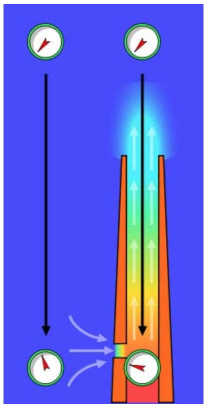
Buckley Rumford Fireplaces

Chimney Draft



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Chimney draft can be complicated but the principles are well known. If we consider three factors that affect draft separately, we can build chimneys to vent fireplaces that will work. The three factors are:

1) Pressure differential - the basic mechanism of draft.
2) Flow capacity or rate - getting enough draft.
3) The chimney in relationship to the house.

1) Pressure differential - the basic mechanism of draft.

The combustion flue gases inside chimneys are hotter than the ambient outside air and therefore less dense and lighter than the ambient air. The column of warm air inside the chimney, being more buoyant, rises in the chimney, reducing the pressure at the bottom of the chimney so that ambient air flows into the combustion zone and moves the flue gases up and out of the chimney. That movement or flow of combustion air and flue gas is called "natural draught", "natural ventilation", "chimney effect", or "stack effect". The taller the stack, the more draught is created. The equation below provides an approximation of the pressure difference, ΔP, (between the bottom and the top of the flue gas stack) that is created by the draught:

$$\Delta P = C\, a\, h \left(\frac{1}{T_o} - \frac{1}{T_i}\right)$$

where:

ΔP = available pressure difference, in Pa
C = 0.0342
a = atmospheric pressure, in Pa
h = height of the chimney, in m
To = absolute outside air temperature, in K
Ti = absolute average temperature of the flue gas, in K

The above equation is an approximation because it assumes that the molar mass of the flue gas and the outside air are equal and that the pressure drop through the flue gas stack is quite small. Both assumptions are fairly good but not exactly accurate.

The important thing for us is to note that draft is directly proportional to the height of the chimney, the temperature of the flue gasses and the atmospheric pressure. A twenty foot tall chimney creates a pressure differential twice as great as a ten foot chimney. A chimney at sea level where a = 14.7 pounds per sq.ft. has almost one and a half times the pressure differential as an equal chimney at 10,000 feet in elevation where a - 10 pounds per sq.ft.

2) Flow capacity or rate - getting enough draft.

The pressure differential is only part of the question. Notice that flue size doesn't matter at all. How much air flows into the bottom of the chimney is estimated by the formula below.

$$Q = C\ A\ \sqrt{2\ g\ H\ \frac{T_i - T_e}{T_e}}$$

where:

Q = flue gas flow rate, m^3/s
A = cross-sectional area of chimney, m^2
C = discharge coefficient (usually from 0.65 to 0.70)
g = gravitational acceleration at sea level, 9.807 m/s^2
H = height of chimney, m
Ti = absolute average temperature of the flue gas in the stack, K
To = absolute outside air temperature, K

Again, without getting too concerned about the math or the units, the important thing for us is to note that the flow is directly proportional to the cross-sectional area of chimney and to the square root of the height of the chimney and the temperature differential multiplied by a big number. In other words the height of the chimney and the temperature of the flue gasses, while directly proportional to the pressure differential in the static case above are a little less important due to friction or drag and energy it takes to accelerate the gasses.

3) The chimney in relationship to the house.

That's all great if the chimney were standing out in the middle of a field. But most fireplaces are inside houses. Houses are filled with warm air relative to ambient air in the heating season and, like in a chimney, the warm air in a house is less dense than the ambient cooler air and tends to rise. In other words the house itself can act as a chimney. If you open an upstairs window the warm air in the house would rise and flow out of the window while creating negative pressure downstairs that would cause air to flow in an open downstairs window. Complicate this situation with various fans and other appliances that draw air out of the house.

In a house what matters is the pressure differential between the air in the bottom of the chimney compared with the pressure at the same level inside the house. If the house is taller than the chimney the house could draft better than the chimney and outside air will flow down the chimney into the house. If an appliance, like a kitchen fan, is turned on that could reduce the indoor air pressure and cause a downdraft even if the chimney is tall enough.

Flow matters too. In a tightly sealed up house with no fans on and no leaks or open windows there may not be an excessively negative indoor air pressure but there also needs to be enough flow rate (Q) for combustion and to carry away the smoke in the fireplace.

Effects of Altitude

Altitude affects the pressure differential probably because pressure vs altitude is logarithmic rather than lineal. A 30 foot tall chimney at sea level spans a greater pressure differential than it does at 10,000 feet.

Altitude has no effect on flow rate, but flue size does.

The rule-of-thumb advice is usually to increase the flue area at high altitudes but, if you want to compensate for a decreased pressure differential, the chimney height should be increased.

In our smoky fireplace recommendations we recommend under normal living conditions (furnace, bath and kitchen fans on or off windows open or closed, etc.) there should be an updraft in a cold chimney with no fire in the fireplace. This is the pressure differential test.

We also recommend that adequate outside air be ducted into the house to make up for all the air being leaked out or exhausted by all the appliances and fans likely to be on - and enough extra for the fireplace - at least one cubic foot per minute (CFM) for every square inch of flue area. This is to test for adequate flow.

As a practical matter we recommend that no altitude adjustment is needed because what really matters is chimney draft compared with indoor air pressure. Just like at sea level, if the chimney draws when cold while simulating the one CFM per sq.in. of flue area with a fan, the fireplace will work fine at any altitude. But at altitude if you have trouble getting a pressure differential (updraft) you can increase the height of the chimney and if you can't get enough flow you can use a larger flue size.

Related articles
Wikipedia with good engineering references
Smoky Fireplace Checklist
Calculations and assumptions behind exterior air requirements for fireplaces
How Tall Should the Chimney Be?

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