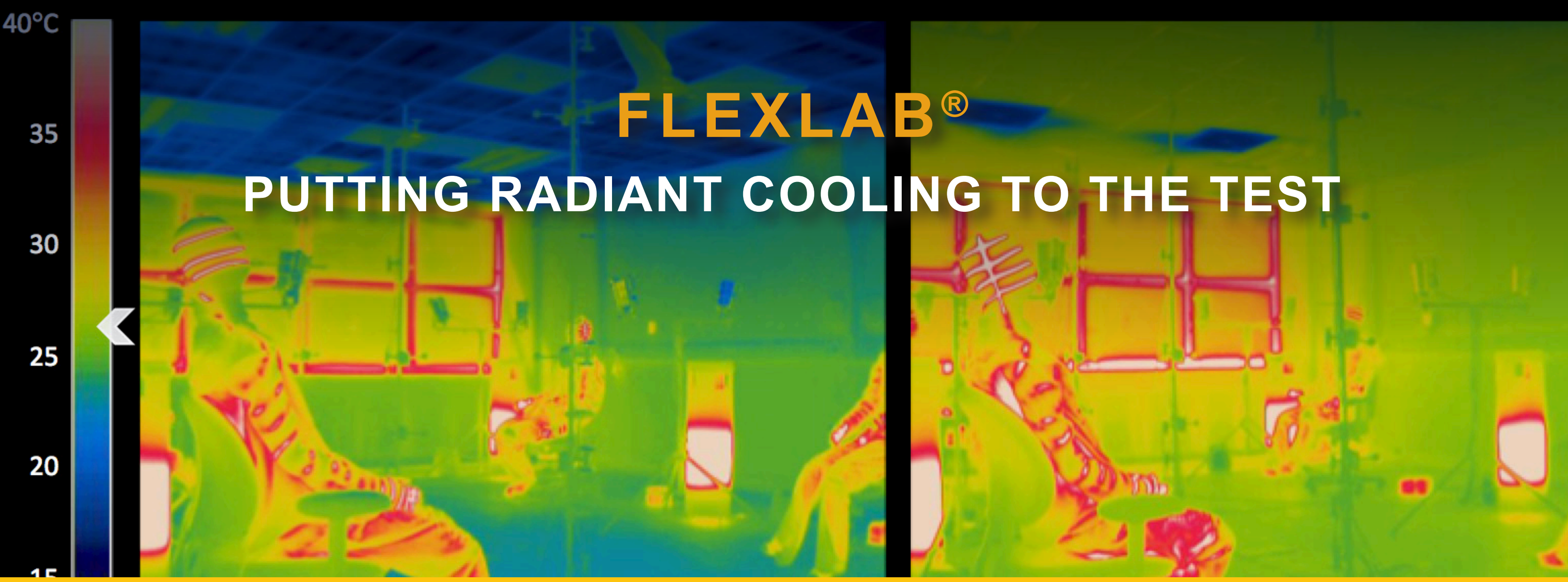

FLEXLAB®

PUTTING RADIANT COOLING TO THE TEST

Researchers derive a wealth of data from a set of experiments in FLEXLAB's® test chambers

THE CHALLENGE

Unknowns in radiant cooling performance

Radiant cooling systems, which use cooled surfaces such as floors or ceilings to absorb heat from a room, can help cut energy use and lower and shift peak electricity demand in buildings compared to conventional all-air systems. But radiant cooling systems aren't yet widely deployed, which means data about how realistic and practical on-site factors such as carpeting, ceiling fans, direct sunlight, ventilation, and control strategies affect their performance are incomplete.

The energy savings from radiant cooling systems depend largely on whether or not the building's cooling plant, hydronic and ventilation systems, and control strategies are optimized to operate with a system that uses radiant heat exchange with high thermal mass, such as the structural or topping concrete slabs of a building. And while previous research has compared radiant and all-air cooling systems in simulation and idealized laboratory settings, there hasn't been a scientific look at how radiant cooling systems perform under more realistic operating conditions.

THE SOLUTION

Researchers at the Center for the Built Environment at the University of California, Berkeley, conducted in-depth and extensive studies of radiant cooling systems at the U.S. Department of Energy's FLEXLAB® facility at Lawrence Berkeley National Laboratory. Using FLEXLAB's test chambers, they assessed the effect of solar radiation, increased air movement, carpeting, control strategies, and other factors on cooling capacity for radiant systems. They also compared radiant and conventional systems side by side to assess heat extraction rates in different scenarios. The experiments yielded three research papers, two of which have been published in the journal *Energy & Buildings*.

> **The benefit of using FLEXLAB® is that it provided our research team an opportunity to test radiant cooling performance in a unique world-class test facility that simulates realistic test conditions. The large, full-scale rooms enabled us to expose the system to direct solar radiation (through windows) over several consecutive days to investigate the transient impacts of thermal mass. It was great to be able to compare two conditions simultaneously.**

Fred Bauman, , P.E., FASHRAE
University of California, Berkeley
Center for the Built Environment
Project Scientist

THE BOTTOM LINE

Experiments enable new insights into the factors that influence radiant cooling system performance

FLEXLAB's® unique facilities made it possible for researchers to evaluate the real-world factors that can affect cooling performance for radiant systems, helping to inform strategies that will maximize energy savings while reducing operational costs and greenhouse gas emissions. The experiments confirmed that cooling load estimates for all-air systems cannot be extrapolated to represent the space heat extraction rates required for radiant systems. And the wide range of impacts observed in different building scenarios have consequences for the choice, design, and control of mechanical cooling systems, especially in buildings that also use passive cooling strategies such as natural ventilation.

THE EXPERIMENT

- Radiant and all-air cooling systems were installed in two side-by-side testbed buildings in FLEXLAB, each with a 620 square foot floor area. Both testbeds were controlled to maintain equal operative temperature setpoints of 26°C.
- The radiant testbed was cooled by a low thermal mass metal ceiling panel system (Twa model MOD-RP1) in the drop ceiling. The panels covered 73% of the ceiling area, with panels arranged in six parallel loops with 19–20 panels in each.
- More than 250 points in each testbed were continuously monitored over a five-day period to assess thermodynamic states and heat transfer rates, with one-minute-average values on one-minute intervals.
- In one set of experiments, the testbeds had equal constant internal heat gains, while another set monitored periodic internal heat gains. Different types of heat gains (convective, mixed, highly radiant) were combined with scenarios that included solar gains and night ventilation precooling, to determine the effect of different conditions.
- A separate experiment monitored a test chamber with an embedded PEX tubing floor cooling system consisting of seven water loops. Researchers assessed the effect of solar radiation, increased air movement, and carpet on the cooling capacity of the radiant floor.

THE RESULTS

- The FLEXLAB experiments quantified the radiant floor system's performance under a variety of circumstances. For example, in an experiment with mixed internal heat gains, solar gains, and night ventilation precooling, the radiant cooling system had to remove 35% more heat than the all-air system in equivalent circumstances to provide a comfortable space; and the peak heat extraction rate was 22% larger.
- In a similar experiment with highly convective internal gains, the differences were smaller: the radiant cooling system had to remove 26% more thermal energy and had a 13% larger peak extraction rate than the all-air system, while in an experiment with highly radiant gains the differences were larger (40% more thermal energy, and a 22% larger peak).
- Comparing periodic heat gains with constant internal heat gains, results showed radiant cooling must remove more heat than all-air cooling: 2% more in an experiment with constant internal heat gains, and 7% more with periodic scheduled internal heat gains.
- Because radiant floors absorb heat without releasing it back into the space, they are ideal in atria, lobbies, and airports; spaces that need to directly capture solar radiation before it creates occupant discomfort. Previously, there was little information on how much the cooling capacity of these systems may increase. However, a FLEXLAB experiment with the chilled radiant floor slab showed that the cooling capacity more than tripled, from 32 watts per square meter (W/m2) up to 110 W/m2 under direct solar radiation. These measurements can greatly increase designer confidence that radiant systems can solve this problem effectively.
- Increasing supply water temperature can increase a cooling plant's energy performance but simultaneously reduce its cooling capacity. This experiment estimated that increasing the slab's chilled water supply temperature from 12°C to 18°C (54°F to 64°F) decreased cooling capacity from ~110 W/m2 to ~95 W/m2. This information may lead to significant efficiency improvements (increased coefficient of performance) without a large cooling capacity reduction.
- Ceiling fans, already known as a cost-effective, energy efficient cooling solution, may also work well with radiant systems because they can increase the system's response time and increase its cooling capacity. These experiments proved that the higher air speeds along the floor created by ceiling fans increased the radiant slab cooling capacity by up to ~19% (40 W/m2) when the operating temperature was 26°C (80°F).