INTRODUCTION TO PRESSURE DIAGNOSTICS

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Special thanks to SDG&E for hosting this event.

Purpose of Pressure Diagnostics

1. Determine how leaky a home is.
2. Locate and define the pressure boundaries.
3. Determine dominate Duct Leakage.
4. Identify Air pathways and blockages.
5. Identify Room pressure imbalances.
6. Determine worst case depressurization of the Combustion Appliance Zone (CAZ)
7. Determine worst case Draft of Combustion Appliances.

Overview

Building Envelope Basics

California Envelope Testing

While the code states that the Home will be pressurized in California, there are a couple of testing opportunities that lend to depressurization.

Therefore this training will cover the set-up for training in both modes, pressurization and depressurization.

Units of Measurement

CFM–cubic feet per minute

CFM_{50}–cubic feet per minute at 50 Pascals (Pa)

ACH–air changes per hour for a volume of air

ACH_{50}–Air changes per hour with a pressure difference of 50 Pa.

ACH_n—Air changes per hour with the pressure normalized to account for wind effect, stack effect and temperature difference accounted for, uses LBL tables.

Pascal–metric unit of pressure, ~250 Pa/inch of water column

Units of Measurement

Example of ELA

$$ELA = 0.055 \times CFM_{50}$$

$$CFM_{infil} = ELA \times (A \times \Delta T_2 + B \times V^2)^{.5}$$

Where:

CFM_{infil} = Infiltration in cubic feet per minute (cfm)

ΔT_2 = difference between indoor and outdoor temperature for previous hour (^{o}F)

A = stack coefficient, ($cfm^2/in^4/F$)

B = wind coefficient, ($cfm^2/in^4/mph^2$)

V = average wind speed for current hour (mph)

ELA = effective leakage area (in^2).

Table R3-5 – Infiltration Coefficients

Coefficient	One Floors	Two Floors	Three Floor
A (stack)	0.0156	0.0313	0.0471
B (wind)	0.0039	0.0051	0.0060

(Shielding Class 4)

Units of Measurement

SLA—Specific Leakage Area, In California it is a unit that describes the leakage area ratio in proportion to the size of the building.

For example:

Both homes below have a **SLA = 3.0**

House 1 has a **CFA of 1500 ft^2** and a Blower door result of **1178 CFM$_{50}$**.

House 2 has a **CFA of 3000 ft^2** and a Blower door result of **2357 CFM$_{50}$**.

House 1 has an **ELA** of: **65 in^2**

House 2 has an **ELA** of: **129.6** (130) in^2.

Mathematic expressions—SLA

Using SLA and CFA to Calculate a target CFM_{50}.

$$CFM_{50} = (SLA * CFA) / 3.819$$

Using CFM_{50} and CFA to calculate the SLA.

$$SLA = (CFM_{50} * 3.819) / CFA$$

Other Trade Mathematical Expressions

Air Changes per hour:

$$ACH_{50} = (CFM_{50} \times 60) / \text{Building Volume } ft^3$$

Example:

1500 ft^2 ranch style home with 8' Ceilings has a volume of:

$$1500\ ft^2 \times 8\ ft = 12{,}000\ ft^3$$

The Blower door test had a result of $1178\ CFM_{50}$

$$ACH50 = (1178 \times 60) / 12{,}000\ ft^3$$

$$ACH_{50} = 5.89$$

Causes of Pressure Differences (ΔP)

Stack, Mechanical, and Wind Effects

Pressure differences are constantly moving:

Air

Vapor (Moisture)

Heat

Air Movement Through Buildings is Caused by:

Differences in Air Density

Differences in Air Pressure

What Causes the Differences?

Heat-stratification

Mechanical-imposed pressures, internal to structure

Exhaust

Supply

Wind-imposed pressures, external to structure

Air Movement Through Buildings is Caused by CONTINUED

Heat—Stack Effect

Stratification of Heat due to Heat Content

Mechanical

Exhaust (Depressurizing the home, room or area)

Supply (Pressurizing the home, room or area)

Wind

Pressurizing and Depressurizing differing parts of the house.

When there are pressure differences, things are constantly moving

The movement of Air, Heat and Moisture affect building occupants:

Health & Safety can be effected,

Durability of the Structure can be affected,

Comfort of the Occupants can be affected,

Home Operating Costs can be affected.

Things Moving Affect . . .

Very often occupant behaviors and habits make conditions worse for:

Inside/Outside Zones

Inside Zones (Rooms)

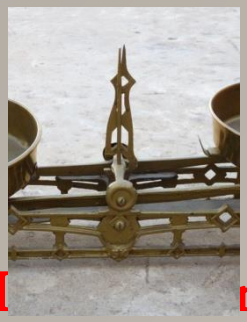
Outside Zones

How are buildings affected?

Consider a home in any California subdivision winter to mid Spring.

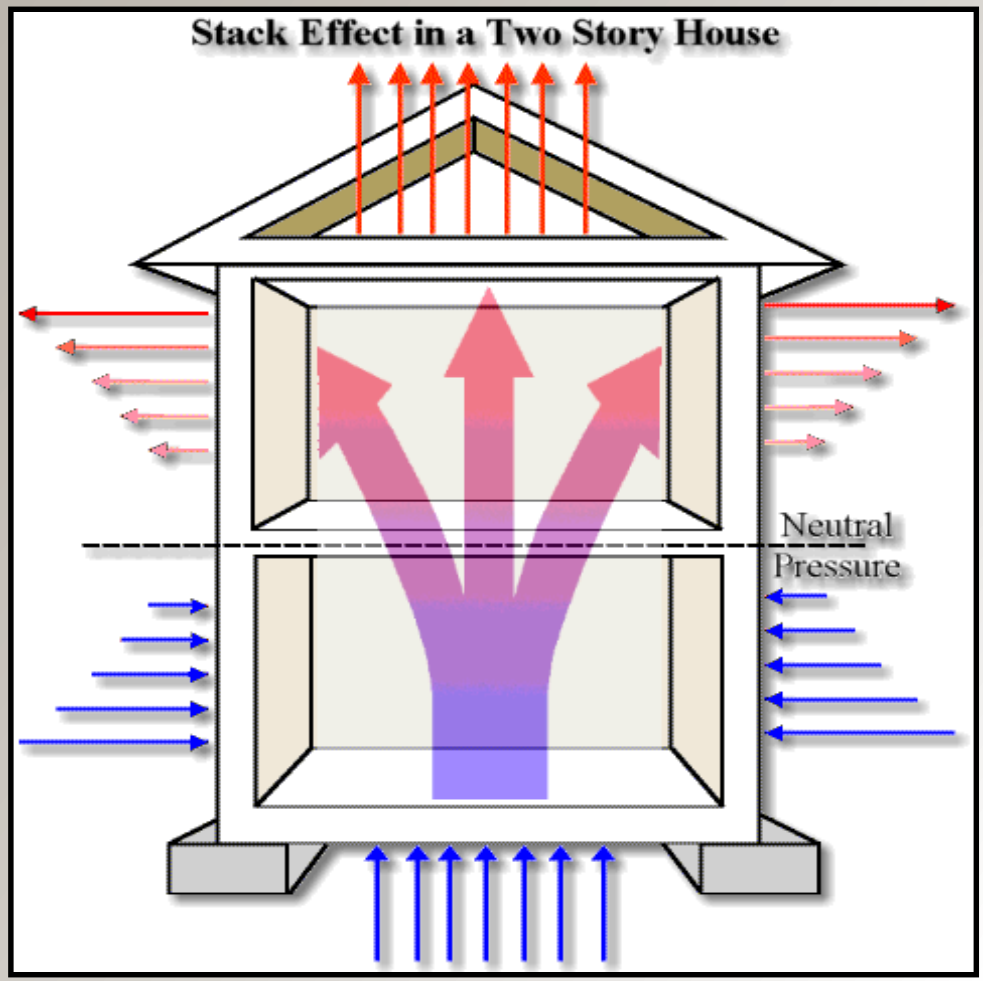
Stack Effect

IF the temperature of all objects, surfaces and air are exactly the same,



Balanced H nt

AND



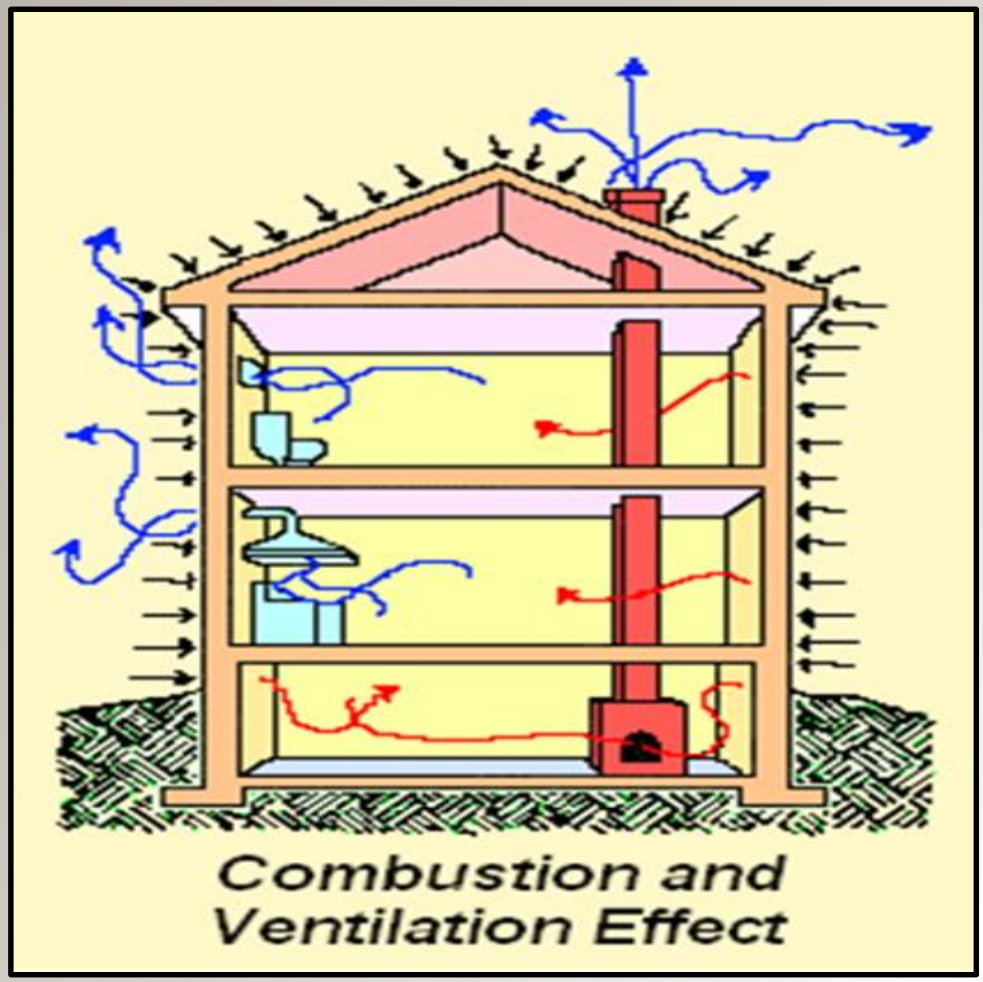
Combustion Effect

IF There are no operating combustion appliances.

No Combustion

Appliances

AND



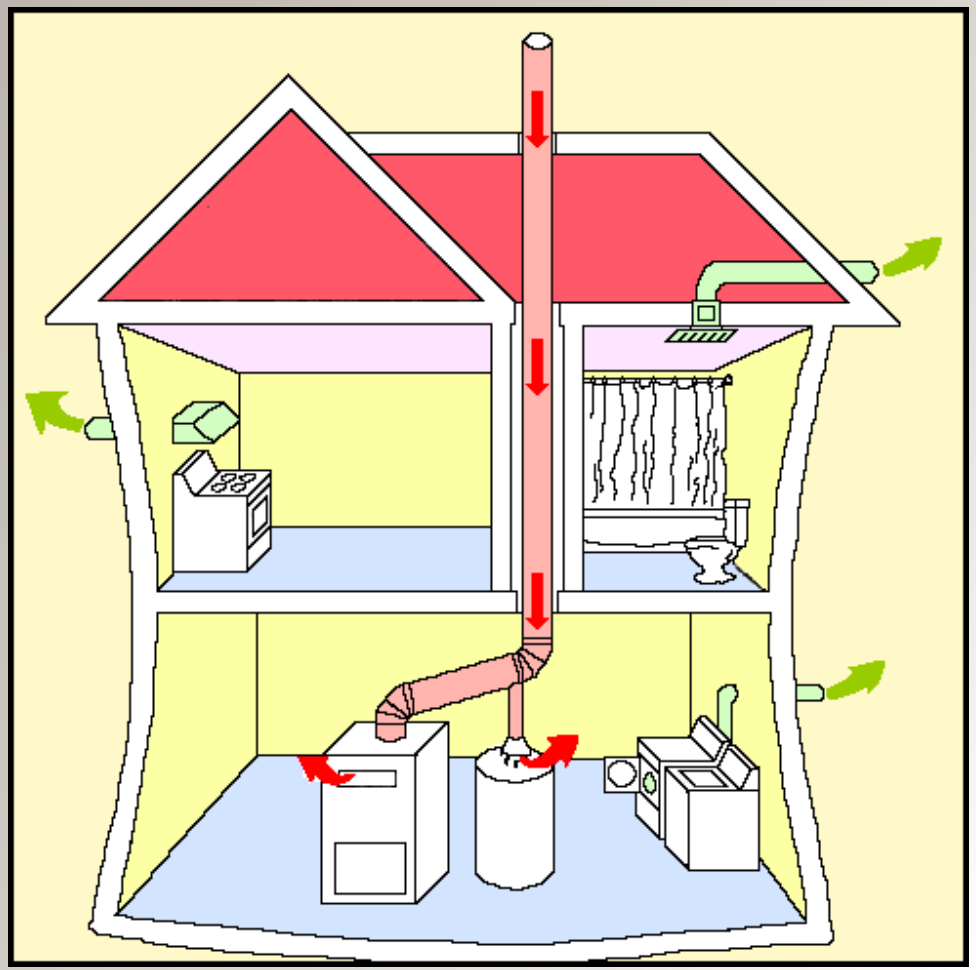
Mechanical or Fan Effect

IF There are no mechanical units moving any air within the building.

No Mechanical

Ventilation

AND

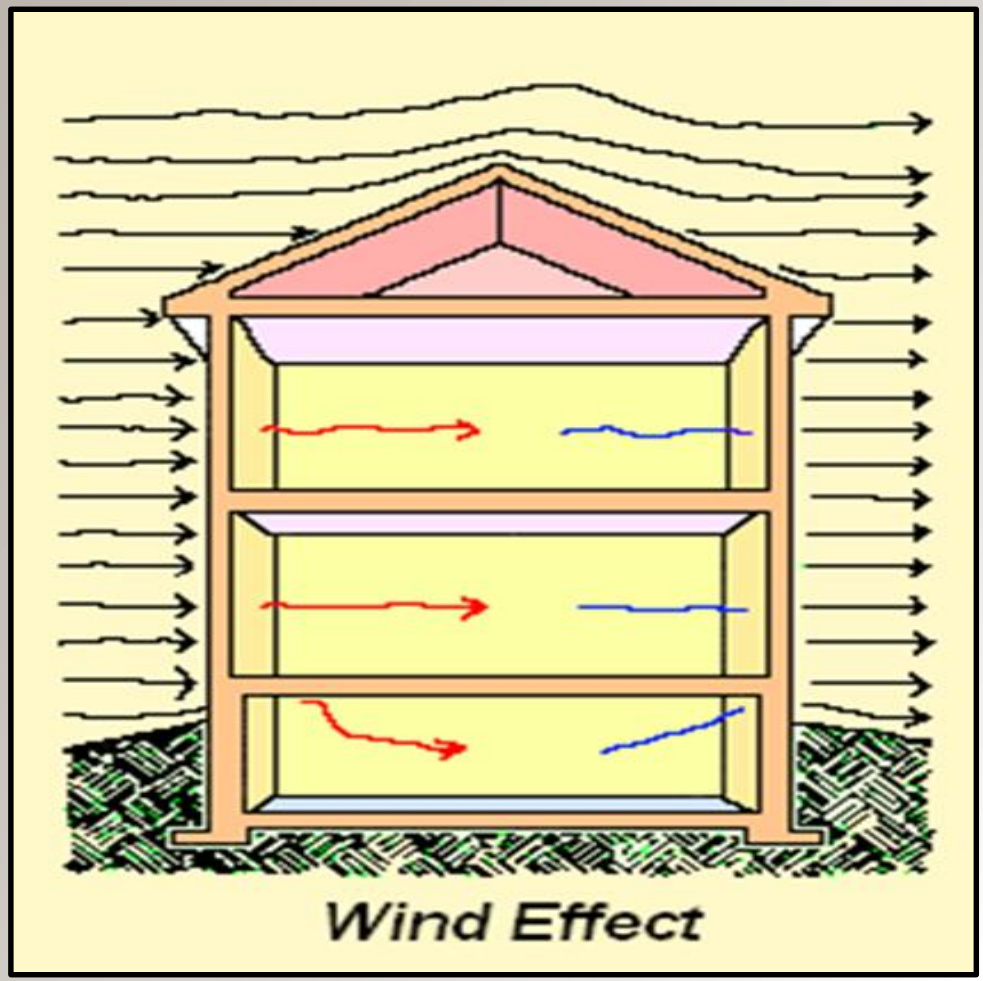


Wind Effect

IF There isn't any breeze or wind.

NO Wind!

AND



Result?

There would be no air movement in or out of the building at all.

BECAUSE, there is

no pressure difference.

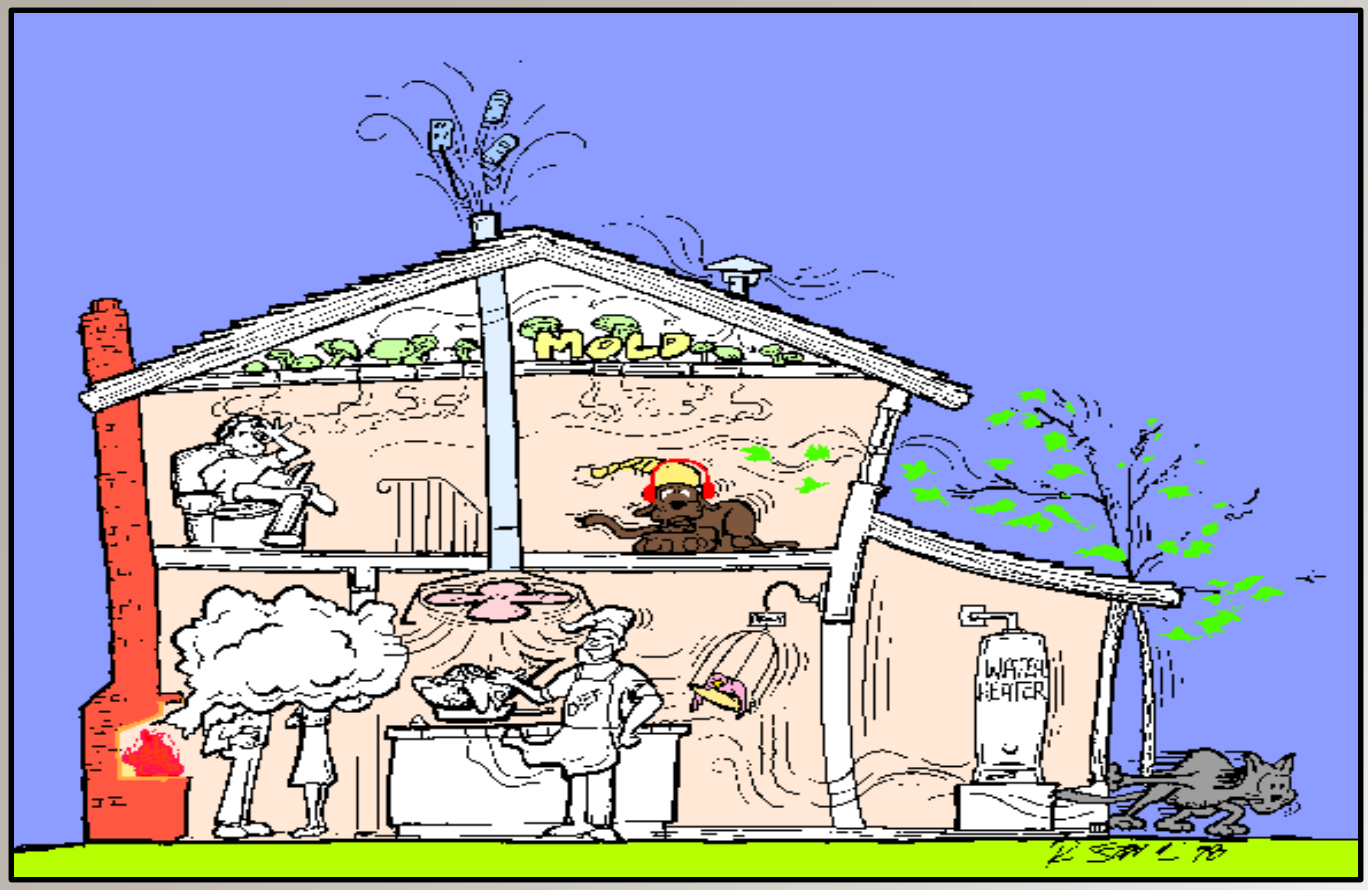
DELTA Pressure

ΔP

Does this ever happen?

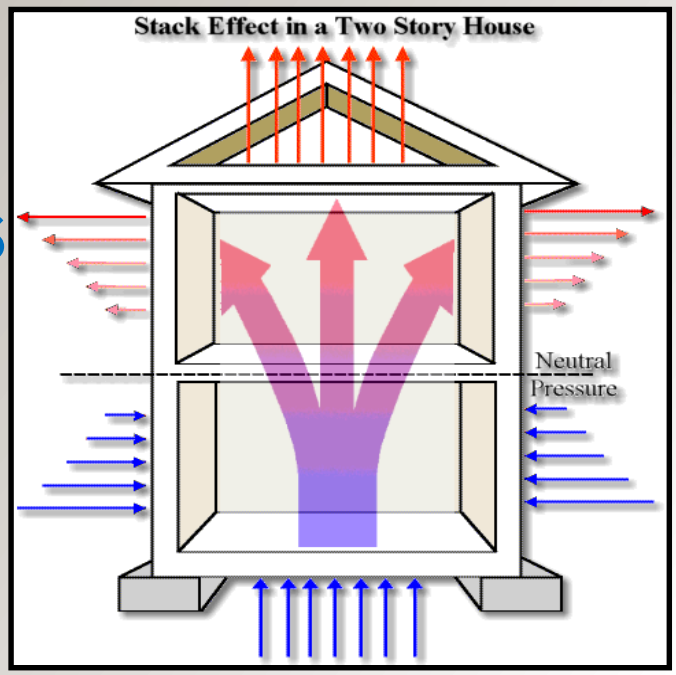
In the real world, Fluid Dynamics are truly fluid.

It's a snapshot in time.



Stack Effect

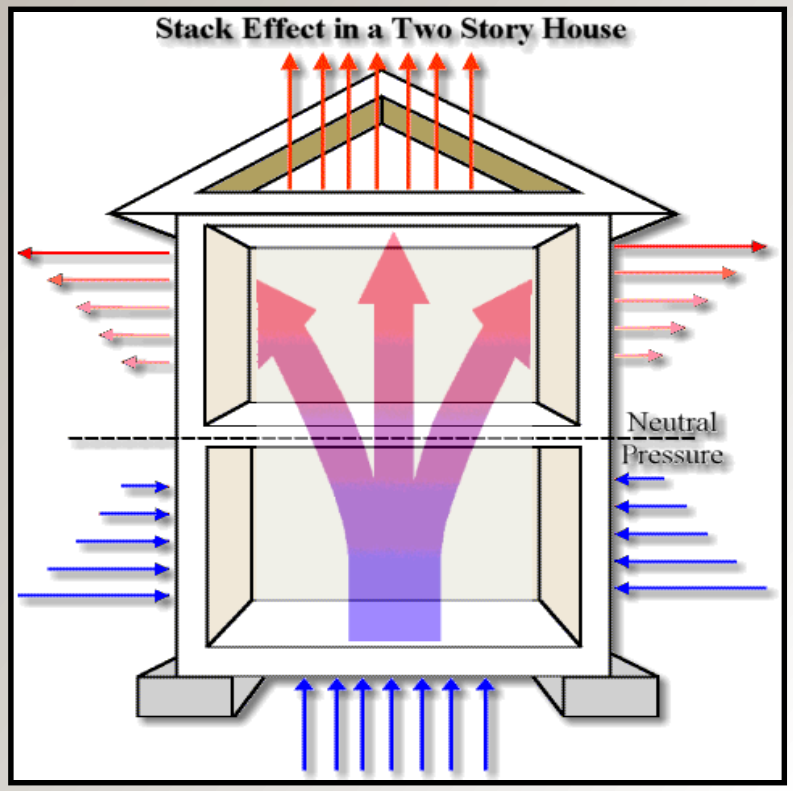
How it works



Stack Effect

HEAT transferred to the AIR within a building that causes an AIR pressure difference within that building.

The result is the AIR leaks-out (exfiltration) at the upper portion of the building, and the AIR leaks-in (infiltration) at the lower portion of the building.



Stack Effect—Continued

If the temperature of all objects, surfaces and air were exactly the same, inside, inside/outside and outside the building.

Then Air would not circulate based upon heat content

Balanced Heat Content

Heat Content and Temperature of Objects, Surfaces and Air are constantly in flux 24 hours a day, 365.24 days a year.

1 CFM in = 1 CFM out

Heat Stratification

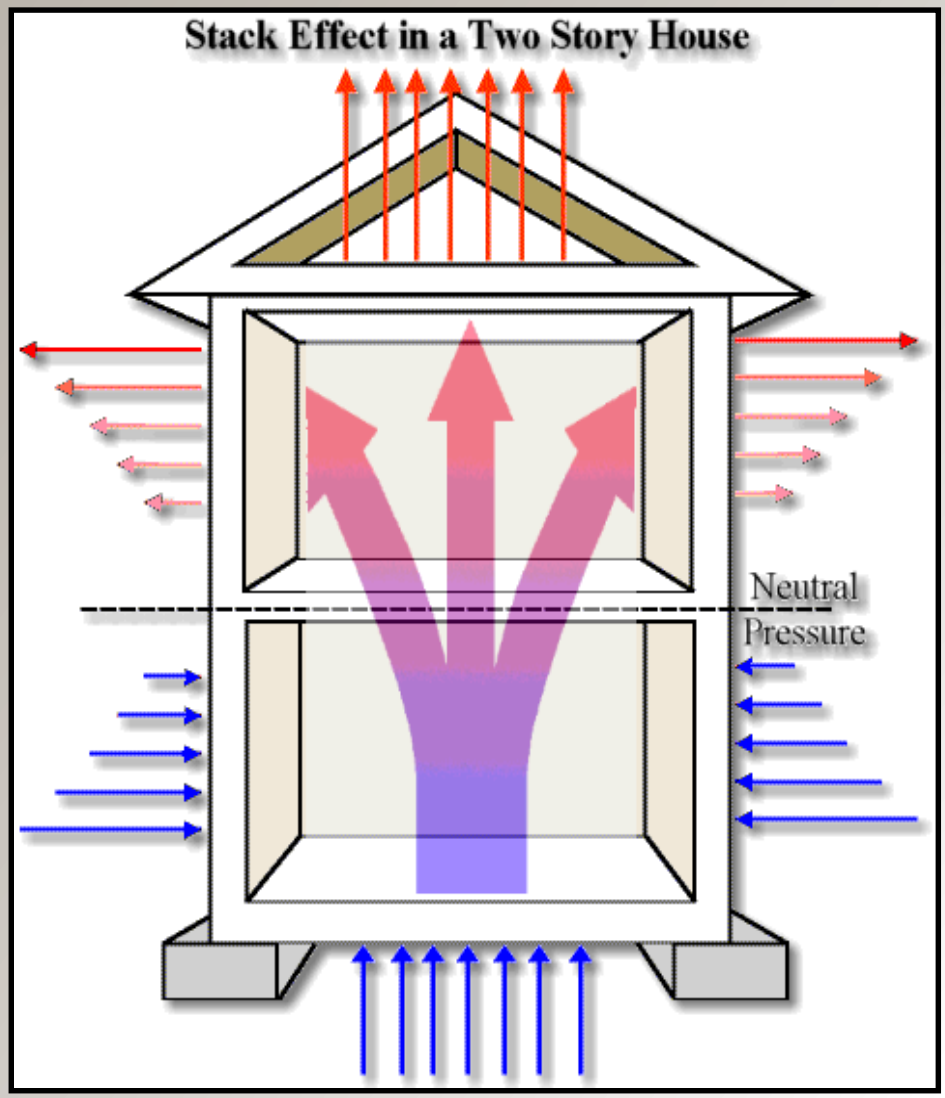
Effect of Air Temperature on Stratification and Air pressure distribution.

100 ^{0}F

75 ^{0}F

50 ^{0}F

1 CFM in = 1 CFM out



Stack Effect Demonstration

HEAT does not RISE!

BUT

A warmer fluid will rise above a cooler fluid.

BECAUSE

The warmer fluid is less dense than the cooler fluid.

BECAUSE

Heat added to the fluid will accelerate molecular action thereby increasing the repulsion rate between the molecules.

THEREFORE

There are fewer molecules per given volume.

THEREFORE

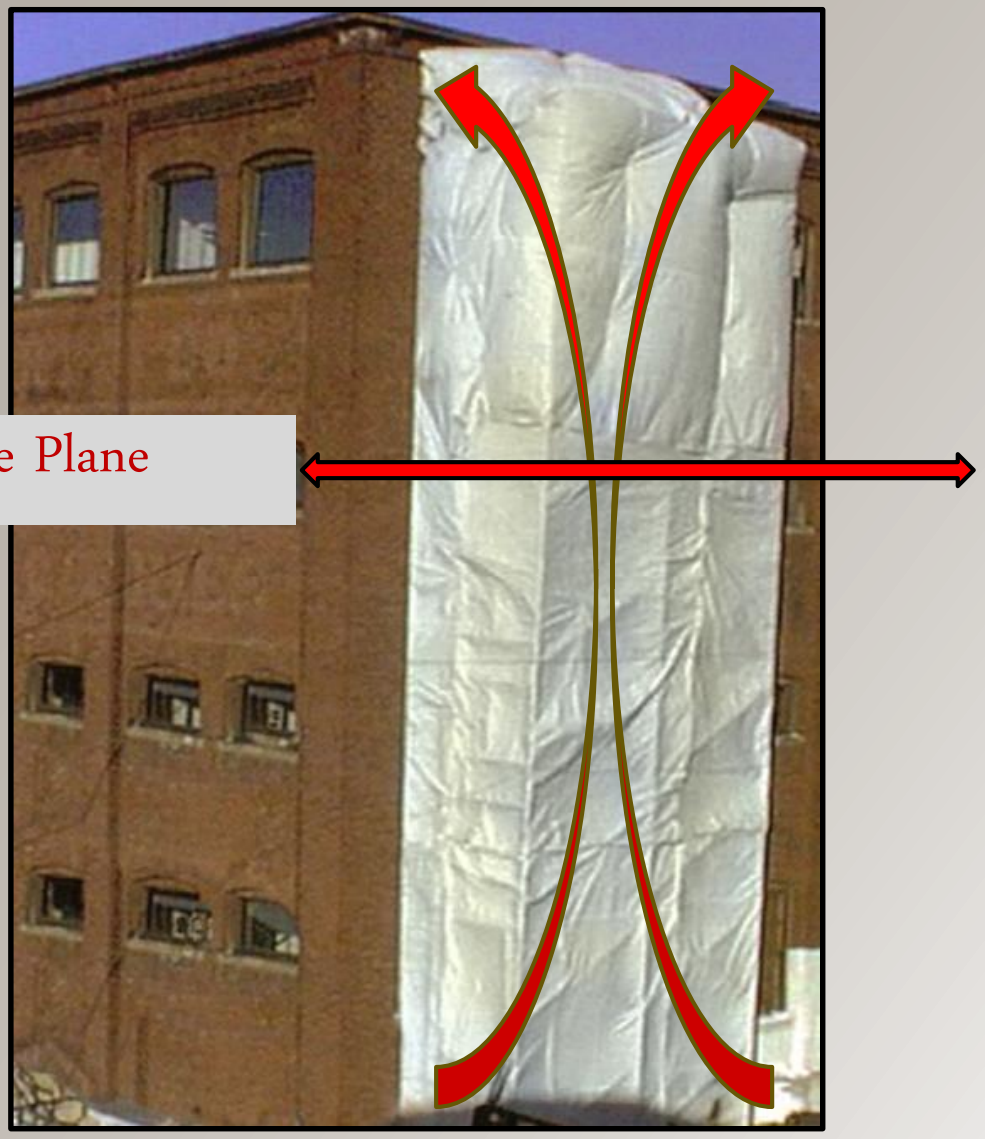
Gravity has less attraction on the warmer less dense fluid than the cooler more dense fluid.

THEREFORE

The Hot Air Balloon rises in the AIR.

Stack Effect Demonstration

Neutral Pressure Plane



Source of Heat

The Heat that contributes to Stack Effect comes from many sources.

Intentional

Heating

By-product

Lighting, Laundry, Water Heating, Appliances, Plug Load, Etc.

Defect

Air Barrier (holes), Thermal Barrier (insulation), Thermal Bypass, Windows (U-factor, SHGC), Etc.,

Stack Effect Review

Is a driving force that results in infiltration and exfiltration.

What may affect the driving force behind Stack Effect?

How does the difference in temperature between the outside and inside affect Stack Effect?

Which has the greatest impact on Stack Effect Cold winter temperatures or Hot summer temperatures?

1 CFM in = 1 CFM out

Stack Effect Factors

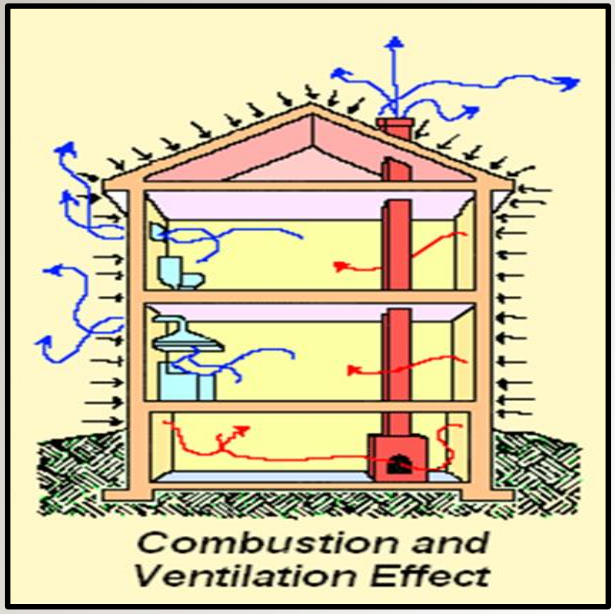
1. Temperature Difference

2. Leakage Area

3. Effective height of building

Combustion and Mechanical Effect

How it works



Combustion and Mechanical Effect

We have many combustion appliances in our homes and these have a potential for increasing air movement by causing air pressure imbalances.

That imbalance may increase Infiltration and exfiltration.

1 CFM in = 1 CFM out

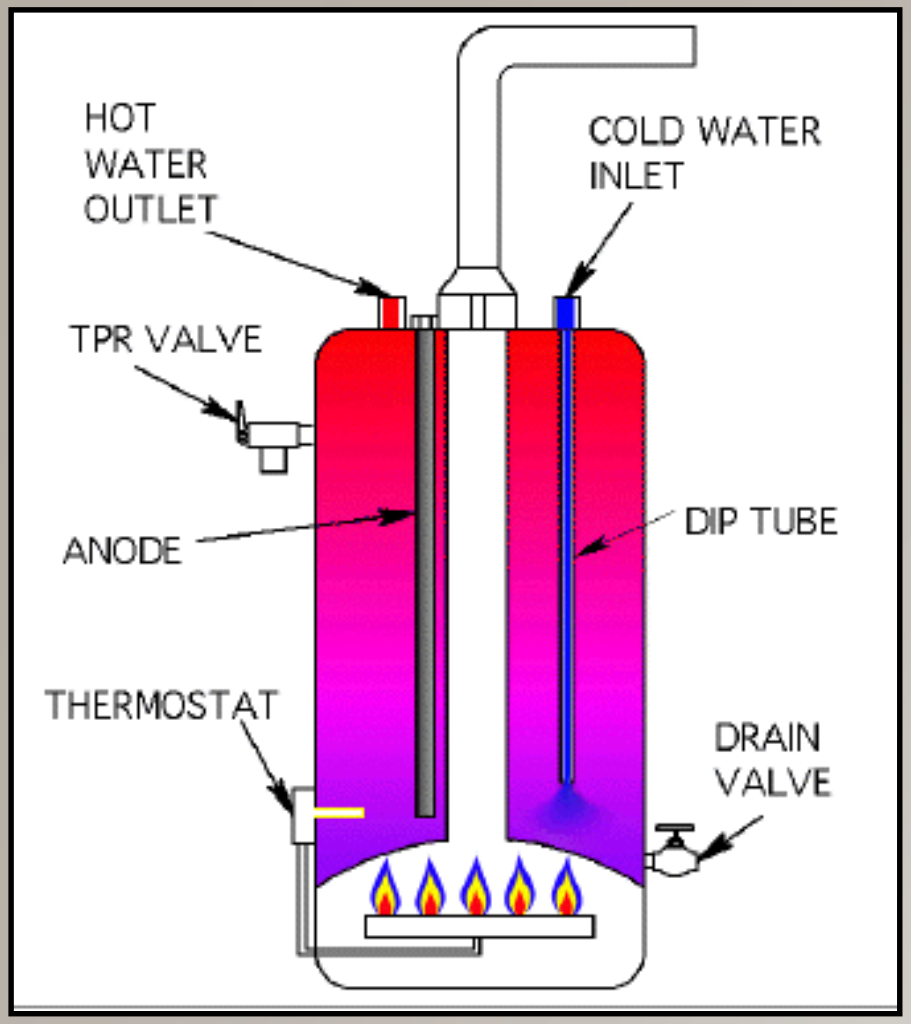
Combustion and Mechanical Effect

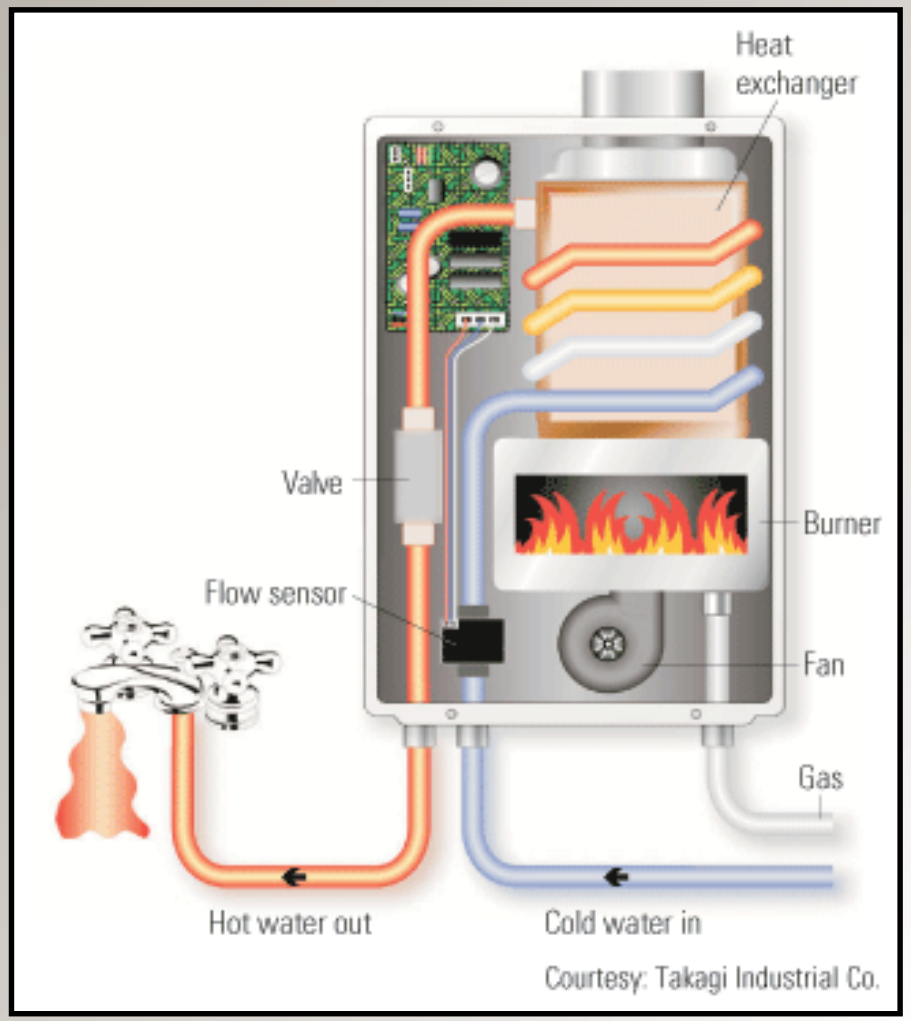
Air is needed in the combustion process and any natural draft appliances within the home use air from within the home for combustion and dilution.

Indoor air is drawn out the home though the appliance chimney.

1 CFM in = 1 CFM out

1 CFM in = 1 CFM out





1 CFM in = 1 CFM out

Typical Fan CFM Ventilation Rates for Units

1 CFM out = 1 CFM in

Residential Bathroom Exhaust	20-160 CFM
Residential Range Hoods	70-350 CFM
Residential Down Draft Range Evacuators	250-750 CFM
Commercial Range Hoods (residential application)	700-2000 CFM
Central Vacuum Systems	100-200 CFM
Residential Clothes Dryers	75-350 CFM
Residential Whole House Fans	750-8,000 CFM
Residential Direct Evaporative Coolers	500 to 3,500 CFM

Mechanical/Combustion Effect Factors

1. Exhaust Fan CFM

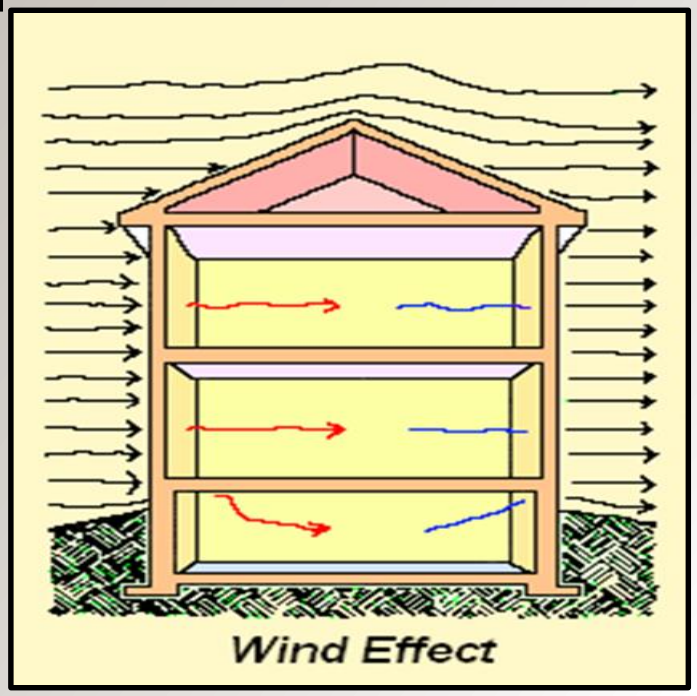
2. Leakage Area

3. Duct Leakage

4. Combustion (Water heaters, furnaces, etc.)

Wind Effect

How it works

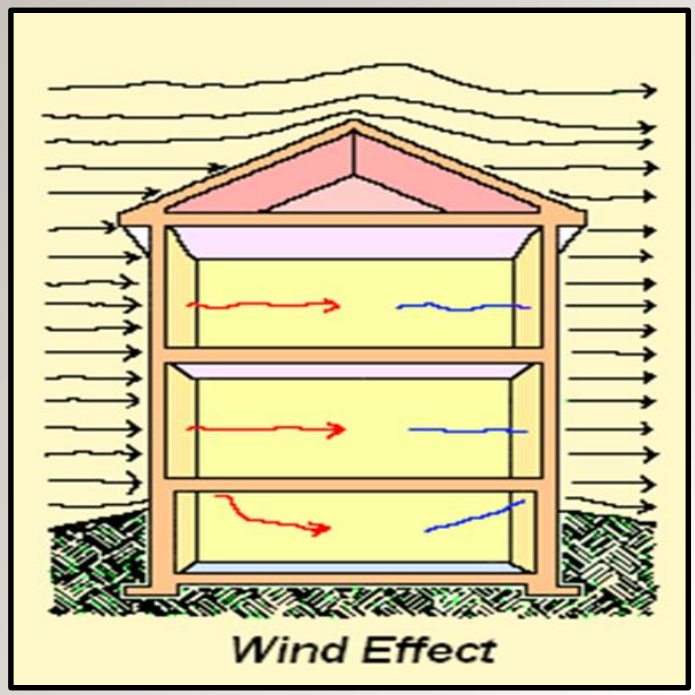


Wind Effect

Is a driving force that results in infiltration & exfiltration.

Wind Effect replaces indoor conditioned air with outside unconditioned air.

Typically outside air and its hitchhikers are not desirable.



Wind Effect

Natural phenomenon—wind increases the positive air pressure acting against the building on the windward side while simultaneously producing a negative pressure on the leeward side and on the walls parallel to the wind direction.

Not a huge component in the infiltration/exfiltration effects of most single family homes.

Dependent upon severity and amount of wind. Look for other related effects, such as wind washing of attic insulation.

Wind Effect Factors

1. Wind Speed

2. Leakage Area

Important principle

Pressure and Openings (HOLES)

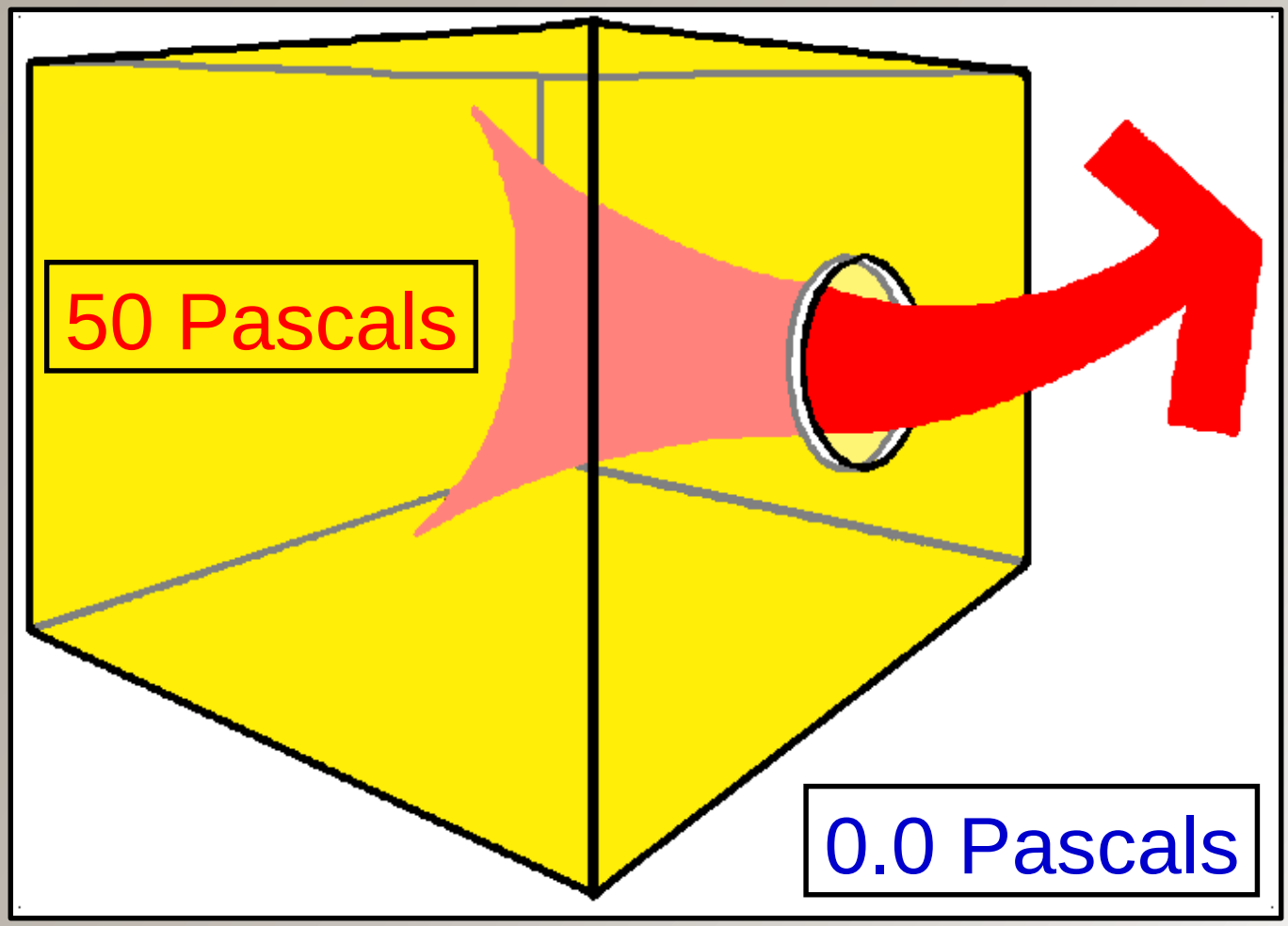
When is a hole a hole?

Air, Heat and Moisture movement require a difference in pressure across the opening and an open pathway between the pressure difference.

ΔP + HOLE = Movement

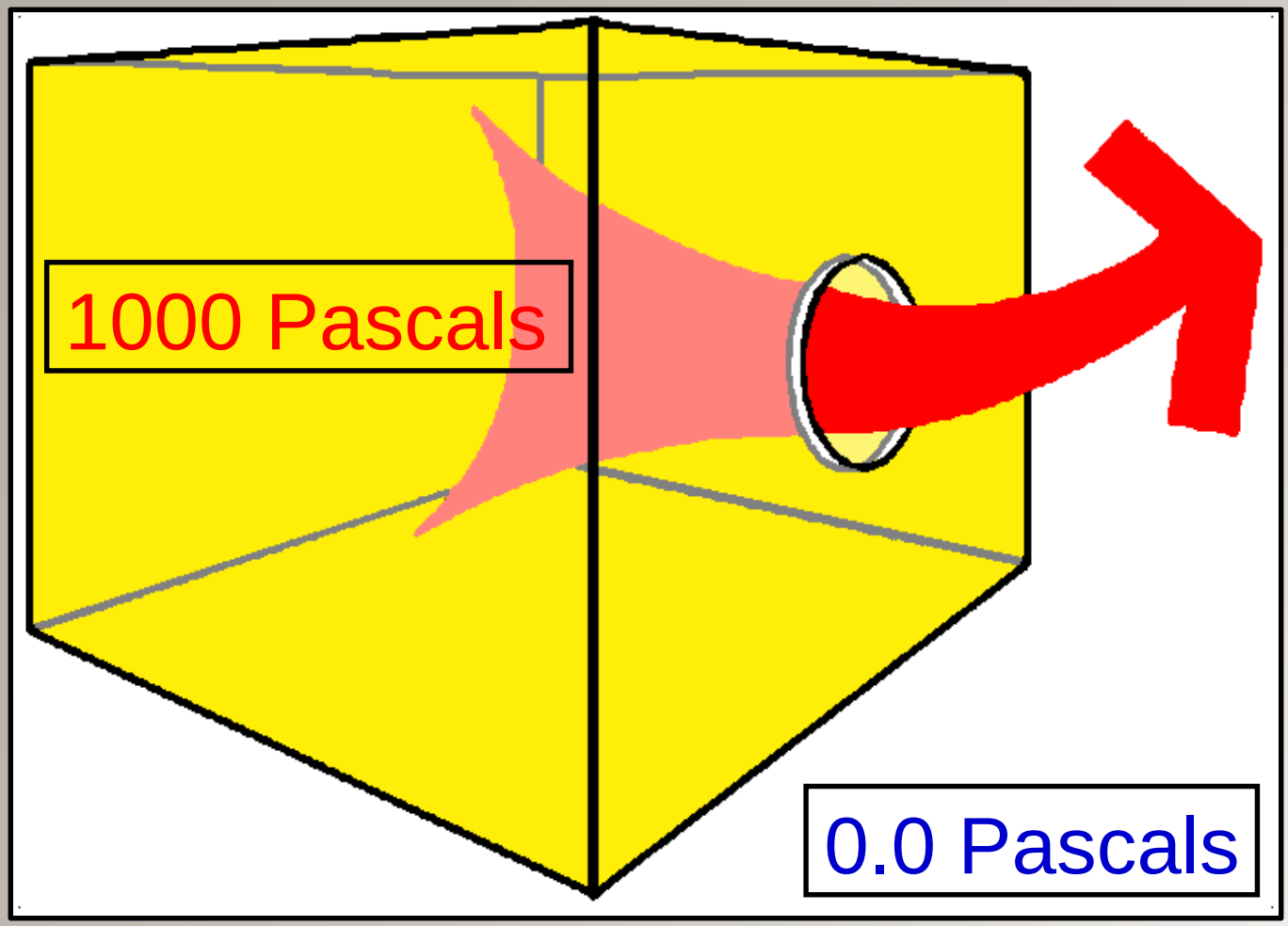
For air to move, we need a Hole

And a pressure difference across that Hole



The bigger the pressure difference

The faster the air moves



Studies show, that in a typical California home all of the openings about equal the area of a small window being open all year long.

There are holes all over our homes.

Some of the holes are intentional most are not.

In general, new construction is steadily becoming tighter.

There still opportunity to tighten the envelopes of the existing housing stock in California.

There is also opportunity for errors while tightening up the existing housing stock.

Movement of Air, Heat and Moisture impacts the occupant:

Health & Safety

Durability of the Structure

Comfort of the Occupants

Home Operating Costs

Often occupant behaviors and habits make things worse.

How does Air, Moisture and Heat Move (Transfer)?

Through openings between the conditioned and unconditioned spaces.

Gaps in the construction, chases, holes in the ductwork and unsealed areas around windows, doors and utility penetrations, (a starters list).

Intentional Holes

Weep holes in windows

Security Service Panels

Outside Fresh Air

Audio Visual Service Panels

Combustion Air Penetrations

Manufactured Fireplace Flue & Make-up Air

Tight cracks
Small cracks
Medium cracks
Large cracks
Micro holes
Small holes
Medium Holes
Large holes

Unintentional Holes

Construction Issues

Poorly fitting doors

Poorly fitting windows

Poorly fitting skylights

Attic Access

Sheathed Exposed Beam Ceiling

Paneling

Dropped ceilings

Raised floors

Interior Crawlspace Access

Tight cracks
Small cracks
Medium cracks
Large cracks
Micro holes
Small holes
Medium Holes
Large holes

Unintentional Holes

Electrical/

Mechanical Issues

Shafts and Chases

Low Voltage Penetrations

Plumbing Penetrations

Flush Mount Speakers

Whole House Fans

Recessed Lights

Switch Boxes and Receptacle Boxes

Tight cracks
Small cracks
Medium cracks
Large cracks
Micro holes
Small holes
Medium Holes
Large holes

Unintentional Holes

Weatherization Issues

Floor to garage

Floor to exterior

Lack of Weather-stripping

Wrong weather strip materials

Weather strip in wrong location

Just about all weather stripping

Tight cracks
Small cracks
Medium cracks
Large cracks
Micro holes
Small holes
Medium Holes
Large holes

What is pressure?

Force pressing against a surface.

Weight per unit of area

Pounds per square inch (PSI)

Inches water column (IWC) or (IWG)

Pascal: Newtons per meter squared

Pressure Equivalents

1 PSI = 6894 Pascals

1 PSI = 12 Lb/ft²

1 PSI = 27.7 i.w.c.

1 inch water column = 246 Pascals
1 Pascal = .000145 PSI

Car Tire = 35 PSI Or 241,290 Pascals.

Natural Gas inlet 7" w.c. Or .25 PSI

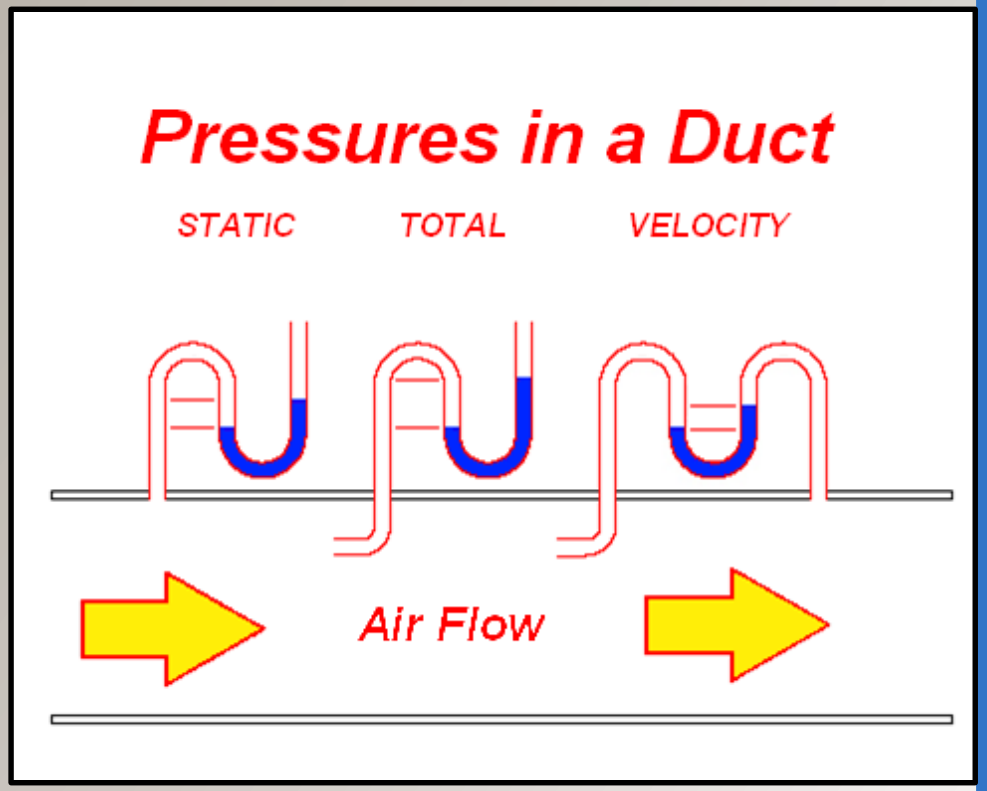
HVAC fan external static pressure = 0.5" w.c. Or 125 Pascals

Three Types of Pressure

STATIC—"Bursting" pressure. The pressure exerted against the sides of the duct.

TOTAL—The combined effect of both static and velocity pressure.

VELOCITY—The pressure created by the flow of air through the duct. Calculated by subtracting the static pressure from the total pressure.



Review—What is required for a building to leak?

1. A hole

2. Pressure difference across that hole.

Pressure Effects

Infiltration, Exfiltration, and Ventilation

Properties of Air

Delivered Btu/h Sensible based on CFM and Supply and Return Air temperatures

$$Btu/h = CFM \cdot 1.08 (\Delta T)$$

CFM = quantity of supply air in ft^3

$$(\Delta T) = (t_s - t_r)$$

t_s = Temperature supply air

t_r = Temperature return air

Properties of Air

Infiltration Air

Required Btu/h to change the temperature of the Infiltrated outside air to Inside air.

$$Btu/h = CFM \cdot 1.08 (\Delta T)$$

CFM = quantity of Infiltrated air in ft^3

$$(\Delta T) = (t_i - t_o)$$

t_i = Temperature inside

t_o = Temperature outside

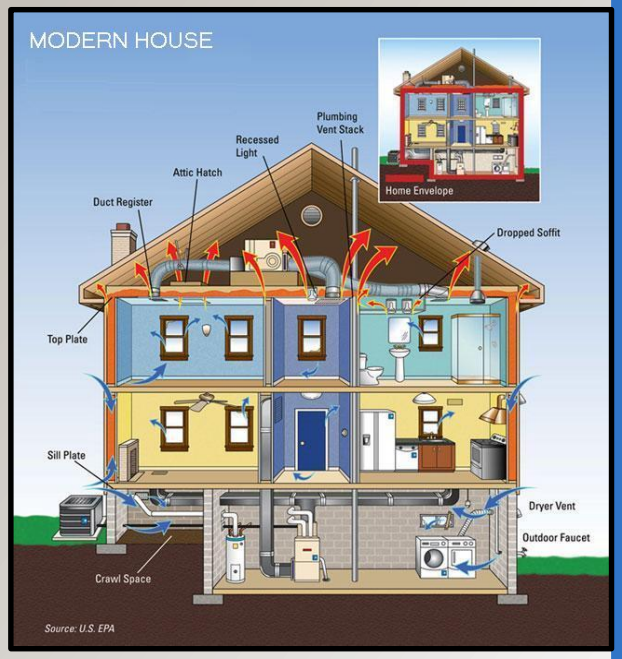
Infiltrated Air Side Effects

Negative Pressure

Moisture from outside if humid.

Pesticides or other pollutants.

Backdrafting.



A home can become the **'Air Pit'** of the surrounding area.

Exfiltration Air Side Effects

Positive Pressure

Pushes moisture toward outside if humid indoors.

INFILTRATION

Random and uncontrolled air movement into a building bringing with it any hitchhikers that are outside.

EXFILTRATION

Random and uncontrolled air movement out of a building bringing with it any hitchhikers that are inside.

VENTILATION

Intentional and controlled (hopefully) air movement into or out of a building, possibly bringing with it any hitchhikers that are inside or outside.

Diagnostic Basics

No Equipment

Use the tools that we have available

Use your Hand.

Your hand is a great diagnostic tool.

Use All the Senses

Our Eyes

Our eyes detect unsafe conditions, can help us to identify signs of air movement, moisture accumulation.

They assist us to determine potential solutions and areas of concern.

Diagnostic procedures begin with noticing

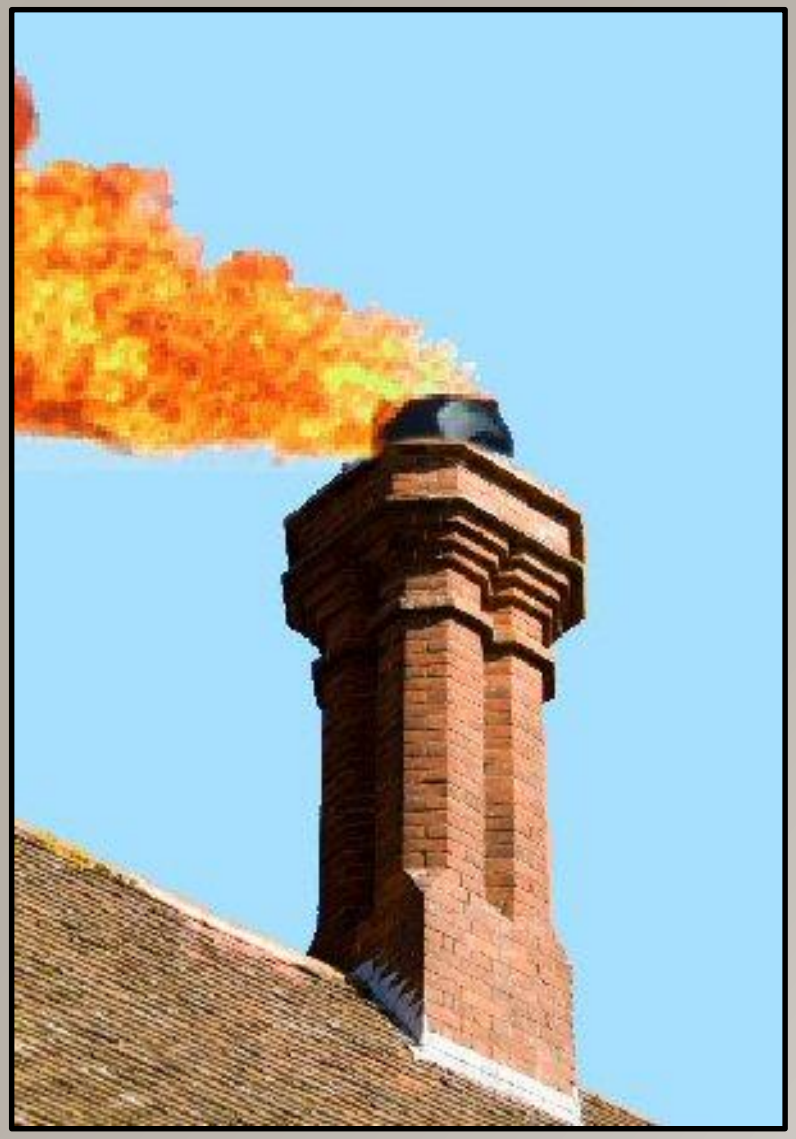
Problem? Cause or Effect?

Tree growing out of chimney.

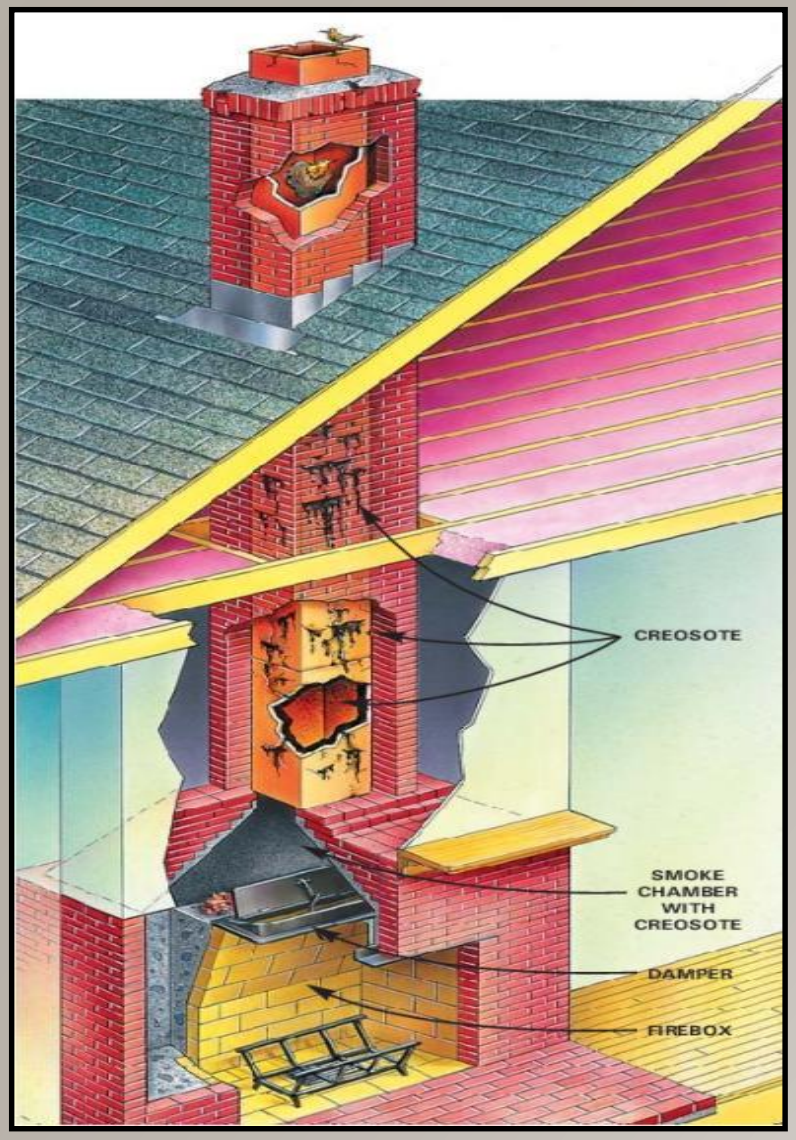
Problem? Cause or Effect?

Soot on fireplace.

Problem? Cause or Effect?



Cause and Effect

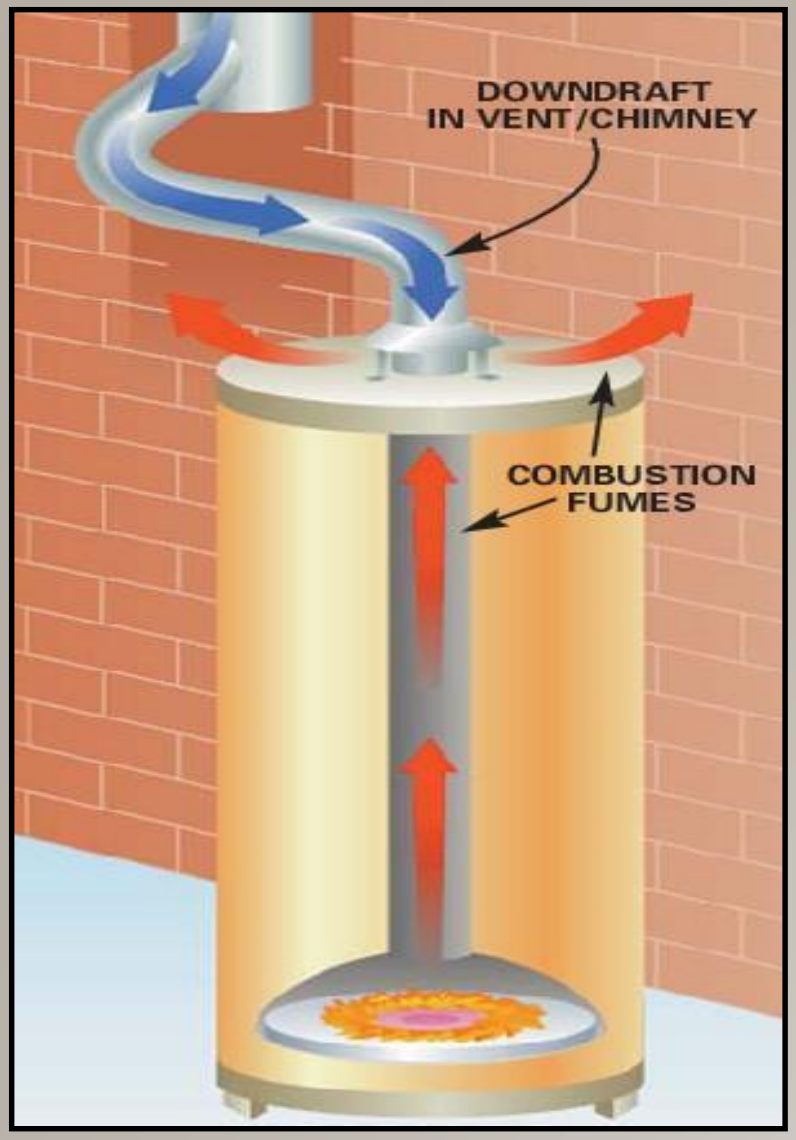


What might be going on?

Problem? Cause or Effect?

SOOT, RUST AND SCALE

Cause and Effect



Back-drafting of flue gasses.

Presence of

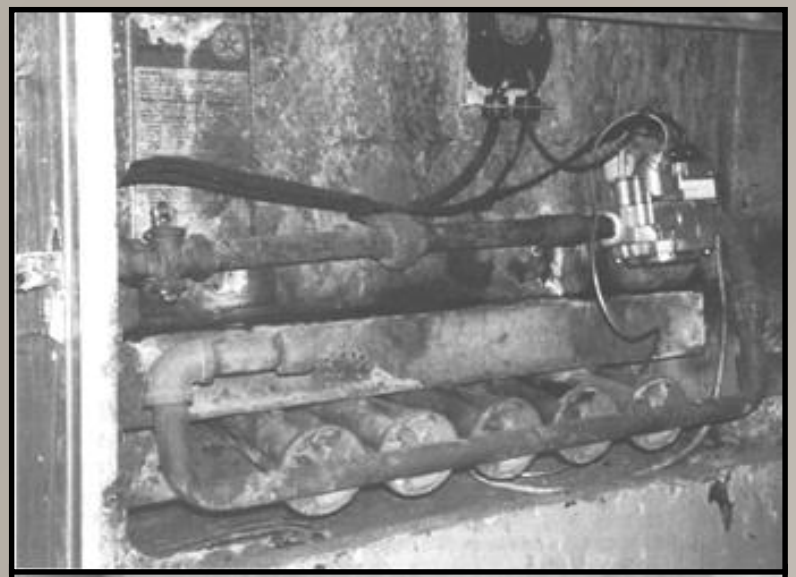
corrosive chemicals

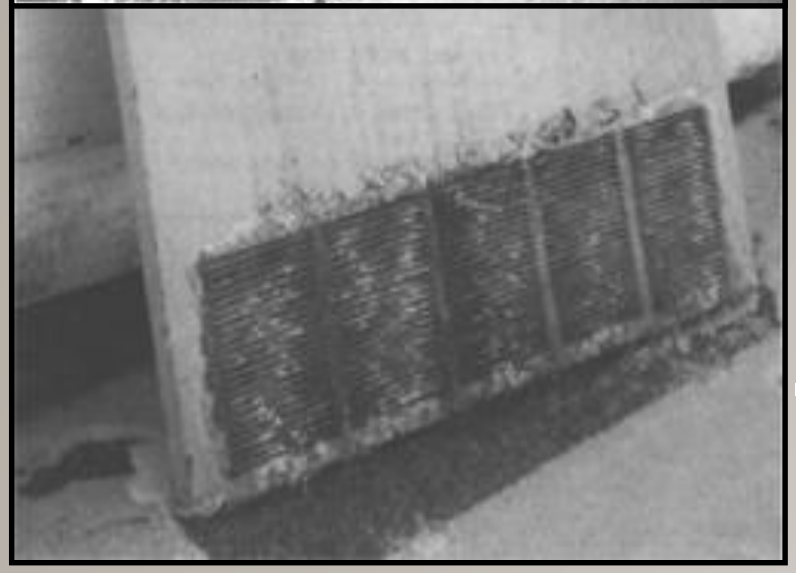
And Carbon Monoxide

Problem? Cause or Effect?

Flame Roll-Out

Problem? Cause or Effect?





Gas or Oil Fired Furnaces

Look for the same tell-tale signs

Important principle

Manometers—WRT

Manometers


DG-700 Pressure & Flow Gauge
DEVICE
CONFIG
MODE
TIME AVG
DEVICE
UNITS
CONFIG
MODE
CLEAR
TIME AVG
BASE LINE
START
ENTER
INPUT
INPUT
A
B
ON/ OFF
LIGHT
HOLD
REF
REF
The ENERGY CONSERVATORY


Dual Channel Digital Micromanometer and Control
Baseline
Time
Zero
Pressure
Mode
Set
Range Config
Speed
Device
DM-2 mark II
Mode 1
Range Config 2
Setup 3
Baseline 4
Time Avg 5
Auto Zero 6
Set Pressure 7
Set Speed 8
Jog/ Hold 9
Device 0
@ Pressure .
On/Off Backlight
Enter Volume Area
Exit
retrotec

MANOMETERS

Principle: Basis of pressure diagnostic testing is to compare the pressure in one zone to the pressure in another (WRT).

WRT: With Reference To

Usually the manometer is connected to different zones via flexible hoses.

MANOMETERS—CONTINUED

MANOMETER LAW

The simple expression that allows us to keep things straight when taking pressure measurements in a building.

THE LAW

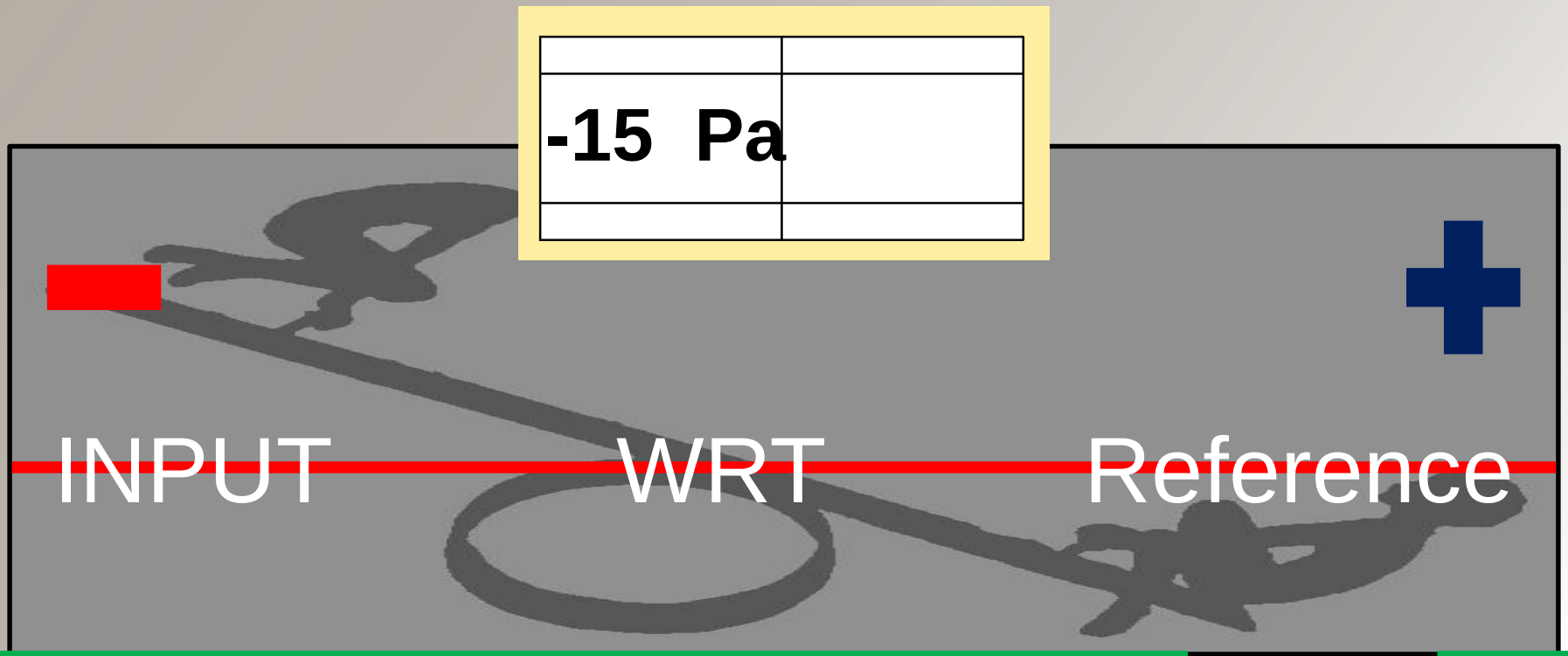
_____With Reference To (WRT) _____

INPUT Reference

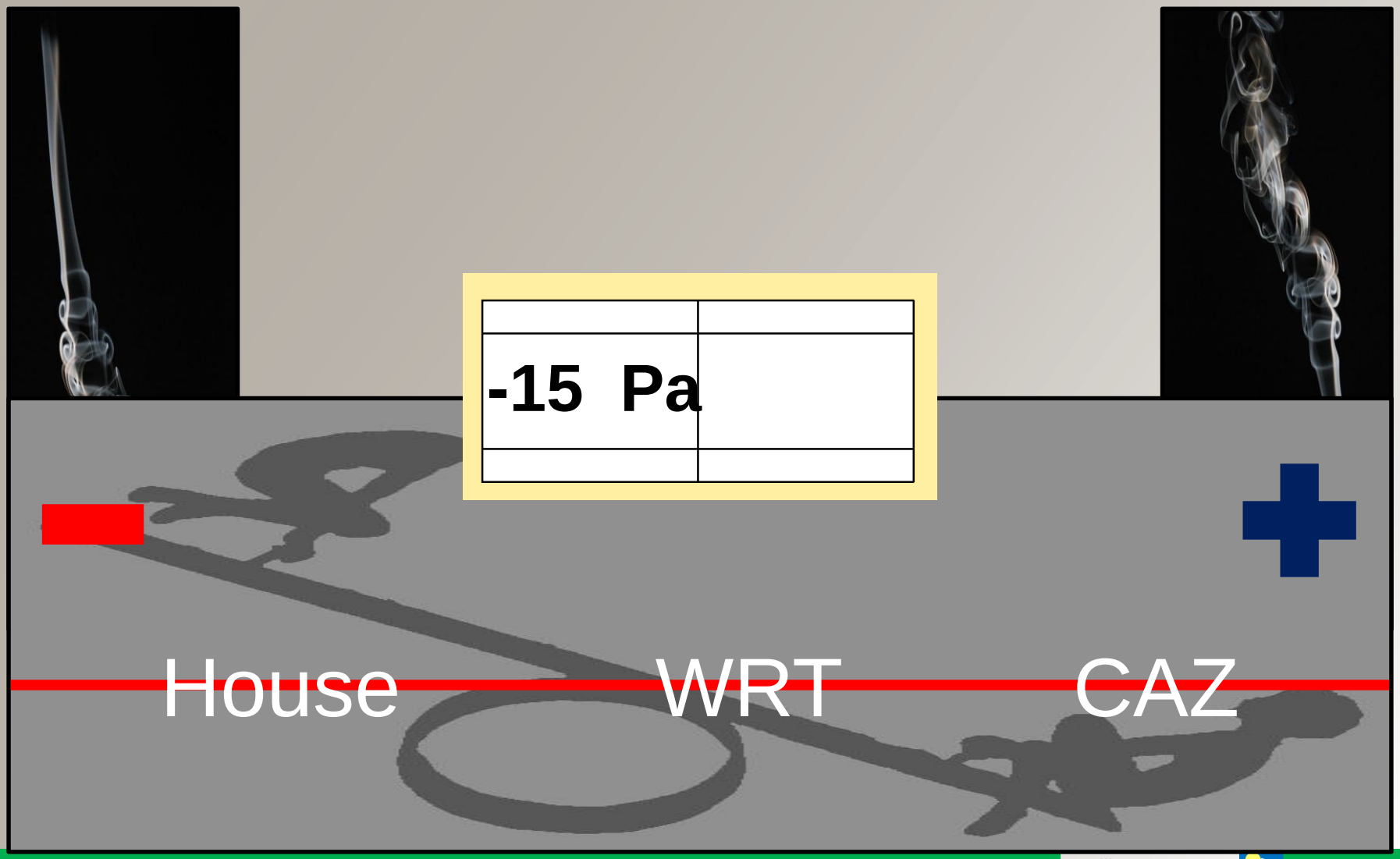
MANOMETERS—CONTINUED

MANOMETER LAW

Following this law is critical in keeping negative and positive pressure readings correct.



MANOMETERS—CONTINUED



MANOMETERS—CONTINUED

MANOMETER LAW

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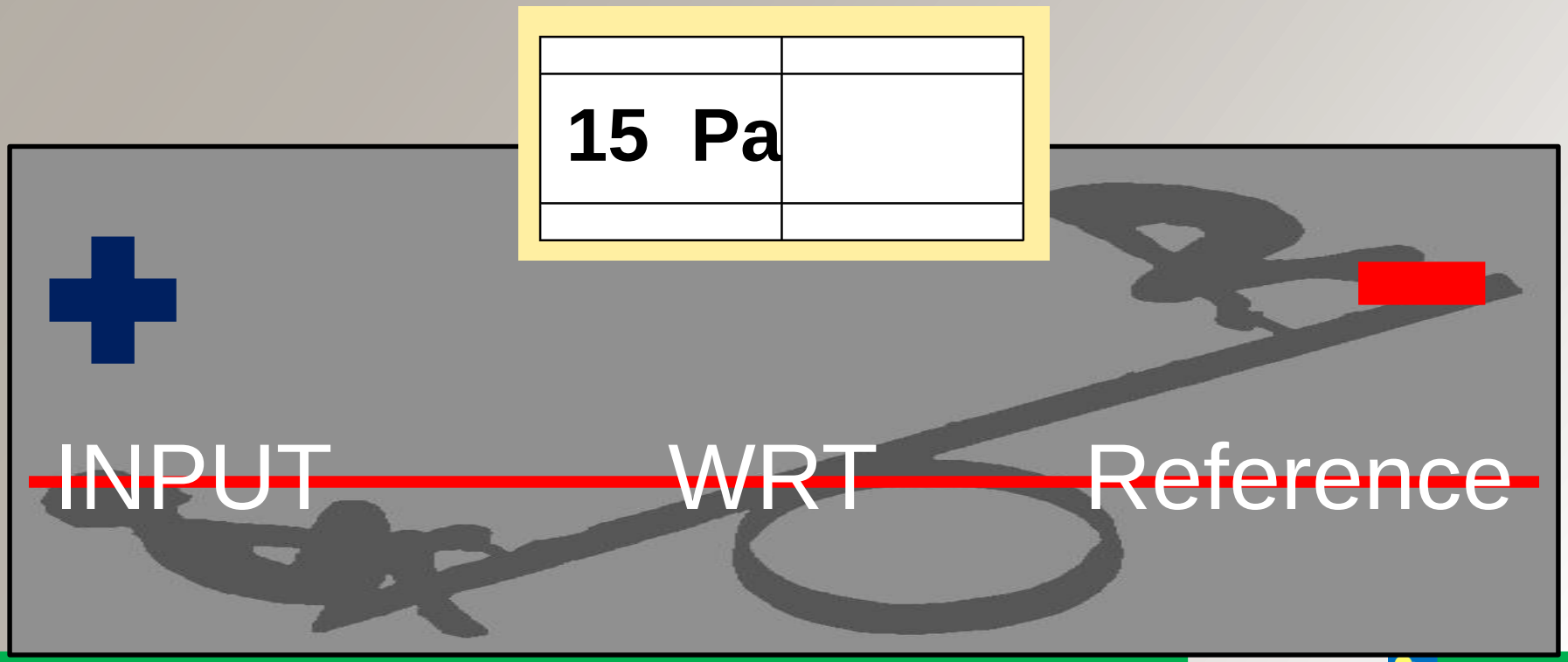
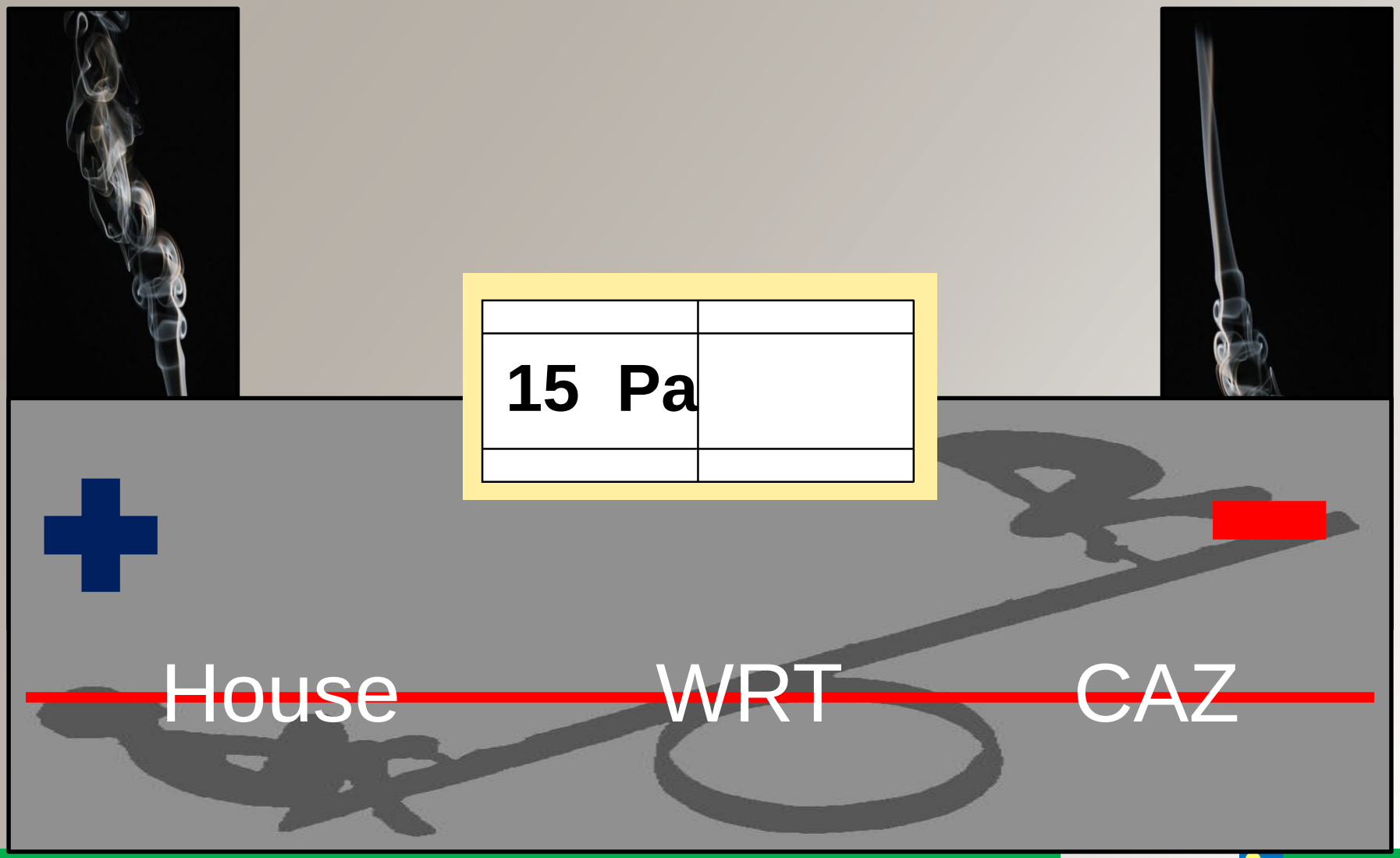
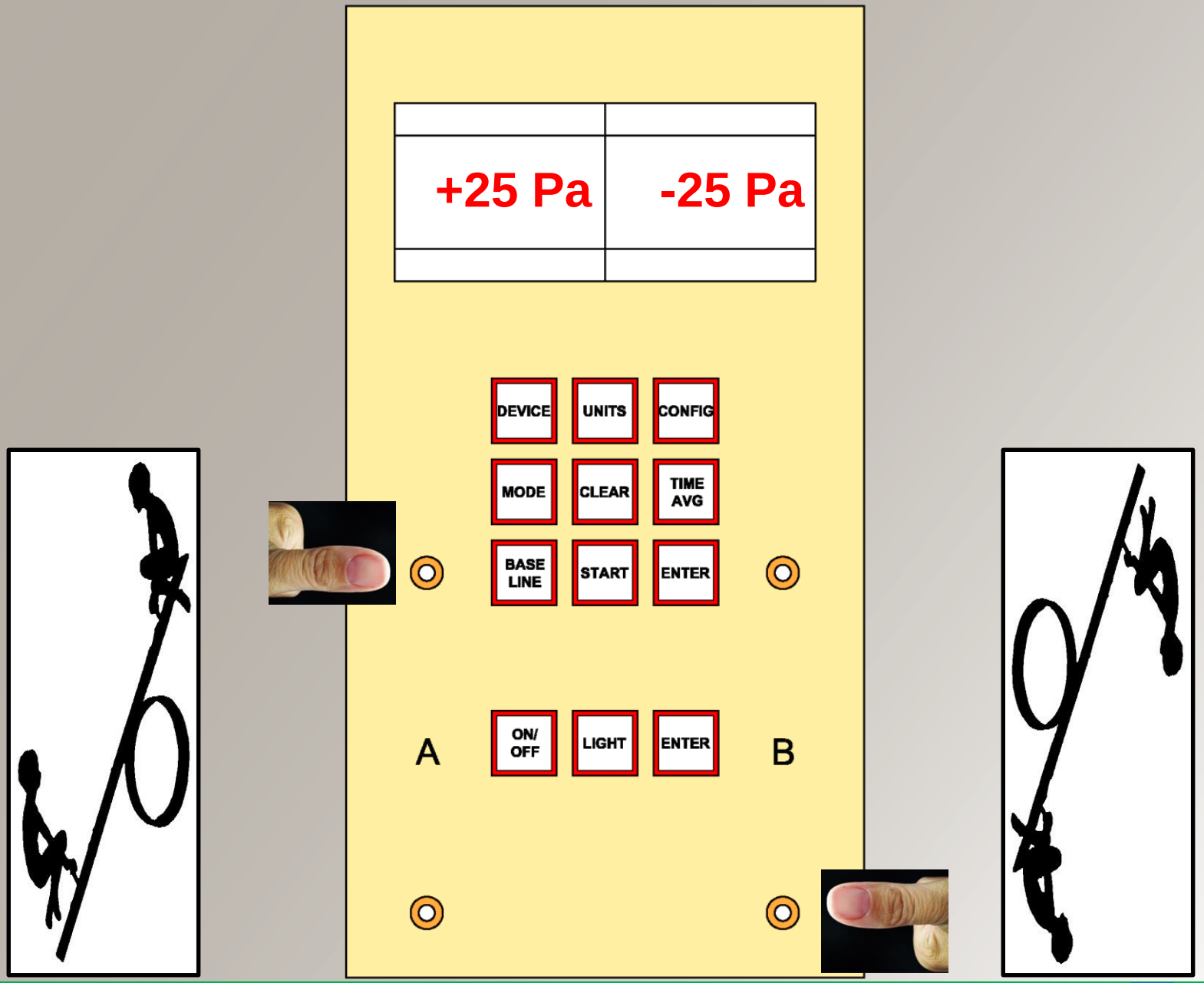


MANOMETERS—CONTINUED




+25 Pa
-25 Pa
DEVICE
UNITS
CONFIG
MODE
CLEAR
TIME AVG
BASE LINE
START
ENTER
A
ON/ OFF
LIGHT
ENTER
B

MANOMETERS—CONTINUED

MANOMETER LAW

For Instance:

The difference between a + 0.3 WCI draft and a – 0.3 WCI draft is obviously very important.

Equally important is whether the pressure in the mechanical room is negative or positive WRT outside.

THE LAW

_____With Reference To (WRT) _____

INPUT (With Respect To) Reference

MANOMETERS—CONTINUED

Draft: The difference between the pressure in the flue **With Reference To** the pressure in the mechanical room.

Device Pressure Drop: The difference between the pressure from one side of a device, (i.e. evaporator coil) WRT the other side of the device.

MANOMETERS—CONTINUED

External Static Pressure: External Static Pressure (ESP) is the static pressure sum, external of the manufactured air handler unit.

Manufacturers supply fan performance data that specifies **delivered air flow WRT External Static Pressure.**

Example: Furnace, Fan-coil, Package Unit, Exhaust fan, Supply Fan, etc.

Pressure

WRT

Pressure

Even Large Buildings can be tested