BY KRISTOF IRWIN

Radiant Cooling in a Hot, Humid Climate

I'm founder and principal of Positive Energy (positiveenergy.pro), a building science consulting and engineering firm headquartered in Austin, Texas. Our company motto is "Design around people, a good building follows." One of our functions in the local and national market is mechanical system design, which we do partly because we recognize that this is an area where the industry and our society generally is due to evolve.

For these reasons, we've been taking a close look at radiant heating and cooling for the past few years; we have a working system in our office and several designs on the books.

Radiant cooling is a new idea for most people, but in principle, it's the same as radiant heating: It's an efficient way to deliver outstanding thermal comfort. But just as radiant heat is fundamentally different from forced-air heat, radiant cooling is a radically different concept from traditional air conditioning.

Air conditioning is aptly named. It's not the same as occupant conditioning. Air conditioning systems cool and dry your air, but they don't directly cool you. When you live or work in an air-conditioned space, you don't experience the air temperature directly. Your predominant thermal experience in any space is of the temperature of the surrounding surfaces in that space. In a room with radiant heat, your skin directly receives the warm infrared rays that radiate from the radiant floor, wall, or ceiling surfaces. In a space with radiant cooling, you have the same experience in reverse. Your body becomes the radiator, and cooler surrounding surfaces absorb your heat.

This works because the main way that human bodies shed and absorb heat is through radiation: Long-wave infrared radiation goes in a straight line at the speed of light from the radiator (your skin) to the absorber (the cooler surfaces that surround you). Your skin, at about 90°F, is like a radiator that radiates heat to those floor, wall, and ceiling surfaces, and that's what cools you off. When we operate an air conditioning system to cool the people who live or work in a space, we're accomplishing the same thing, but indirectly: We're cooling large volumes of air and moving them through the space in order to absorb heat from the interior surfaces in that space, which in turn cool off the building occupants by absorbing the radiant heat that those occupants emit plus the heat that leaks in from the outdoors.

So why not cool the surfaces directly? That's the idea behind radiant cooling, one that imbues the enclosure with more of an active, engaged role with those inside. Instead of moving high volumes of air through the living space to cool the interior surfaces of a structure, we move low volumes of glycol and water coolant through the surfaces themselves to do the same thing, more efficiently. Exposed to those cool surfaces, people's bodies cool themselves by radiating heat. If you've ever experienced the coolness inside an old stone building, or even a new parking garage, you have experienced radiant exchange

Photos by Ted Cushman

The radiant-panel ceiling, left exposed in the author's offices for educational purposes, consists of a gypsum board layer over aluminum heat-transfer fins, backed by a $1\frac{1}{2}$-inch layer of EPS insulation. Ink patterns on the surface of the drywall help installers avoid screwing into and puncturing coolant-circulating tubing within the panels.

A manifold (above, left) allows the system to be zoned room by room. In a lower-floor mechanical room (above, right), a buffer tank isolates the indoor side of the system from the outdoor side, allowing the heat pump that powers the system to run efficiently without having to directly answer calls for cooling from the occupied space.

with cooler surrounding surfaces. In our offices in Austin, we have installed what we believe is the first radiant cooling system in the state of Texas. We built the system using components generously supplied by Messana Radiant Cooling (radiantcooling.com). Let's take a walk through the system.

OVERVIEW

The radiant system uses cool ceiling panels as the heat-absorbing surface. These are premanufactured panels that consist of aluminum heat conductors sandwiched between a layer of gypsum board and a 1½-inch layer of EPS insulation that isolates the cool fins and gypsum board from the framing of the building. Polyethylene tubing filled with glycol and water fluid runs through the aluminum fins in a serpentine pattern to transport heat into or out of the panels. Because of the EPS insulation, the radiant exchange from the hydronic tubing occurs more strongly with the room-facing panels than the framing-facing structural members. This allows for a rapidly variable panel surface temperature—important in a humid, cooling-dominated area like central Texas.

In operation, the gypsum-board ceiling is maintained at about 68°F. Humans (and their dogs) in the space radiate heat to the gypsum board, which absorbs the heat and conducts it into the aluminum fins, which conduct it to the tubing. The fluid circulating through the serpentine tubing at about 60°F absorbs the heat and transports it to a manifold, which directs the warmed fluid into the return line leading to a buffer tank in the mechanical room. We have four rooms in our office, so our manifold has four loops. But you could manage as many zones as you wish by extending the manifold.

The buffer tank in the basement separates the source side from the system side. The buffer tank plays an important role in maintaining equilibrium for the system, because the fluid in the system maintains a reserve of heat and cooling that is always available to answer short-term demands. Our system has a 30-gallon buffer tank, maintained at about 60°F during the summer cooling months. If there were to be a massive call for cooling upstairs, and we needed to send an increased volume of thermally absorptive fluid up there, the reserve in the tank would be available to answer that call and our cooling source (an air-to-water heat pump located outside) would be able to carry on at its usual measured, consistent pace.

So we separate the source from the system using the buffer tank. The buffer tank can be considered a thermal battery, and could be larger than 30 gallons if needed for the application. For example, we could design an off-grid system with sufficient thermal storage that the high-COP (coefficient of performance) heat pumps run only when solar photovoltaic power is available during the day. In that case, we could use an array of 80-gallon or 100-gallon buffer tanks to store cool water that could answer the demand for cooling without the need for an energy-hungry compressor to operate. For larger

Outside the building, a 3-ton SpacePak Solstice air-to-water heat pump dumps excess heat from the building to the outdoor air—just one of many possible solutions that are possible with radiant cooling.

projects or projects with critical loads, these thermal storage reservoirs can be extremely well insulated and hold thousands of gallons of thermal fluid, or even a combination of thermal fluid and phase change materials (PCM), capable of absorbing or delivering tens of thousands of Btu of energy.

The buffer tank provides a thermal mass that lets the system smoothly ride out fluctuations in the demand for cooling or heating. Outside the building is our heat source and sink: a 3-ton SpacePak Solstice air-to-water heat pump. Here, the heat that was originally absorbed as direct radiation from the bodies of people in the space into the ceiling panels is finally shed from the system out into the outdoor air. This same energy could have been shed directly into the ground around our building using a ground-coupled heat exchanger and a pump to circulate the hydronic fluid. In our climate, we can avoid the installation cost, soil ecosystem disruption, and embodied resource use with ground loops by rejecting the waste heat into the air. We can even first shed waste heat into a domestic hot-water storage tank, while maintaining high coefficients of performance.

Of course, radiation between people and their surroundings is not the only way that people get warm or cool. You're also affected by direct contact with the air in a space. In a room with radiant cooling, such as our offices, this process also takes place. Warm air in the rooms expands, becomes buoyant, and rises to the ceiling; when it contacts the ceiling, it cools off and falls toward the floor. So people in the space are continually bathed in a gentle cascade of cooled air falling from the ceiling and trickling over us. But there's no need for fans or ductwork to move that cool air around.

It is important to bear in mind that a radiant cooling or heating system is focused on occupant thermal comfort. The fact that we also live our indoor lives immersed in an indoor pool of air means that reliable supplemental systems for ventilation, filtration, and dehumidification for healthy indoor air quality (IAQ) are a must.

WHAT ABOUT CONDENSATION?

Outdoor air here in Austin, Texas, can be very humid in the summer (we regularly hit 78°F dew point and even into the low 80s). Thus, cool radiant surfaces are well below outdoor dew points and run the risk of significant condensation and sorption into materials. The last thing we want is for moisture in our building to condense on our ceiling drywall and support mold, mildew, bacteria, and other indoor microbiomes associated with damp buildings and poor occupant health. Fortunately, the system is designed to prevent that.

In the first place, we control humidity in the space using a dedicated, ducted dehumidifier (an Ultra Aire 98H). That unit is continually paying attention to humidity and removing any excess moisture. We have a MERV-13 filter on our 98H and benefit from full-time particulate capture because it's always circulating and filtering air in order to measure humidity. The indoor dew point is held at or below 56°F, so the 68°F temperature of our ceiling radiant absorbers is well above the dew point. Of course, dedicated dehumidification is important in humid climates generally, and not just when radiant cooling systems are used.

Even with the dedicated dehumidifier, if someone were to open up the doors and windows and let a blast of humidity into the building, there could be a risk of condensation on the ceiling drywall. However, this is a low-mass system that can be controlled very rapidly to maintain the surface temperatures above dew point. The controls for the radiant system include humidity sensors that know if there's a sudden spike in the indoor relative humidity. If so, the flow of cooling water is instantly halted and the cool drywall surface is allowed to equilibrate with the space conditions so that it remains above the dew point in the space. At that point, it's time for the occupants to close the doors or windows so that the dedicated dehumidifier can remove the excess humidity until the cooling system can start up again.

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