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EXPLANATIONS & EXAMPLES

Engineering for Dummies Redux – Part 2 - Radiant and Convection Heating, *or,* Where to Put the Heat?

The next to last link in the last issue was to a piece on radiant heat where the writer stated radiators are primarily convection heaters, implying the appellation *radiator* is a misnomer.

While not to the level of esoterica necessary to determine how many angels can dance on the head of a pin, examination of the differences between convective heaters and radiant heaters points in the direction of a distinction without much of a difference. Both types of heaters radiate heat *and* conduct heat to the adjacent air molecules they actually touch, but the meaningful difference is which type of heater might be more effective where.

That is, that while the "convective heating" delivered by a radiator is different from the radiant heat delivered from a sun lamp, both the lamp and the radiator deliver their energy by both radiant and conductive means, but because there's less sun lamp surface area in contact with the air than that of a radiator, less air is warmed to convect to anywhere, and while a radiant floor has enormous surface area, it's low temperature can't deliver the heat transfer necessary to warm the air in contact with it to the point that it will begin to convect.

I put the words convective heating in quotes above because while radiation and conduction describe types of heat transfer, convection is more accurately simply the motion of a fluid that has had its temperature increased. Heat lamps and radiant floors warm you without changing the temperature of the air they're in contact with, while the sun, what with space (so named because it's empty, duh!) being a vacuum, warms you without there being anything to be in contact with in the first place.

Conversely, one of the reasons you feel cold when walking in a supermarket's refrigerated food aisles is because you're radiating your body heat to the adjacent refrigeration equipment, though in this case, there's also the issue of cold air spillage from the refrigerated cases, which is so pronounced at really low temperatures that your refrigerator and the supermarket's frozen food cases have doors on them, and this air spillage is a clue to the need for convective heating rather than radiant heating in some instances.

As I harp upon when discussing or writing about heating systems, even the best insulated windows are about a quarter to a fifth as resistant to heat transfer as are the walls they're cut into, and the interior surface of the glass is cool to cold on a really cold day. Air in contact with the relatively cold glass is colder than the surrounding air and would thus fall to the floor as a draft were it not for heating elements located at windows, which, if the balance were perfect, would maintain the air at room temperature, preventing the flow of warm air up, or cold air down, but absent providing supplemental heat along the walls to make up for their heat losses, under window radiation has to deliver enough heat to also make up for the wall losses, so instead of a draft at a window with a heating element below, you feel toasty.

Continuous baseboard heat along exterior walls results in overheated spaces, or continued cold drafts at windows because the heat output of the baseboard being delivered by lower temperature water so as to not overheat a room, will not deliver enough heat at windows to overcome the additional local heat loss. While this can be overcome by stacking heat elements three or four high at a window, there are limits as to how much hydronic radiation can be sucked out of fintubes before they become ineffective, or the water returns to the boiler at such low temperature as to damage it, or both. Low temperature is not much of an issue with condensing boilers, but additional fintube isn't free.

A related error I've seen, is providing heat in interior rooms – if all the rooms surrounding a room are heated, there can be no heat *loss* from that room. More often, heat is provided in bathrooms with exterior walls and/or windows, and entry vestibules where there is heat loss which needs to be accounted for, but the heating elements are put next to walls between adjacent heated rooms rather than at the exterior wall which is where the heat is being lost. One could make excuses for this in bathrooms where tubs or floor mounted toilets and sinks are against the exterior wall, or vestibules which are no wider than their entry doors, but the latter is cured by in-floor heating with removable drop-in grating to allow for vacuum cleaning while the former can be cured by some unconventional thinking, even when there's a heat–sucking window in the wall.

So, with heat in the wrong place, or not concentrated where necessary, the answer seems to be radiant flooring, which has to use lower temperature water so as to not make barefoot walking uncomfortable. Such systems have the entire floor filled with embedded heat tubing so as to make up for the lower temperature water, but what sort of temperatures are we talking about?

Well hydronic perimeter radiation uses water supplied near the atmospheric boiling point of 212°F with the water returning to the boiler at a temperature 20°F lower than the supply temperature and the radiation delivering heat at 750 to 1500 BTUH per linear foot or so depending upon flow rate, fintube materials, and fin size and quantity, not to mention enclosure type.

Radiant flooring uses water at about 140°F (hence the applicability of condensing boilers) with plastic tubing on 8″ centers, delivering 25-35 BTUH per square foot of floor area at a floor temperature at 75°F to 80°F. The tube spacing is squeezed to 6″ or so for a foot or two from the exterior wall to make up for perimeter heat loss, with wood floors being a bit more complex than concrete floors, but since current standards do not account for the difference between wall and window heat losses, what's a designer to do about convective drafts?

It depends on how much perimeter glass there is. With a glass wall or yards of floor to ceiling glass, it may make sense to try and squeeze the tube spacing to 4″ or so, but with the 4″ minimum bend radius of the smallest (3/8″ dia.) PEX tubing, tube spacings of less than 8″ require 270 or so rather than 180 degrees of bend with reverse bends for the spacing, and the ¾ circle 8″ diameter direction reversals touching each other. If you didn't get that, don't worry, I'm not too clear on it yet myself

Such a customized level of heat loss compensation implies three different tubing spacings rather than the two shown in the wood and concrete floor radiant heating details linked to earlier– normal (8″) spacing in the core of a room to make up for general heat loss, reduced (6″) spacing at the perimeter for increased heat output at the heat loss boundary, and further decreased spacing (4″) at large expanses of glazing to counteract convection drafts. I'd not yet come to this conclusion on any of my completed projects, but you can be sure I'll take a close look at it the next time I have a project with copious amounts of glazing.

The other option I may explore on such a project is a hybrid system with a low-temperature radiant floor for general heat loss along with high-temperature fintube supplemental heat at high heat loss portions of the project's envelope, but the key is to not forget the principle of "good enough" engineering, which is one of the things which separates engineering from empirical experience.

What I'm trying to say here is that while oversized (contractor's favorite) or over-refined (engineer's favorite) systems will certainly (contractor) or should certainly (engineer) preclude perceived inadequacies in operation, such adds cost to a project for no discernible advantage over adequately sized and refined systems. Or, to put it another way, while the optimist says the glass is half-full and the pessimist says it's half-empty, the engineer should say the glass isn't optimally designed.

The previous paragraph refers, of course, to the level of the glass immediately after liquid is poured into it, not the situation which occurs when the glass is defective. That is, though I have searched far and wide in countries on 2 continents, I have yet to find a dispensary of adult beverages where the glass is *not* defective – no matter how well or how often the glass is filled, it invariably ends up empty.

I have found a similar situation to exist in the case of wine bottles. No matter the care I take in handling one, by the end of the meal it accompanies, it too ends up empty. On occasion I have opened a second bottle, believing or hoping the first was an aberration, and have gone so far as to select a completely different wine, counting on the product of a different vineyard to display more deference to it's reverent consumer, all to no avail. *Sigh!*