SZÉKELY ENGINEERING

EXPLANATIONS & EXAMPLES

Engineering for Dummies Redux – Part 3 - In the Cooling High-Ceilinged Spaces, It's Neither the Height nor the Volume, but Where the Heat Comes From, *or Why* are We De-Stratifying With Ceiling Fans, Again?

So, one of the beliefs of the uninitiated is that rooms with high ceilings require more cooling than rooms with standard (approximately 8') ceilings heights, *because* of the high ceiling – another example of something that "everyone knows", which is incorrect . The fallback position from this error is that it's actually the larger volume of high-ceilinged rooms which necessitates greater cooling, also incorrect.

But wait! The larger room contains more air which needs to be cooled, doesn't it?

Does it really? - No, no, it's obvious there's more air, but does all of it need to be cooled? To answer the last question, we must first know what causes a room to be hot, and what or who are we trying to cool down.

So, what does cause a room to be hot, or if you're outdoors what causes you to be hot? In both cases the answers are the sun, and the hot air, and with closed windows and shades, the effects of both hot air and sun are mitigated, but with lights and people in a room, we have internally generated light with its concomitant heat, and depending upon how energetically pontification is being practiced, hot air, neither of which will be addressed in this piece.

All this is a clue to the related misconception that *interior* rooms also require heating in winter, with the key terms to understand being heat gain and heat loss.

Entropy is the fancy term for the property, that left to *themselves*, things cool off, implying that heat loss is natural, while heat gain requires and energy source – room temperature water won't boil of its own accord, but hot water will cool to room, or *ambient* temperature as will ice melt to *that temperature*, with the energy source in the latter case being the higher temperature of the room air than that of the ice.

If you clicked on the heat gain and heat loss links in the paragraph before last, you were presented with graphics illustrating the percentages of the total heat gains and losses attributable to the various portions of a building's envelope.

Air infiltration (cracks and leaks) and purposeful ventilation are seen to account for a small percentage of a buildings total heat gain or loss, with the whole purpose of thermal insulation being to trap air because it's such a lousy heat transfer medium. With that being the case, and since no one lives on a cathedral ceiling, why would we want to bring that hot air down to room level in summer, and why would we want to heat air rather than objects in winter? (See the last issue via the link at the top left of this page for an explanation of *radiant* heat.)

So, other than the relatively small contribution of the heat from outdoor air , whether via leakage or intentional ventilation, what means causes exterior heat to find its way into a building through its windows, doors, walls and roof?

The fancy words for this are conduction and insolation, where the former is the result of direct contact by the envelope with the outside air, while the latter is what sunlight does to the envelope, as well as directly to objects within the envelope through glazing, and is why there is such a thing as passive solar heating in winter.

With a building's envelope being the two-dimensional surface which is in contact with the outdoor environment, and separating the latter from its indoor three-dimensional volume, we see it's the **surface area** of that envelope through which heat enters a space in summer and leaves a space in winter, and that this movement of heat has nothing at all to with how much volume is comprised within a building.

Imagine a one-story square home cut into a hillside compared to a rectangular one with its long walls extending into the hillside four times as long as the square home's walls with the rectangular home's short walls the same length as those of the square home. The rectangular home has 4 times the floor area and volume of the square one, but only one quarter of the amount of surface area exposed to the outdoors, the one exterior short wall.

If that's too abstract, how about a typical townhouse between two adjacent townhouses? Just as the long walls lose no heat in winter because of the adjacent heated houses, they gain no outdoor heat in summer from those walls for the same reason, i.e., the adjacent cooled (or cooler than outdoors) houses.

What can be inferred from this is that, all other things being equal (which is almost never the case), because of the greater amount of exposed envelope surface, a corner townhouse will need *very* approximately (because the roof areas are all the same area) twice the heating and cooling as one in the line of equally sized townhouses sandwiched between the two townhouses at the ends of the block, and that a freestanding home of the same dimensions will require in the neighborhood of twice as much as a corner townhouse, or four times as much as a townhouse anywhere between the two corner townhouses. Getting the picture?

But What *is* it?

And now , for a pedantic interlude, how do the various means of heat transfer actually work?

Way, way back in May of 2006, in Volume 6 Number 5, I expounded upon the difference between temperature and heat, but I never bothered to talk about what we understand heat to actually be, and that understanding is necessary to understanding how heat is transferred.

So, we call heat one of the various forms of energy, like electrical, chemical, and mechanical energy, with the hint of what's actually going on in what we mean when we say someone or something is moving *energetically*.

That is, not to go all Quantum Physics on you, but you see, solid matter isn't. It's not really empty space, either, but for the purposes of this discussion, let's say it is, and it's the zooming around of subatomic particles in this "empty space" that we sense as heat, and the transfer of that heat via conduction is the result of atoms banging into their neighbors in succession. Heat transfer via radiation is a bit more arcane where the receiver of heat gets zapped by waves without a sea, so to speak, what with there being no necessity of an intervening medium (outer space) between the source (the sun) and the receiver (Earth).

And Now For Something Completely Different (*Again* with the Airplanes?).

In the same genre as a child's question as to why the sky's blue comes the question of how an airplane – or even large birds – can be held up by something so insubstantial as air.

I mean, we can almost convince ourselves that something as lightweight as a sparrow can beat itself into the air much as a fish propels itself through the water. But 908 *tons* of a 747? All this stuff about Bernoulli's theorem and lower pressure on the top surface of a wing than on the bottom seems a bit much to swallow when pondering such stupendously heavy weight.

OK, so let's do the math, but we'll try and make it more understandable by considering a single engine airplane such as a Cessna 172, which has a MGTOW of "only" 2450 pounds.

With its wing area of 174 square feet, each square foot has to lift 2450/174 or 14.08 pounds (its wing loading) of airplane and with a square foot comprised by 144 square inches, each square inch of wing has to lift 14.08/144 or 0.098 pound of airplane. Let's round it up to 0.1 pound to make things easy. Hmmm.

Lemme see, standard atmospheric pressure at sea level is about 14.7 pounds per square inch, so if ol' Bernoulli lowers the pressure at the top of Cessna 172 wing to 14.6 pounds per square inch, we get the pressure difference of 0.1 pound per square inch, which is enough to support the airplane's weight in the air.

Holy hot air, Batman! Who'da thunk it?

Considering whether a wing is pushed from below or sucked from above into the air by the pressure difference is a pointless exercise, but for cocktail-party fun, take a strip of facial tissue about a half-inch wide and, say, six inches long and hold it directly below the center of your lower lip. Blow straight ahead, and watch it levitate.

Lotta square inches on a 747's wing.