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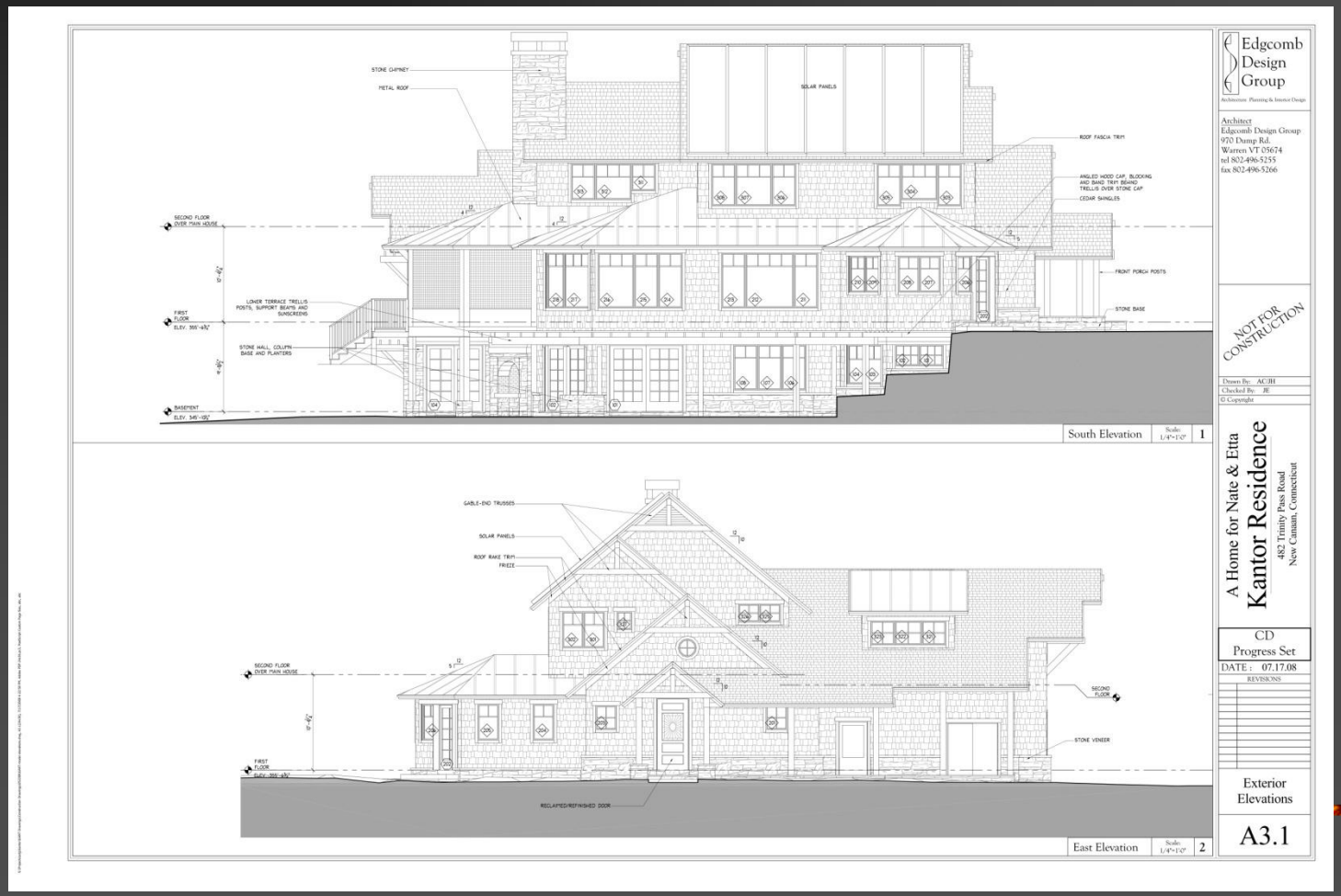
Fireplace Design

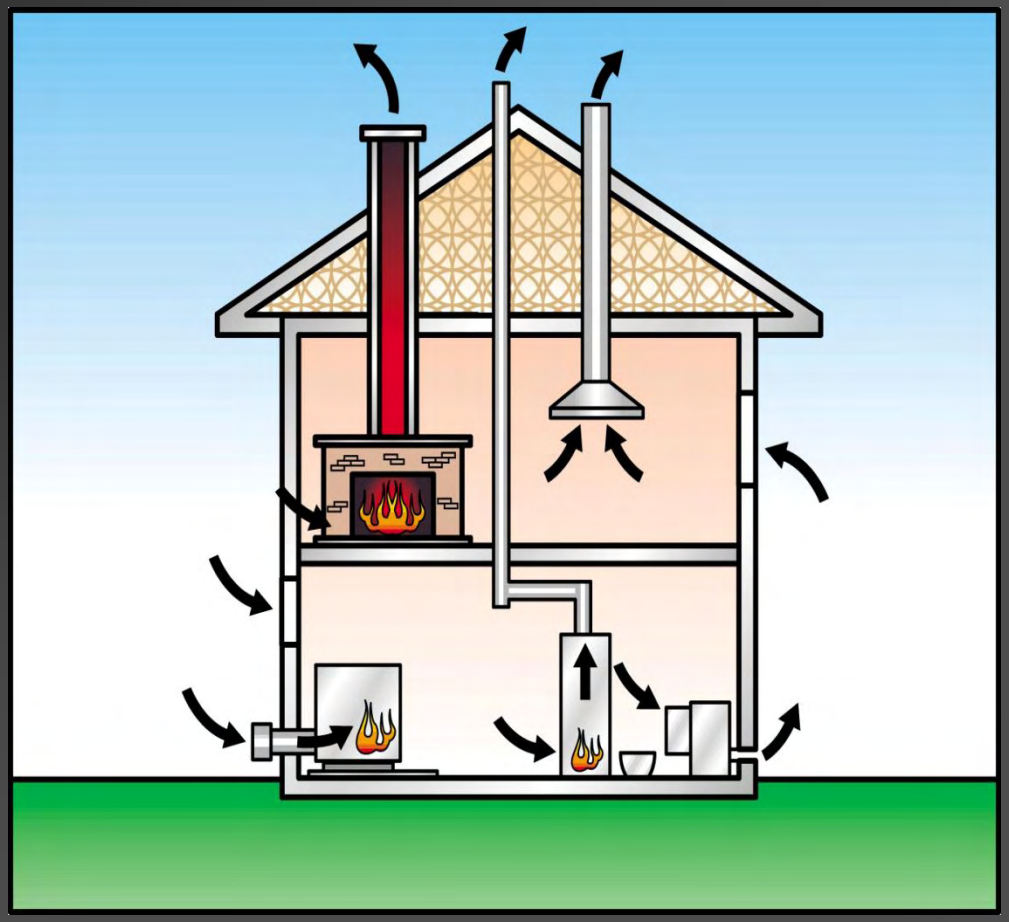
“The House as a System”

House as a System



What does it mean, The “House as a System”?

- The house as a system refers to how air moves in, out and around a house.
- Air moves in and out of a house through the “building envelope”.



Why Consider the “House as a System”?

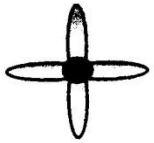
- Many chimneys fail to operate because of aspects of the house and its surroundings.
- If air flows out of a house, air must flow back into the house

Building Air Needs

COMBUSTION AIR--An adequate supply of air (oxygen) necessary for the complete combustion of a fuel.

DILUTION AIR--Air that enters a draft hood or draft regulator and mixes with the flue gasses.

In fireplaces, air that enters the fireplace opening that does not contribute to the combustion process, but mixes with the flue gasses.



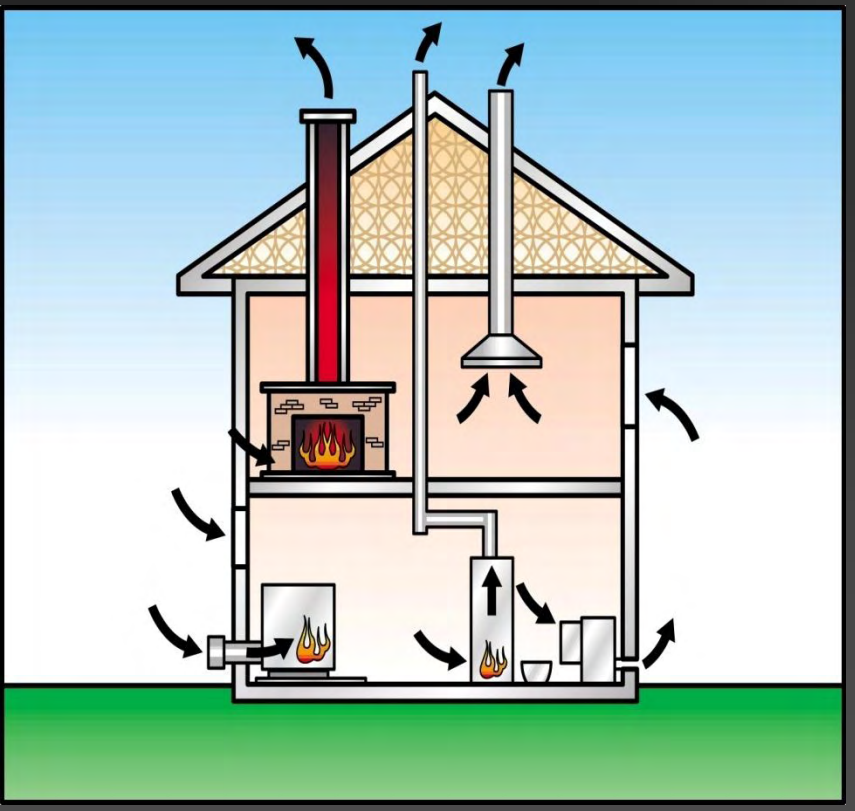
MAKE-UP AIR--Air needed to supply the needs of exhaust equipment (fans, range hoods, clothes dryers, etc.) that prevents these appliances from creating negative pressure backdrafting of atmospherically vented combustion appliances.

VENTILATION AIR--The air needed for moisture control and the health of the building's occupants--the equivilant of 0.35 ACH or 15 cfm per person (plus one).

Pressure Differences, What Pressure Differences? My Ears Don't Even Pop!

- 1 Pound per square inch (Psi) = 27.71 inches of water column (W.C.)
- 0.1 inch water column (W.C.) = 25 Pascals (PA)
- House pressures range from 5 to –25 PA

What Causes These Air Pressure Differences?



Appliances that take air out of the house

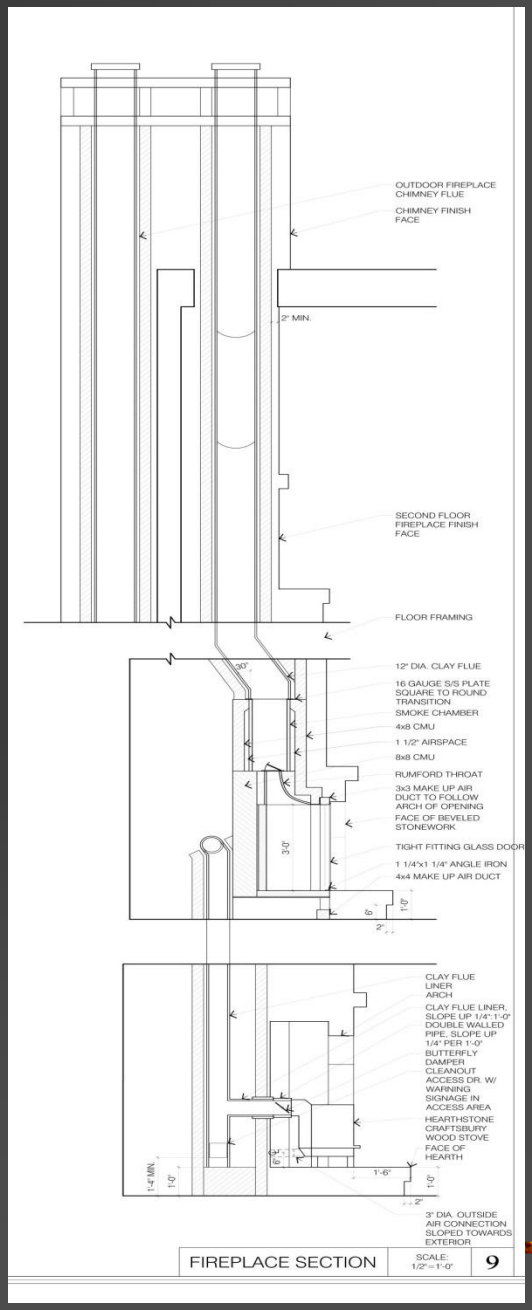
- Exhaust fans – bathrooms, kitchens
- Clothes dryers
- Furnaces
- Atmospherically vented combustion appliances; fireplaces, furnaces, boilers, hot water heaters.

Typical Air Flows of Exhaust Fans

Device	Air Flow (CFM)
Bathroom Fan	32-64
Standard Kitchen Fan	85-127
Downdraft Kitchen Fan	210-425
Clothes Dryer	85-160
Central Vacuum	50-110

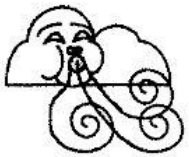
When air goes out - more air must come in!

Fireplace Needs

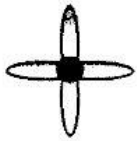


House Pressure Impactors

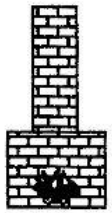
Stack Effect



Wind Effect



Fan and Flue Effect



Air Handler Effect

Other Causes affecting Air Pressure Differences The Not-So Obvious Reasons

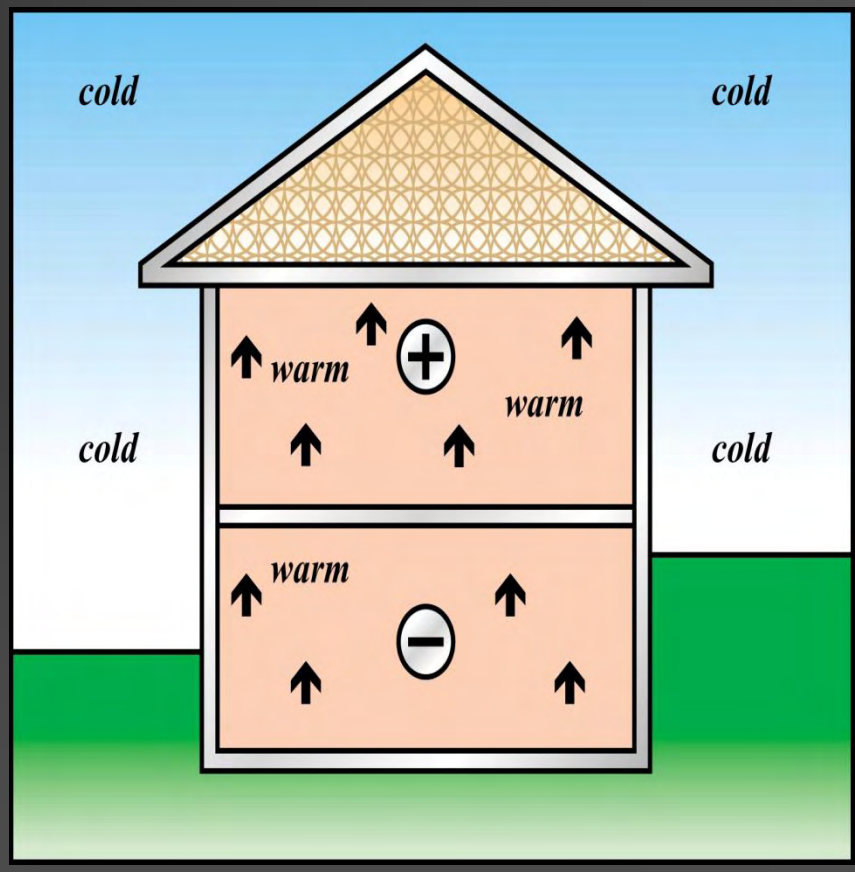
- Buoyancy of warm air – **“Stack Effect”**
- Wind
- Furnaces

Buoyancy of Warm Air?

- Everyone knows hot air rises – Why?
- Hot air is lighter than cold air (air expands when it is heated)
  - That's why candle flames go up
  - That's why hot air goes up a chimney
- Buoyancy of hot air causes a pressure difference in the house relative to the outside pressure which is called "Stack Effect"

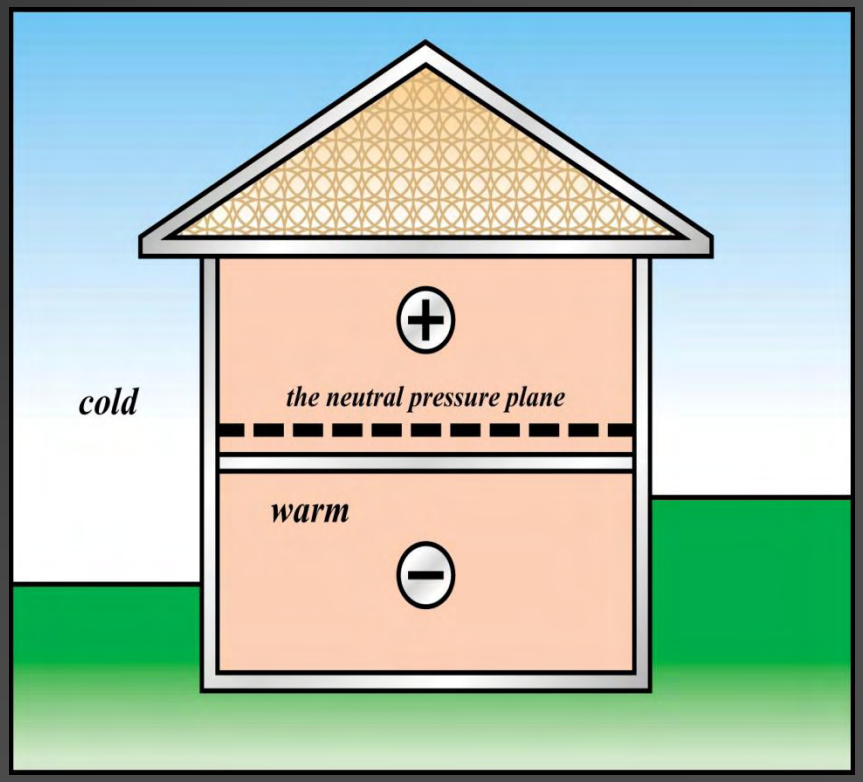
Stack Effect?

- Stack Effect - The pressure difference created between the warmer air in a building and the colder air outside.
- The bottom part of a house is under the outside pressure (negative pressure)
- The top of the house is over the outside pressure (positive pressure)



Stack Effect?

- Hot air rising due to stack effect causes the top of a house to be slightly positive compared to the outside, and the bottom of the house to be slightly negative compared to the outside of a house.



Stack Effect

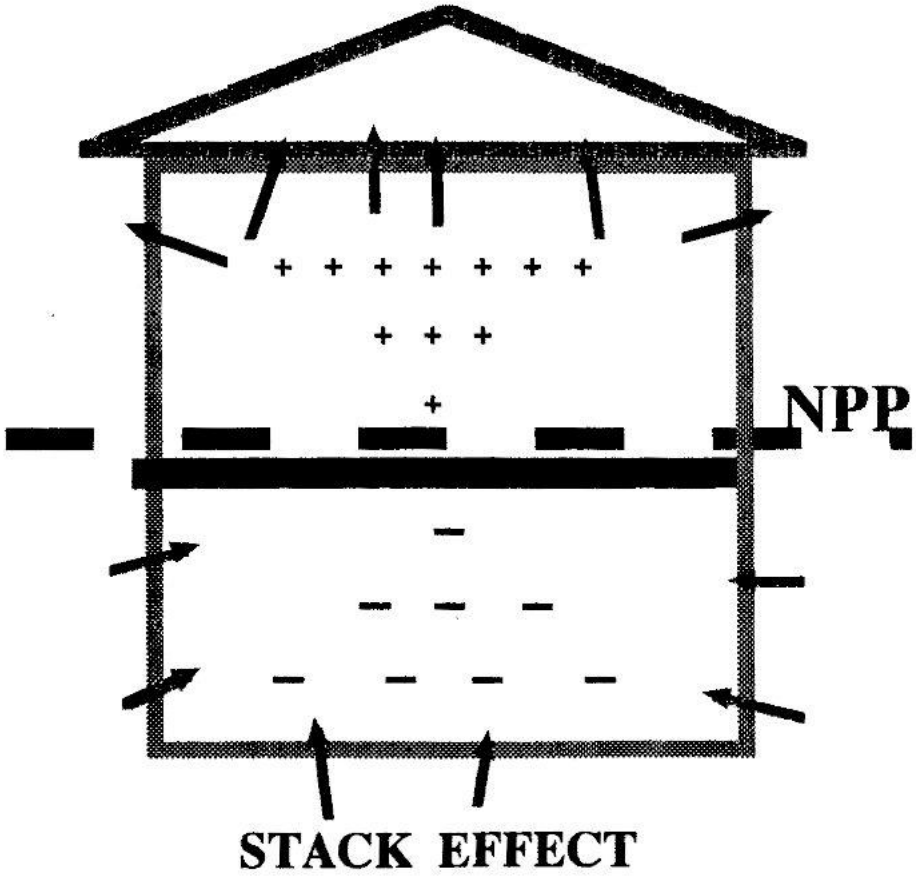
- The greater the temperature difference between the outdoor temperature and the indoor temperature, the greater the stack effect.
- The leakier the house, the more air flow through the house due to stack effect.
- But somewhere in between the bottom and the top of the house the pressure is exactly the same as outside or neutral. This neutral “layer” is called the **“Neutral Pressure Plane”**

Stack Effect-- air flow basics

- A house is a chimney with warm air rising.
- Pressure higher at top than bottom
- Air flows from area of Hi P to area of Lo P

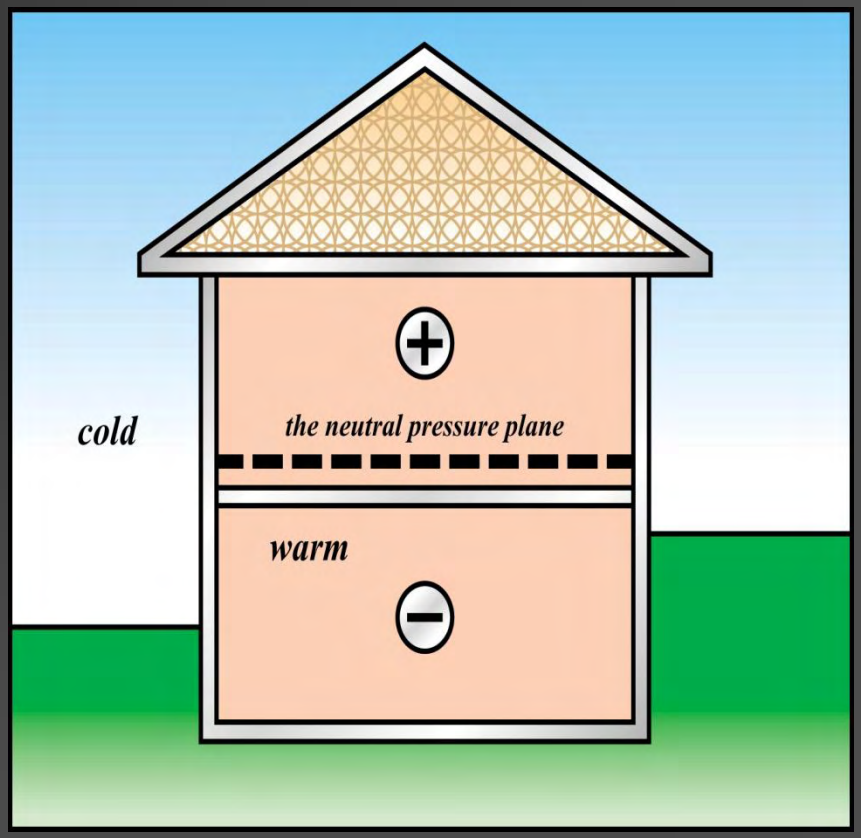
→ For air to move, you need a hole and a driving force (Δ P)

→ Air CFM out = Air CFM in



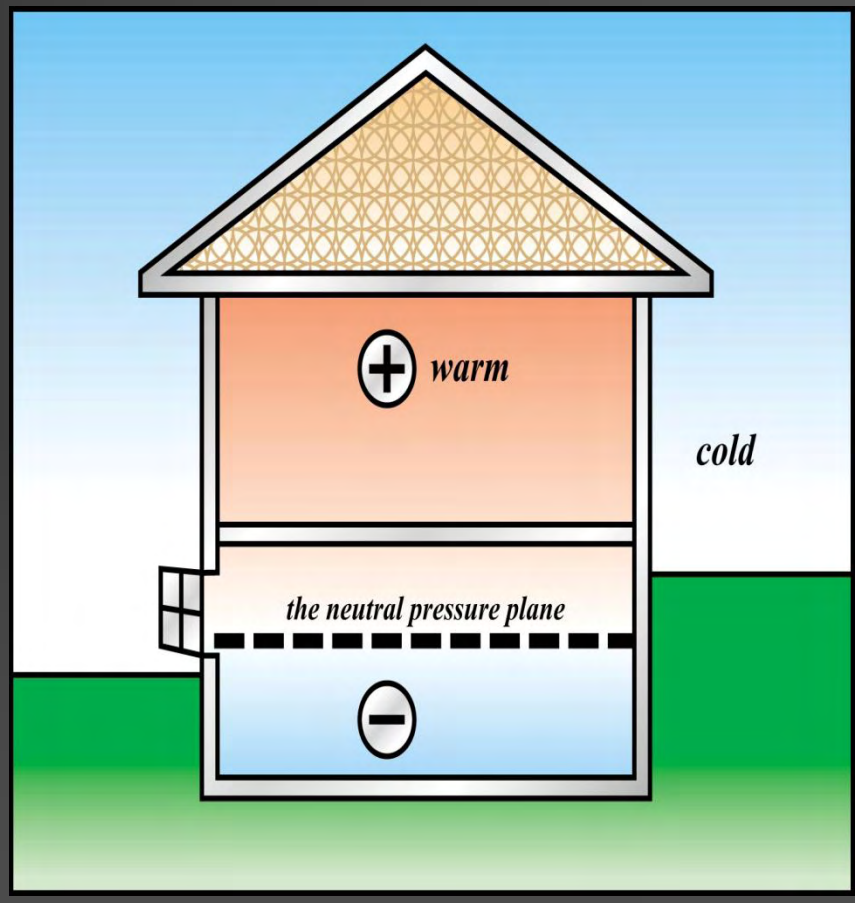
Neutral Pressure Plan (NPP) What a concept!

- It's called the "Neutral Pressure Plane" (NPP)
  - The place in the house where the pressure inside the house matches the pressure outside the house (the atmospheric pressure).
  - It's not really a plane because of the affects of furnaces, exhaust fans, etc. Just a theoretical concept to make it easier to explain the effects of pressure.



Neutral Pressure Plane (NPP) You can't see it or feel it.

- The location of the Neutral Pressure Plane moves and distorts.
- If someone opens up a door or window the pressure of that room will be the same as the pressure outside, so the NPP is now located at the height of the window.
- Exhaust fans, furnaces and wind distort the NPP. More on the affects of wind later.



Stack Effect Exfiltration

Any opening (leak) at the top of the building that lets air escape

- Recessed lights
- Attic hatches
- Skylights

The house is acting like a chimney!! Is the house a better chimney than the actual chimney?

Stack Effect Infiltration

Any opening (leak) at the bottom of the building that lets air in.

- Cracks in a foundation
- Leaky doors
- Leaky windows

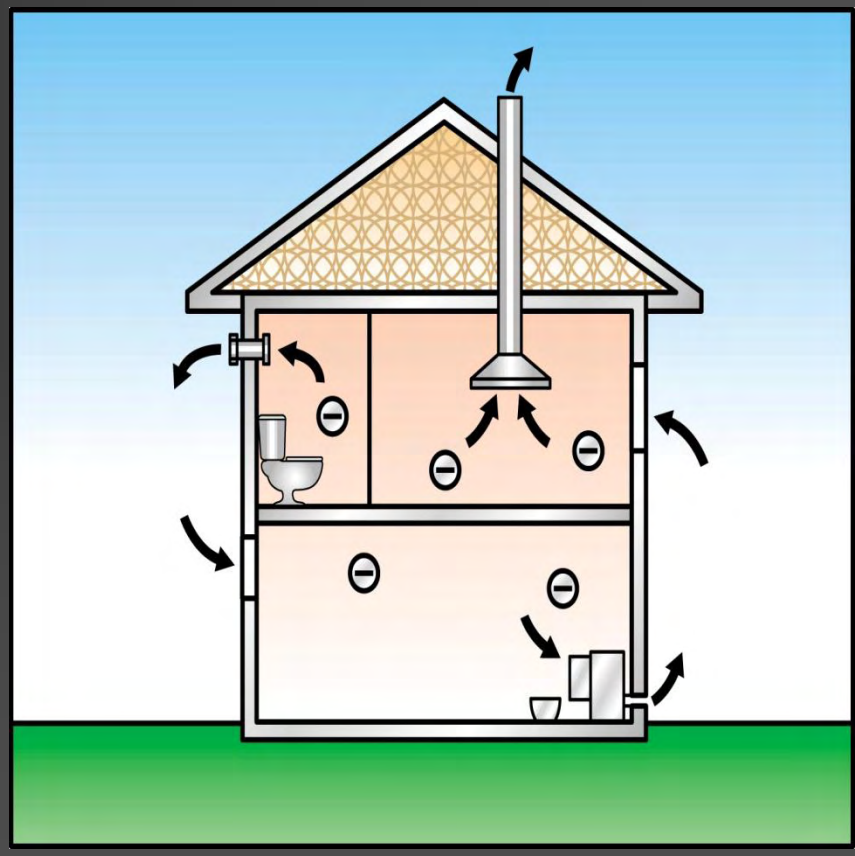
Usually these types of thermal envelope leaks are the ones to get repaired because they cause drafts in cold weather. So where does the air come from now to replace the air leaving at the top of the house?

House Pressures

- The entire house can be positive pressured, negative pressured or neutral depending upon many different aspects of the house.
  - The size of the exhaust fans
  - How tight the thermal envelope is
  - How many chimneys there are
- Generally houses are slightly negative due to the fact that most of the forces on a house take air out of it.

Exhaust Fans Affect House Pressures and the NPP

- Exhaust fans, depending on the size of the fan and how leaky the house is can have the effect of bringing the entire house under a negative pressure or distorting or moving the neutral pressure plane.
- Depending on the configuration of the ductwork in a house and the configuration of the house, different areas of the house could be put into a negative or positive pressure.



Furnaces Affect House Pressures

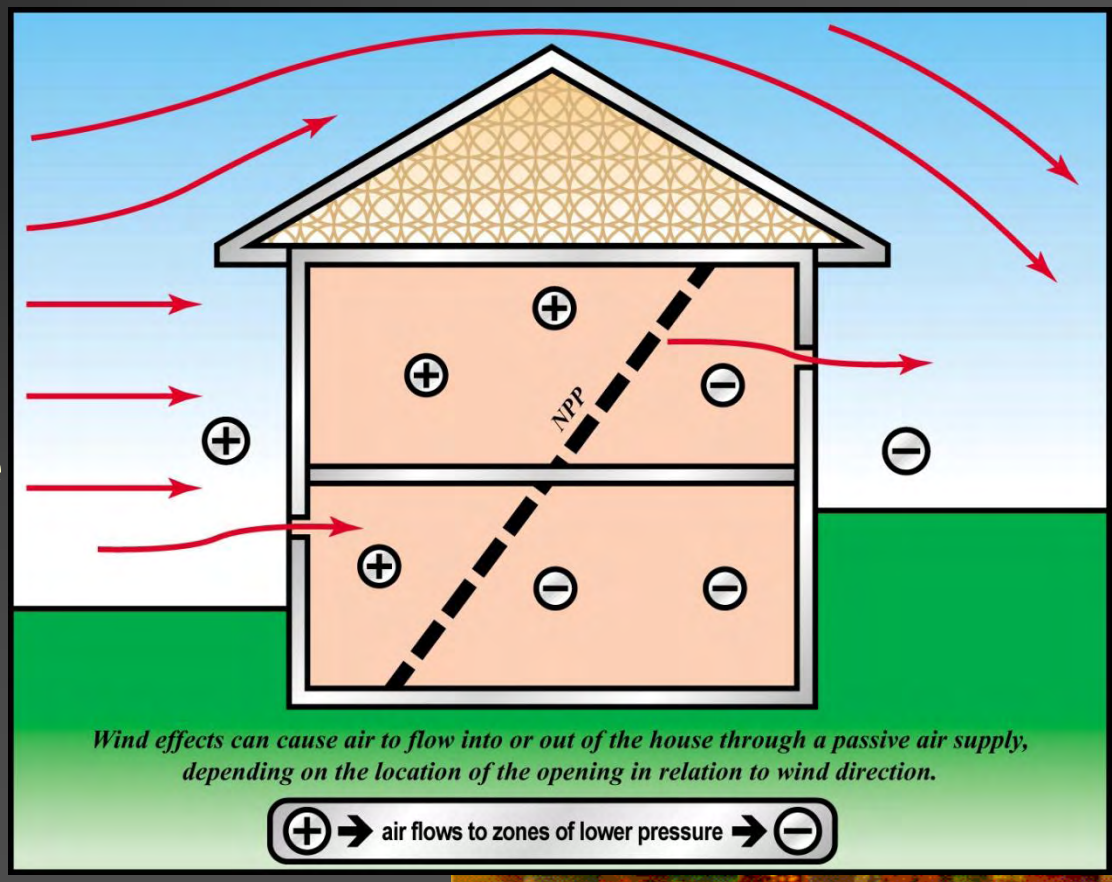
- Depending on the configuration of the ductwork and the design of a house, a furnace can distort the neutral pressure plane causing some areas of the house to be negative and other areas of the house to be positive.
- Sometimes supply ductwork is run outside the building envelope and if that ductwork is leaky, this can cause the house to be negative

Furnaces affect house pressures

- Furnaces will most likely cause a problem if there is only one central return air grill in a main room of a house and many supplies typically throughout the house.
- The house will remain balanced if all doors are left open. If doors are closed the house goes out of balance

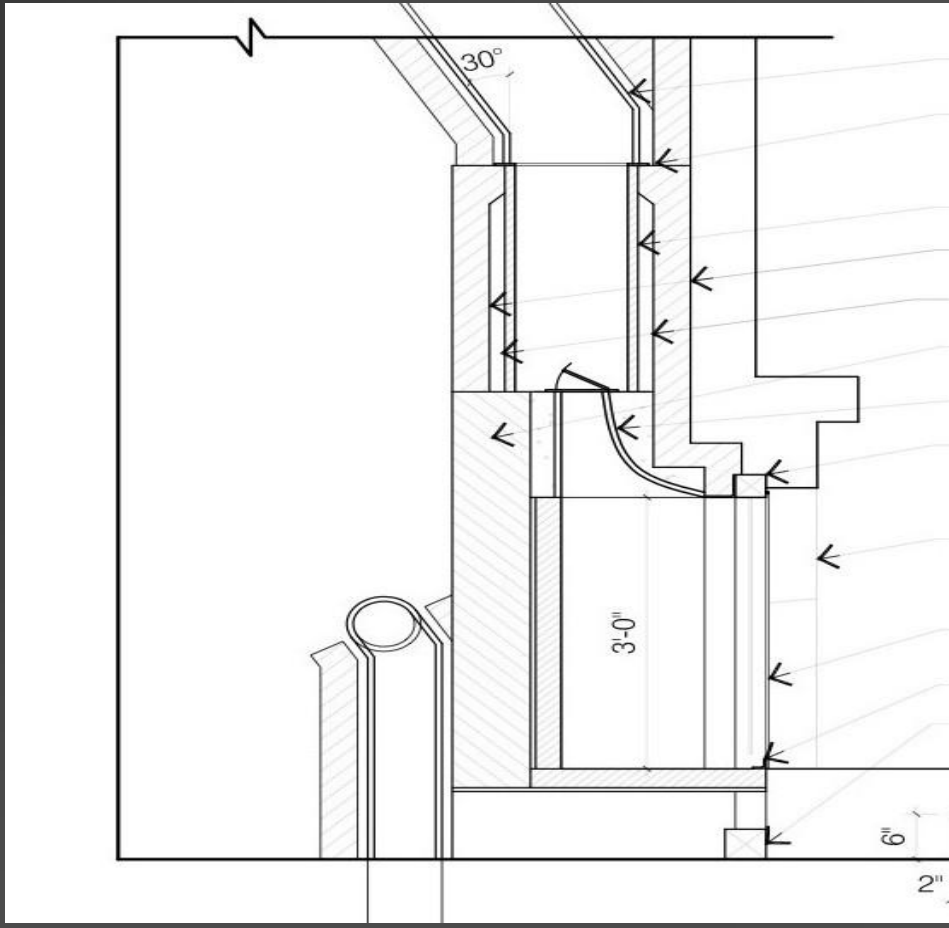
Wind Affects the Pressure in a House?

- Wind affects the pressure inside and outside of a house.
- The wind blowing on the side of a house will cause that side of the house to be positive pressured both just outside the house and inside the house.
- The downwind or leeward side of the house will be negative pressured both inside and outside.
- The NPP caused by stack effect is angled theoretically.



Fireplace Geometry

- Count Rumford was correct in the 1700's

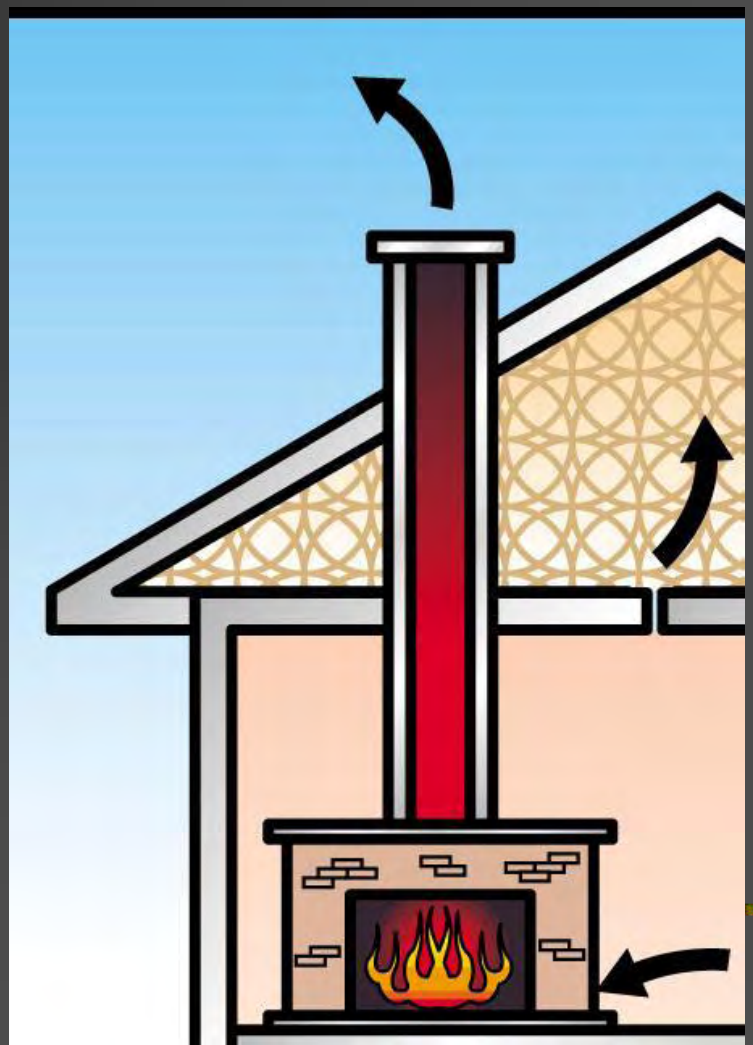


Measuring Leakage Rate of a Thermal Envelope

- Remember that measuring the leakage rate of an entire house does not tell the entire story.
- The location of the leaks play a critical role.
- There may be problems with the location of the appliance or chimney.
- Wind may be a problem.

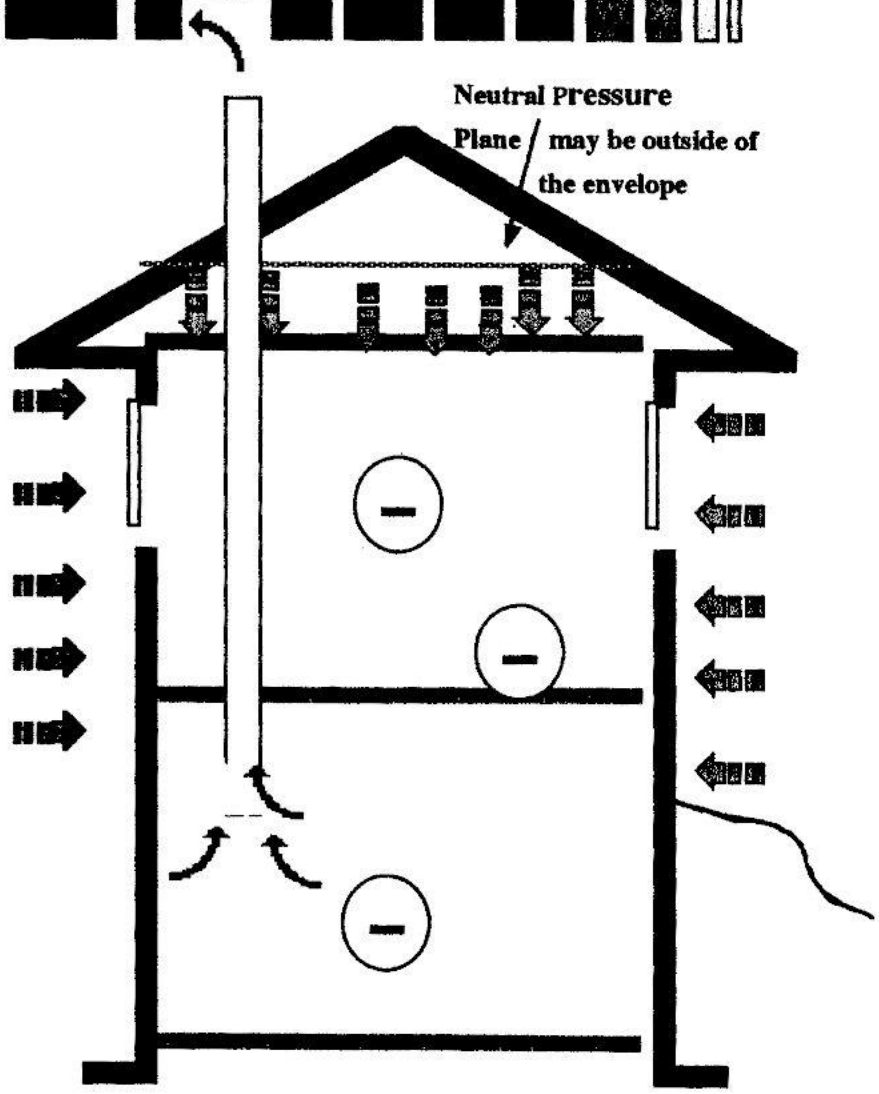
But what about chimneys in the “House as a System”?

- Fireplaces, woodstoves, and other chimney vented appliances in a house as a system take air out of a house, but their “motor” is the buoyancy of warm combustion gases. The same way stack affect works in a house.



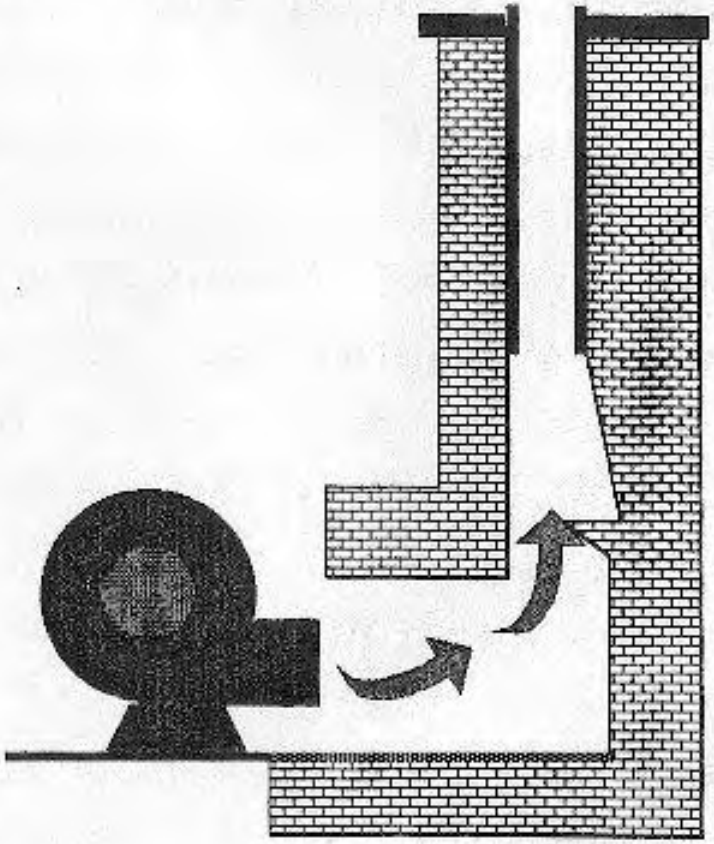
Ventilation and Flue Effect

- Chimneys, Vents and Exhaust fans work to depressurize a home.
- Fans and Flues "Fight" for control.
- When a Flue loses-- Backdrafting and Spillage results.



CONVENTIONAL FIREPLACE IS A LARGE EXHAUST DEVICE

- A vigorously burning fireplace may exhaust 400 cfm or more of combustion and dilution air up the flue. - Skip Hayden-CCRL
- Tests in Minnesota have shown the flow rate to be in excess of 800 cfm. -Klossner/Stegmeir

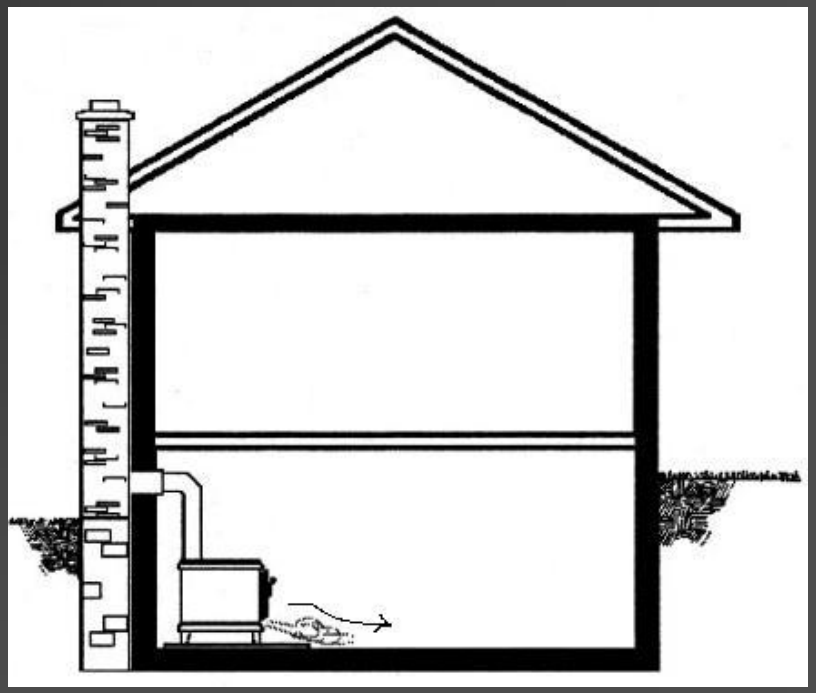


The Types of Chimney Vented Appliances

- Atmospherically vented appliances
  - Gas B-vent
  - Fireplaces
  - Woodstoves
- Power vented appliances
  - Pellet stoves
  - Oil burners
- Sealed appliances – with 100% of the combustion air coming from outdoors.
  - Some woodstove and fireplaces
  - Direct vent gas

Chimney Venting Definitions

- Backdrafting – When the upward flow in a chimney reverses and 100% of the combustion gases from the appliance (if it is firing) and air in the chimney flow into the building.
- Spillage – When some of the products of combustion are released into the building.



Predicting Backdrafting and Spillage

(CANADIAN MORTGAGE AND HOUSING CORP)

Pa = Pascal ; 5 Pa = 0.02" wc

APPLIANCE	CHIMNEY HT. (FT.)	UNLINED OR EXT. WALL	METAL LINED OR INT. VENT/CHIM.
Gas fired furnaces, Boilers, DHW htrs.	13	5 Pa*	5 Pa
	14-20	5 Pa	5 Pa
	>20	5 Pa	7 Pa
	<		
Oil fired furnaces, Boilers, DHW htrs.	13	4 Pa	4 Pa
	14-20	4 Pa	5 Pa
	>20	4 Pa	6 Pa
Fireplaces	NA	3 Pa	4 Pa
Low excess air fireplaces and wood stoves (Hi Tech)	NA	10 Pa	10 Pa
	(EPA Phase II---7 Pa)		
Induced draft appliances	NA	15 Pa	15 Pa

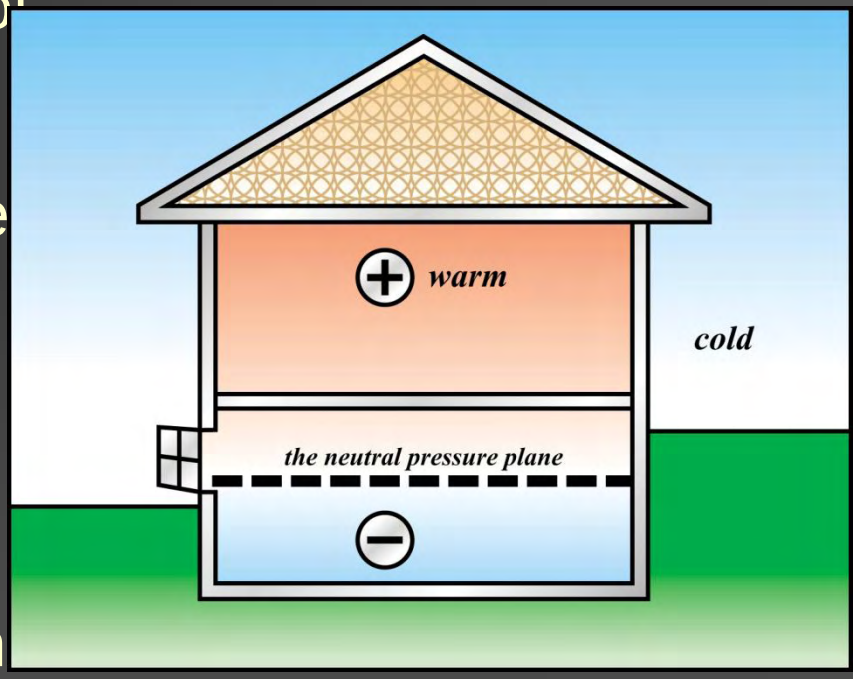
HOUSE DEPRESSURIZATION LIMITS (HDL'S)

Draft

- The draft of a chimney vented appliance must be able to overcome any negative pressures created in the house.
- If a chimney vented appliance is located below the NPP or in an area that is under the outdoor pressure for any given reason, the draft must be **greater than that negative pressure.**

What affects Draft?

- **Location of the neutral pressure plane** The vented appliance cannot withstand significant negative house pressures. The lower the neutral pressure plane is, the better the draft will be for an appliance. Appliances located in a basement level can be a problem.
- The neutral pressure plane will follow the location of leaks in a house. Opening a window up high raises the neutral pressure plane while opening a window down low, lowers the NPP.



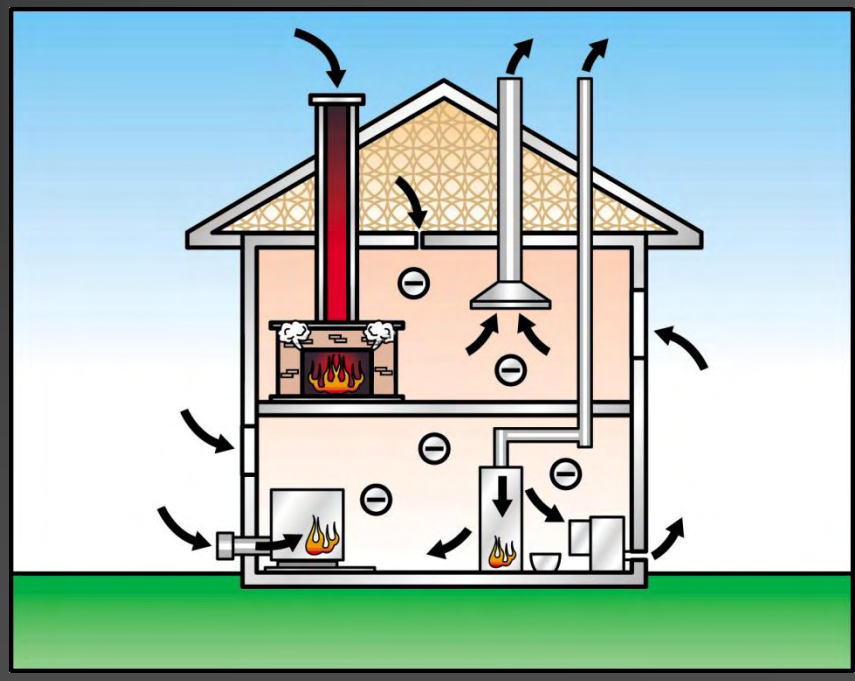
What affects Draft?

Weatherizing an existing home –

Installing new windows and caulking leaks often has the effect of raising the neutral pressure plane. This occurs because the most noticeable leaks are those low in the structure where cold air leaks in and directly affect comfort. There still may be leaks on the upper levels of the house allowing air to escape.

What affects Draft? Anything Affecting the Pressure Difference

- Exhaust Fans – Anything taking air out of a house affects the pressure in the house and therefore the location of the neutral pressure plane.
- Exhaust fans can even eliminate the stack effect by bringing the entire house under negative pressure. This would generally only happen in a tightly constructed house.



Intermittent Exhaust Fans

- Intermittent Exhaust Fans – These are your typical bathroom, dryers, central vacuums or kitchen exhaust fans.
- Good venting systems are generally tolerant of negative pressures due to intermittent exhaust fans

Continuous Exhaust Fans

- Continuous exhaust must be looked at differently from intermittent exhaust fans because have a greater impact on draft and the operation of chimneys.
- Exhaust only ventilation systems are an example of continuous exhaust.
- These systems are more likely to cause failure because they can bring the house under a negative pressure during start-up and tail out periods such as when there are only coals lefts in a wood burning fireplace.

Powered Attic Exhaust

- When the attic is not properly ventilated, powered exhausters can contribute to building depressurization
- Without adequate soffit or gable vents, powered exhausters may pull air from the building through any opening or leak between the attic and indoors

Central Furnace Airflow

- The furnace blower causes air to flow through the ductwork
  - Return ducting under a negative pressure
  - Supply ducting under a positive pressure

Ducting Problems

- Ductwork can have a tremendous effect on building air flow patterns
- These effects are caused by:
  - Imbalanced duct design
  - Duct leakage (especially if it is outside the building envelope)
  - Duct outlet isolation

Ducting Problems

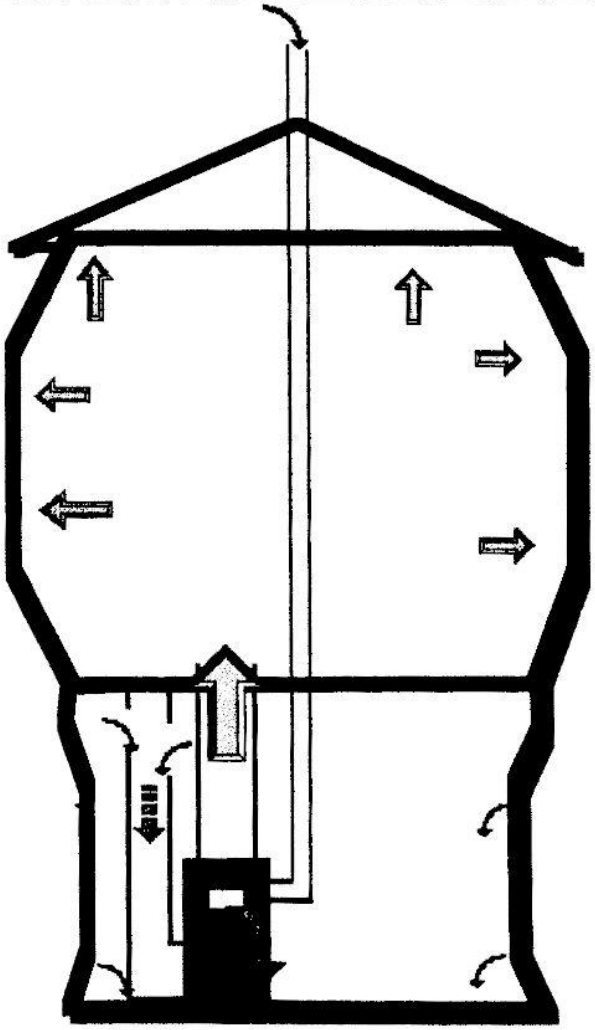
- Balanced System
  - In a well designed HVAC system the return air flow out of the living space equals the supply flow into the living space.

- Duct leakage 15-20% of air flow is not uncommon.

Air Handler Problems

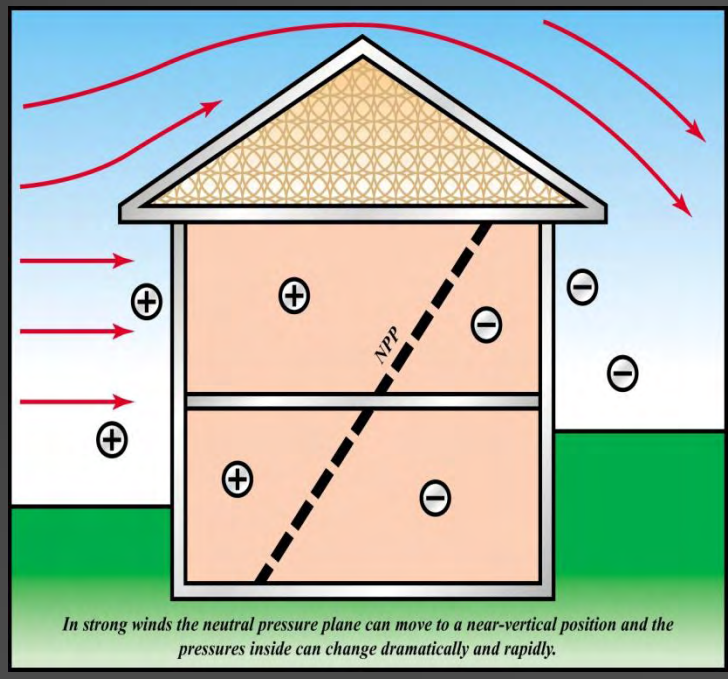
Leaky cold air returns

- **Leaks in cold Air returns may cause hi pressures in some heated spaces.**
- **Causes depressurization in lower levels**
  - **Spillage and backdrafting of appliances in these areas is likely**



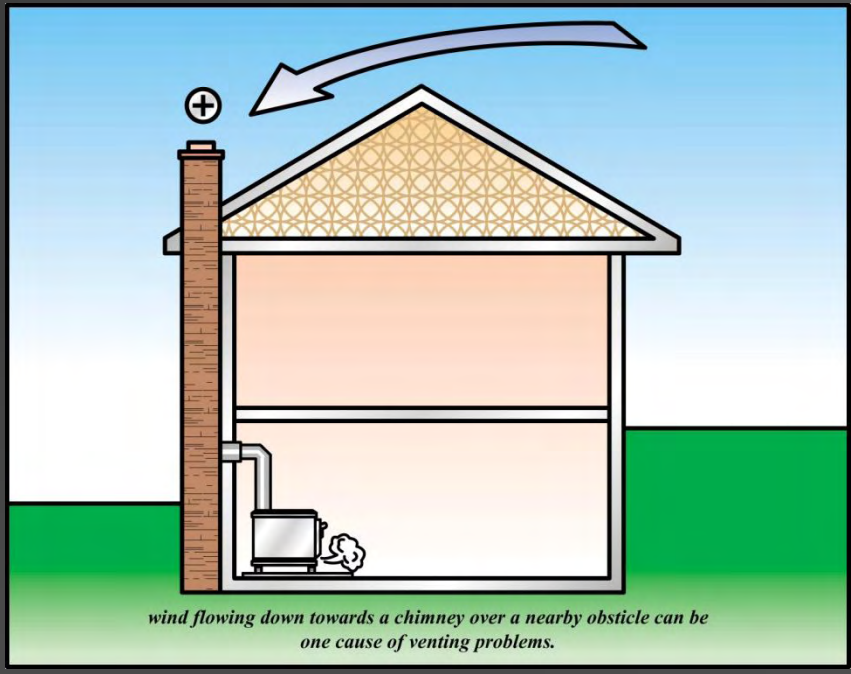
Wind

- The force of wind blowing around a house produces a positive pressure zone on the windward side and a negative pressure zone on the downwind side of the house.
- Remember that wind may not be the only cause of poor draft. Low flue gas temperatures, or a tight building envelope, cold exterior chimney or incorrect flue pipe configuration.



Wind

- **Adverse pressures** decrease draft and can cause Wind Induced Downdraft (WID). Any time wind flows down on top of a chimney it causes adverse pressures. Sometimes this problem can be resolved by the use of a chimney cap.



Wind

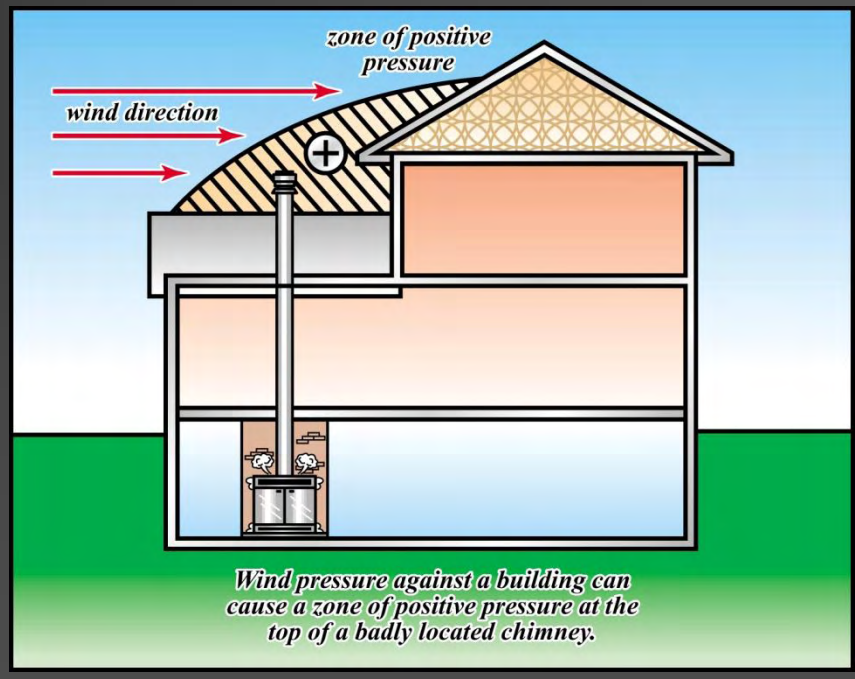
- **Driving pressures** caused by wind will increase draft but are as unreliable as the wind itself. Air flowing over the top of a chimney or through well designed chimney caps increase draft.
- But wind usually has adverse effects on draft.

What Affects Draft? Wind-Chimney location

- The location of the chimney can have a dramatic effect on its performance as shown with the way wind can effect the chimney top.
- The difference between the chimney being inside the building envelope or outside can also have an effect.

Wind

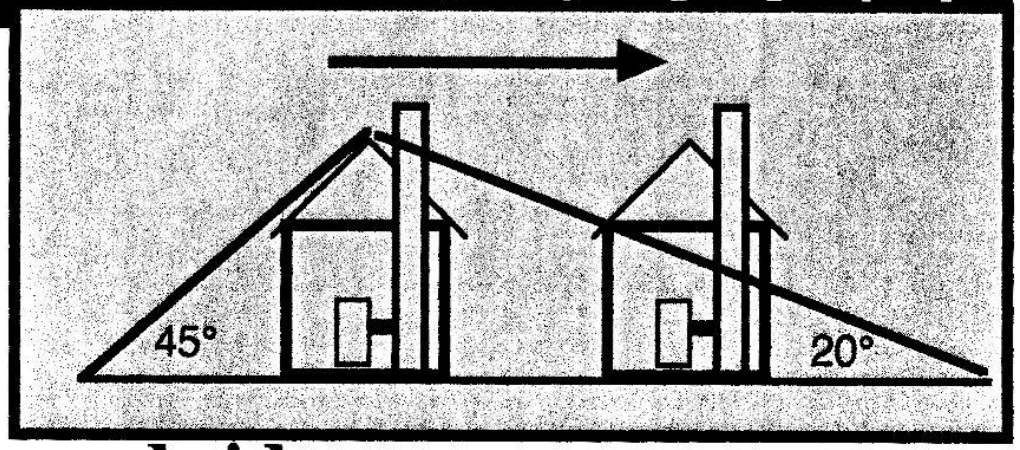
- Sometimes the top of the stack is in a positive pressure zone caused by the wind and the shape of the house. Trees and hills in close proximity might also cause this same effect.



Wind pressure against a building can cause a zone of positive pressure at the top of a badly located chimney.

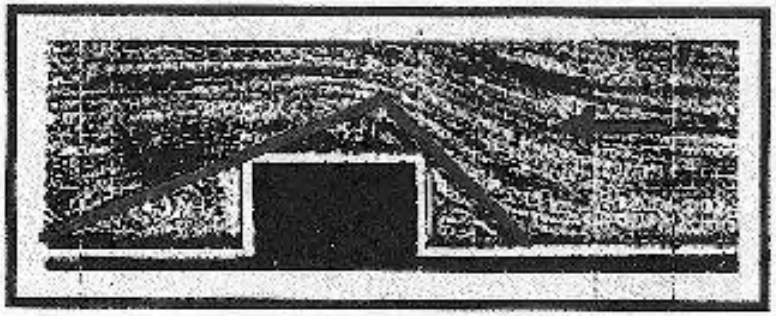
Turbulence--Rule of Thumb

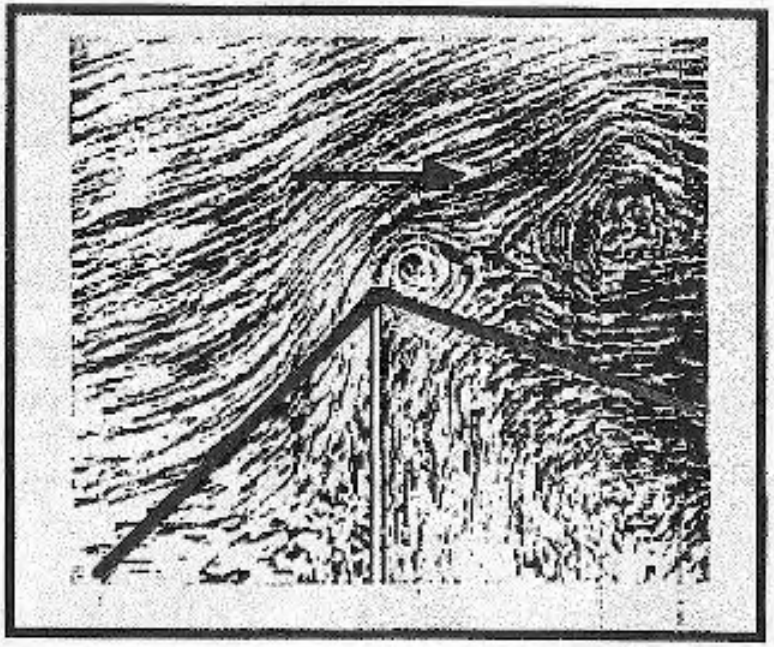
For dimensions of turbulence affected zones



- **Windward side**--An area of approx. 45° from ground to highest point
- **Lee Side**--An area of approx. 20° from ground to highest point. Problem zone 1 to 2 times bldg. ht. away from highest point.
- **Flat Buildings**--Chimney should terminate outside the affected zone, or 6 to 10 ft. above roof

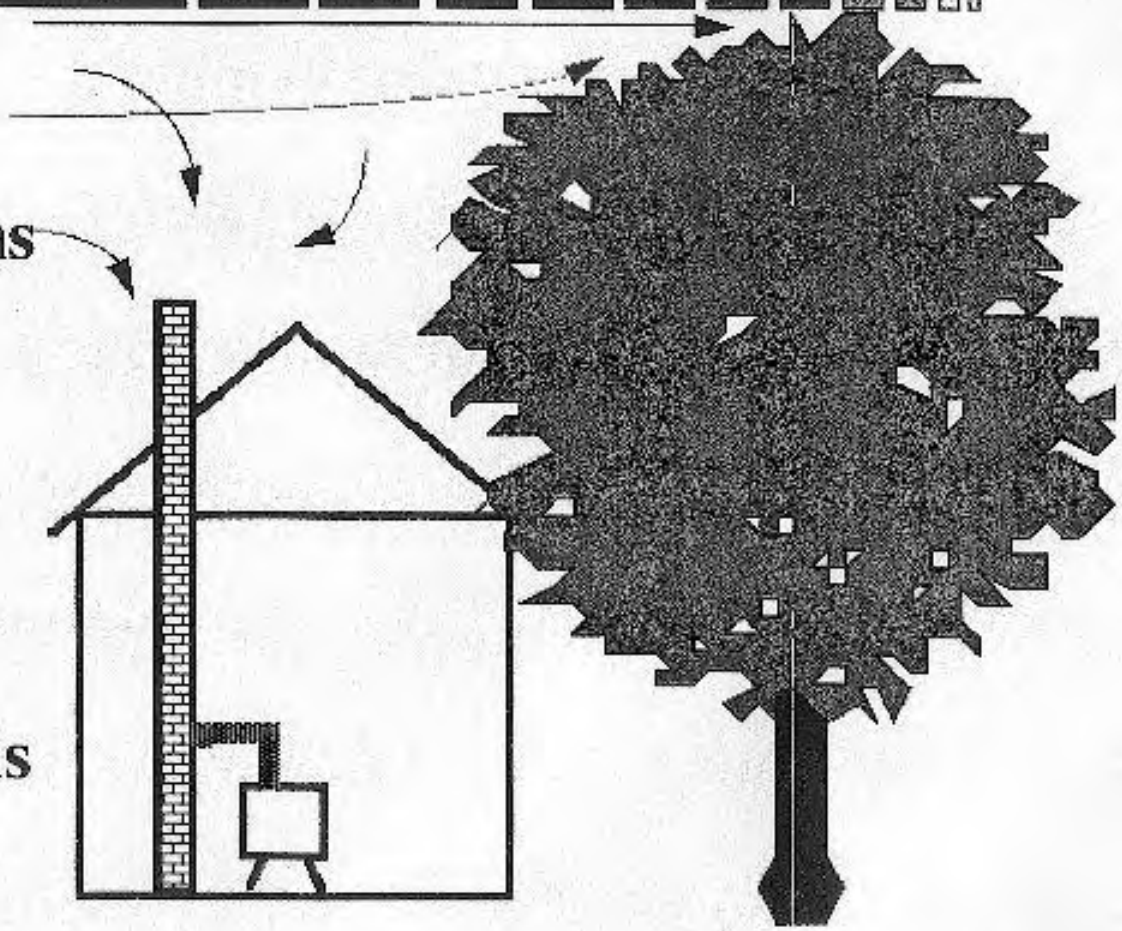
Turbulence Patterns



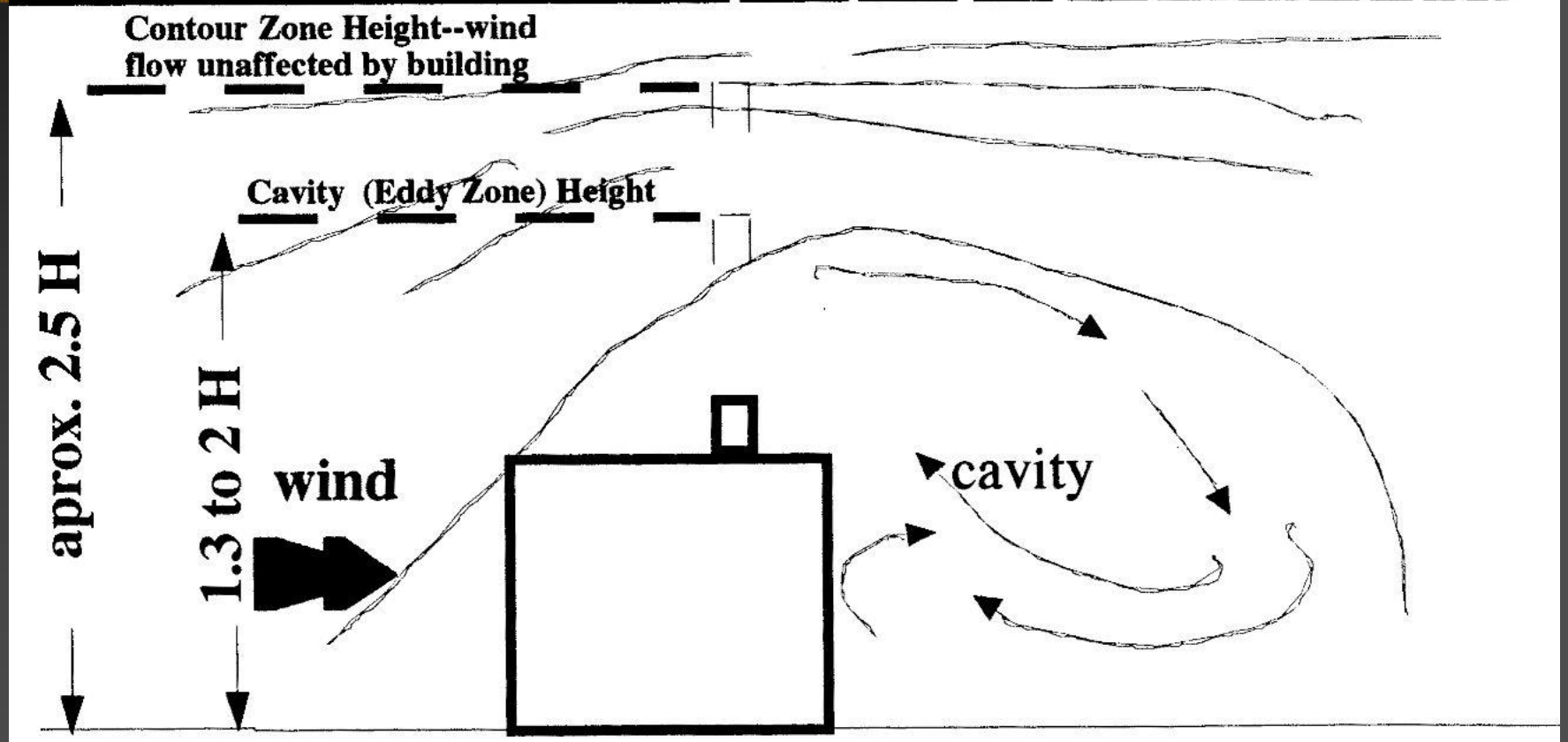


Draft Complications

- Trees, buildings, land forms, etc. affect wind patterns and create turbulence zone, back draft conditions.
- Caps don't work when termination is in pos. press. zone.



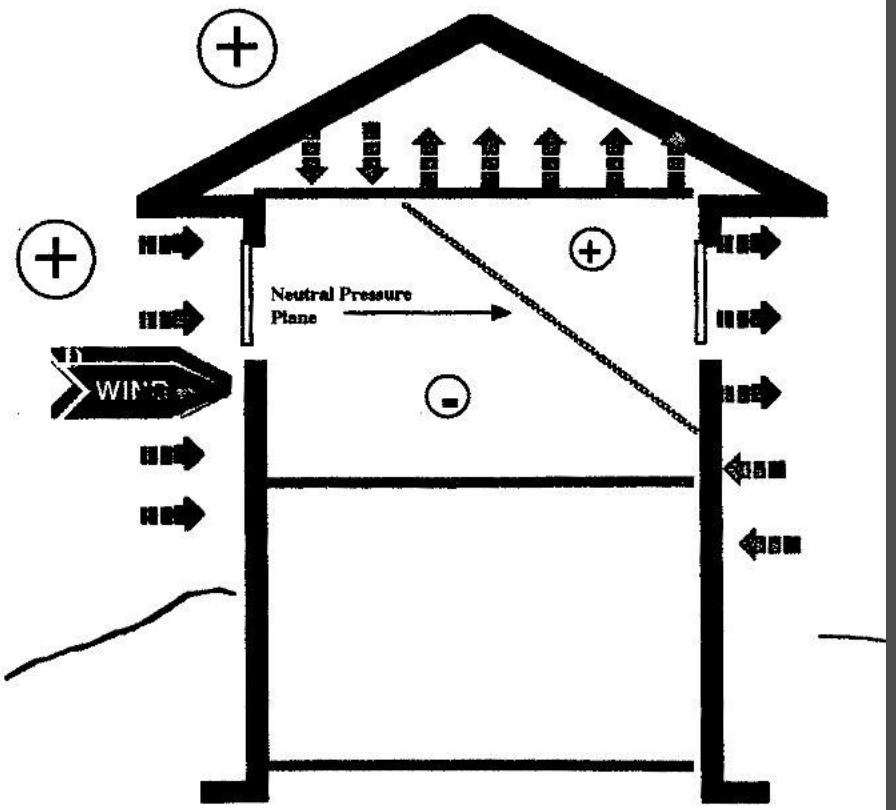
Eddy and Contour Zones
For 1 & 2 Story Buildings



Air flow affects on chimney gas discharge

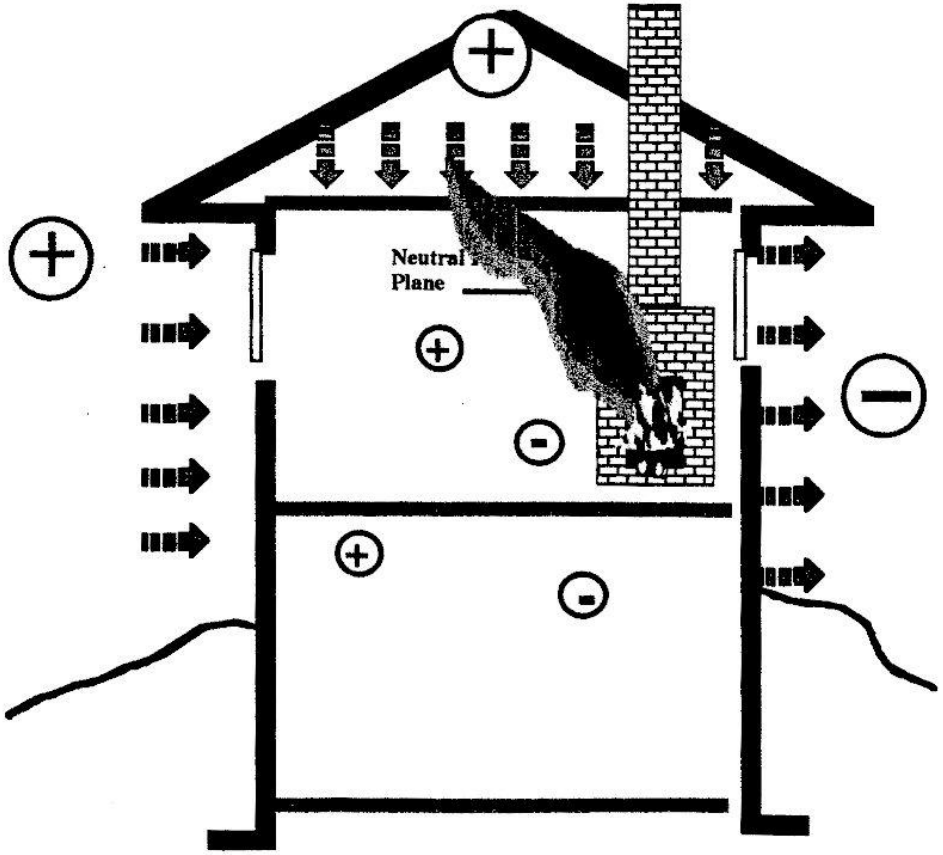
Wind Effect--Combined with stack

- Wind patterns, when combined with stack effect, can cause some unusual pressure regimes within a structure.
- The NPP can move about and change direction, depending on wind velocity and direction

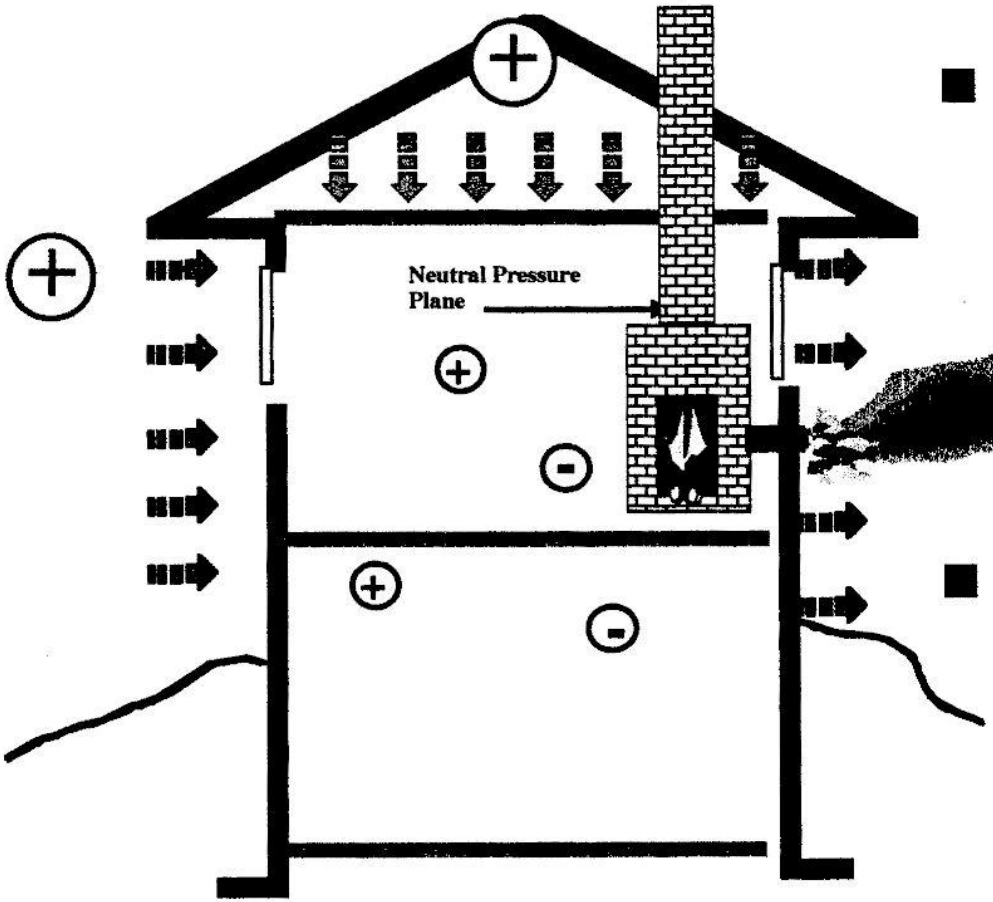


Wind Effect and Spillage

- Wind problems may be difficult to solve
- Wind may have impact only when from certain direction(s) at specific speeds.
- Caps may work if internal pressure does not override



Outside air (OSA) and the wind



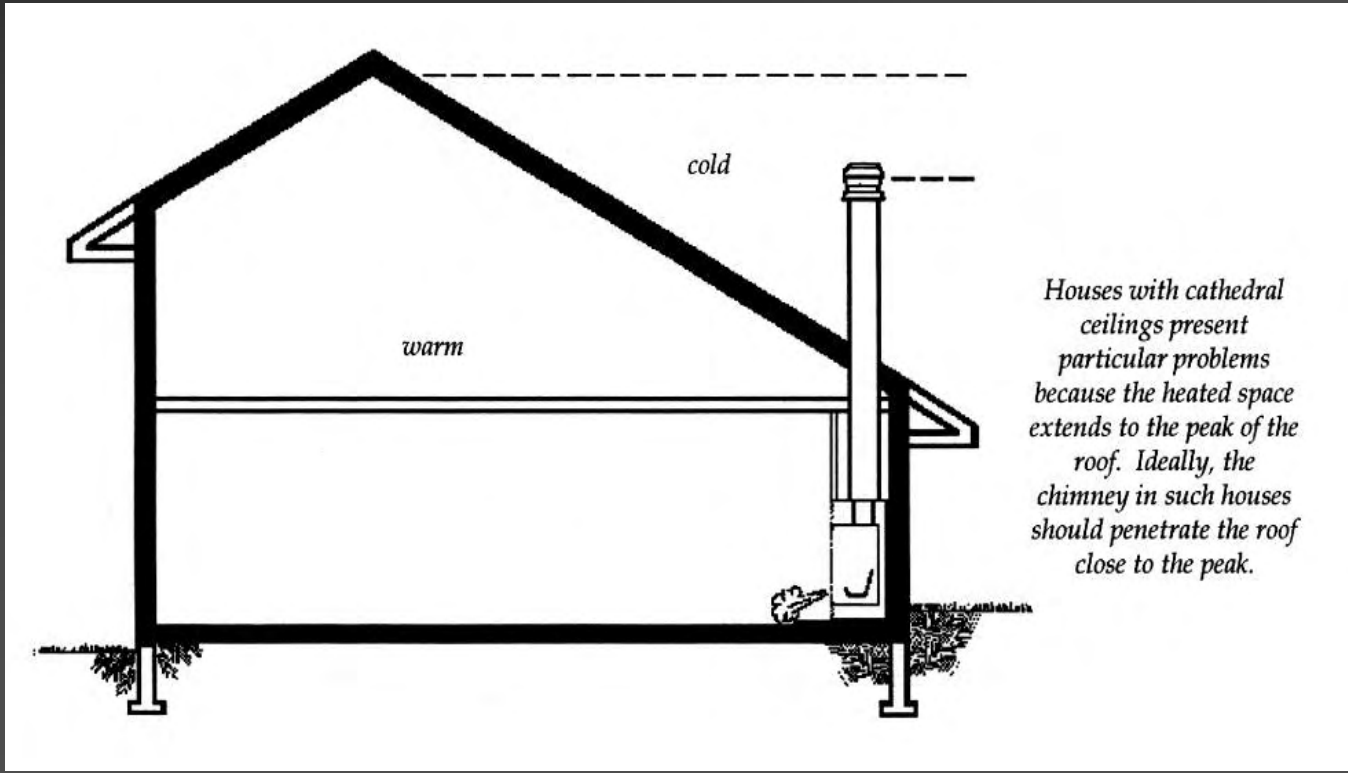
- Out side air connected to the firebox may create backflow thru the OSA connection
- Integrated OSA should be backflow resistant to 80 Pa or more.

Is the house a Better Chimney Than the Chimney?

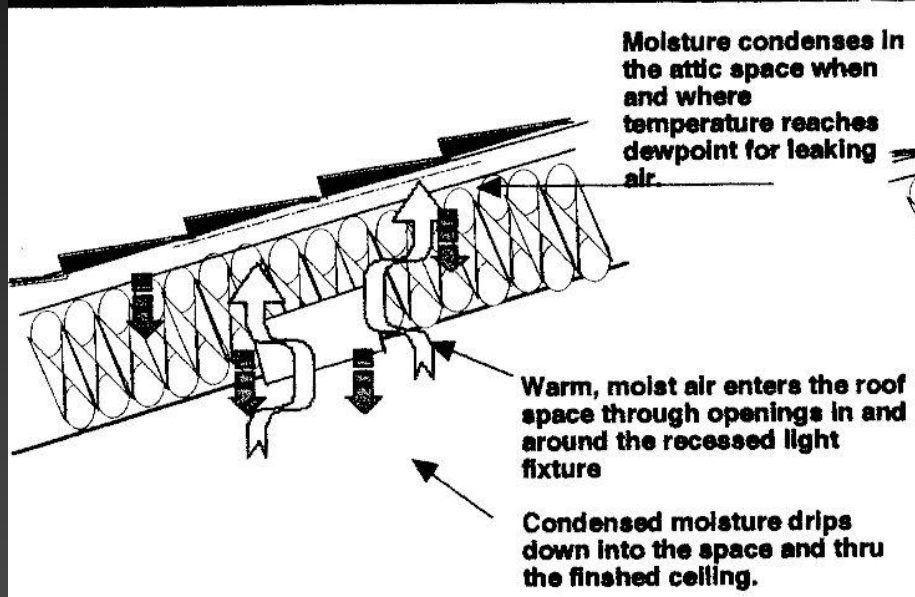
- If the house can cause enough of a stack effect it can overpower the chimney causing a poor draft or backdraft the chimney in extreme cases.
- A house is a better chimney if
  - It is taller than the chimney – taller effective stack
  - The thermal envelope is leaky up high and tight down below.
- Houses become better chimneys if the temperature difference between inside and outside is greater.

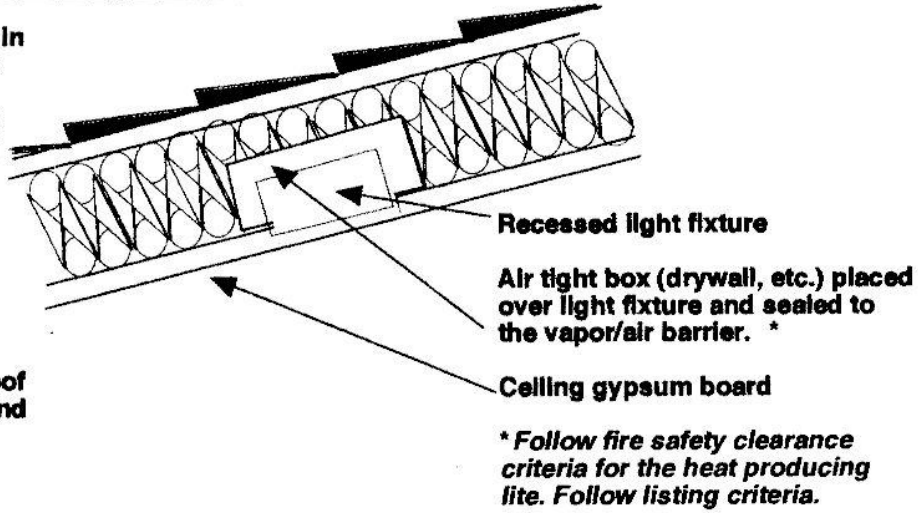
If The House is Taller than the Chimney –

The house can be a more effective stack



Recessed Light Fixtures



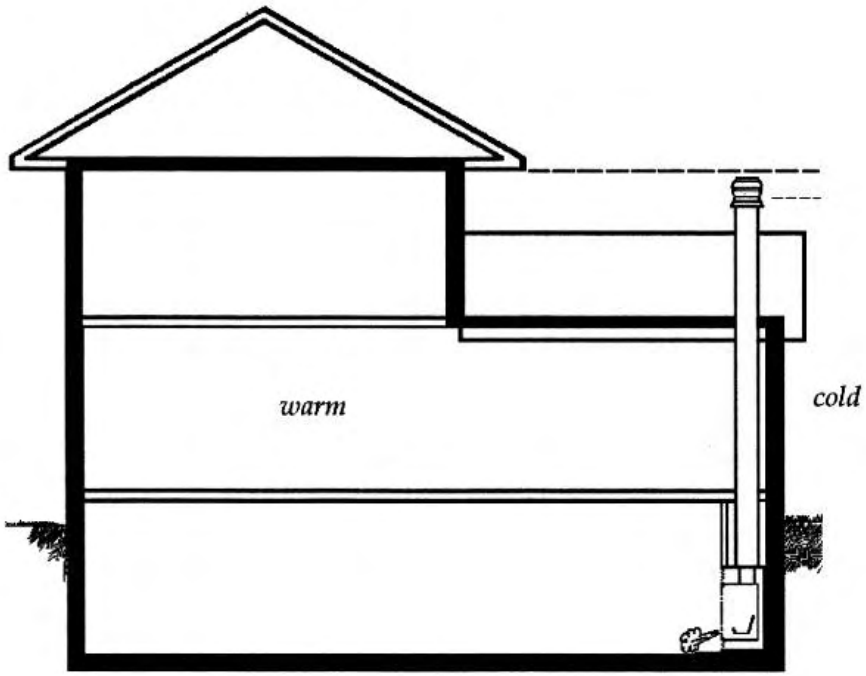


- Major source of upper level air leaks.
- Major contributer to Stack Effect/Negative Pressure related spillage and back-drafting problems

RECESSED (CAN) LIGHTS SHOULD BE SEALED WITHIN A BOX

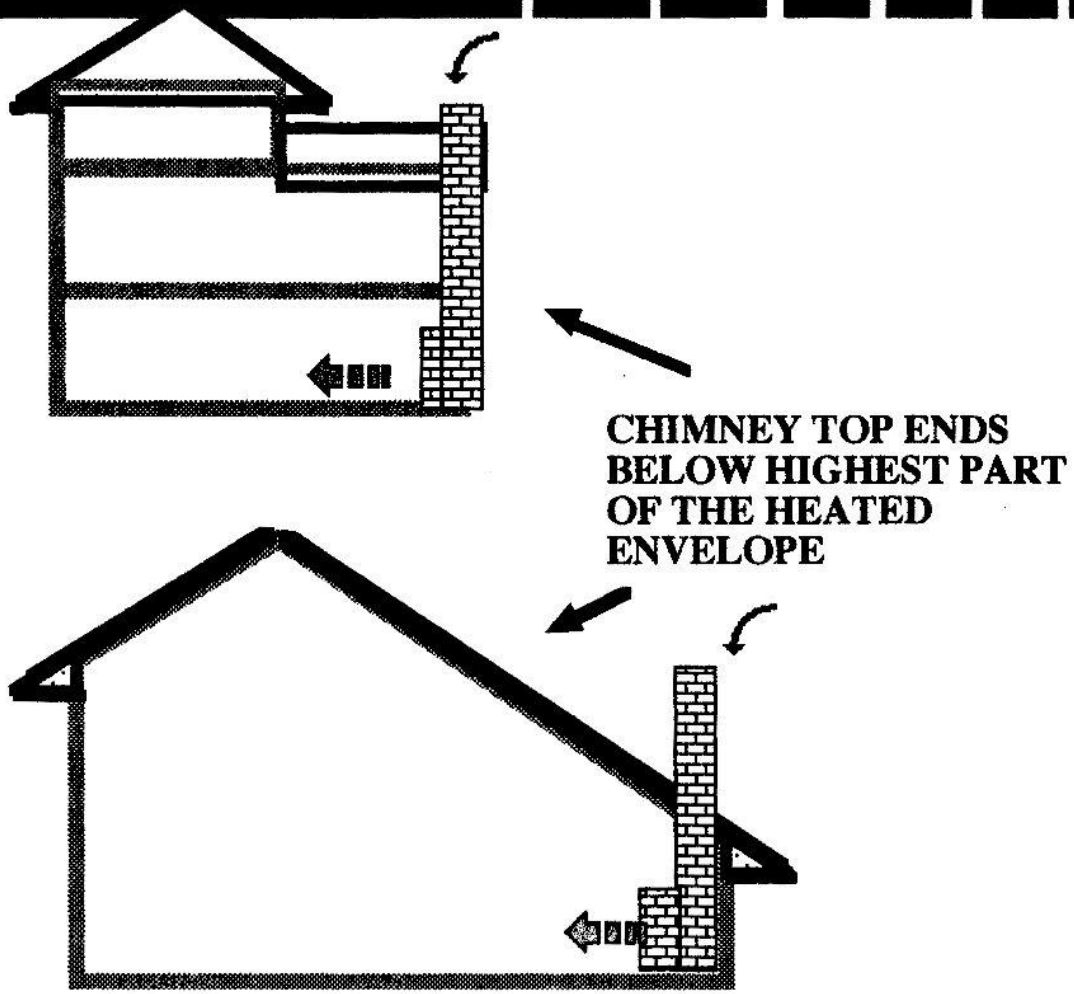
The House is Taller than the Chimney

And that's a common problem!



The best solution in this case would be to move the appliance and chimney to a wall next to the two story section of the house. In this way, the chimney could be installed to run inside the envelope and would be higher than the top of the envelope.

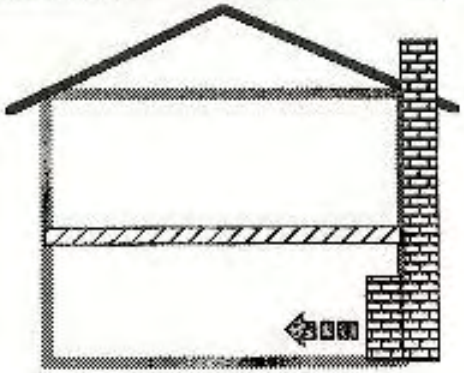
Designs to Assure Chimney Malfunction



Cold Chimney Syndrome

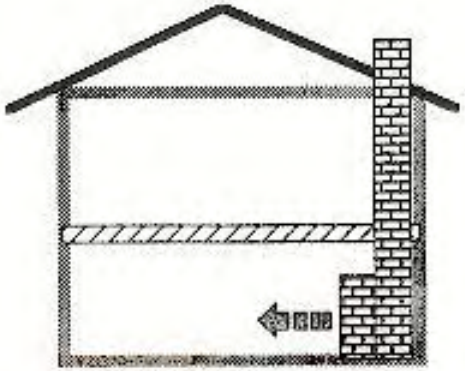
- Exterior brick chimneys have been an architectural feature for hundreds of years.
- They work fine in a loosely constructed home, especially if they are kept warm by fire or a leaky damper.
- With today’s construction practices, exterior chimneys often lead to operational problem of vented appliances.

Draft Encumbered Chimneys



CHIMNEY OUTSIDE OFF
BUILDING ENVELOPE

COLD CHIMNEY
DOWN DRAFT AT STANDBY



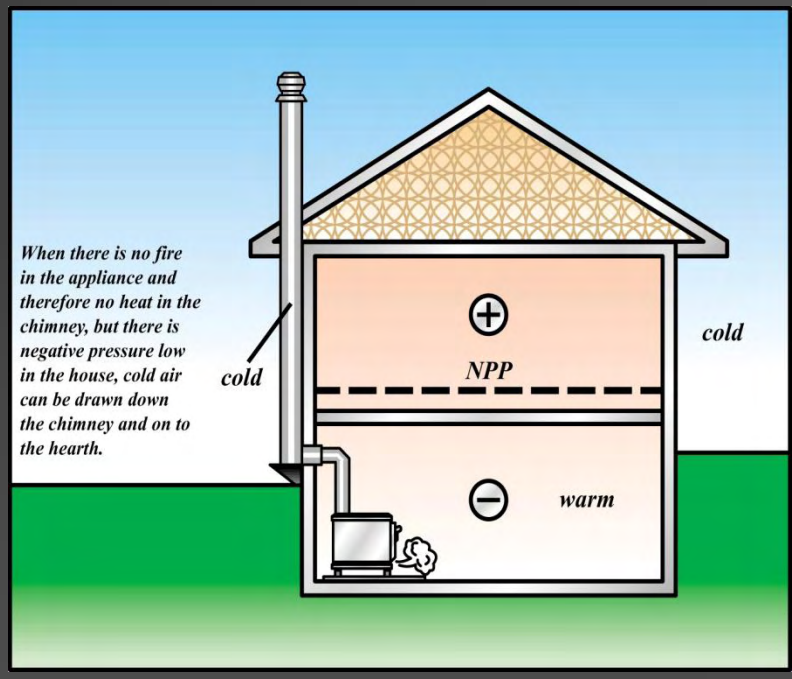
FIREPLACE / CHIMNEY
OPENING BELOW
NEUTRAL PRESSURE
PLANE

Cold Chimney Syndrome

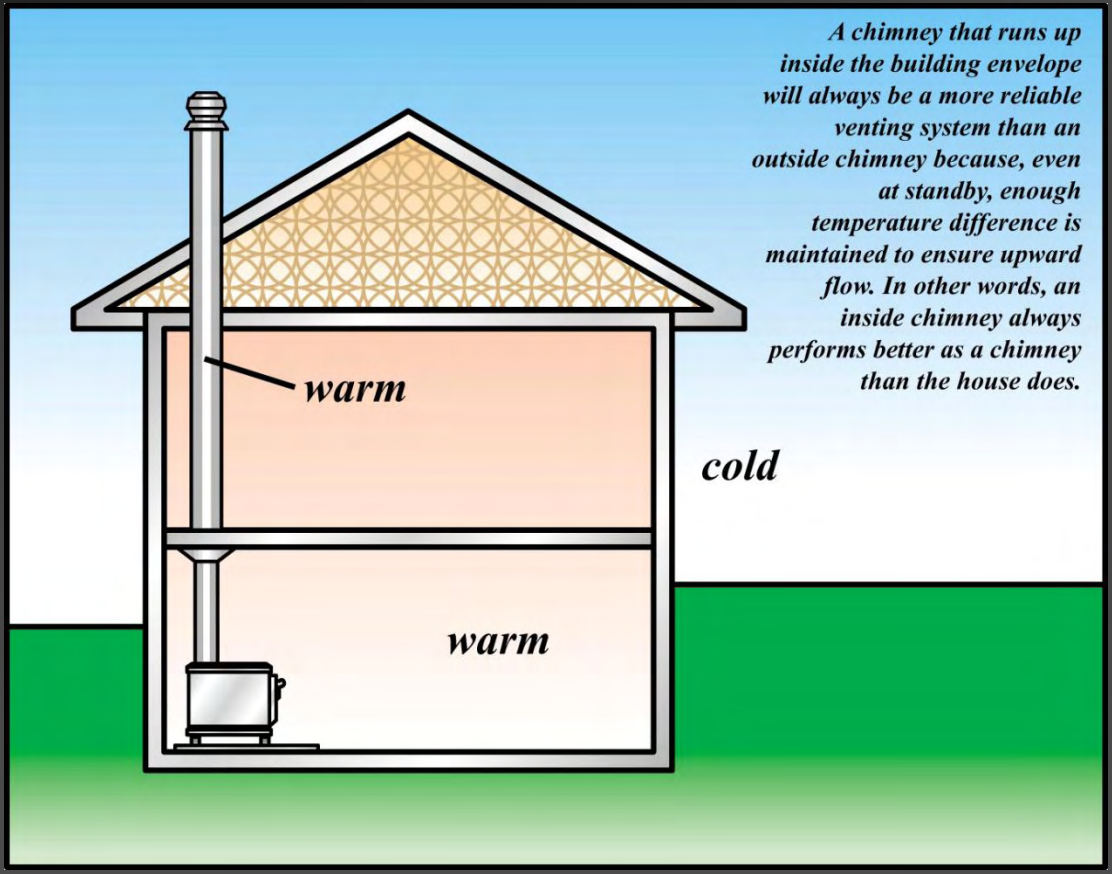
- Cold Chimneys have difficulty establishing a draft.
- Interior chimneys rarely have this problem because they are kept warm.

Cold Chimneys don’t work, but why?

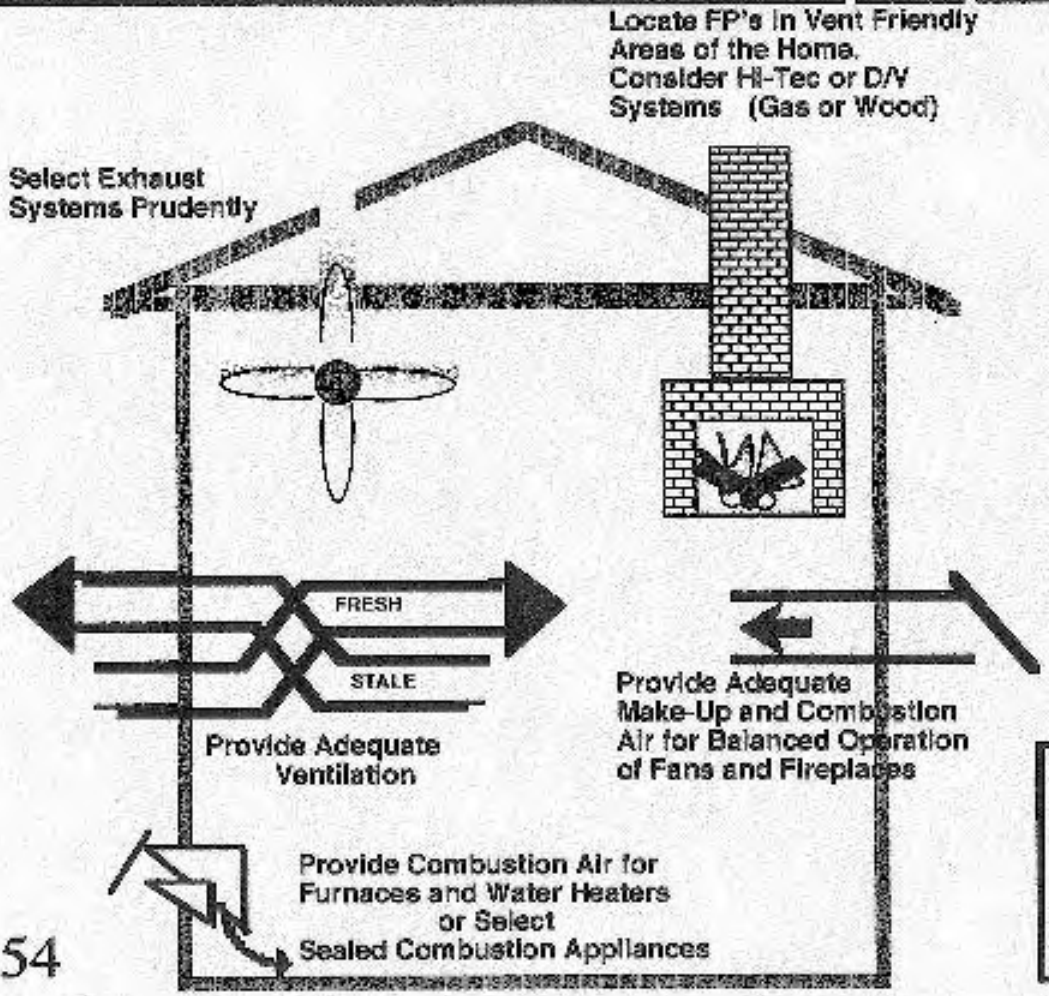
- As mentioned a chimney works because warm gases are more buoyant than cold ones.
- A cold chimney doesn’t have that temperature difference even as hot gases are trying to go up the chimney.



Interior Chimneys – They Work



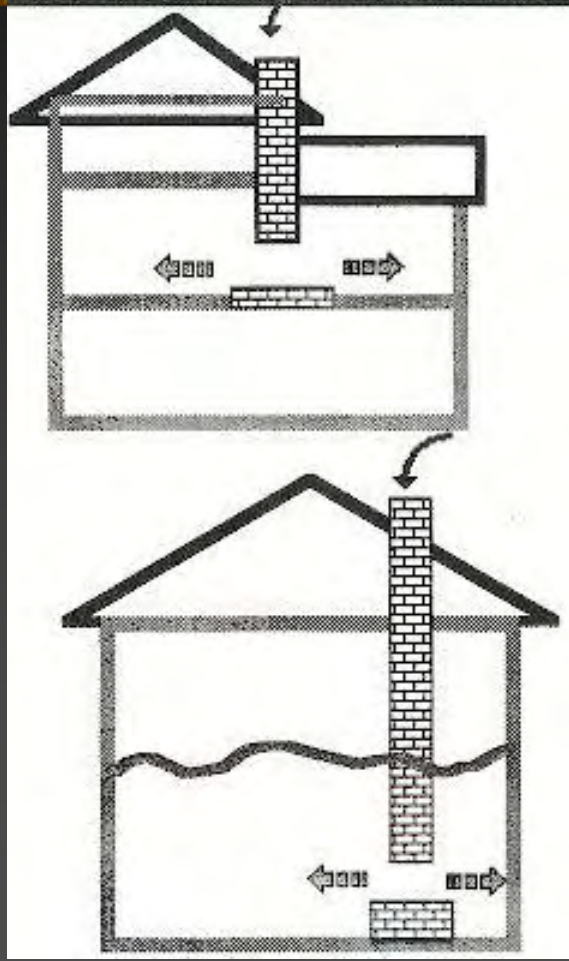
KEYS TO HOUSES THAT WORK AS A SYSTEM



BUILD TIGHT

VENT AND VENTILATE RIGHT

SEE THRU FIREPLACES



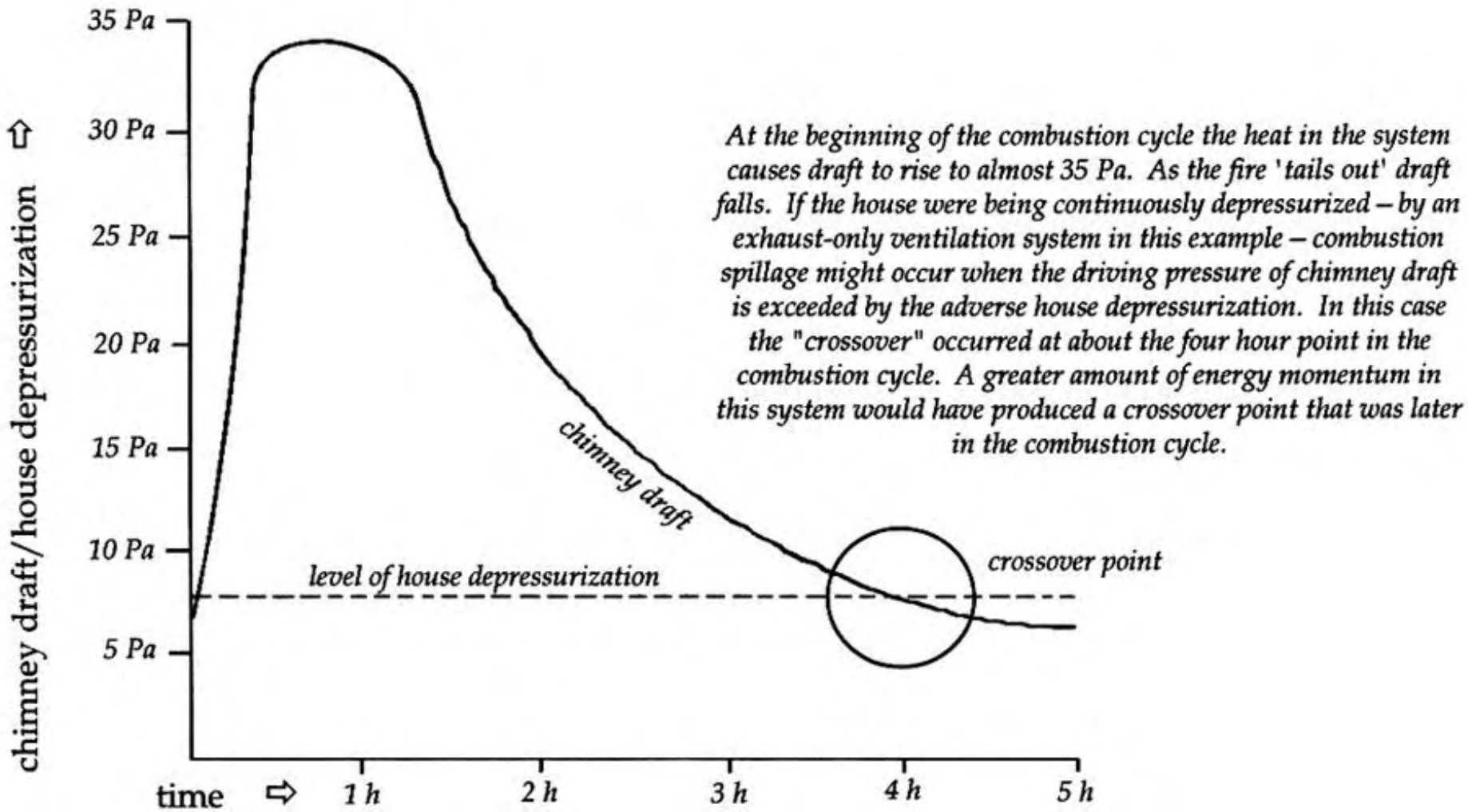
- BETWEEN SPACES WITH DIFFERENT ENVELOPE HEIGHTS ARE GUARANTEED TO SPILL

- SEE-THRU OR MULTI-SIDED FIREPLACE OPENINGS BELOW NEUTRAL PRESSURE PLANE WILL BE VERY SUSCEPTIBLE TO CHRONIC SPILLAGE- EVEN IF ENVLOPE PENETRATION IS CORRECT.

I can get my fireplace started with a Hair dryer! What?

- It’s true, once the chimney is warmed up, and the draft is established it works fine….until it cools down.
- That’s why at the end of a fire when there are only coals a fireplace will smoke.
- Blow dryer solutions are not for everyone.

Draft During a Fire



What Else Effects Draft?

- Blockages in the flue
- Too many direction changes in the chimney
  - Air, like all fluids resists making a change in direction.

Supplying Combustion Air to Vented Appliances

- Supplying combustion air to a chimney vented appliance may not be as simple as following the codes if you want the appliance to draft properly. The goal of supplying combustion air to an appliance is to create a neutral pressure relative to the outside.
- Supplying combustion air to an appliance lowers the NPP.

The Science of Supplying Combustion Air

- Combustion air must be supplied to an appliance while maintaining the comfort of the occupants, meeting the appropriate codes and allowing the appliance to operate properly.
- Combustion air supplied to the living space should be conditioned and filtered.

The Science of Supplying Combustion Air

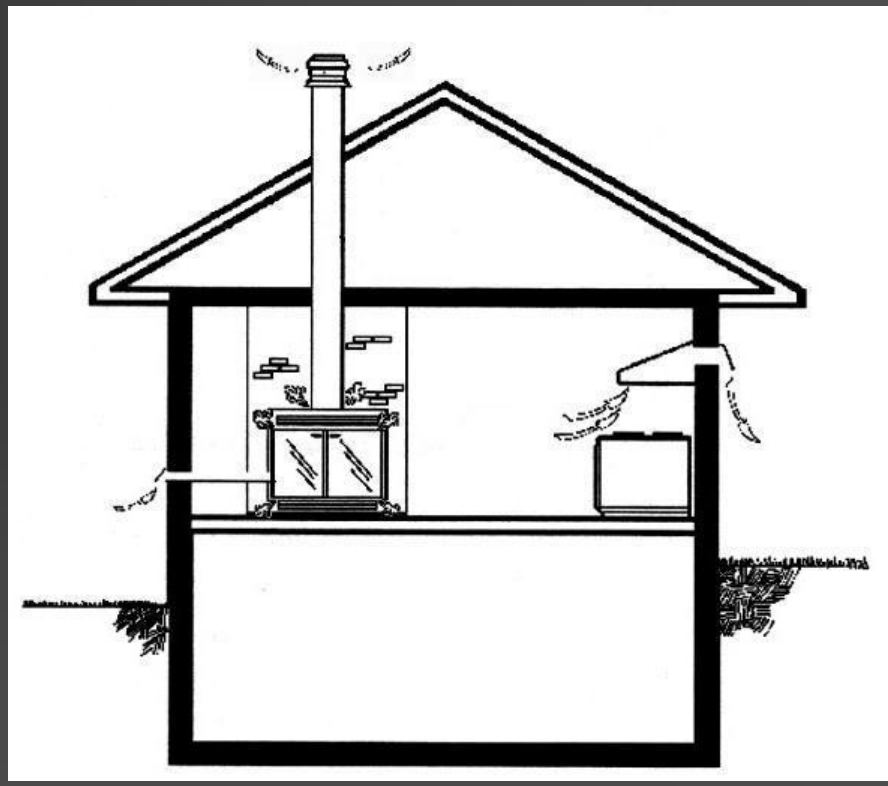
- Combustion air can come from infiltration with no direct supply. The ability for a house to supply combustion air in this manner depends upon how the house is operating as a system; the draft, the flow, the size of the exhaust fans, tightness of the thermal envelope, etc.

The Science of Supplying Combustion Air

- If combustion air is not or can not be supplied by infiltration, it has to be supplied by other means.
- There are two ways of supplying combustion air to an appliance. (Assuming it is in a heated space)
  - Supplying air directly to the appliance
  - Supplying air to the room.

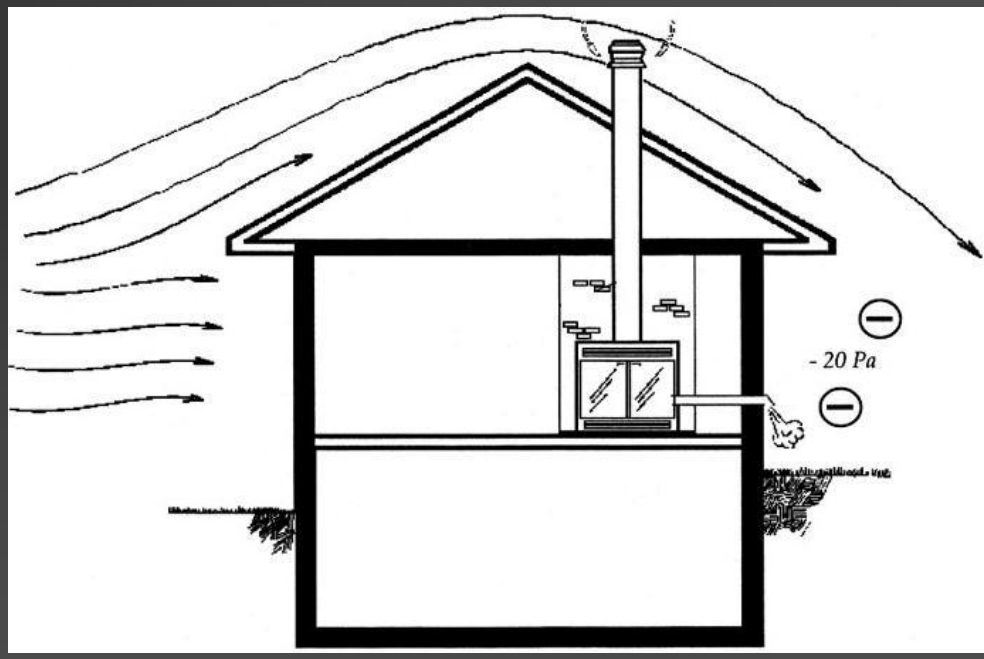
Supplying Combustion Air Directly to the Appliance

- Supplying combustion air directly to an appliance is very effective when the combustion chamber is sealed tightly from the room.
- If the combustion chamber is not sealed, the appliance will spill if the room is under a negative pressure greater than the draft due to any reason, such as wind, fans, or stack effect.



Supplying Combustion Air Directly to the Appliance

- Another issue with supplying combustion air directly to a combustion appliance is the chance of flow reversal.
- This is a fire hazard due to hot combustion gases flowing through the combustion air supply ductwork which is not designed to handle the high temperatures. Wind can cause this.



Supplying Combustion Air to the Room

- For vented appliances that do not have a tightly constructed combustion chamber, air must be supplied to appliance from the room where it is located.
- If air is not flowing into an appliance such as a fireplace, the appliance will spill. This is because there has to be a flow going into the appliance to create what is called a capture velocity. This is generally considered to be 35 ft/min.

Supplying Combustion Air to the Room

- Supplying combustion air directly to a room from outdoors can cause comfort problems.
  - Outdoor air can pool at the floor level or cause cold drafts in the winter. If this happens, the occupant will block the opening
  - Outdoor air supply to a room can effected by wind. The air flow may actually flow out of the house instead of into the house.

Supplying Combustion Air

- The best place for combustion air to come from is from within the house. Make up air may be able to be provided by through an air handling system if one is available.
- The disadvantage to this is that the house pressure is can adversely affect draft if the house is unusually tight and something in the house is dropping the pressure below the draft created by the appliance.
- Appliances such as fireplaces can take large volumes of air out of a house and actually be the cause for other appliances backdrafting.

Combustion Air to the Fireplace