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Radiant cooling

The perfect marriage between a geothermal heat pump and radiant hydronic distribution

ALTHOUGH TEDD BENSON and others have published books on timber framing since 1999, there is minimal documentation for integrating electrical, heating, cooling, and plumbing systems. Most timber frame builders simply default to forced air heating and cooling, although these are less than ideal. The great open spaces and floor-to-ceiling glass of many timber frame structures create unique challenges better suited to hydronic heating and cooling. This article addresses radiant hydronics—the use of water as a medium of heat exchange - with emphasis on cooling with radiant floors. When installed correctly, radiant cooling systems are elegant and functional; without proper engineering, they can lead to catastrophic results.

We appreciate the coolness of a cave on a hot day— high mass cooling and very comfortable. Yet mechanically delivering cooling to a structure via hydronic tubing in high mass floors is relatively new. Unlike boilers, water-to-water ground source heat pumps (GHPs) eliminate the need for a separate chiller, as they can both heat and cool from one unit. Similarly, ground water can cool a structure without a heat pump. If the hydronic heat in-floor distribution system can be used for cooling, it reduces the need for the large ductwork (and noise, and discomfort) of air conditioning.

Radiant cooling technology was first introduced in Europe 20 years ago. After implementing commercial projects with radiant cooling in Sweden and Thailand, Uponor Corporation hosted the first engineering summit on radiant cooling in the U.S., in April, 2010. I attended it. Our company is now partnered with Uponor to monitor radiant floor cooling performance in two new homes in Colorado. Combined with GHPs, this technology seems well-suited to beat HVAC challenges in timber frame homes with great spaces, offering unparalleled comfort, superior indoor air quality, and minimal ductwork. To achieve these benefits, proper design and implementation are critical.

Some common user misperceptions are that radiant cooling:

- necessarily creates condensation, and therefore mold;
- creates uncomfortably cold floors;
- doesn't work, since heat rises; or
- is expensive, as it needs a chiller anyway.

With proper design, radiant cooling does not create condensation. The largest iradiant cooling installation in the world is at the Bangkok (Thailand) Airport. The concourses and main terminals contain over 1.6 million sq. ft. of radiant cooling. In North America, the new National Renewable Energy Laboratories research support facilities in Golden, Colo., targeted for LEED Platinum certification, feature radiant slab heating and cooling.

The condensation issue is the dew point, which depends on both temperature and humidity. When a surface is colder than the dew point, condensation occurs. (Imagine a glass of iced water sitting on a counter in the summer) . Simply keeping floor temperatures above the dew point eliminates condensation. To ensure cooling without condensation, the designer must reduce humidity and provide enough ventilation.

Radiant cooling system fluid operates at warmer temperatures than traditional forced air cooling systems. Smaller temperature ranges when heating or cooling provide further comfort and more efficient energy, as the GHP doesn't work as hard to cool water. And the high thermal mass (usually lightweight concrete) of a radiant floor moderates temperature fluctuations that would be found in air conditioning (simply blowing cold air).

A radiant cooling system extracts heat differently. Radiant cooling is the reverse of radiant heating: people living in (or sun shining on) the space are heat radiators and the floor is the absorber. To cool, a radiant floor system typically circulates water at 55 to 58°F, as contrasted to supply-air conditioning at an uncomfortable 40°. The temperature of a radiant floor is within 2° of the floor temperature of a forced air system, yet it has the capacity to remove significantly more heat from *direct* solar surface heating (rooms and hallways exposed to direct sunlight) than air conditioning alone.

While hot air rises, heat does not. Heat moves from hot objects to cold ones. The indoor climate gains heat from building occupants, electrical appliances, lighting, mechanical systems, and solar radiation. Heat is retained in the thermal mass of the structure, as hot air (*sensible* heat) and as heat trapped in water vapor (*latent* heat). In-floor radiant cooling is most effective at removing *direct* solar heat gain, followed by *sensible* heat gain. (It has no inherent capacity to remove latent heat since it does not dehumidify air.) Insulated floor coverings like carpeting limit the capacity to 25 – 30% of the capacity of hardwood or tile floors on top of lightweight concrete.

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A separate chiller is not required for radiant cooling if the home incorporates geoexchange technology (a GHP connected to a ground loop). GHPs are available in configurations that provide hot or cold air (water-to-air) or hot or cold water (water-to-water). These units can be four to five times more efficient than a comparable gas appliance, and two to four times more efficient than electrical air conditioners. Traditionally, in homes using radiant heating alone, the owner had to pay for a separate air conditioner or water-to-air heat pump. With radiant heating and cooling, one water-to-water heat pump can provide hot water for heating and domestic use, cold water to cool the floor, and dehumidification via a water- based air coil. This is the most efficient, most comfortable form of heating and cooling at the lowest first costs.

A radiant cooling system designer balances performance with user comfort. Because the greatest risk is condensation resulting in mold or structural degradation, a proper design controls humidity, then temperature, and finally user comfort — in that order. Radiant cooling can be incorporated in most homes.

To what degree does radiant cooling contribute to the structure's overall cooling? At high dew points, radiant cooling need is minimal as compared to dehumidification and, when required, air conditioning.

The ideal climate for radiant cooling has the low humidity and nominal cooling loads typical of Colorado. At the other extreme are the high humidity and high cooling loads found in the southeastern U.S. (or Bangkok). In a symbiotic relationship, dehumidification acts to reduce the dew point, making radiant cooling more effective. As dew point drops, the temperature of the water in the radiant cooling system can be lowered, thereby removing more heat from the space, and thus reducing the dew point further.

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European standards fill the U.S. standards gap in radiant cooling design. An excellent article* explores the EU standards. The author is director of Denmark's International Centre for Indoor Environment and Energy and a member of the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). He recommends maximum and minimum floor temperatures for user comfort. ISO standard 7730 recommends an upper limit to humidity at 60 to 70% when indoor air temperature is 79°F. (Here in Colorado, except for a hot summer day with incoming thunderstorms, the ISO standard is easy to maintain without dehumidification. In our house, however, anything above 50% humidity feels a bit stuffy.) In the southeastern U.S. in the summer, mechanical dehumidification will always be required. Assuming proper dew point control, floor surface temperatures should be designed for a minimum of 64–66°F when cooling and maximum of 84° when heating. For sedentary persons, the minimum floor temperature increases to 68°F when cooling. At an absolute humidity of 80 grams/lb, the dew point at these recommended standards is 61°F: several degrees below the floor temperature, eliminating the risk of condensation. As with most building science issues, proper installation and controls are critical to ensure these design guidelines are met.

In our partnership with Uponor, we will research and report on actual radiant cooling performance. Stay tuned. - Al Wallace

*Bjarne Olson, Ph.D., "Radiant Floor Cooling Systems," ASHRAE Journal, September 2008

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