Radiant Floor Cooling in Practice

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Although radiant cooling has a limited scope of applications where it is viable, in specific applications, radiant cooling is an effective means of providing cooling comfort to occupants. Typical complaints, such as increased condensation and cold floors, are outweighed by the comfort it provides to occupants via sensible cooling. While it is limited as a building *conditioning* technology, it shines as an occupant *comfort* measure.

Radiant cooling is only suited for sensible cooling, as any latent cooling (i.e., dehumidification) will result in condensation on the cooled surface, which would create the usual problems that moisture creates.

A separate system is needed to handle latent cooling loads, except in consistently dry climates, where it is possible that latent cooling may not be needed.

To prevent condensation, the temperature of the radiant cooling surface(s) must be maintained at no less than the indoor dew point (for example, 55°F [13°C] if the indoor dry-bulb temperature and RH are 75°F [24°C] and 50%, respectively).

Maintaining a minimum floor temperature of approximately 65°F (18°C) is recommended to provide a safety margin relative to condensation and to avoid the floor feeling too cold to occupants.[1]

While this temperature threshold limits the sensible cooling capacity that can be provided for a given area of cooled surface, there are two main energy efficiency benefits of radiant cooling. First, due the relatively high surface temperature level compared to conventional evaporator coils, the cooling efficiency will be about 25% higher. Second, the cooling capacity is delivered directly to the interior space without any air moving power, which is typically 10% to 20% of the energy used in conventional air-conditioning systems.

Combining radiant ceiling panels or chilled beams with a dedicated outdoor air system is a particularly good application(where the system cools incoming ventilation makeup air and can dehumidify the entire building moisture load. [2,3,4,5]

In general, where cooling is the primary purpose of a radiant heating/cooling system, ceiling and wall surfaces (to a lesser extent) are used because natural convection cooling is more effective from a downward-facing horizontal surface (where buoyancy forces cause cooler air to flow away from the surface) than from an upward facing horizontal surface (the floor). In addition, radiant wall and ceiling panels can be directly exposed, while many floors are covered by rugs or carpets, adding a layer of insulation between the surface and the space.

In applications where radiant floor heating is used, which tend to be areas in buildings with bare floors, the in-floor circulating water tubes also can be used for cooling by circulating chilled water at a temperature above the space dew point.

While natural convection from the floor to the space above is less effective than from the ceiling downward, the radiant contribution is the same and the benefits of higher efficiency sensible cooling without any air moving power can be realized.

A rule of thumb is that a radiantly cooled floor can provide 10 to 15 Btu/hr·ft^2 (1 ton for 800 to 1,200 ft^2 of floor area) of sensible cooling.[1] If direct solar loading occurs on the floor, the capacity per unit floor area can be much higher.

Implementation

Two common methods exist for implementing radiant floor cooling (and heating). Most commonly, plastic tubing is laid out over the subfloor on 4 in. to 6 in. (102 mm to 152 mm) centers and cast into a 2 in. to 3 in. (51 mm to 76 mm) thick layer of concrete. At the low heat fluxes involved, the thermal conduction of the concrete is sufficient to spread the heat or cool over the floor surface.

An alternative with wooden floors in residential construction is to run a plastic tube below the subfloor, parallel to and centered between the floor joists with a sheet aluminum heat spreader. Since the wood subfloor and finished flooring are poor thermal conductors, the cooling performance in this case will be limited.

Energy Saving Potential

The annual primary electric energy consumption in the U.S. for space cooling of residential and commercial buildings is approximately 5 quadrillion Btus (quads).[6] Because of the issue of condensation in more humid climates, radiant floor cooling may be more applicable for drier climates, such as the Mountain Census Division* of the U. S. and parts of California. Approximately

10% of the U.S. space cooling energy, or about 0.5 quads, is consumed in these applicable regions.[7,8]

Research conducted by Oak Ridge National Laboratory (ORNL) on a home in California showed that a conventional forced-air cooling system coupled with radiant floor precooling consumed about half the energy of the forced-air system alone.[9] Another source suggests that homes in New Mexico with radiant floor cooling will conservatively save 15% to 20% compared with typical forced-air systems.[10]

However, about 25% of the space cooling energy in the Mountain Census Division is consumed by evaporative coolers, which are already significantly more efficient than conventional AC systems. Therefore, the overall energy savings potential of radiant floor cooling, assuming full replacement of existing space cooling equipment, is in the range of 0.05 to 0.2 quads.

However, the available market will be reduced by the previously mentioned floor design requirements necessary for radiant cooling to be a reasonable cooling strategy. Furthermore, radiant floor cooling is generally only considered in new construction, unless plumbing for radiant floor heating already exists in a building.

The energy savings of a radiant floor cooling system will depend heavily on what type of water chilling system is used, what additional cooling, dehumidification, and/or ventilation system is installed, and how the systems are operated.

One energy-efficient approach combines an indirect-direct evaporative cooler (already an energy-efficient cooling option in dryer climates) with a radiant cooling option.[10] Evaporatively cooled water, without any active refrigeration, is used directly to cool the floor. In this system, floor condensation is inherently avoided because the cooling capacity of the evaporative cooler declines as the outside relative humidity rises.

Market Factors

As noted previously, the opportunities to apply radiant floor cooling are somewhat limited to situations where radiant heating is the primary reason for installing in-floor water tubing and where no floor covering is used. In the Southwest, where residential homes are commonly styled after adobe dwellings, radiant heating is common, and the drier climate minimizes the potential condensation concerns of radiant floor cooling.

Another important consideration is the precooling capability (i.e., thermal capacity) of radiant floor systems. Air conditioning is the largest contributor to critical peak electric loads in the U.S. In the aforementioned ORNL study,[9] researchers were able to shift the energy demand profile from the afternoon to the night using radiant floor precooling and night ventilation precooling. This capability has value to utilities trying to keep up with peak electric capacity and to end users subject to peak demand electricity prices.

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* The Mountain Census Division includes Utah, Colorado, New Mexico, Arizona, Nevada, Wyoming, Idaho, and Montana.