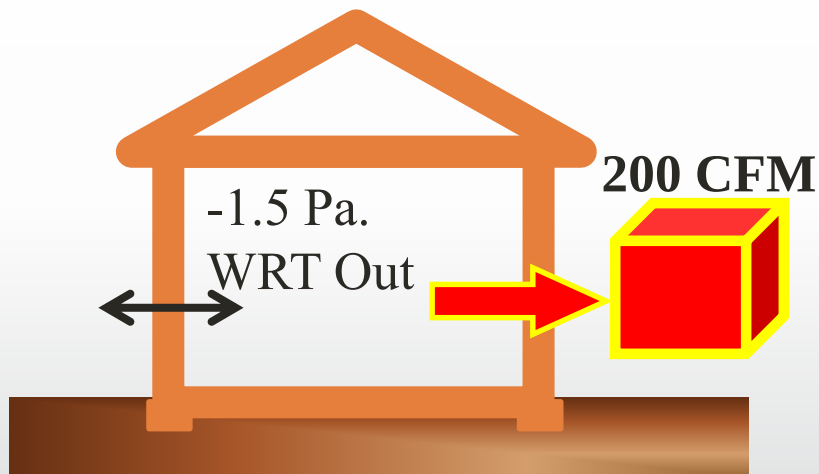
- Building products

- Codes
- Standards
- Specifications

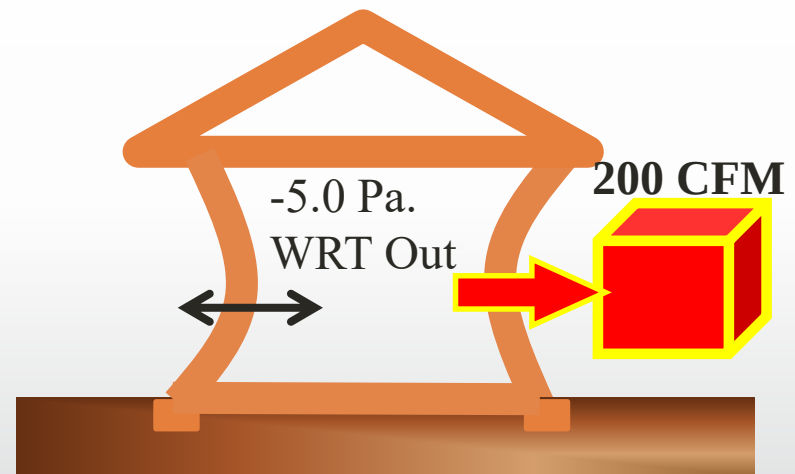
- House tightness
- Duct tightness
- Equipment efficiency
- Fan efficiency

MAD AIR Facts

- The tighter the house envelope, the greater the pressure between inside and out.



Leaky House
2,200 CFM₅₀
7 ACH⁵⁰



Tighter House
800 CFM₅₀
4 ACH⁵⁰

Assumes 1500 square feet with average ceiling height of 8'

3 Driving forces

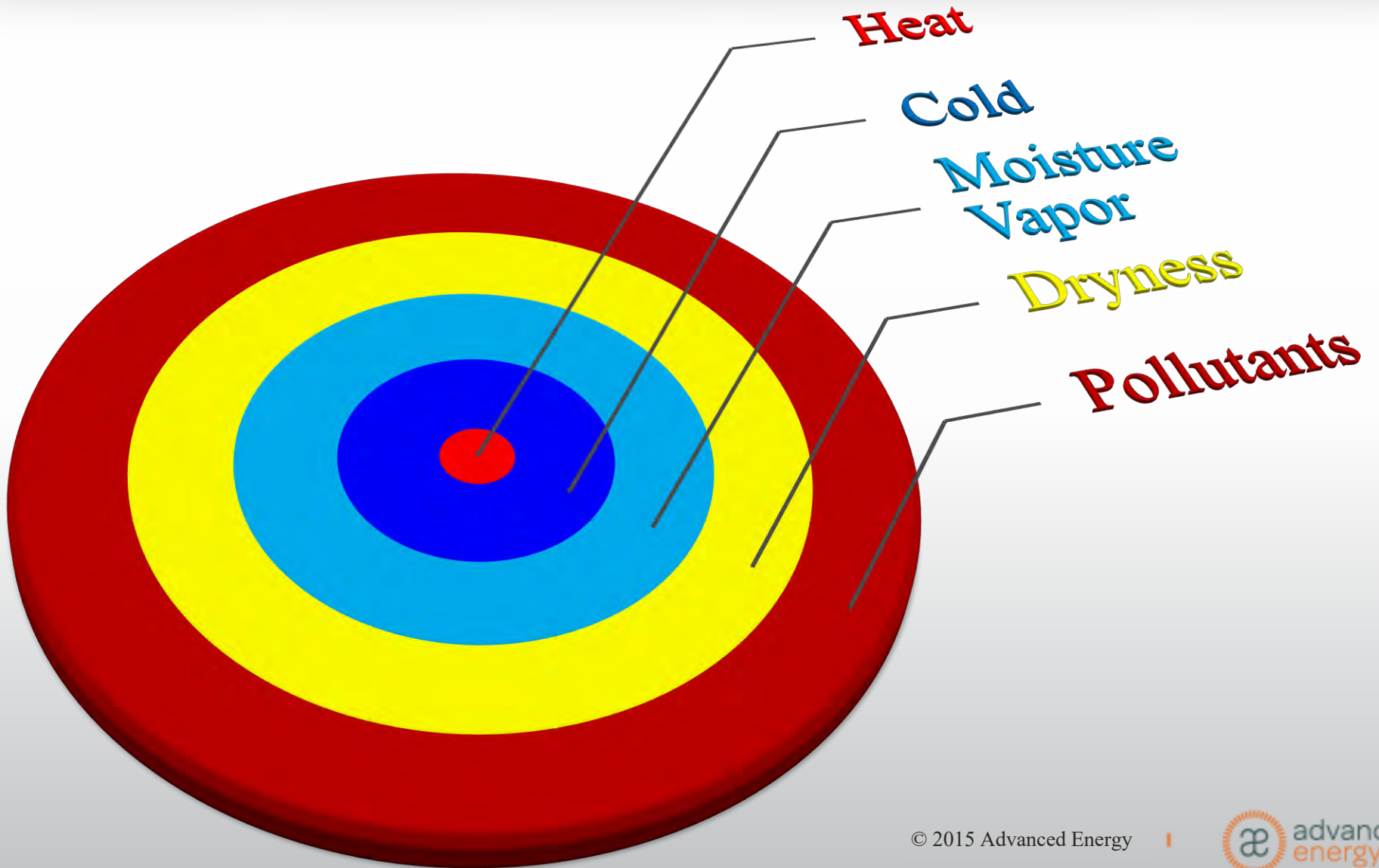
1. Wind

2. Heat (stack pressure)

3. Fans

- Duct leakage
- Interior door closure
- Exhaust and supply fans
- Imbalanced flow in zones

Air Is A Carrier



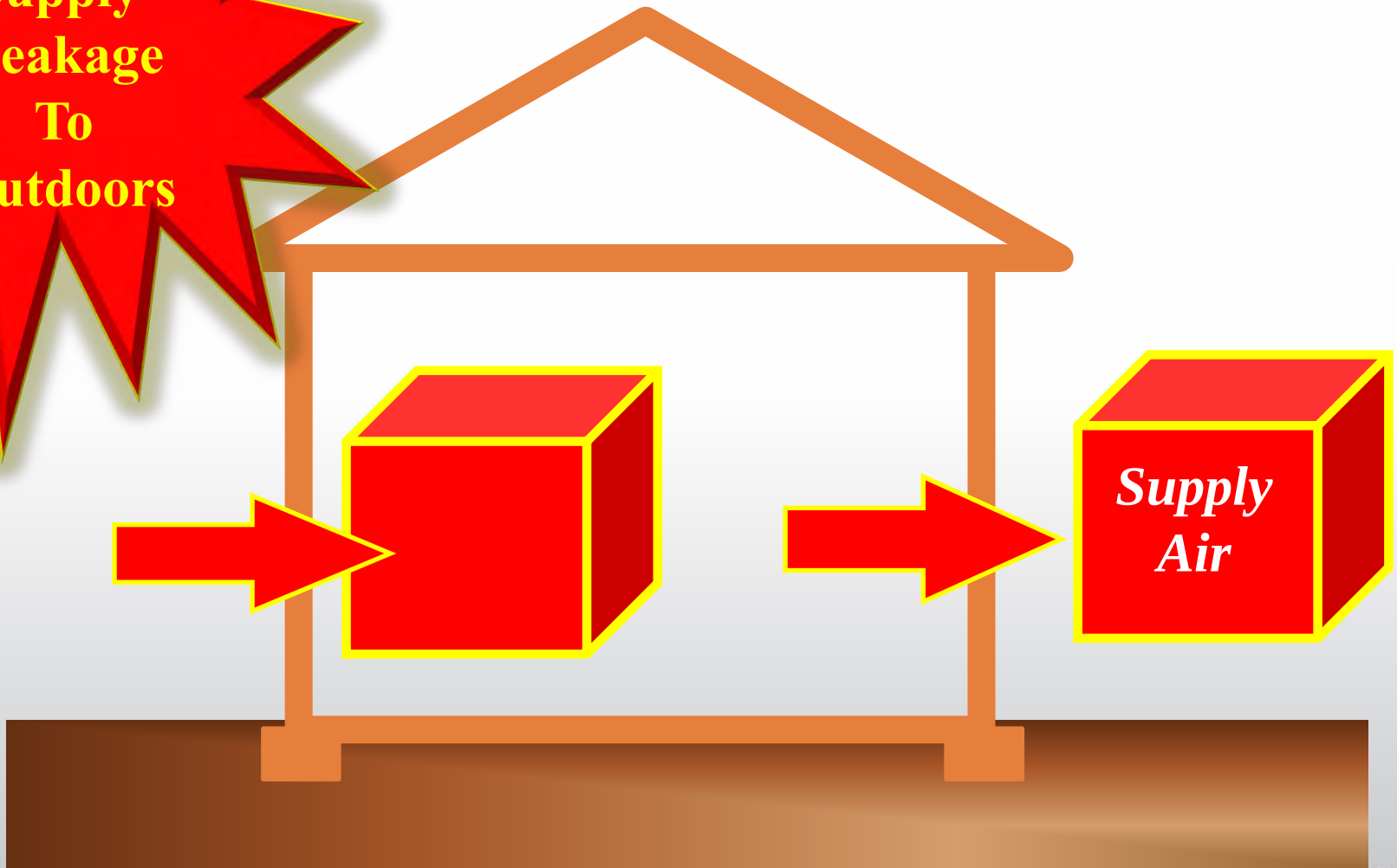
Duct leakage

3. Fans

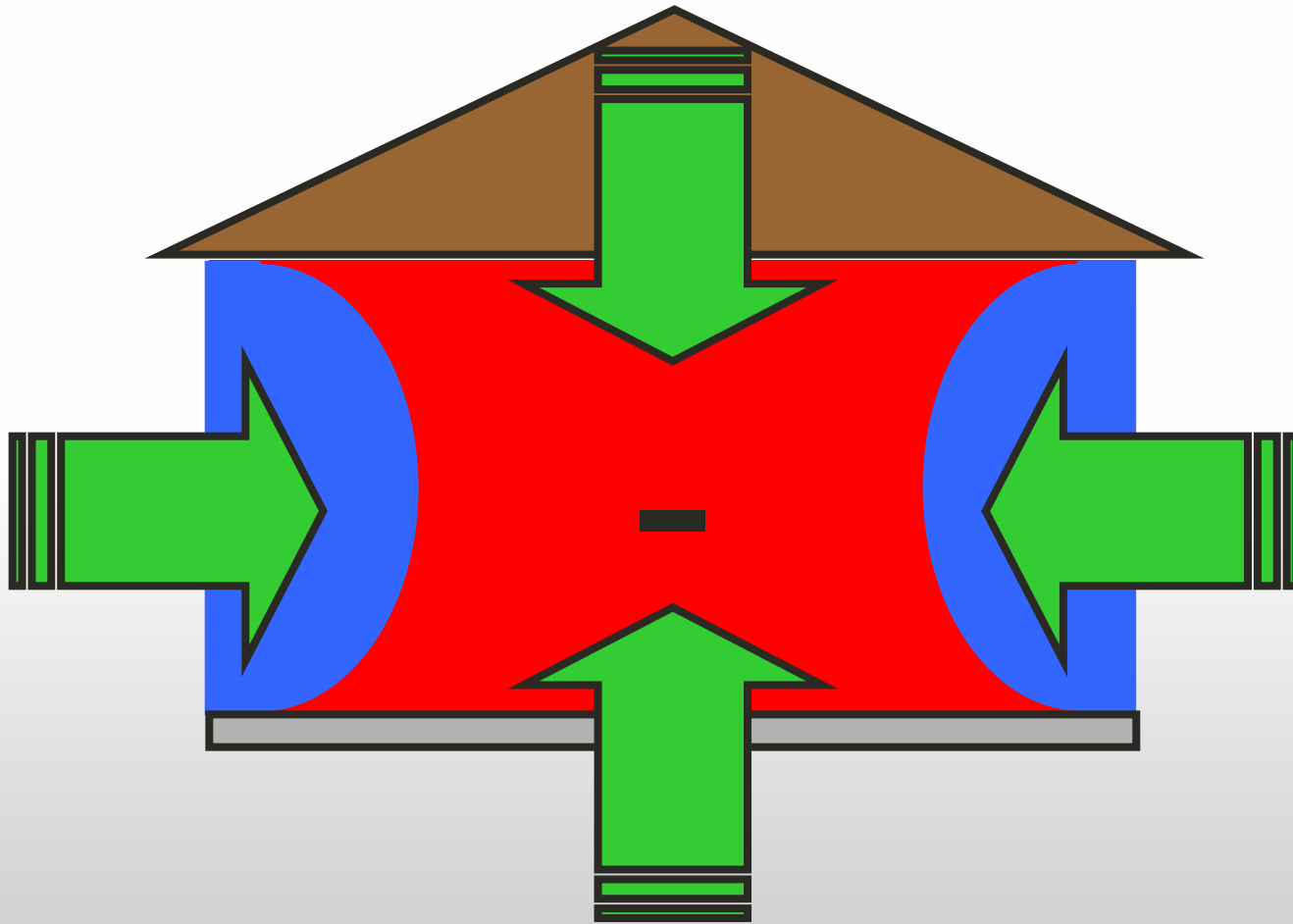
- Duct leakage
- Interior door closure
- Exhaust and supply fans
- Imbalanced flow in zones

One portion of **SUPPLY** air out
= One portion of unconditioned air in

**Supply
Leakage
To
Outdoors**

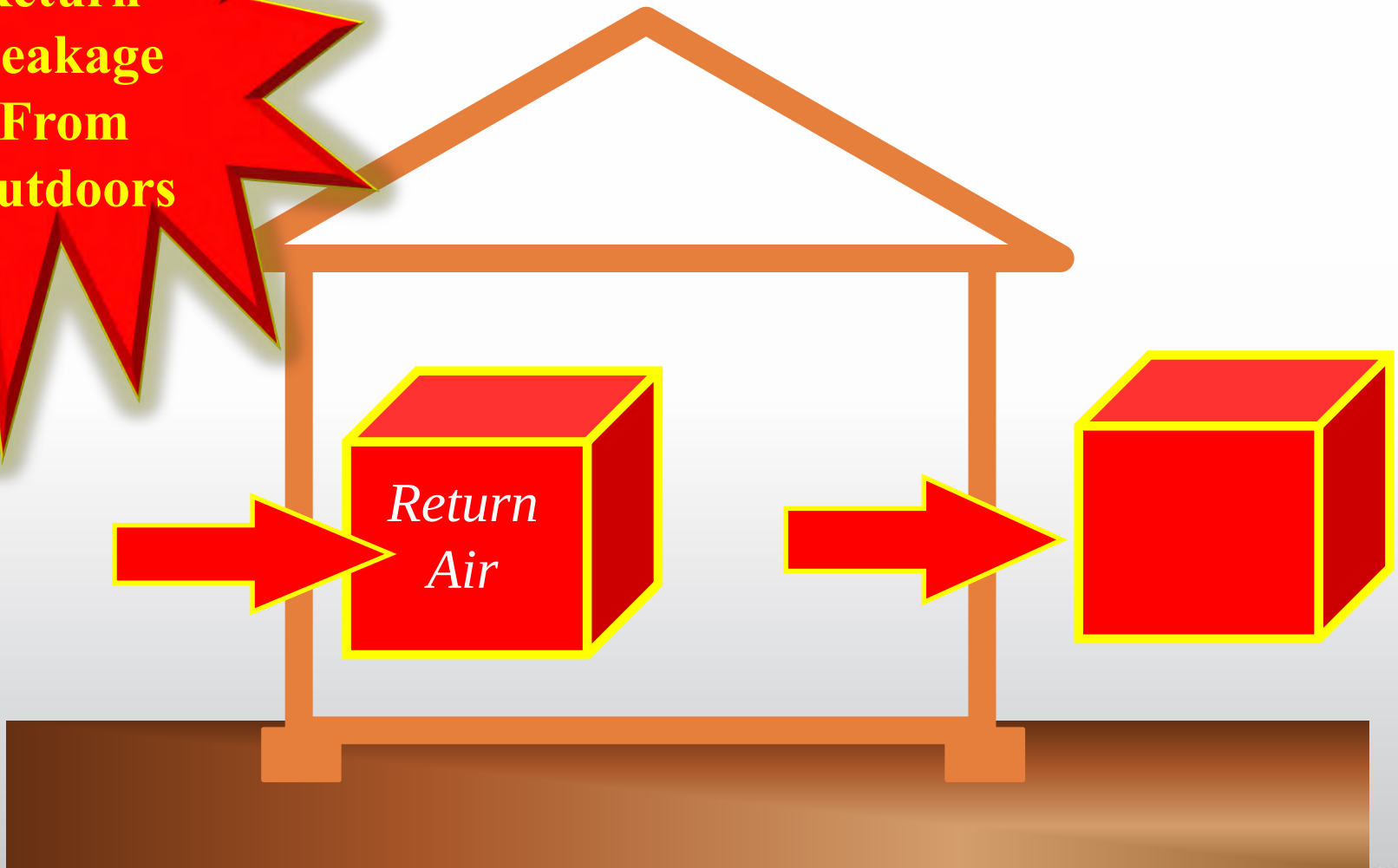


Supply Leakage To Outside Can Cause A Negative Pressure In The House

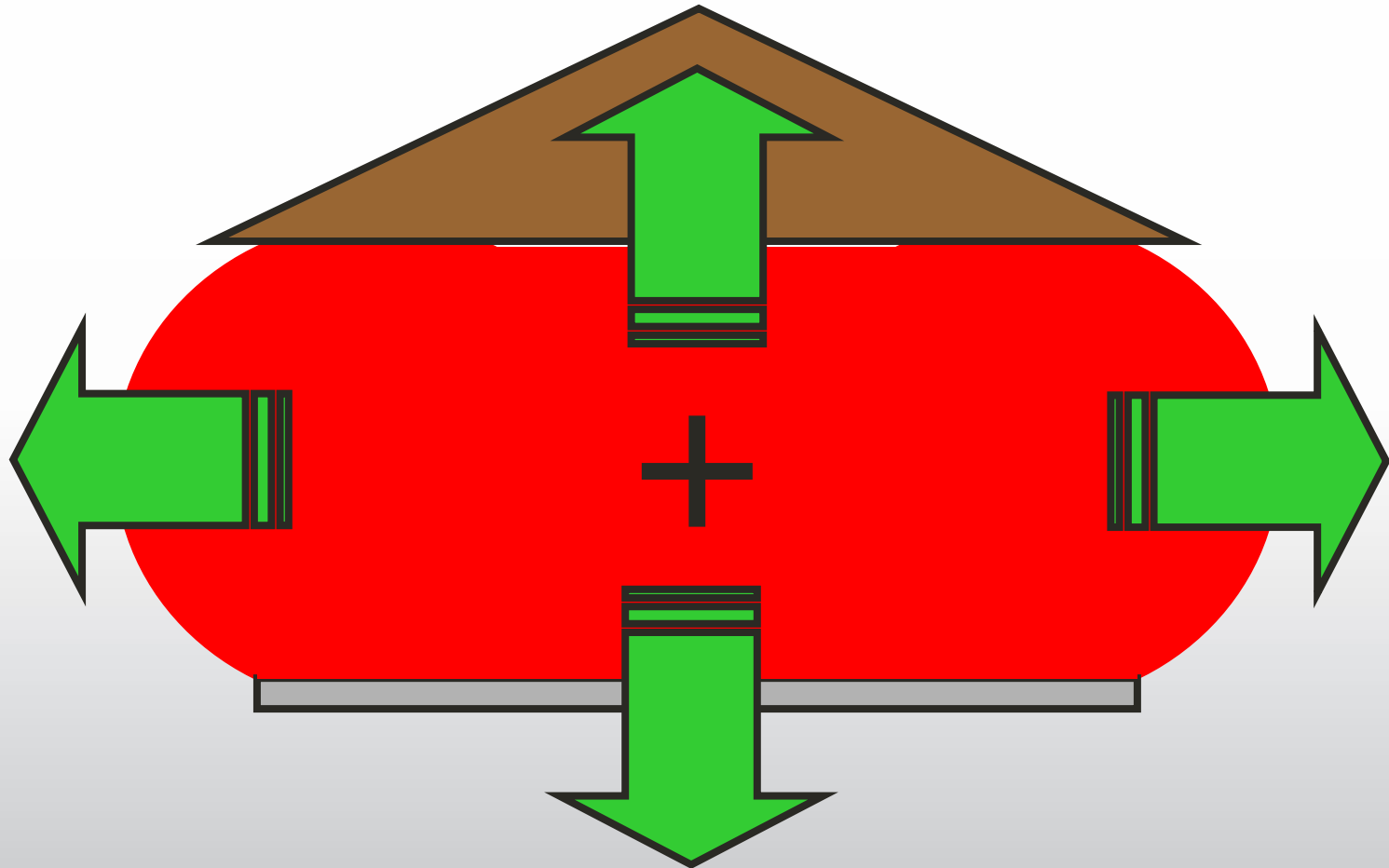


One portion of **RETURN** air in =
One portion of conditioned air out

**Return
Leakage
From
Outdoors**

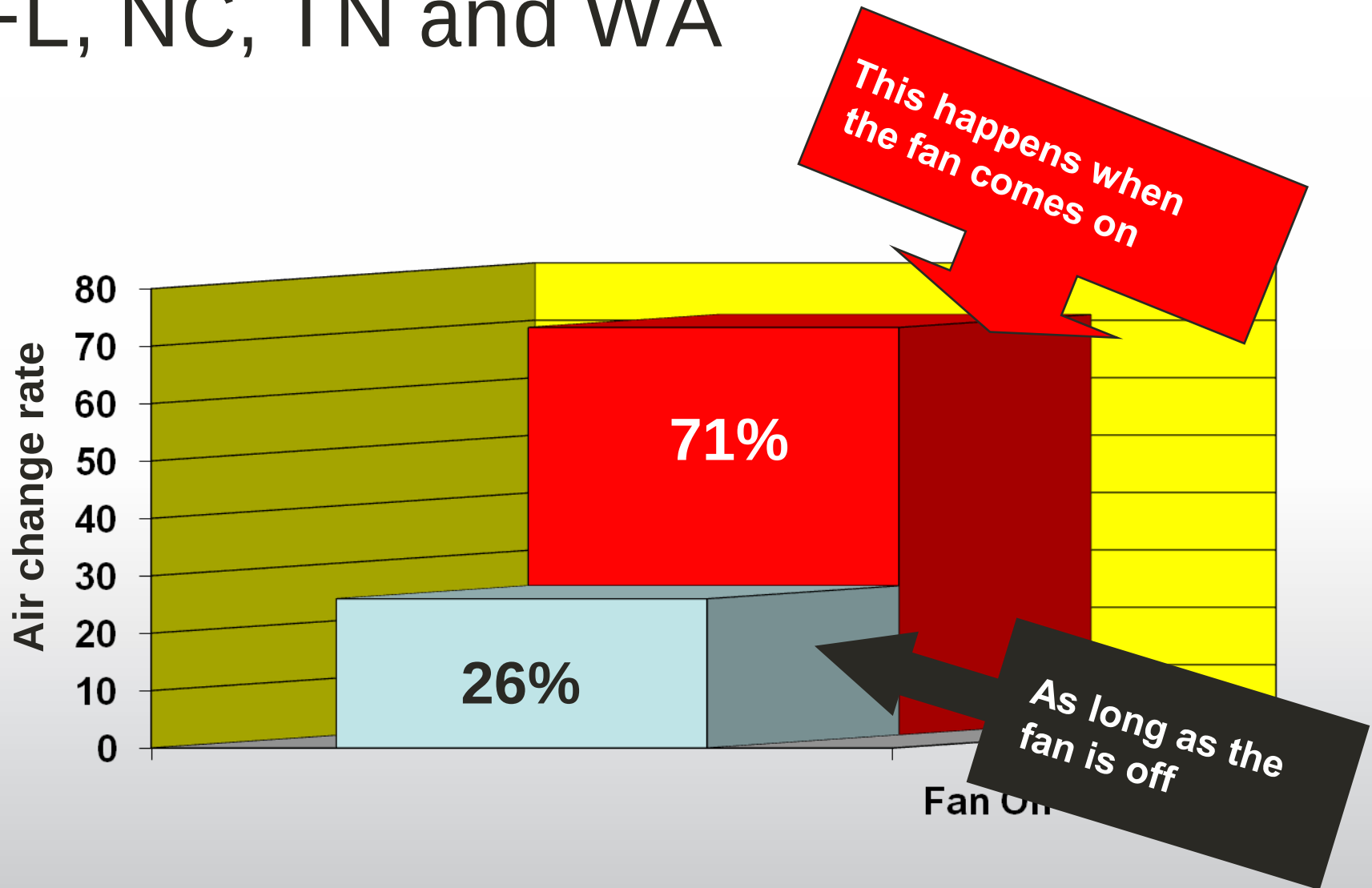


Return Leakage Can Cause Positive Pressure In The House

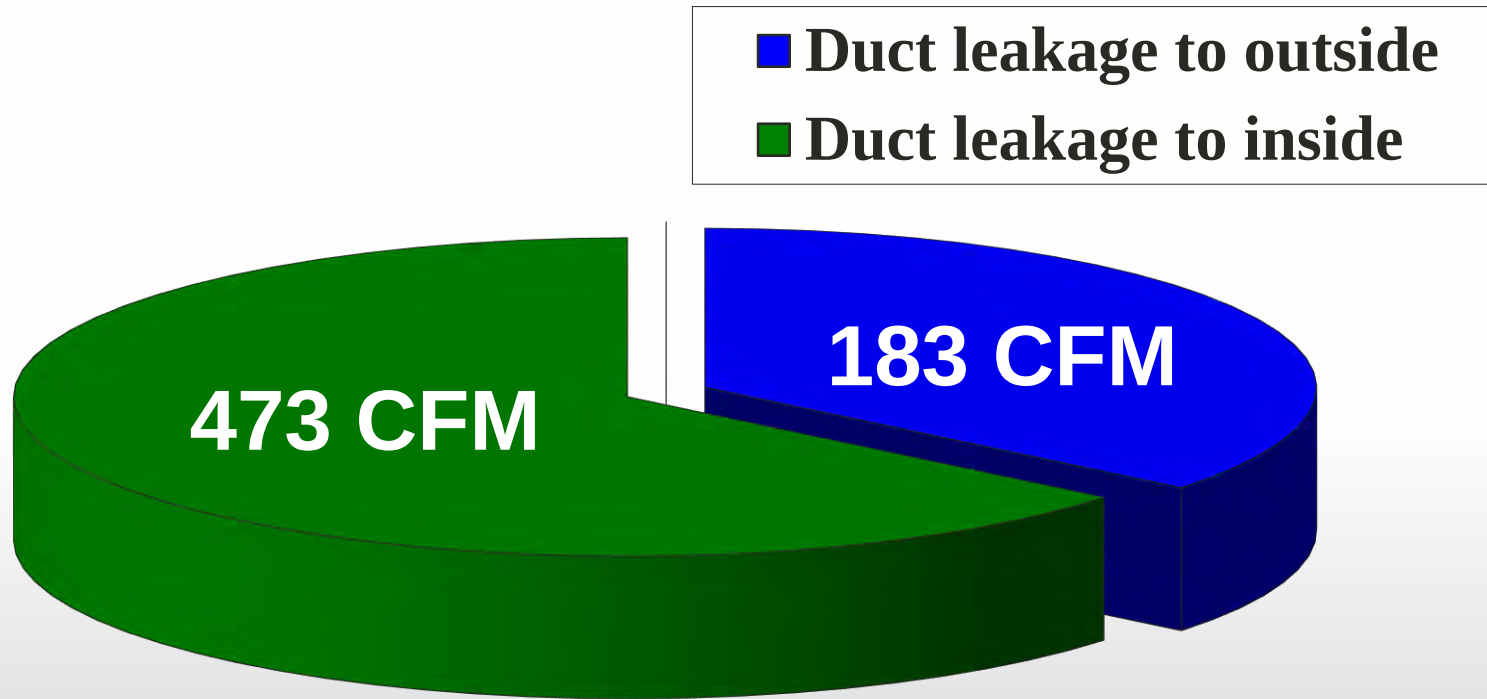


236 Houses

FL, NC, TN and WA



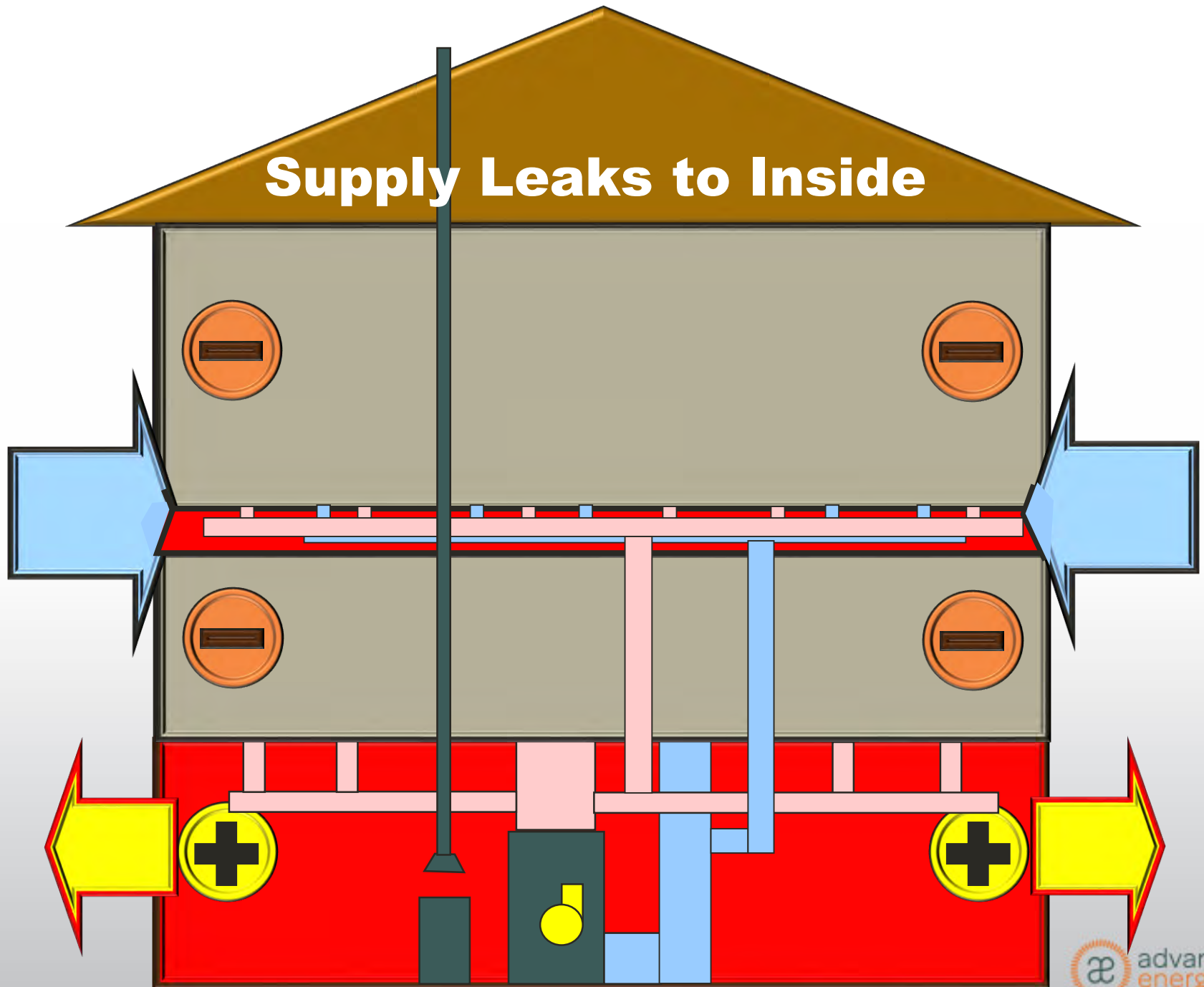
22 Two Story Colonials With Basement Ducts



8 Basements House Air tightness Versus Duct Air tightness

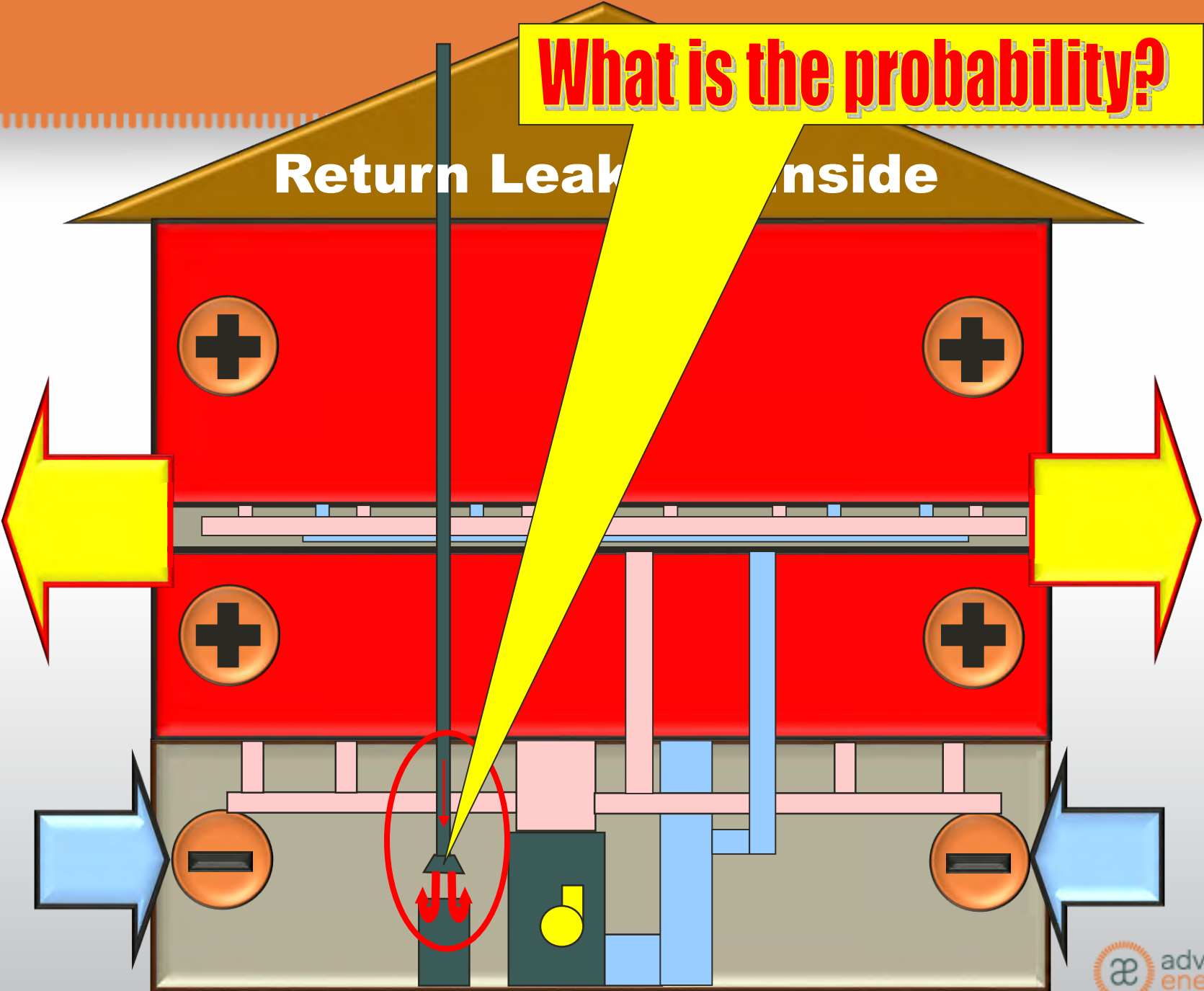
House Number	House Sq. in.	Duct Sq. in.	House Volume	House ACH50	House ACH (Nat)
1	228	NA	32,000	3.27	0.21
2	290	349	34,500	4.05	0.26
3	237	399	27,000	4.04	0.26
4	147	177	15,400	5.06	0.33
5	179	250	16,200	5.09	0.33
6	192	271	24,600	3.60	0.24
7	215	249	20,500	4.83	0.32
8	309	610	41,000	3.48	0.23
AV	229	288	26,400	4.18	0.27

Supply Leaks to Inside



What is the probability?

Return Leak Inside



MAD-AIR 1992

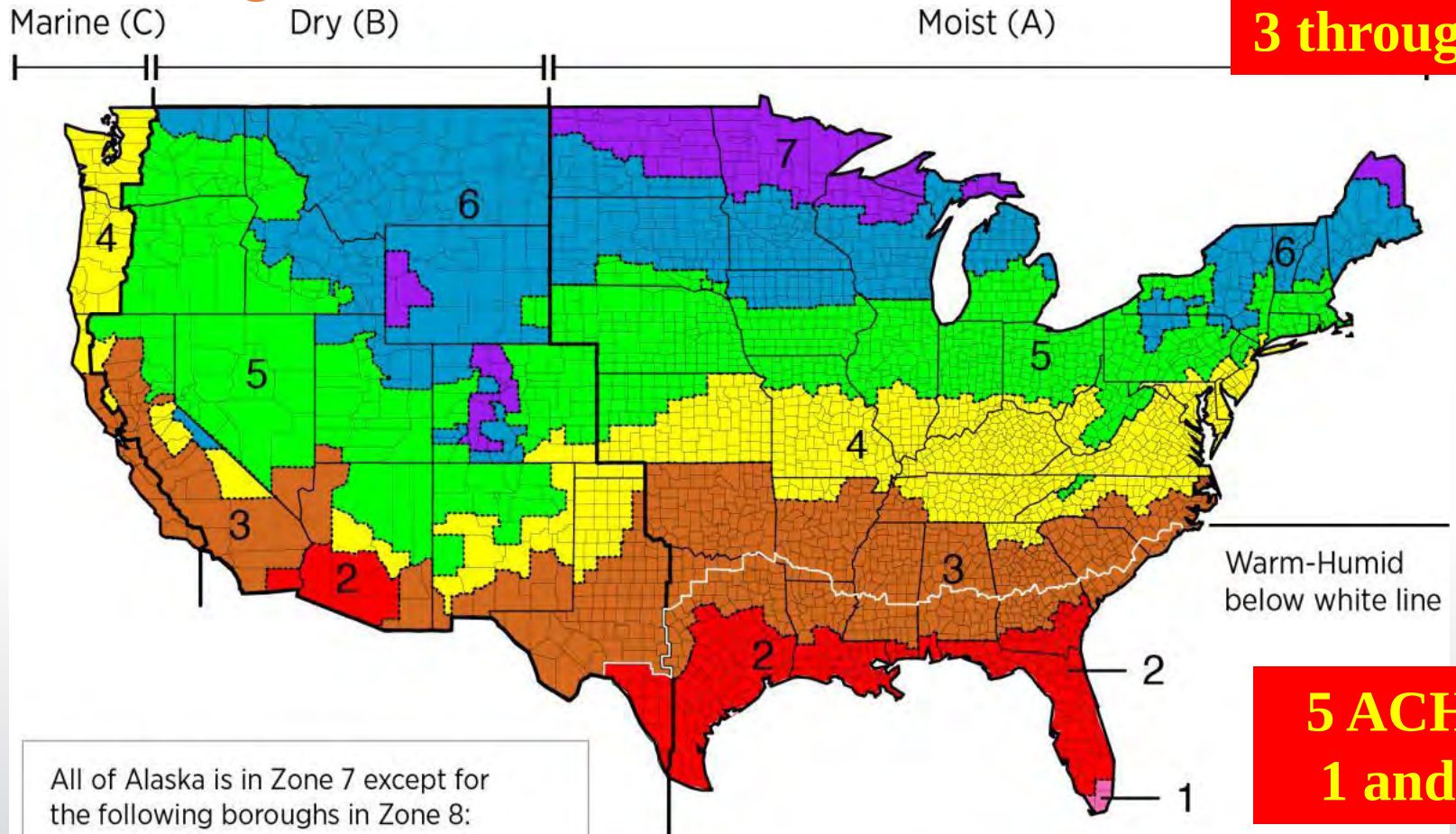
- 26 house study to show interactions
- House age 1-5 years
- Looked at:
 - Duct leakage
 - Interior door closure
 - Exhaust devices
 - Combination

MAD-AIR is a function of...

1. Tightness of the home
2. Tightness of rooms
3. Flow to rooms and house
4. Existence or the free flow of return air (single zone houses)
5. Exhausted air from the house
6. Supply air to the house
7. Occupant behavior

2015 IECC Climate Map & House Tightness

**3 ACH⁵⁰
3 through 8**



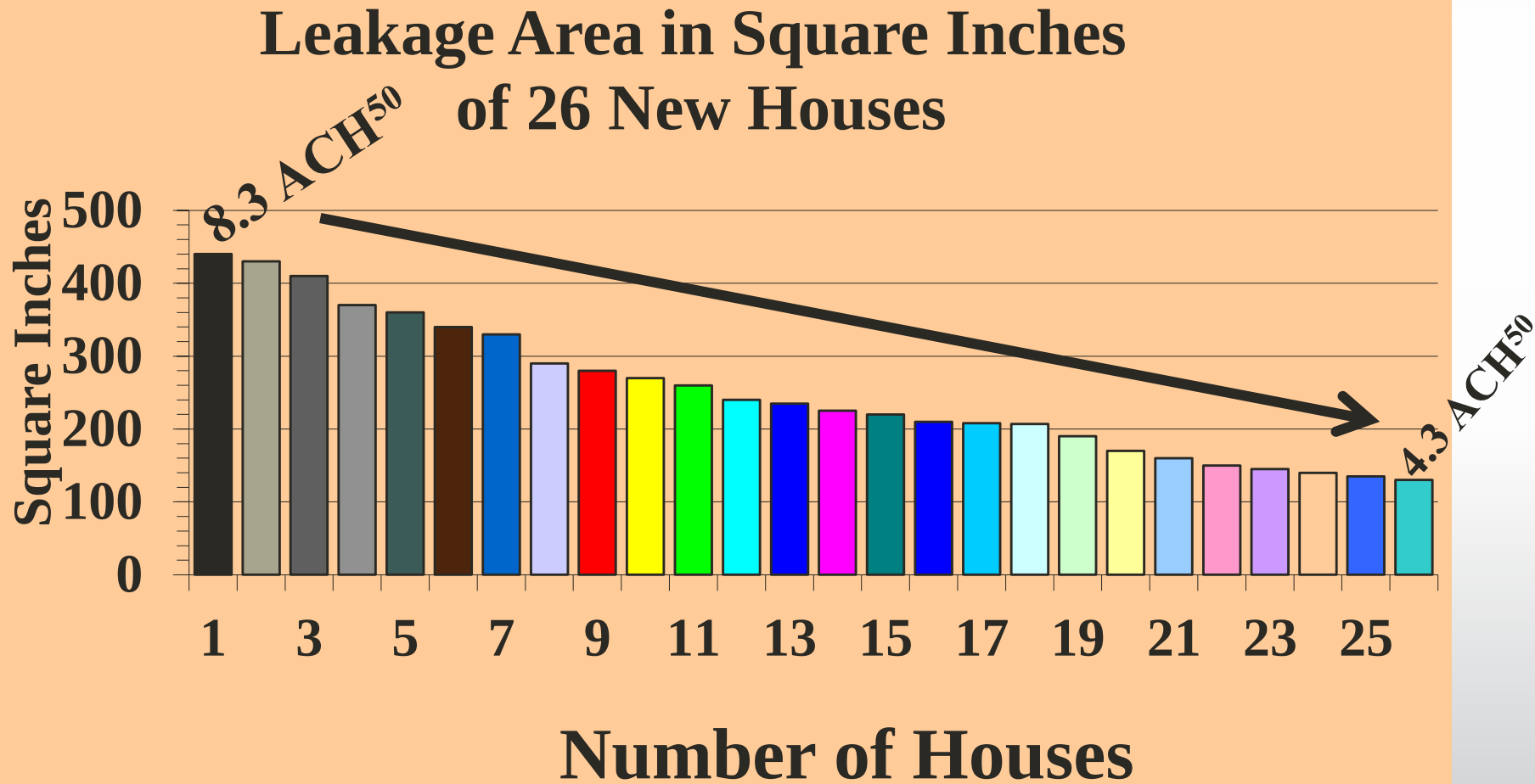
**5 ACH⁵⁰
1 and 2**

All of Alaska is in Zone 7 except for the following boroughs in Zone 8:

Bethel, Northwest Arctic, Dillingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands

All houses leakier than 2015 IECC



Duct Leakage Effects

- Duct leakage
- Interior door closure
- Exhaust devices

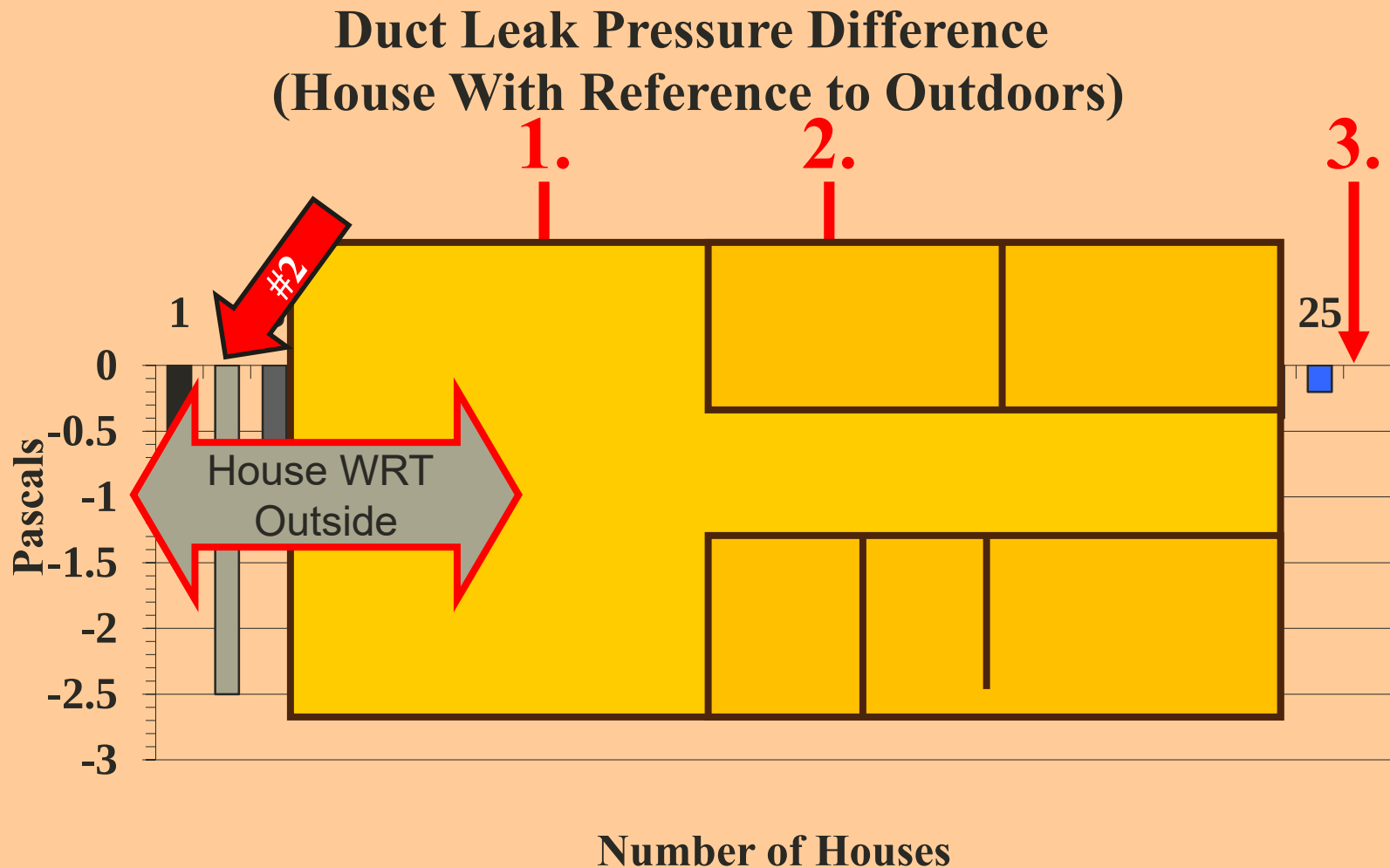


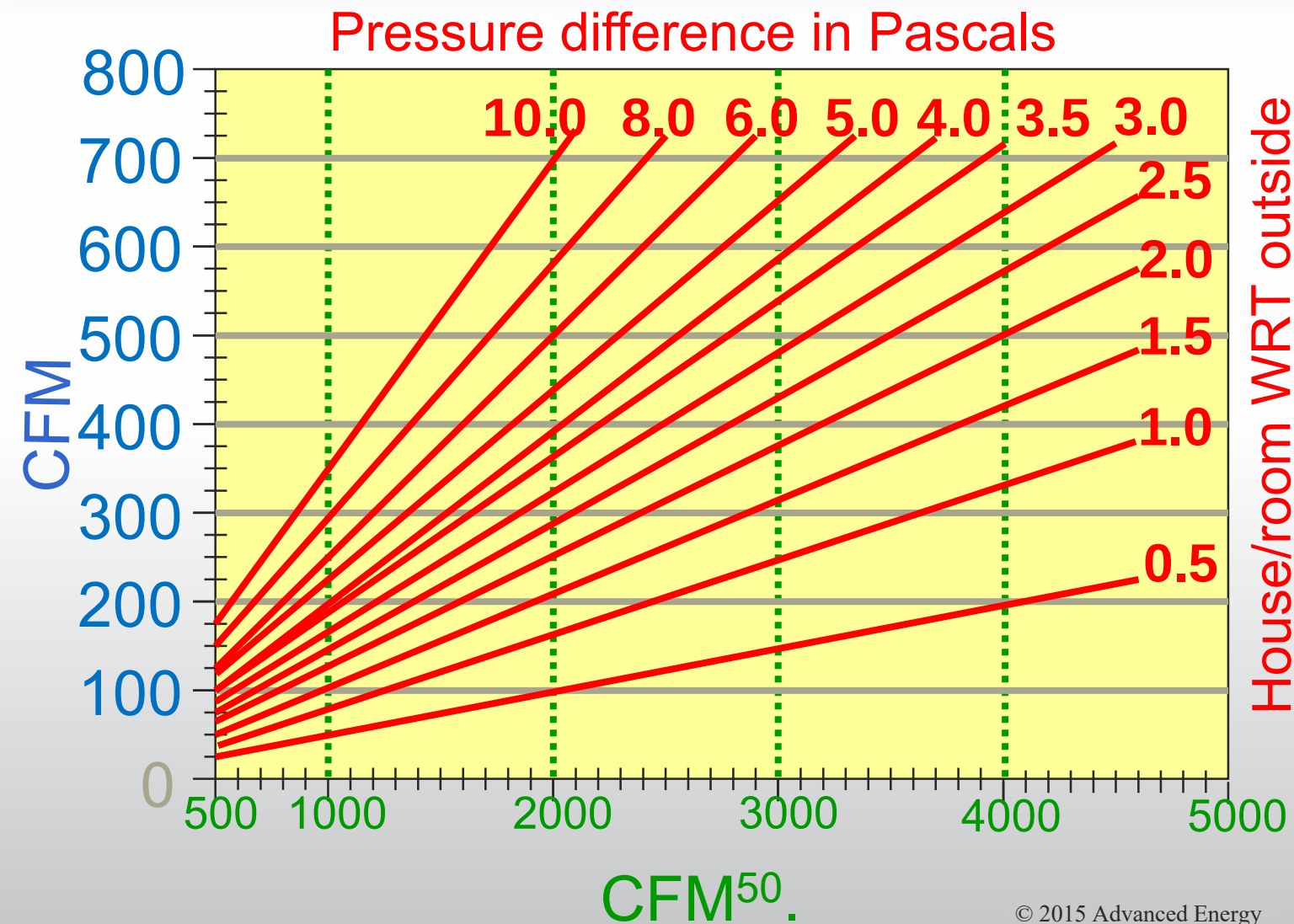
Flex



Metal

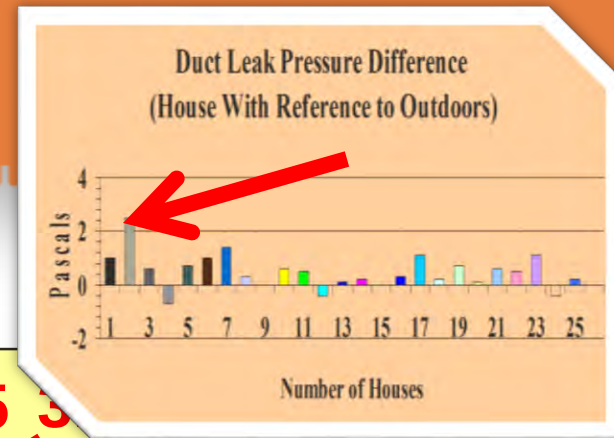
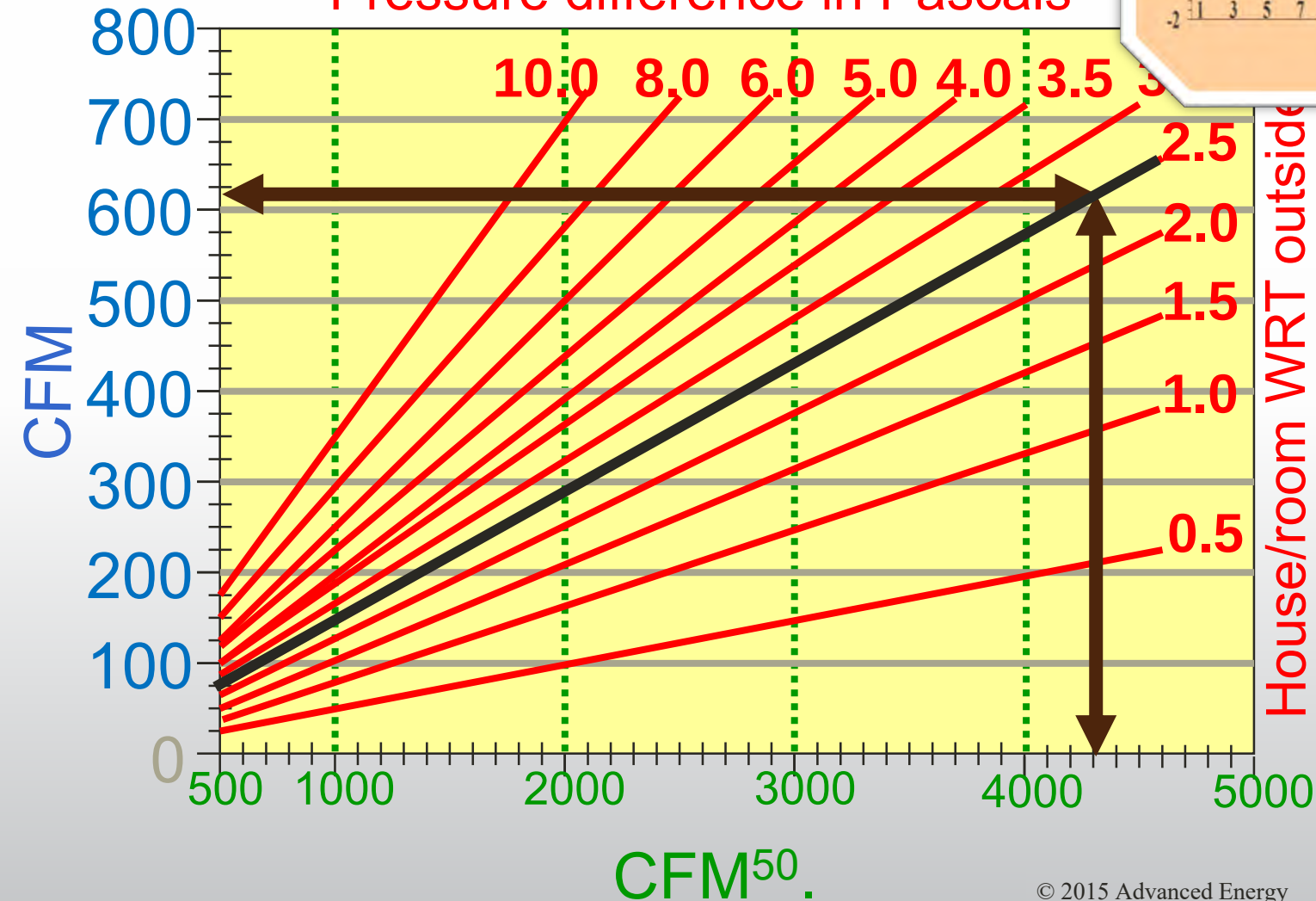
Duct Leakage To Outside Effects





House #2

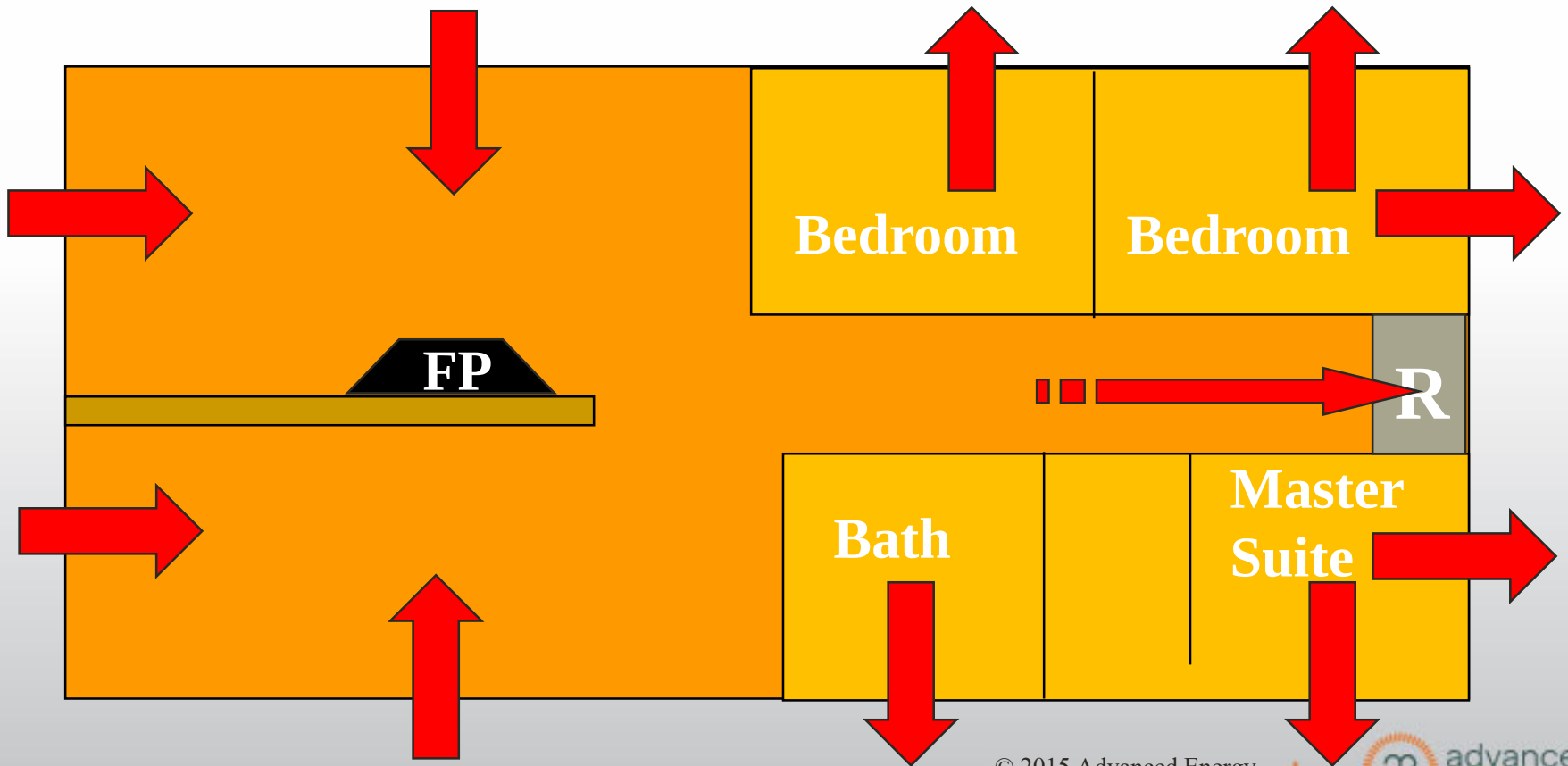
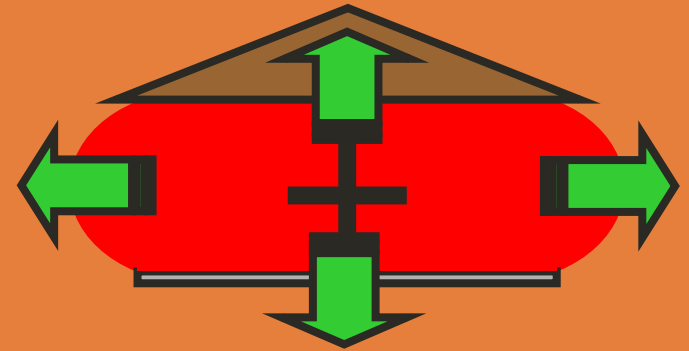
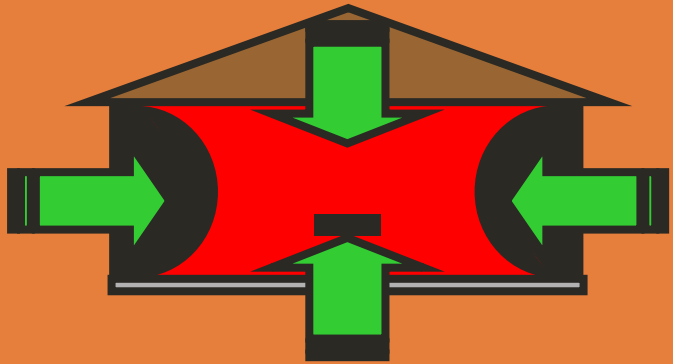
Pressure difference in Pascals



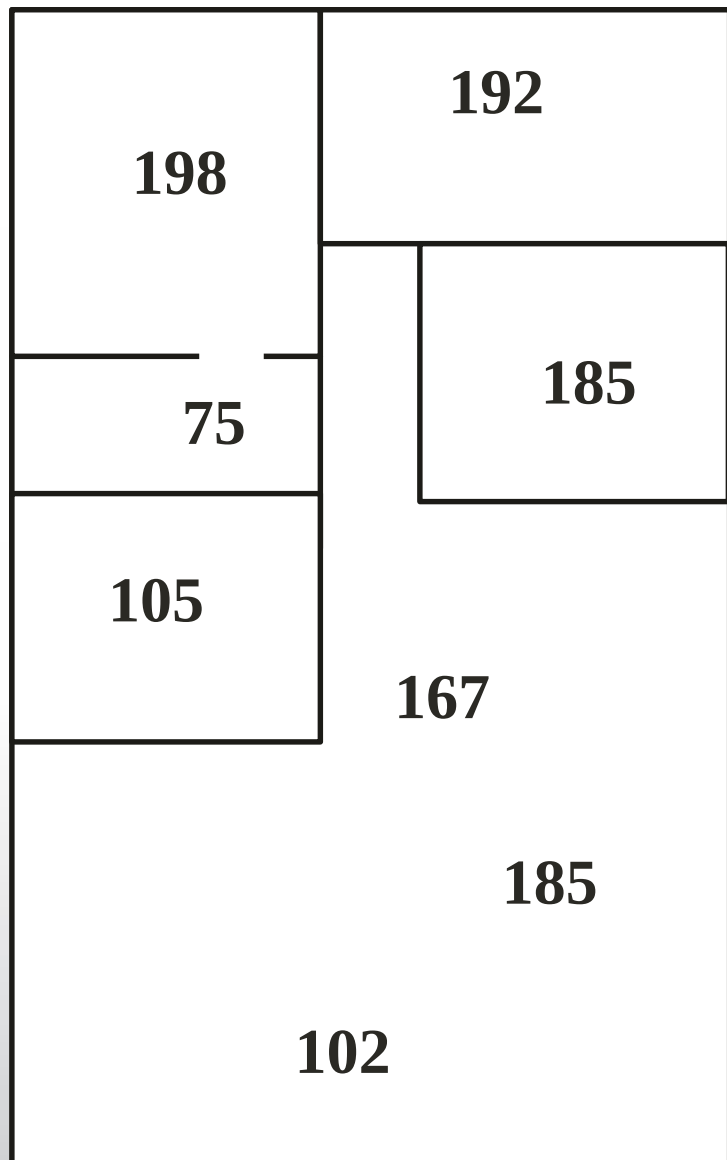
Interior Door Closure Effects

- Duct leakage
- **Interior door closure**
- Exhaust devices



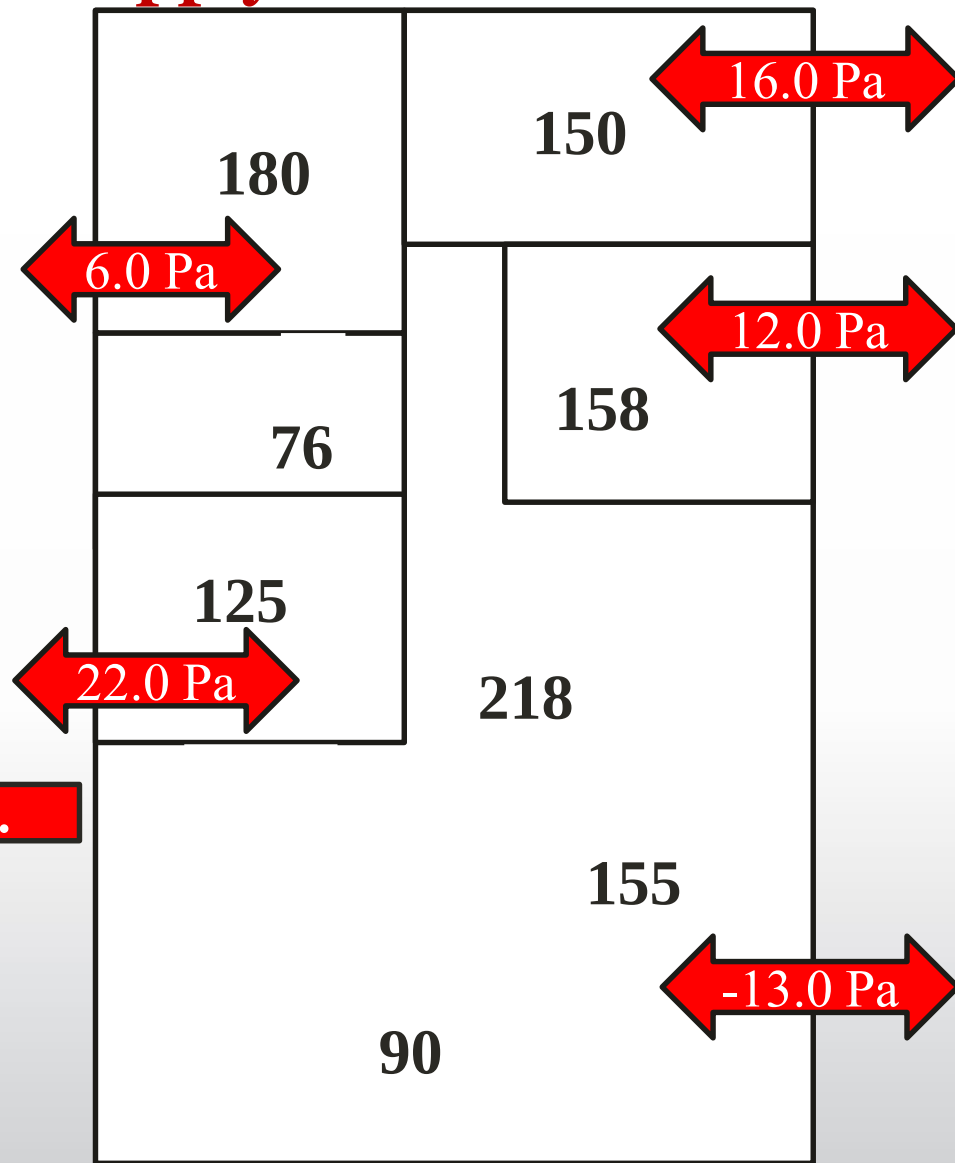


Supply CFM Doors Open



1208 CFM delivered flow

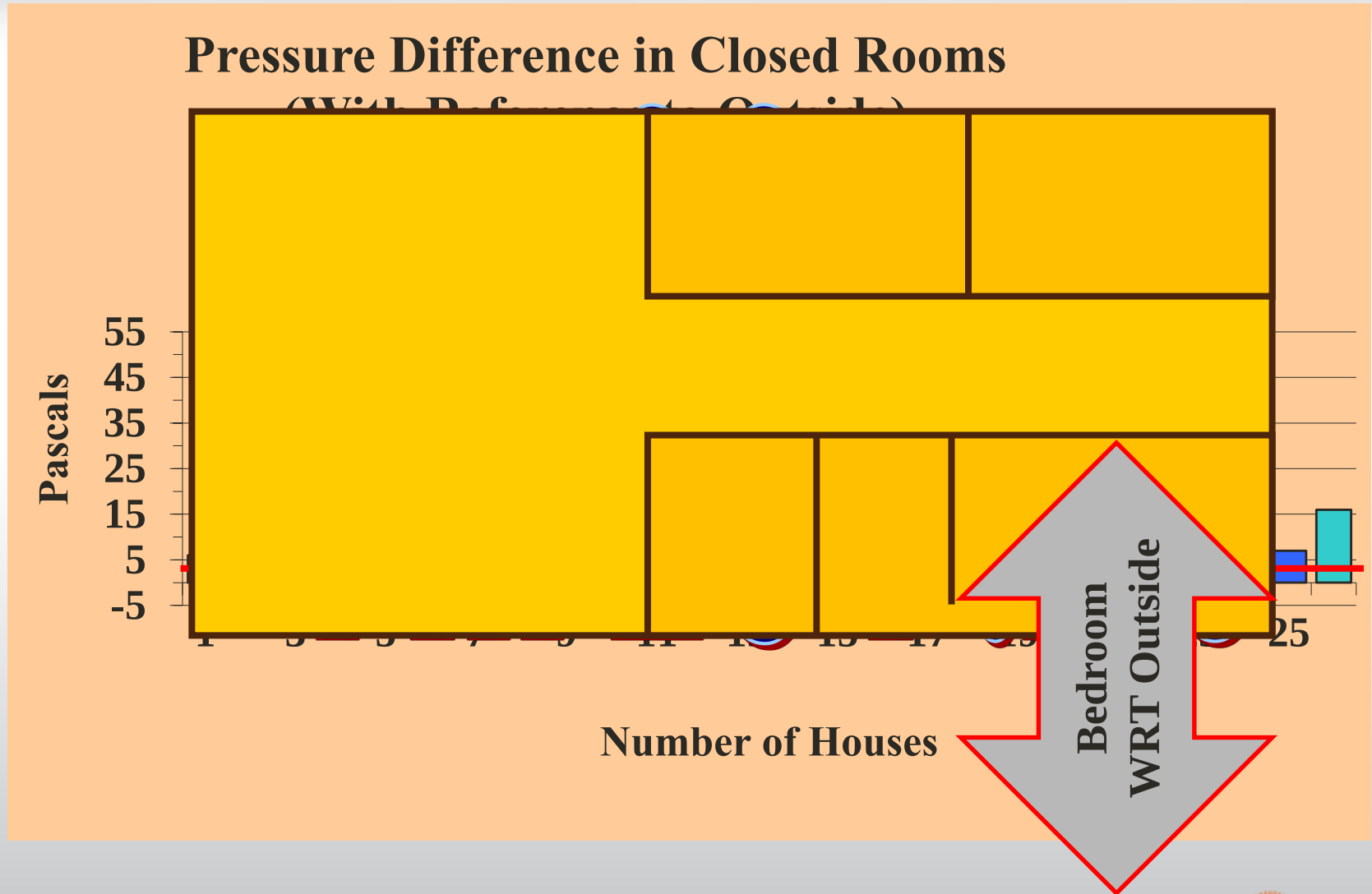
Supply CFM Doors Closed



1152 CFM delivered flow

Pa.

Closed Bedroom WRT Outside



Door Closure Pressure Effect Test

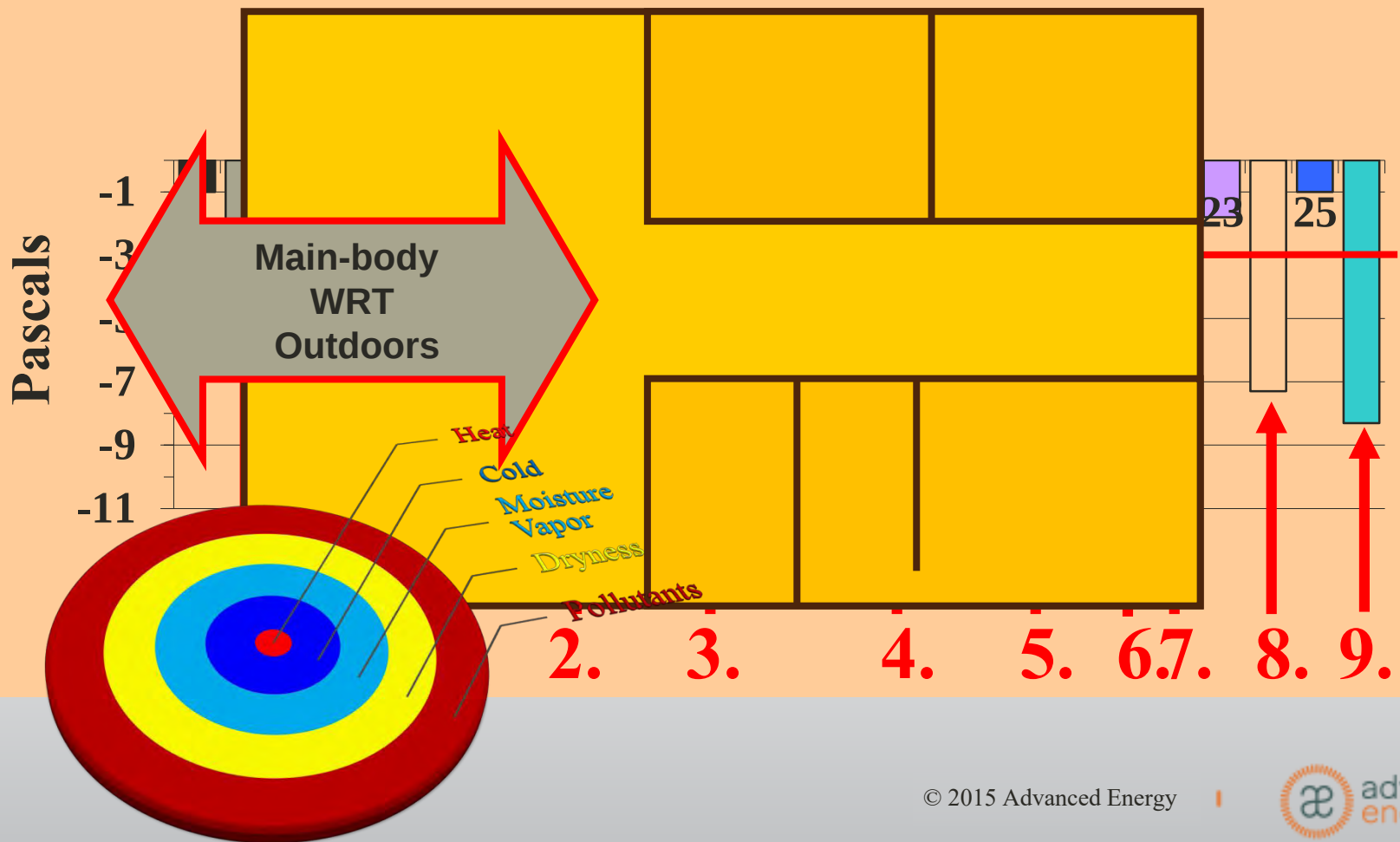


No more than **3 pascals** of pressure difference between the inside and outside with all bedroom doors closed and the heating or cooling system on high speed.

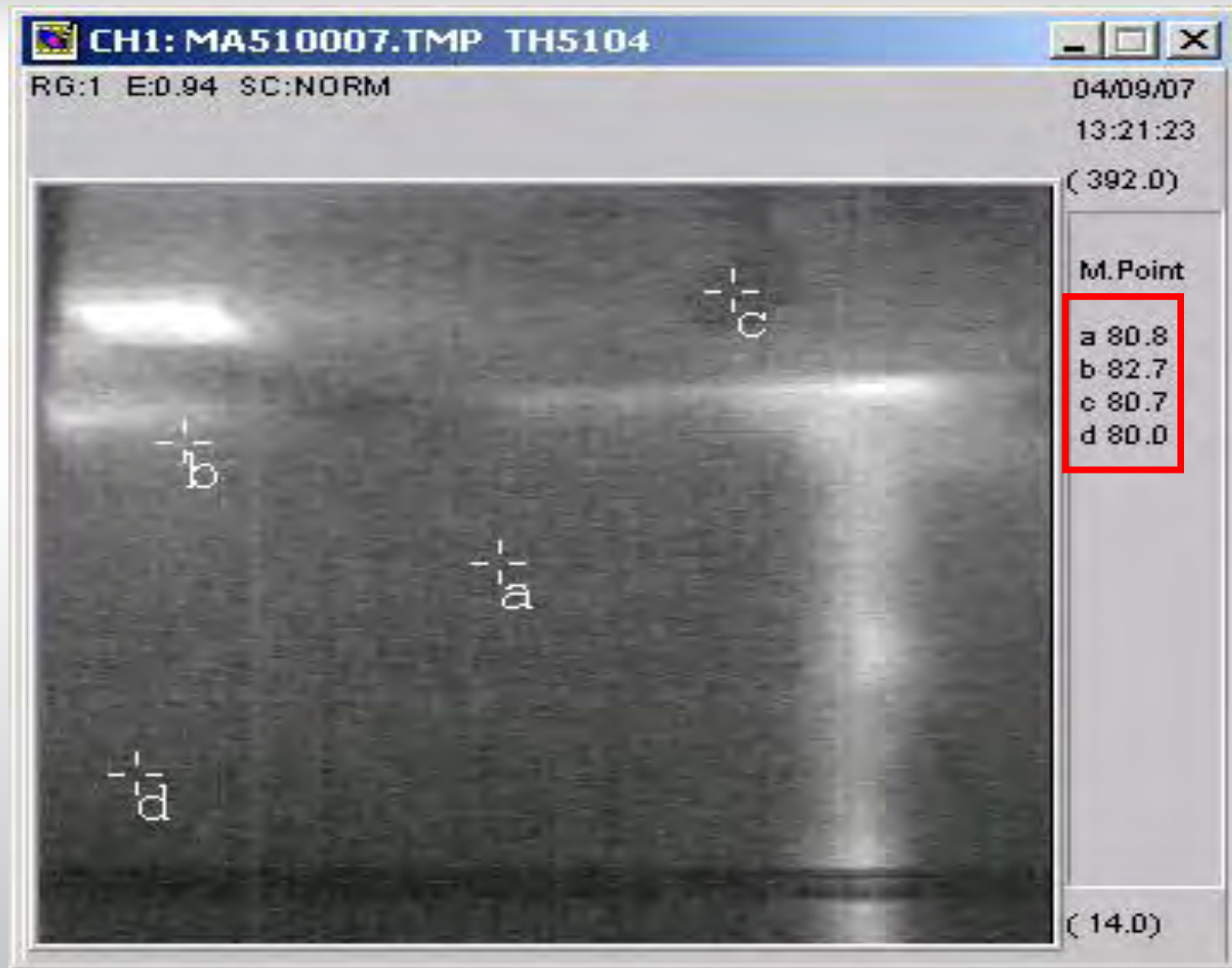


House Main Body WRT Outdoors

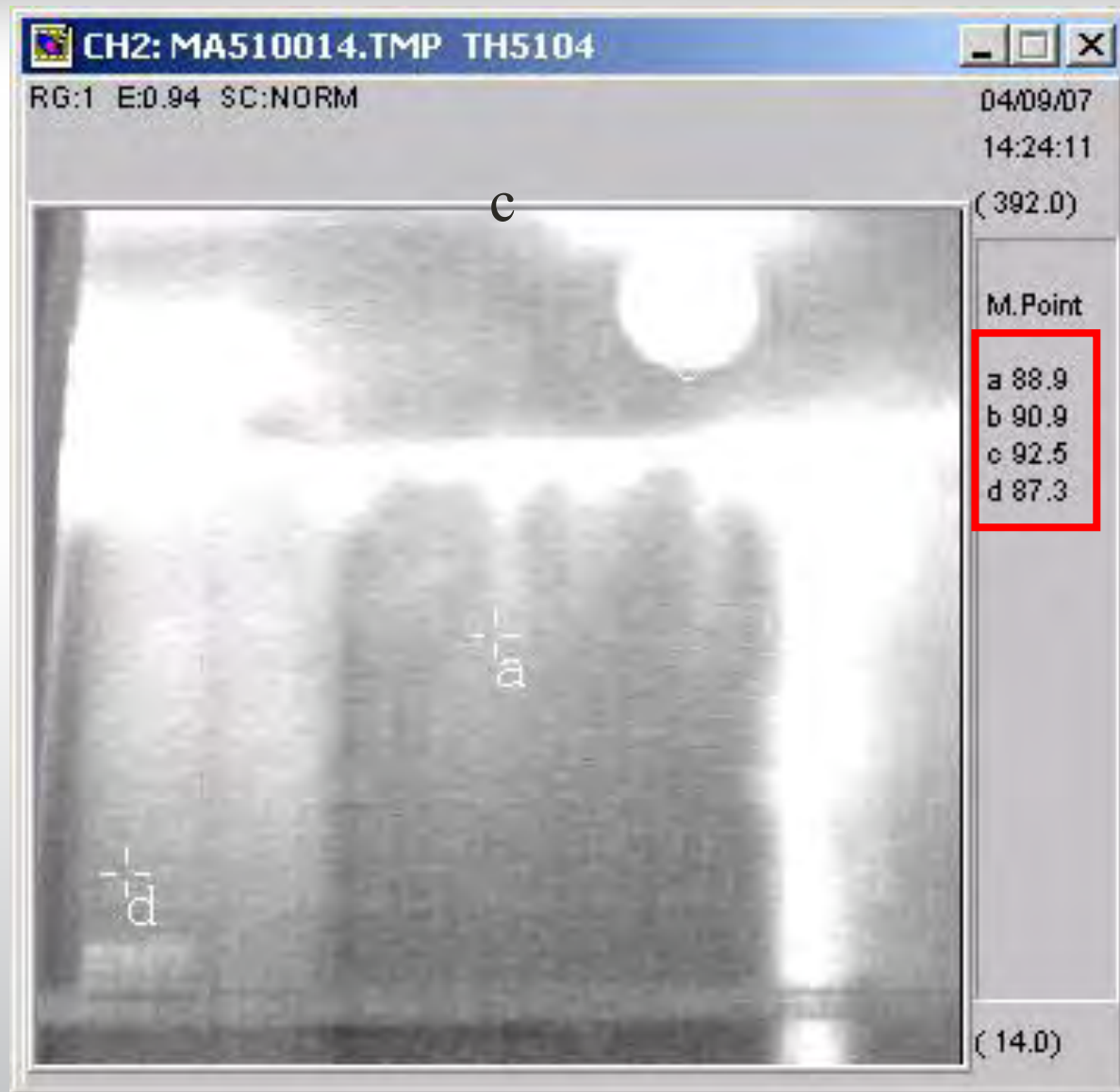
**All Interior Doors Closed
(House With Reference to Outdoors)**



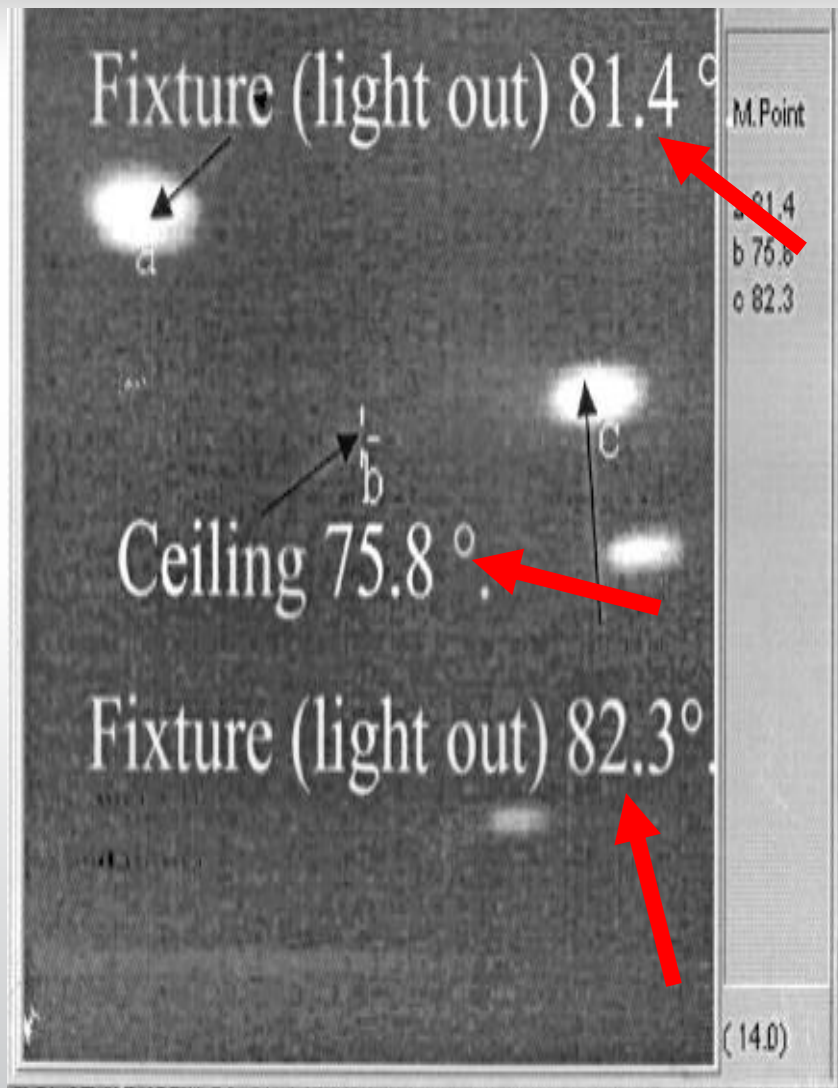
Start of Scan



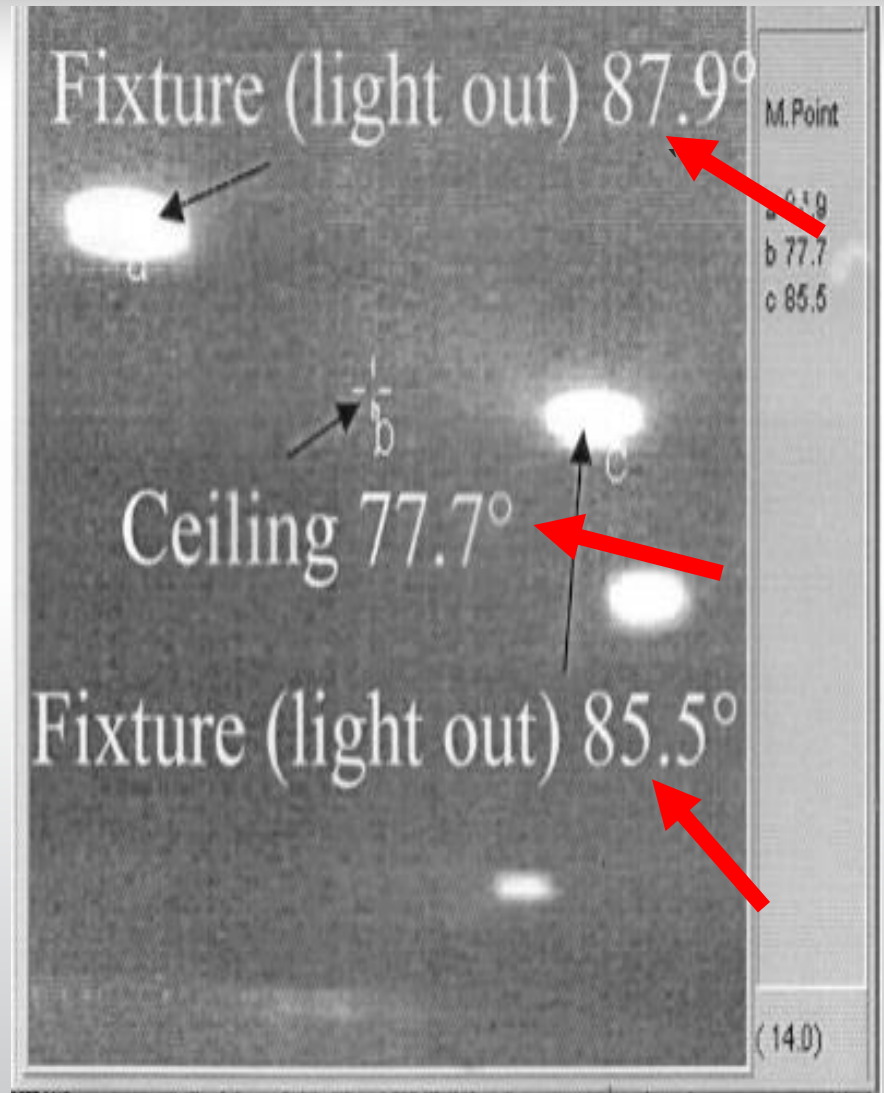
End of filming-20 minutes at 3 Pascals



Doors Open Then Closed 20 Minutes



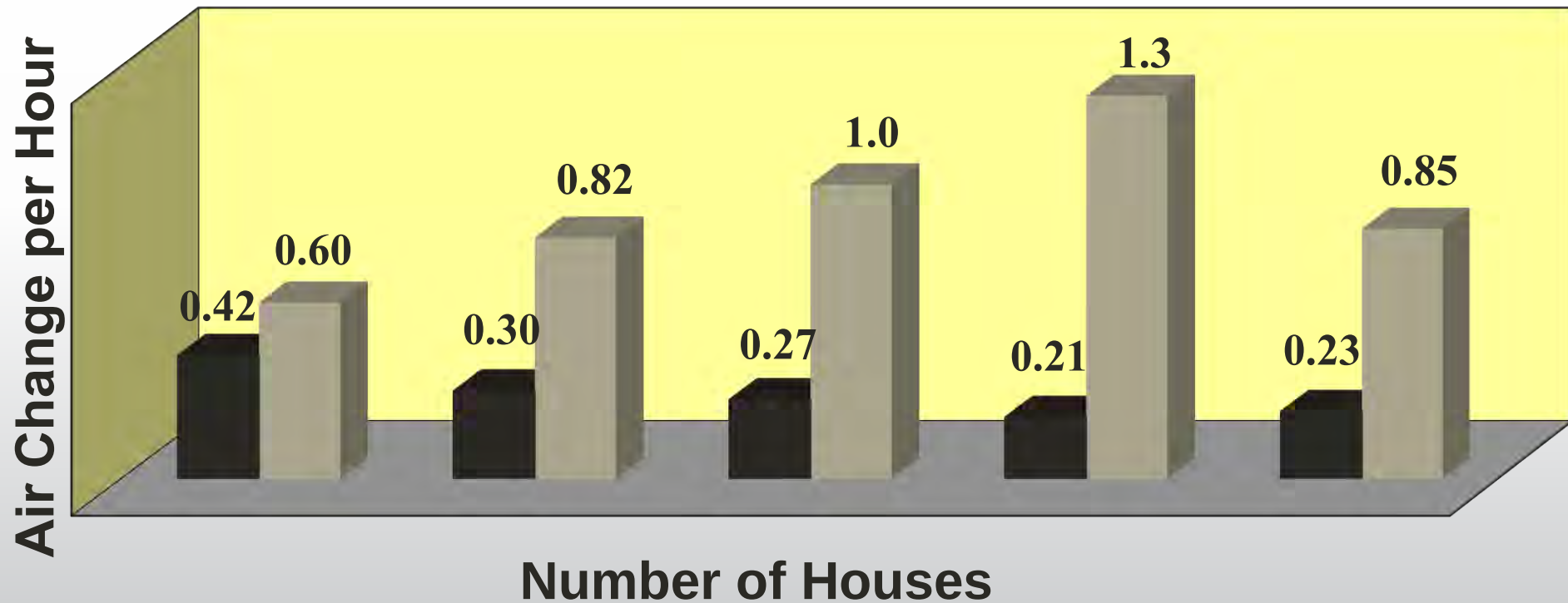
Open



Closed

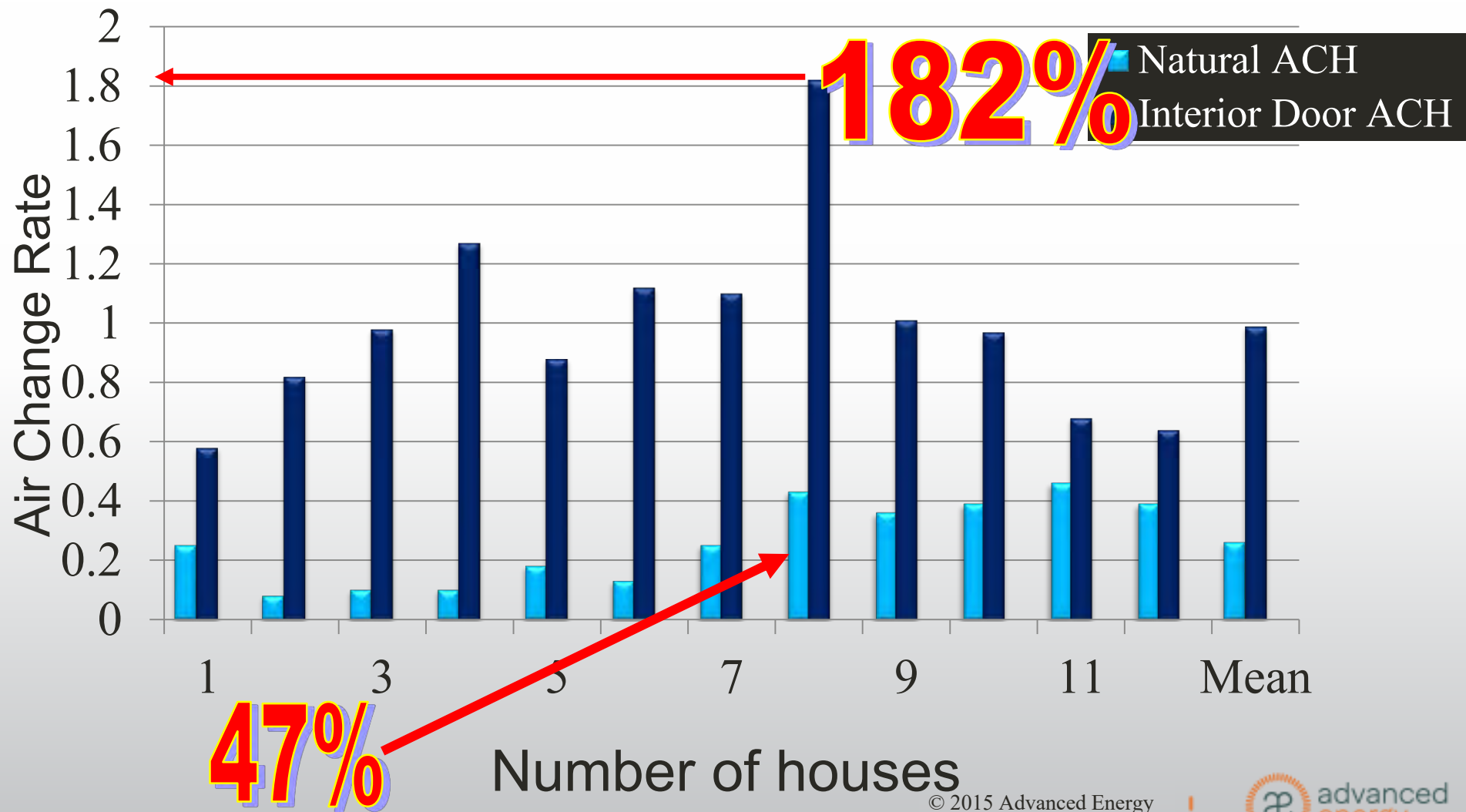
Infiltration Rates In 5 Houses With Interior Doors Open and Closed (Tracer gas)

■ Interior doors open (Ave. 0.31) ■ Interior doors closed (Ave. 0.91)

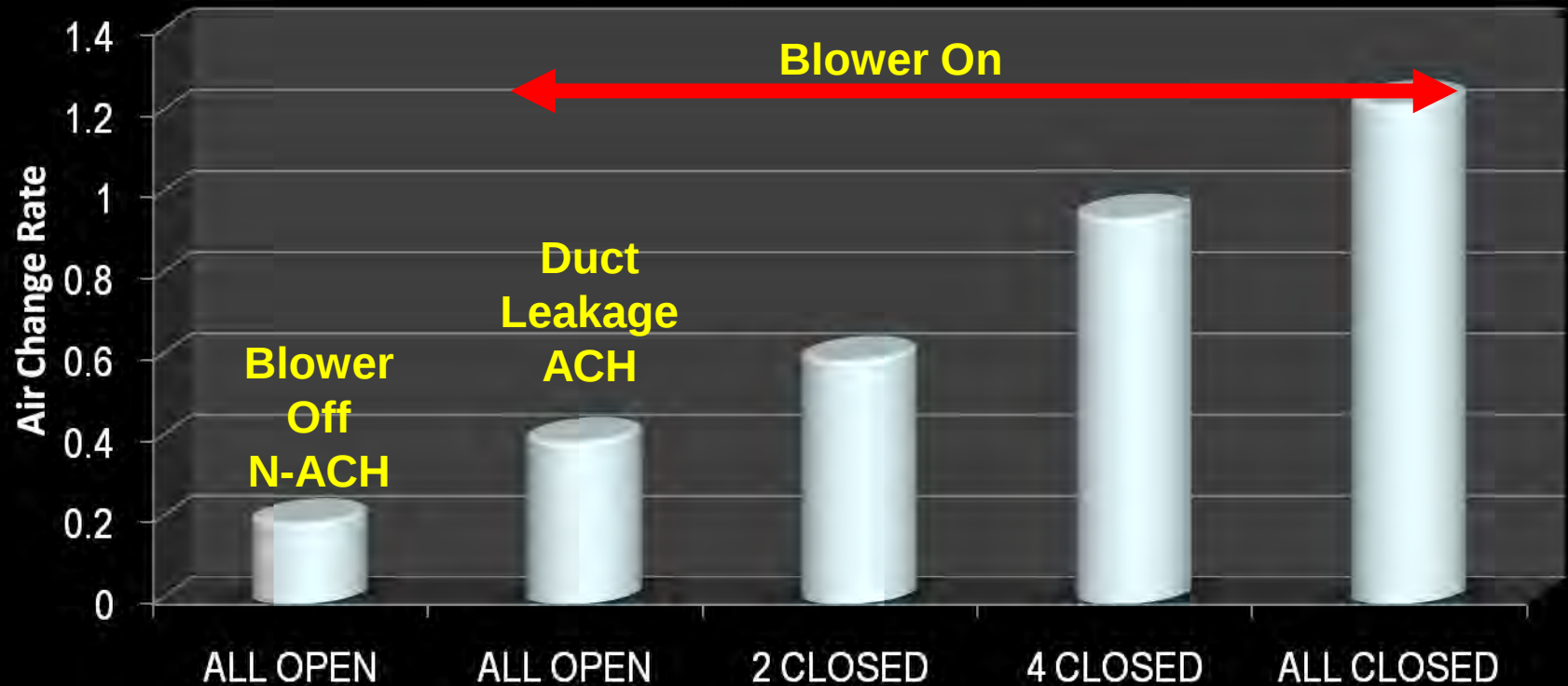


Source: Infiltration Rates and Pressure Differences in Florida Homes Caused by Closed Interior Doors When the Central Air Handler is On FSEC James B. Cummings, John J. Tooley and Neil Moyer

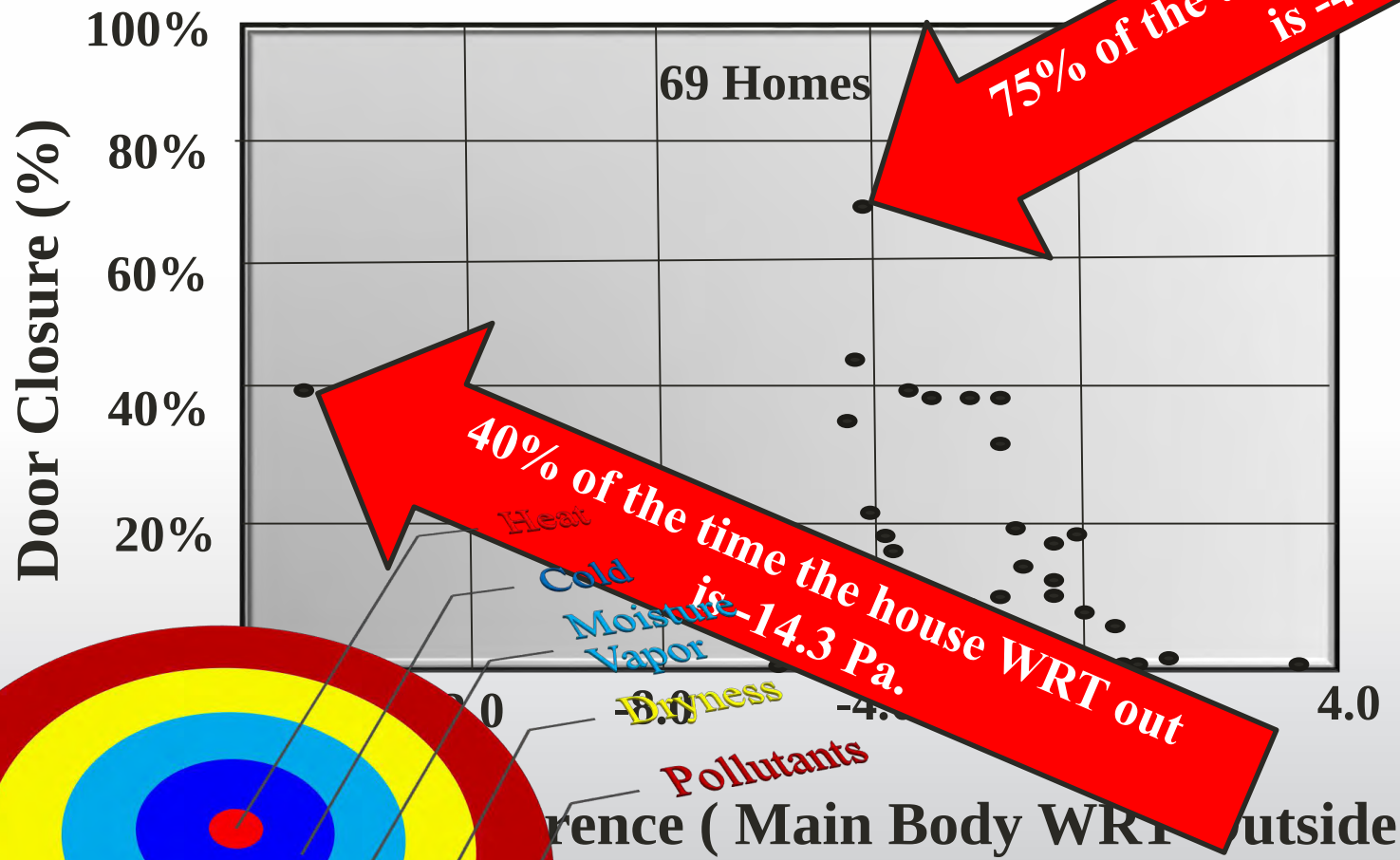
Natural Infiltration Rate Vs. Interior Door Closure Air Change Rate



Measured Infiltration Rates In One Home With Various Interior Door Positions (Tracer Gas)



Depressurization (Pa) of the Main Body Caused by Interior Doors Closed and AHU Operation Versus Estimated Time Occupants Close Doors



Pressure Balance Defined

- All rivers that are dammed, release water in order to manage water levels behind the dam
- Allowing adequate water to the river below, neither too much nor too little



- All air dammed behind a closed interior door must be released to manage levels of comfort, energy use, moisture condensation and mold
- Allowing proper air flow from the closed room to the main portion of the house, neither too much nor too little





A Good Building Code 1997:

- 1902.5 Return Air Intake:
- “Return air may travel through the living space to the return air intake if there are no restrictions, such as **doors**, to the air movement.”

2015 IMC and ACCA Manual D

- **2015 IMC - 601.5.3 Return Air Openings**

The amount of return air taken from any room or space shall not be greater than the flow rate of the supply air delivered to such room or space.

- **ACCA Manual D – Returns:** A low-resistance return path is required for each zone. If a room is isolated from one of the returns, transfer grills can be used to establish a circulation path between the isolated room and the return

Pressure Relief?

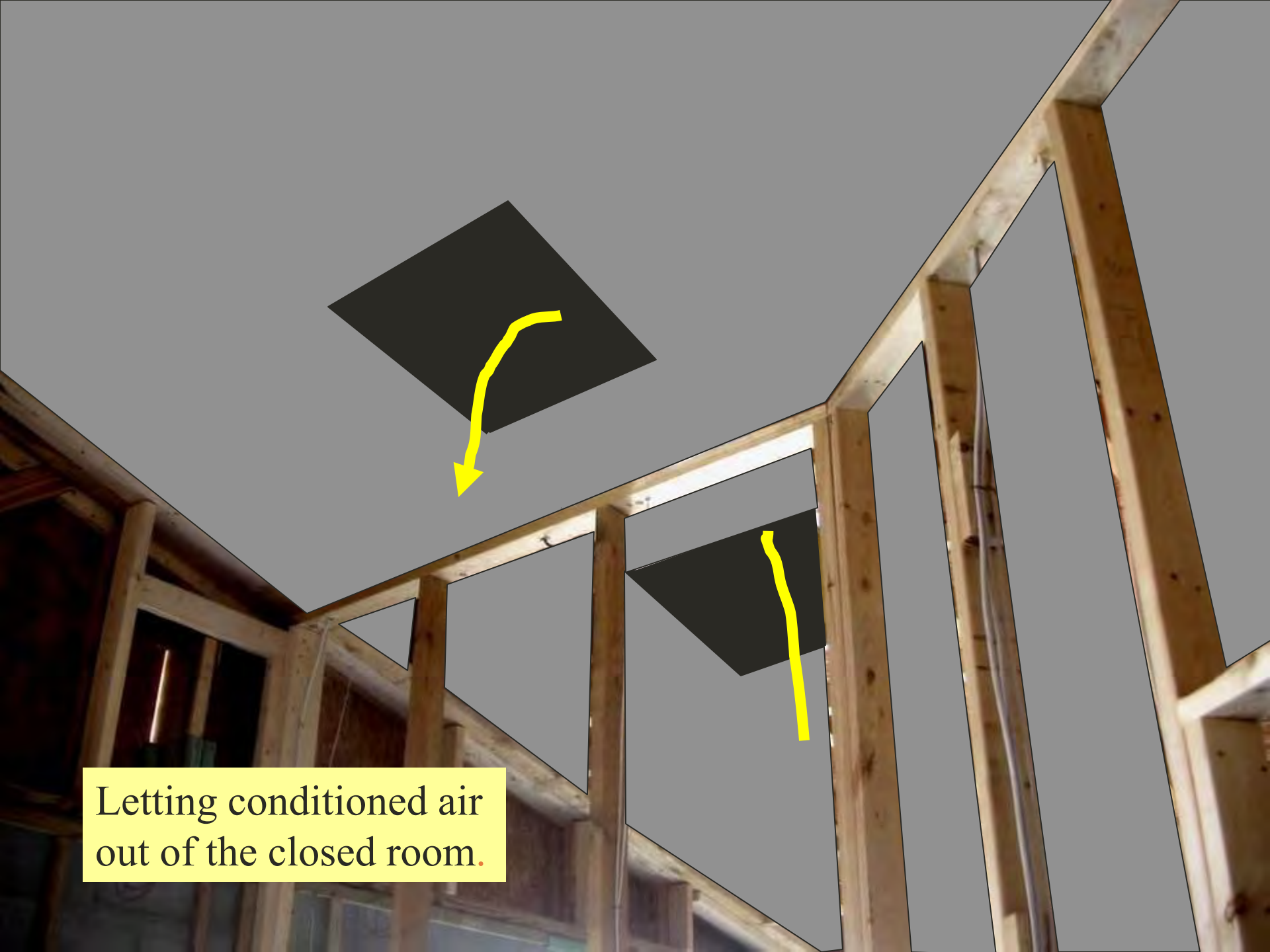


ACCA Manual T

Transfer grilles are typically sized at 200 fpm face velocity or 300 fpm core velocity and in some cases a value of 150 fpm face velocity is used to minimize the pressure drop. If door undercuts are used in lieu of door grilles, allow 1 inch of undercut for each 60 CFM of return air. Also note that privacy (sight and sound) should be maintained. A line of grilles specifically designed for this application is available from many manufacturers.

11-1





Letting conditioned air
out of the closed room.



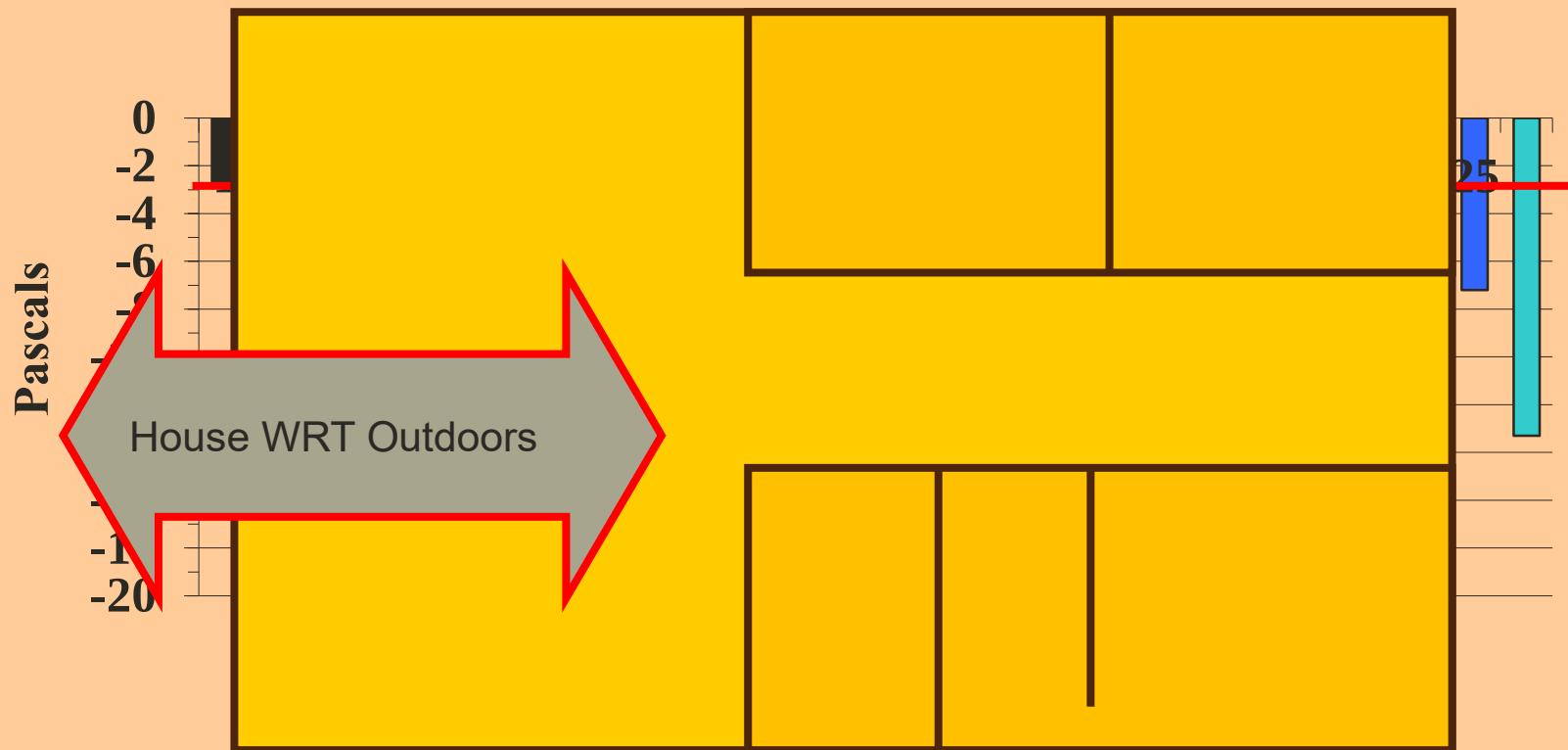
Fan Effects

- Duct leakage
- Interior door closure
- Exhaust devices

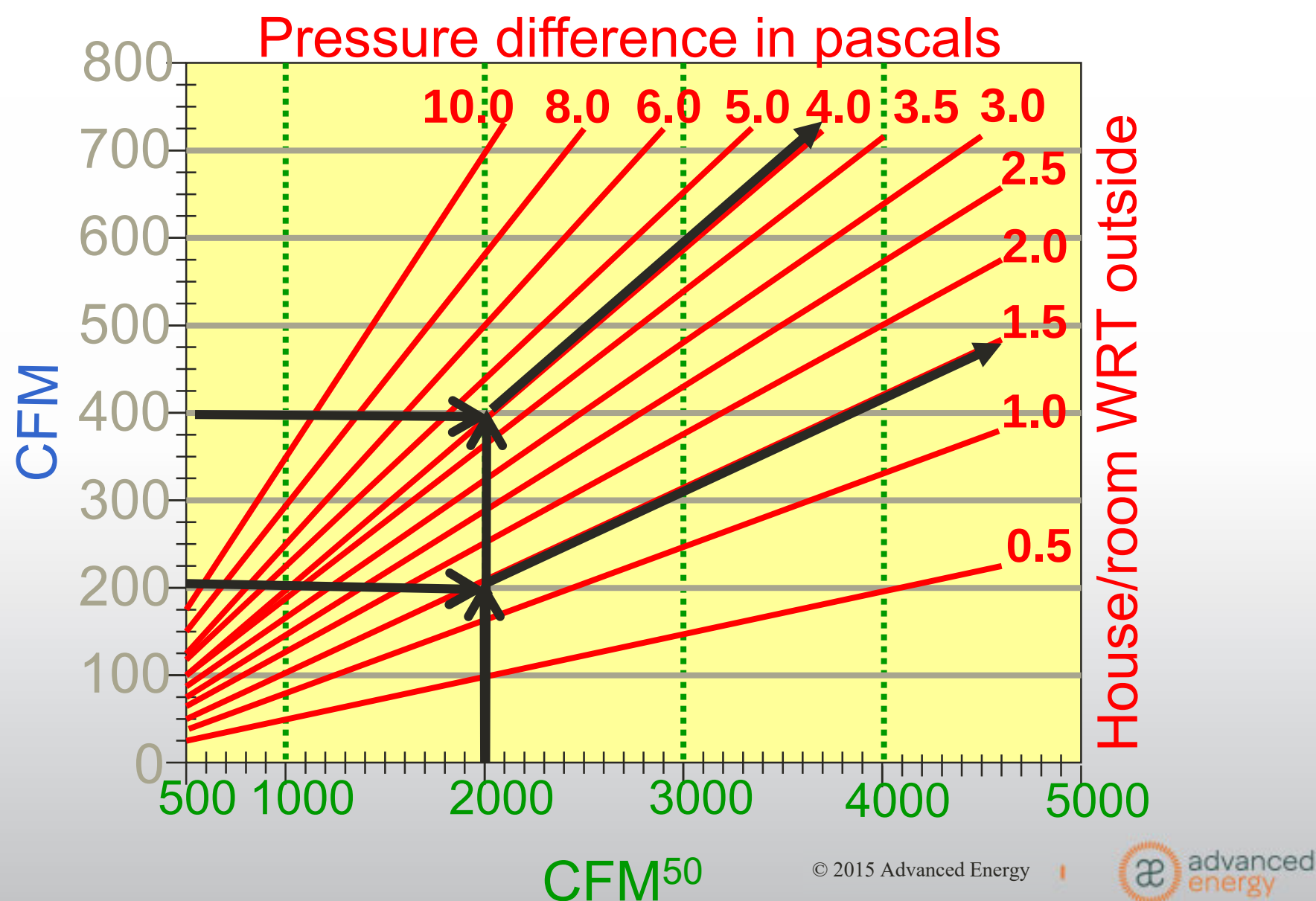


More Flow Out of Tighter Houses?

Interior Doors Closed and Exhaust Fans On (House With Reference to Outside)



Doubling the flow does not double the pressure



House #21 (Tightener)



House #22 (Tightener)

Pressure difference in pascals

30
25
20
15
10
5
0
-5
-10
-15
-20

Dom/Du

Call backs and claims

Doors/Ex

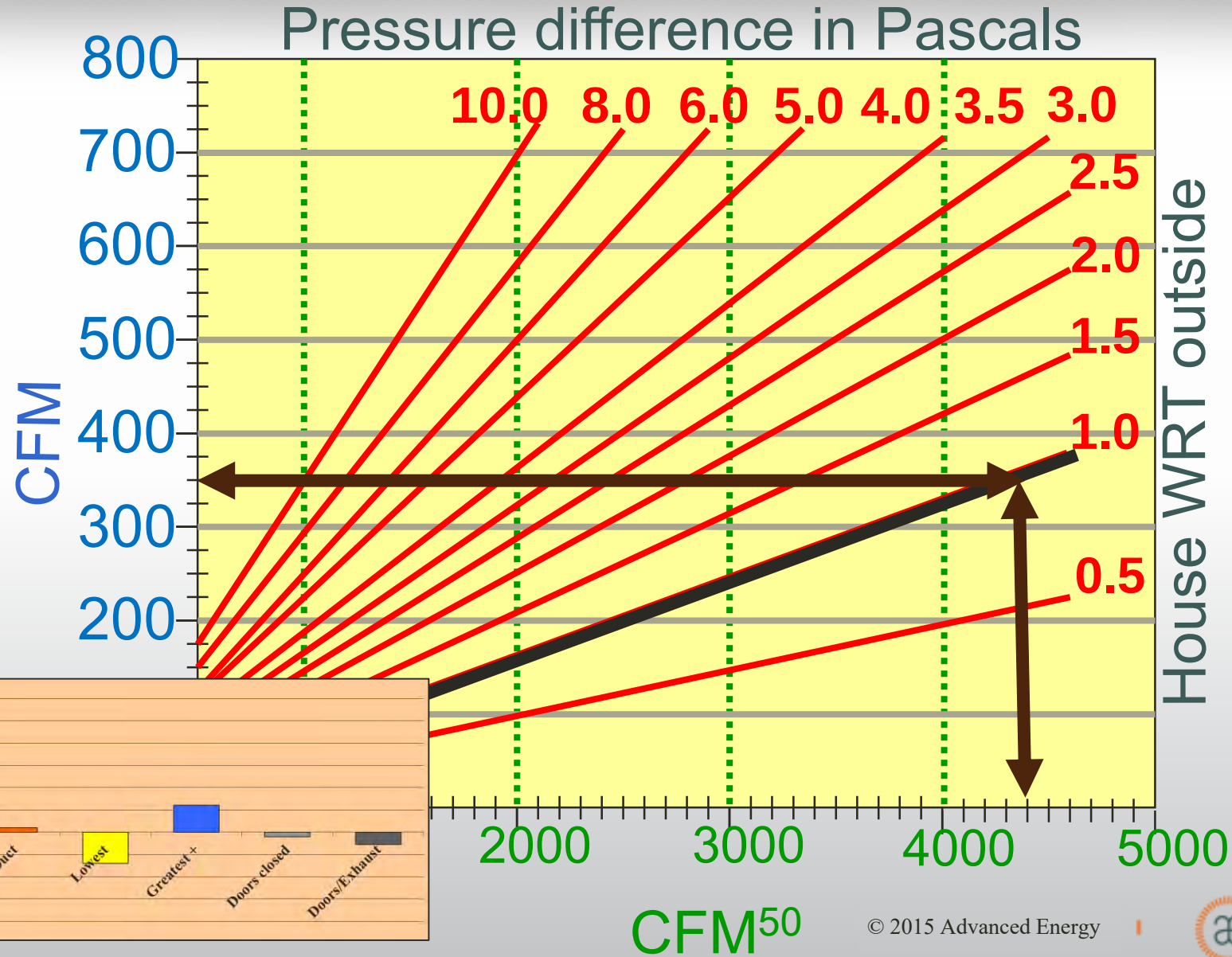
Inst/...

House #1 Leakiest

Pressure difference in pascals



House #1 Dominate Duct Leak Pressure



House #2 Second M leaky

Pressure difference in pascals

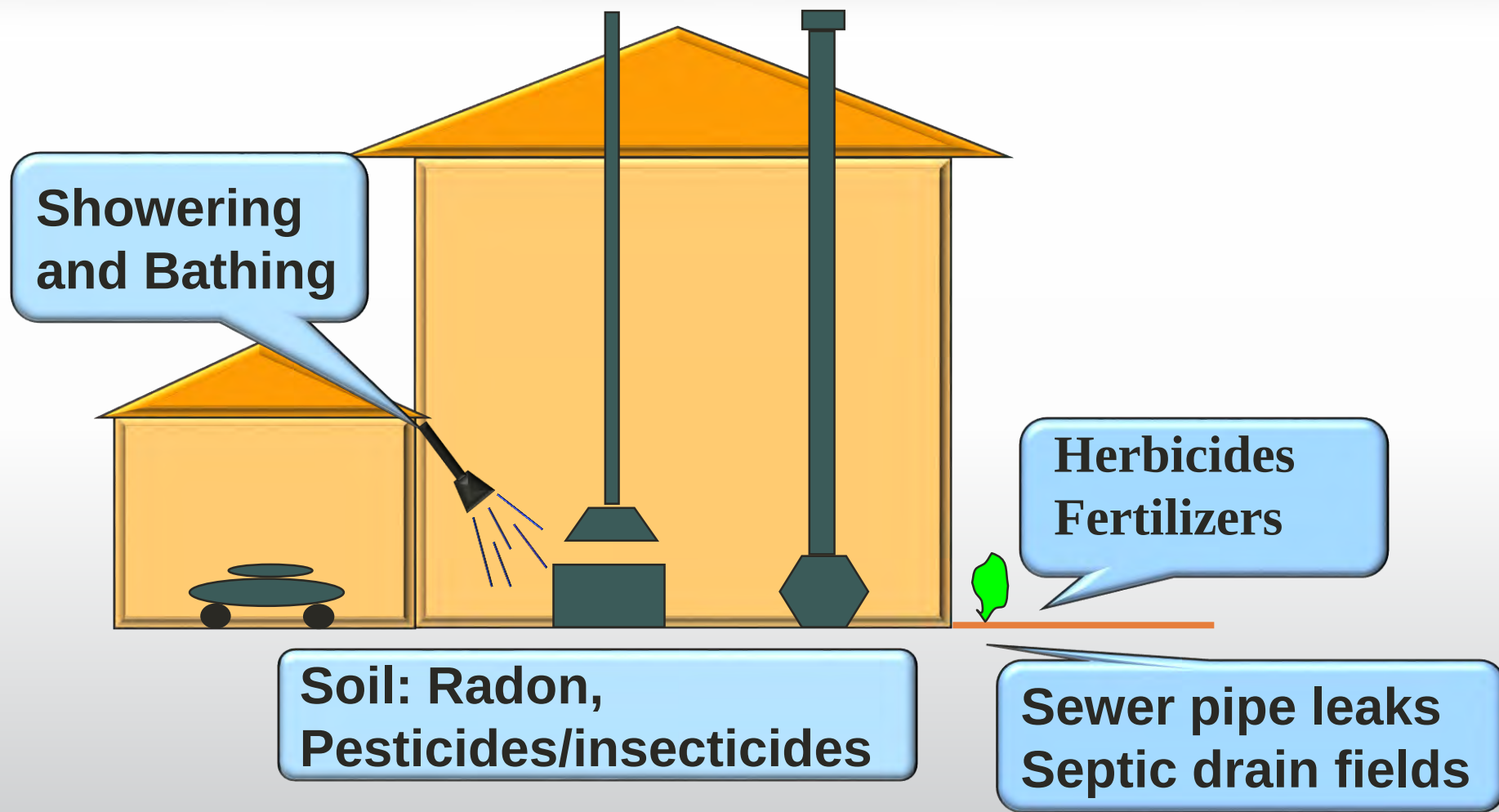


Call backs and claims

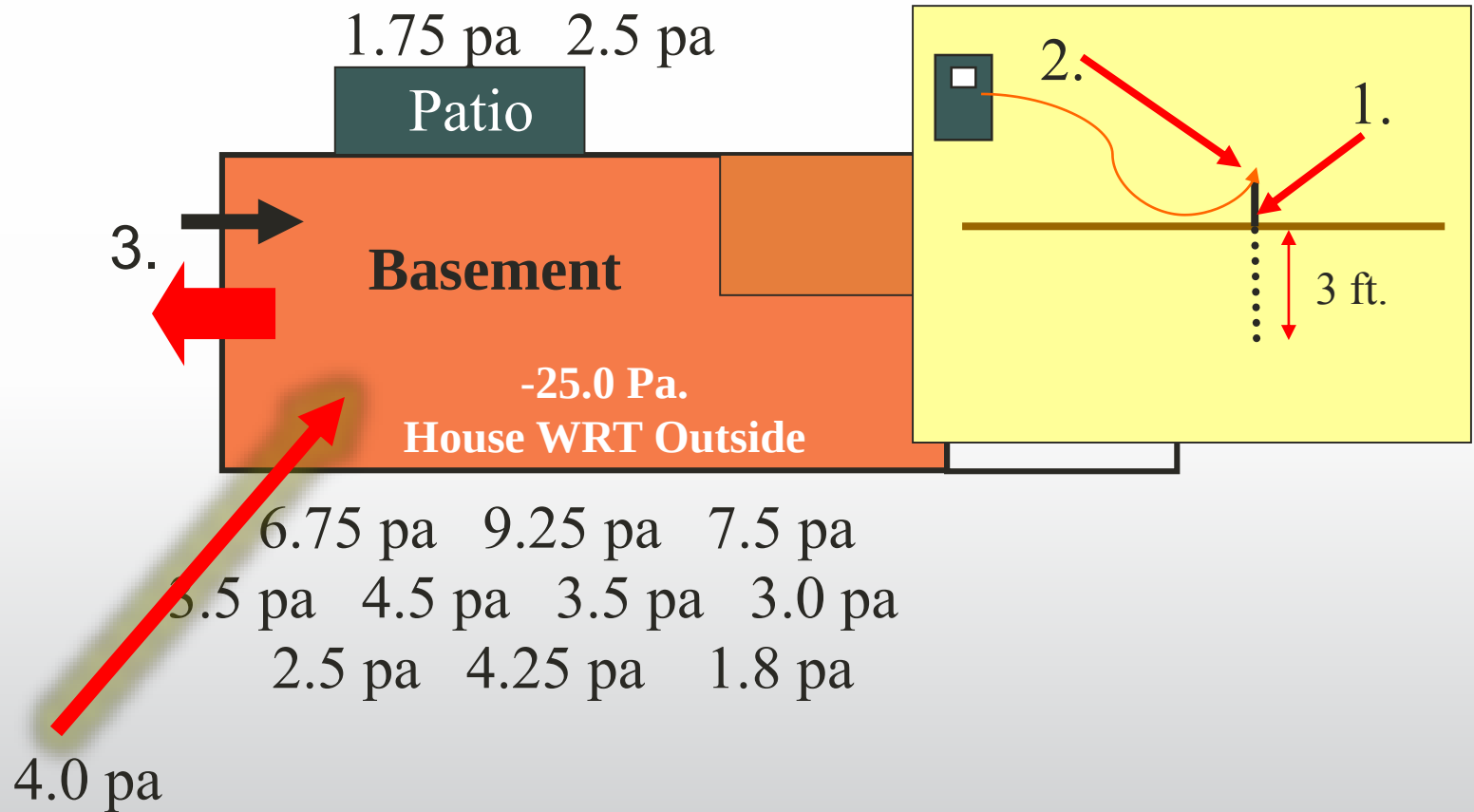
Pressures can cause

- Soil gas entry
- Garage vapor entry
- Combustion problems
 - Spillage
 - Back-drafting
 - Flame roll-out
- Moisture damage and mold

Soil Gas Sources and Pathways Into The House



Soil Depressurization Study



Pest Control



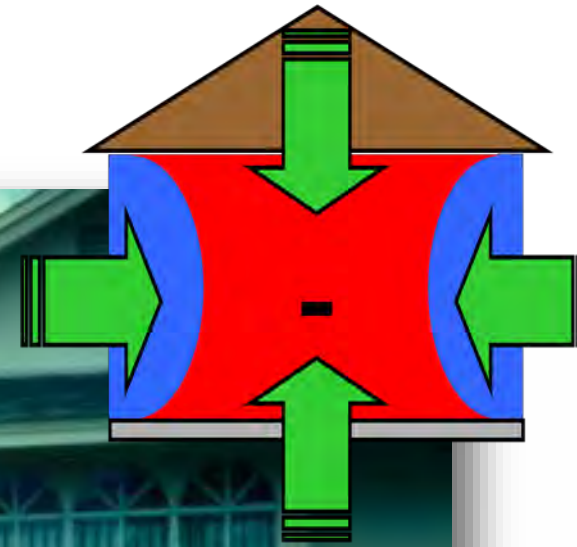


Spray Fertilizer



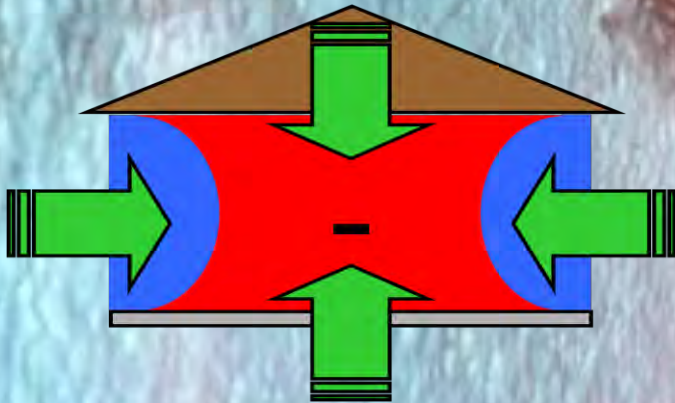
Septic Drain Field



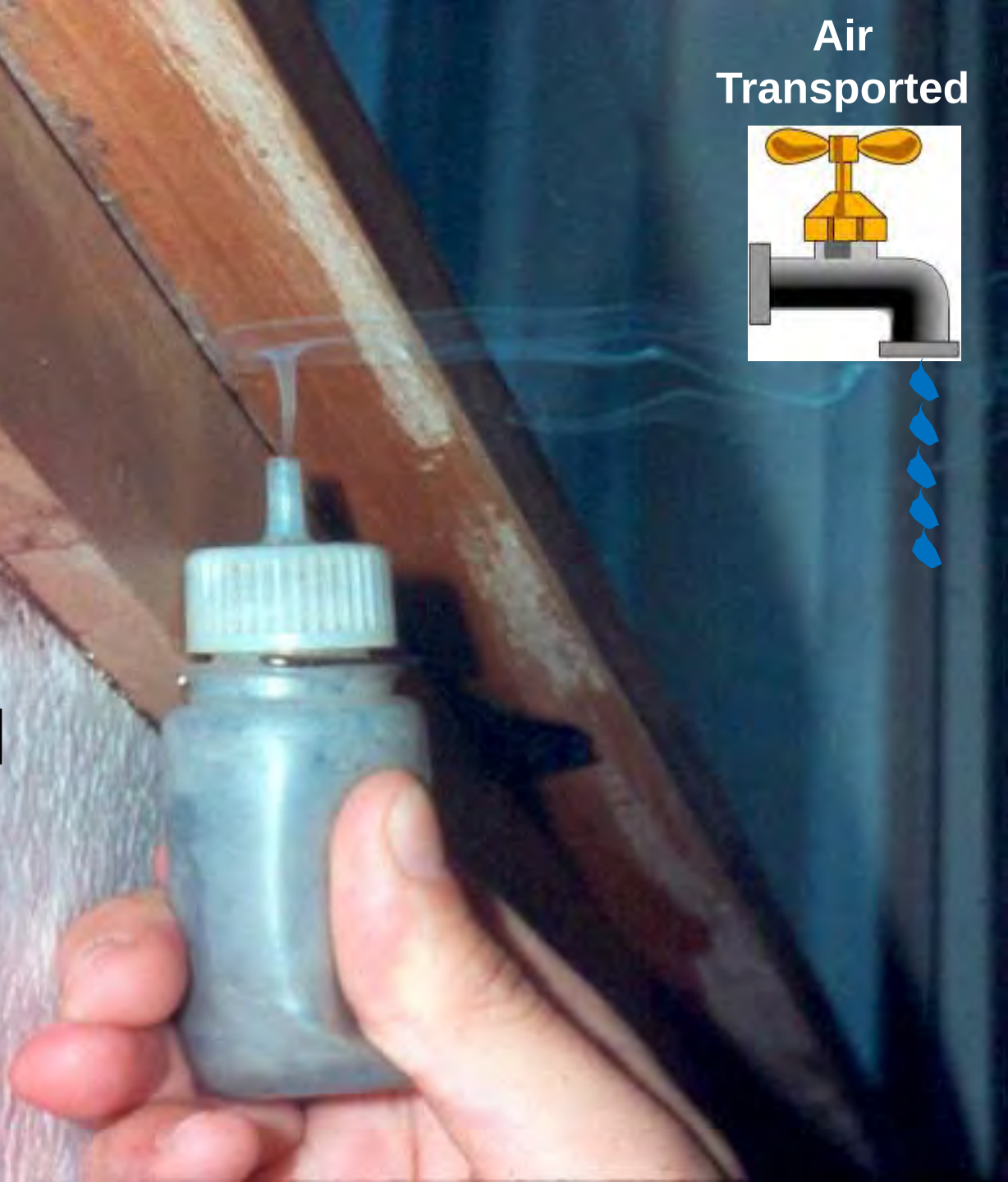




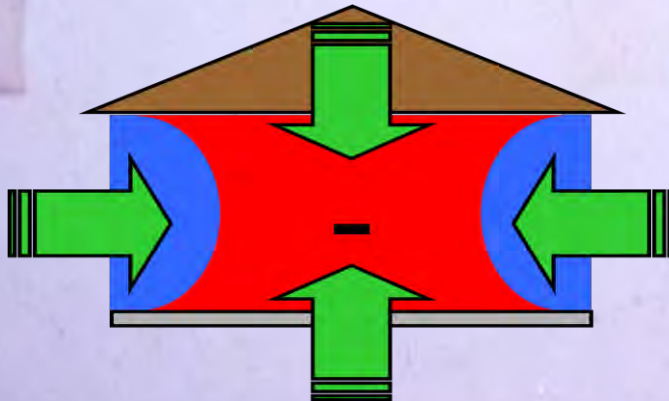
Air
Transported



**This house is
depressurized**

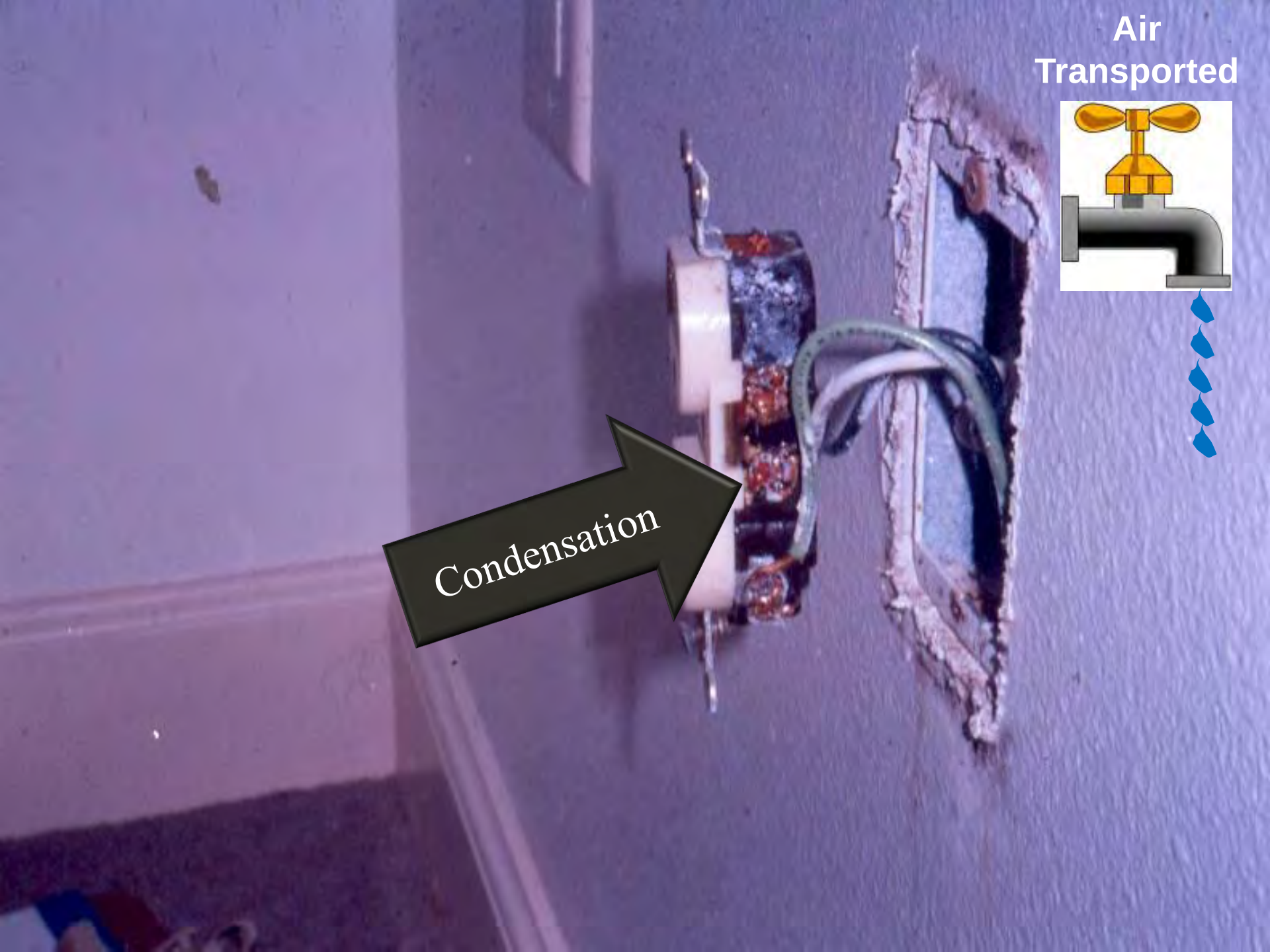


**Air
Transported**

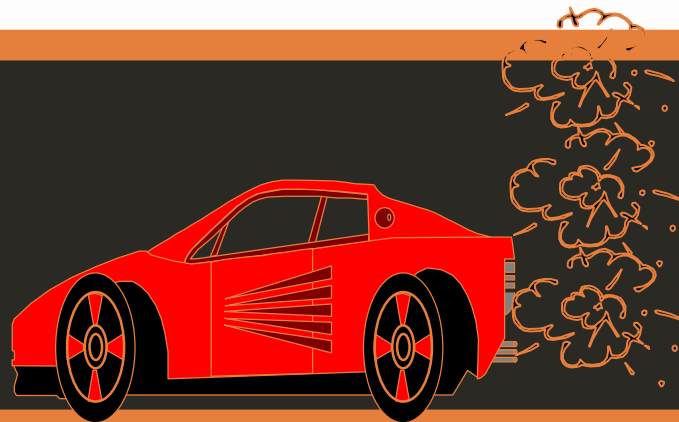


**This house is
depressurized**

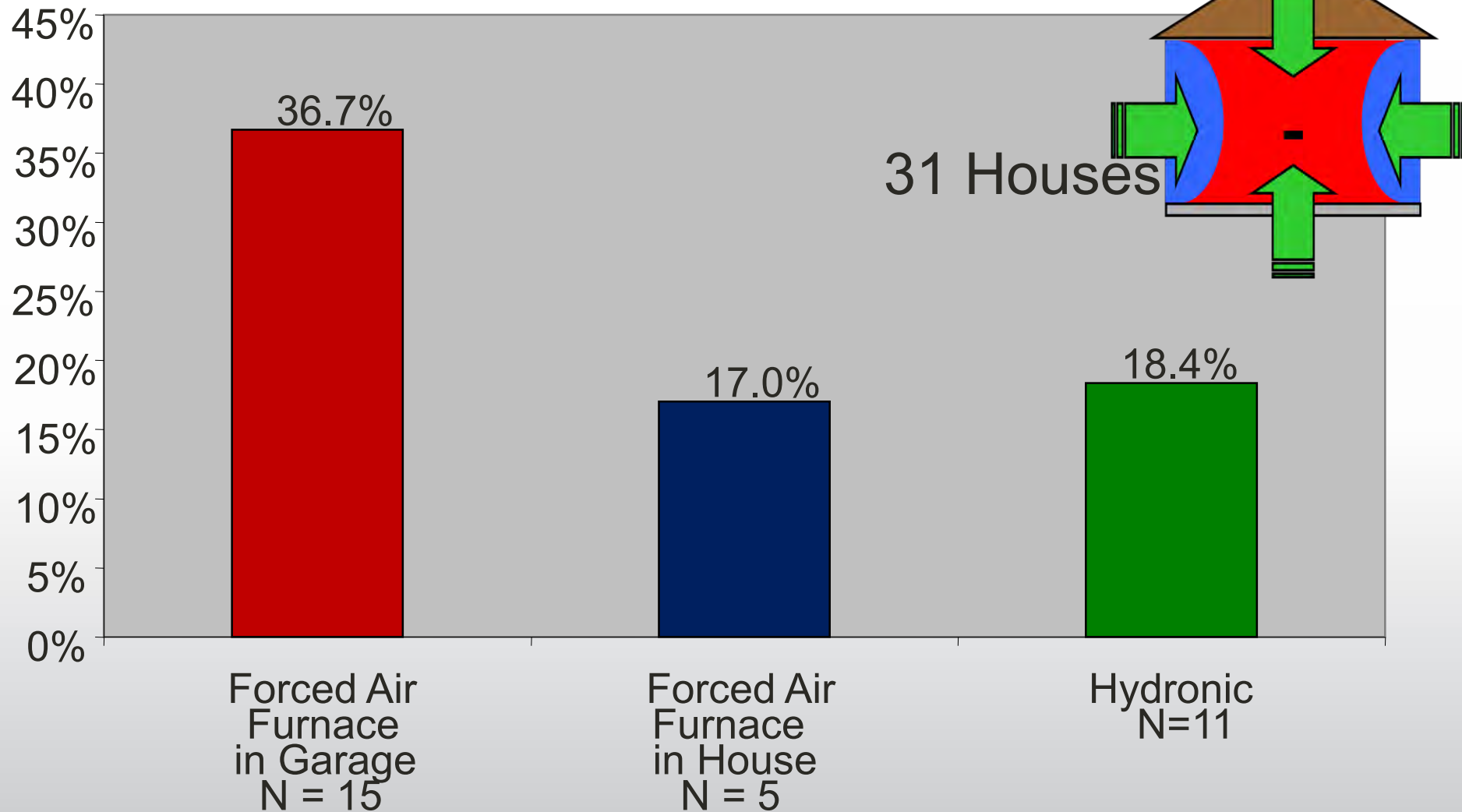
Air
Transported



What is the probability?



Comparison of Median Infiltration Rates Proportion of House Air Originating from Garage



69 House Study (Alaska) Benzene

- **Class A carcinogen**
 - US Govt. Minimal Risk Level (MRL = 4 ppb)
 - **One of the Top Ten Most Hazardous Air Pollutants**
- **Gasoline**
 - 3-5% *benzene*

60% of homes with attached garages had benzene levels that exceeded the US Govt. Minimal Risk Level (MRL = 4 ppb)

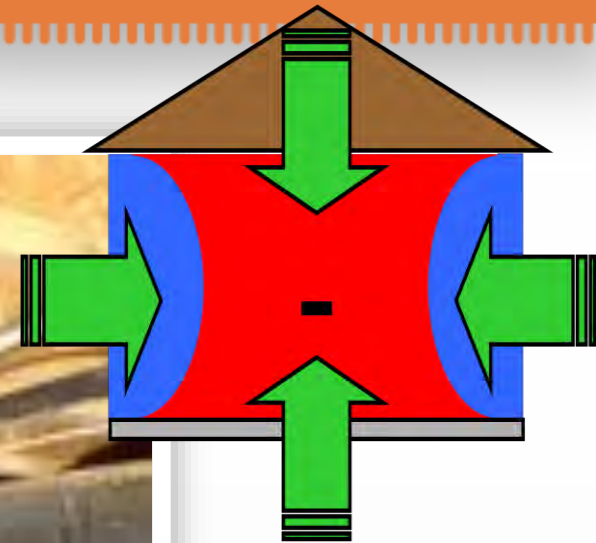


Source: Phil Kaluza, ABSN, Alaska

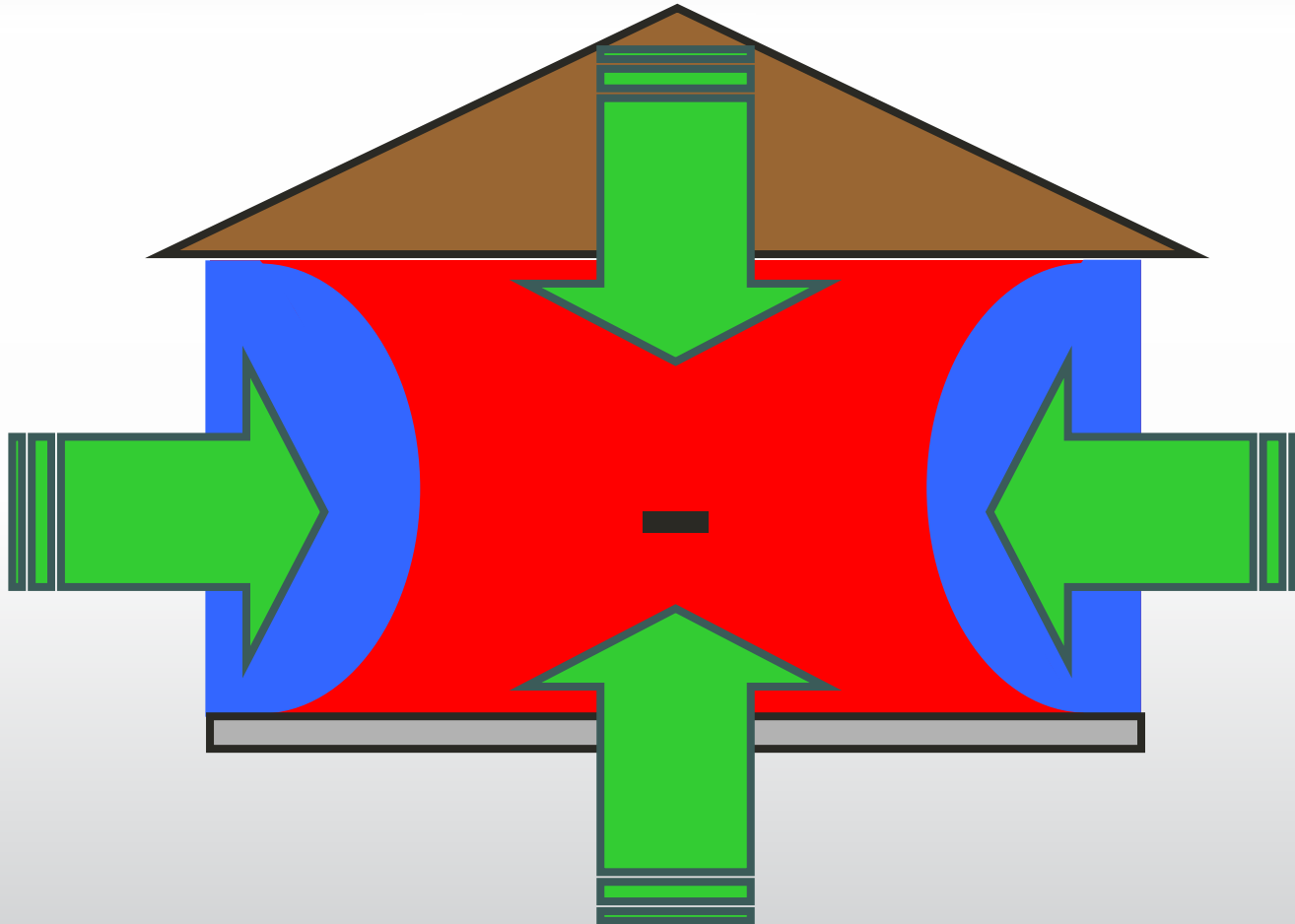
What's in the garage can end up in the house



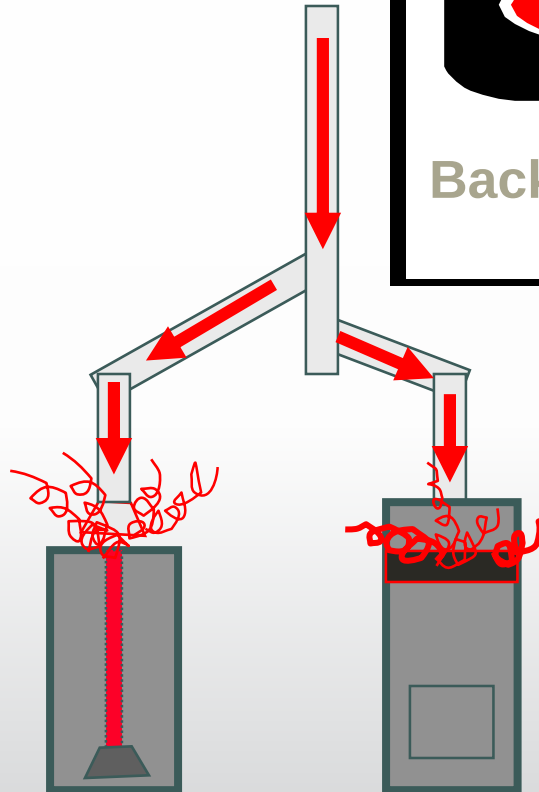
Proportion of House Air Originating from Crawl Space



Negative Pressure



Backdrafting

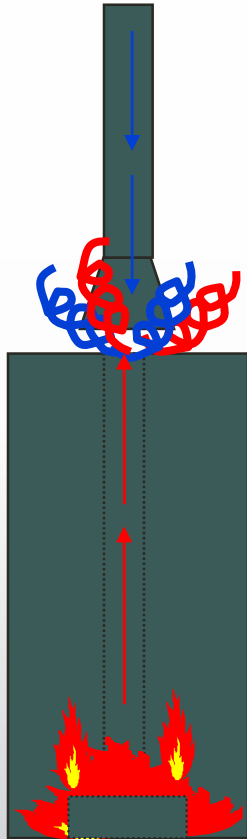


DANGER

Back drafting is a hazardous situation!

**Negative pressure
CAZ WRT outdoors**

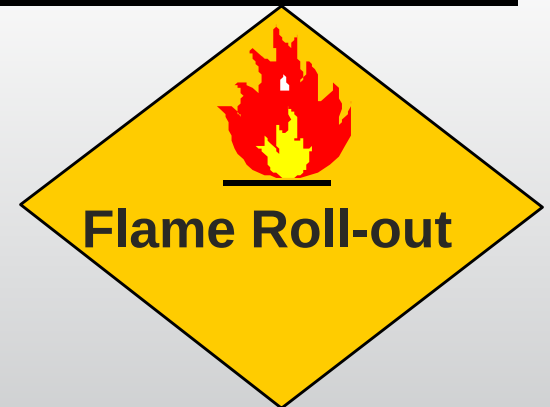
Pressure Induced Flame Roll-Out



DANGER

Pressure induced flame roll-out
is a hazardous situation!

*Negative pressure
CAZ WRT outdoors*







Kitchen sinks

What's behind the door?





Flame Roll-out



Pressure Induced Flame Rollout



What normally happens





CO Detectors

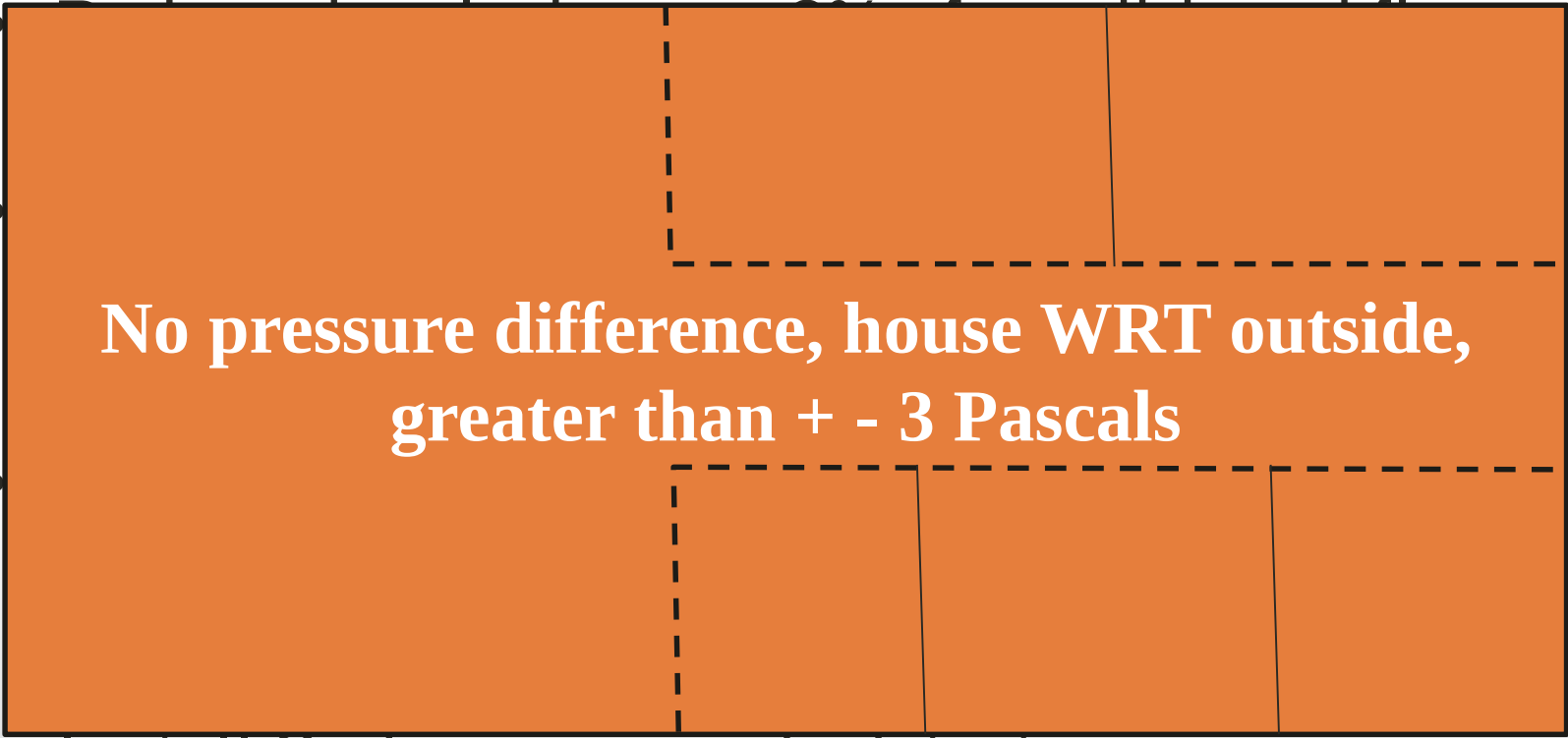
Solution: Sealed combustion or power vented inside living space or all electric.

3 Questions

1. Is **Energy Efficiency** more important than health, safety and durability?
2. Should we cure one problem without creating another?
3. Can we continue to treat buildings as incremental parts, improving one part without considering the whole?

MAD-AIR Demands Codes and Standards....

- Use a system approach to pressure



The diagram shows a cross-section of a house with a dashed line representing the boundary between the interior and exterior. The interior is labeled 'No pressure difference, house WRT outside, greater than + - 3 Pascals'. The exterior is divided into three vertical sections, each with a dashed line indicating a pressure boundary. The interior is a single large space, while the exterior is divided into three smaller sections.

**No pressure difference, house WRT outside,
greater than + - 3 Pascals**

- Install Carbon monoxide detectors in every house
- Installing fresh air ventilation as called for in 2015 IECC

QUESTIONS ?





Thank You