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RADIANT HEATING AND COOLING

A Holistic Approach to Energy Efficiency

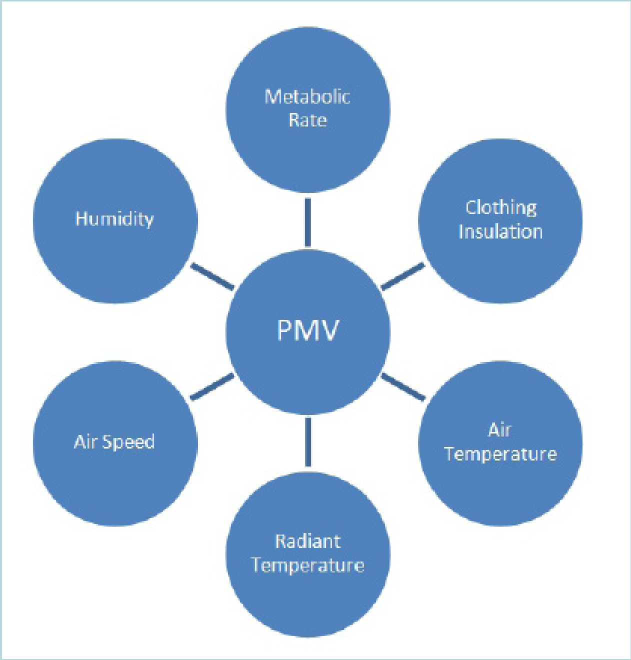
Introduction

Radiant heating and cooling systems are more energy efficient compared to traditional forced air systems for several reasons. But let's start at the building occupant since their comfort is one of the main reasons we have the built environment.

Thermal Comfort Benefit

There are six primary factors that affect thermal comfort (see Figure 1). The use of a radiant heating and cooling system has an effect on the radiant temperature, and air speed which can allow for a wider range for the temperature set point of the space. Instead of a seasonal temperature range of 72°F to 76°F with traditional forced air systems a radiant system could provide thermal comfort with a seasonal temperature range of 68°F to 80°F. This wider temperature range reduces the associated heating and cooling energy needed which equates to annual energy savings.

Figure 1: Thermal Comfort Factors



Heat transfer in a space occurs in three primary ways: Conduction, Convection, and Radiation. With respect to subjective human comfort the optimal split is about 60% by thermal radiation and 40% by thermal convection. Since the

Definitions

- Radiation: the cooling/heating as a result of infrared waves absorbed and emitted from surfaces.
- Predicted Mean Vote (PMV): an index that predicts the mean value of the votes of a large group of persons on the seven-point thermal sensation scale.
- Holistic: relating to or concerned with wholes or with complete systems rather than with the analysis of, treatment of, or dissection into parts.

the body wants to lose most of its heat through radiation a radiant heating and cooling system can provide a higher perception of thermal comfort.

Low-Temperature Heating and High Temperature Cooling

Additional energy efficiency is gained due to the use of low-temperature heating and high-temperature cooling. Since the radiant floor does not want to be too hot or too cold for comfort reasons, the heating and cooling supply water temperatures operate at different set points compared to traditional systems. The radiant heating and cooling system supply water temperature would typically operate at a temperature less than 180°F for heating and greater than 45°F for cooling, which are typical supply water temperatures for a traditional forced air system. The central plant heating and cooling equipment can operate more efficiently at these temperature set points. For the radiant cooling system there is the added benefit of extending the operating range of the water-side economizer.

Also, studies have shown that the use of indirect evaporative cooling coupled with radiant cooling and a DOAS can have significant reductions in cooling season energy costs when compared to traditional forced air variable air volume (VAV) systems. This savings is estimated to be as high as 67% when applied in the San Francisco, California area.

Figure 2 : Heating and Cooling Tubing in NREL-RSF

Photo: NREL

Ventilation Reductions

Since the radiant heating and cooling system serves the zone level sensible heating and cooling loads the air side system is only needed to provide for the ventilation requirements of the space. In a typical office space the airflow required to cool and ventilate the space can be 3 to 4 times greater than that required to just ventilate the space. This allows the central air handling system and associated distribution system to be down-sized accordingly. A system called a Dedicated Outdoor Air System (DOAS) is typically used to serve the ventilation needs (see below for details on DOAS).

DOAS:

Dedicated Outdoor Air System the ventilation loads are separated from the heating and cooling loads for the space. Typically a central air handling unit supplies 100% outdoor ventilation air to meet the occupant ventilation needs for the space. This allows for reductions in the ventilation air required by the ASHRAE 62.1 Standard – Ventilation for Acceptable Indoor Air Quality due to the use of 100% outside air with no mixing of return air.

The use of a DOAS also allows for the effective use of energy recovery on the incoming outside air to further reduce the associated heating and cooling ventilation loads. Localized demand control ventilation can also be implemented to turn off the ventilation air when the space is not occupied which further reduces the total energy of the system. The efficiency gain of this demand control ventilation strategy needs to be weighed against the additional system complication and cost as well as the additional fan energy related to the required air terminals. This brings us to the distribution systems.

Distribution Energy

In traditional forced air systems the heating, cooling and ventilation is provided by a central air handling unit and then distributed to the required space by an air distribution system. The volume of air required to heat and cool the space is then a function of the energy carrying capacity of the fluid, in this case air. With a radiant heating system the heating and cooling energy is carried in water which has much more energy capacity per volume than air. This reduces the distribution energy needed to

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move the heating and cooling energy to the occupied zones. Because there is more energy per volume, the hydronic distribution system also requires less space than an air distribution system. A typical hydronic zone distribution header can be seen in Figure 2.

Also, the traditional air distribution system has air terminal devices to modulate the heating and cooling capacity to each individual space. These air terminals add additional pressure drop and increase the associated fan energy. With a DOAS the air terminals are not required for proper operation of the system. The space saved by using a DOAS can be used to install a low-static air-side distribution system to further reduce the associated fan energy.

Related Resources

- Price Radiant Heating and Cooling Systems Design Guide

  http://www.price-hvac.com/Catalog/Section_H/Design_Guide/Introduction.aspx

- NREL Research Support Facility – A Model of Super Efficiency (August 2010)

  http://www.nrel.gov/sustainable_nrel/pdfs/48943.pdf

- Center for the Built Environment (CBE) – Radiant Cooling Research (ongoing)

  http://www.cbe.berkeley.edu/research/radiant_cooling.htm

Additional Benefits

Not all of the benefits are associated with energy savings. Some additional benefits beyond what were discussed above are as follows:

- Reduced mechanical space requirements
- Lower maintenance costs
- Reduced commissioning cost
- Reduced system noise to occupied space

Summary

There are many ways a radiant heating and cooling system can make a building more energy efficient compared to a traditional forced air system. But alone the use of radiant heating and cooling systems only achieve a small percentage of the potential energy and cost savings. It takes a holistic approach to optimize all of the different heating, ventilation and air conditioning systems to fully realize all of the energy savings.

Training Highlights

California utilities offer outstanding educational opportunities that focus on the design, construction and operation of energy-efficient buildings. Listed here are a few of the many upcoming classes and events; for complete schedules, visit each utility's website.

HVAC System Airflow and Static Pressure Diagnostics

Participants in this hands-on class will use a full-size horizontal HVAC system to measure system variables will include different filters, coils, variable size return ducts, duct testing, and different leakage amounts.

March 29 (Thursday, 9:00 am to 5:00 pm)

Fresno--EOC

http://www.pge.com/mybusiness/edusafety/training/pec/classes/

The Passive House Approach to Zero Net Energy Homes

This class will introduce the Passive House standard and demonstrate its applicability to zero net energy homes, drawing on experience with actual projects.

April 3 (Tuesday, 9:00 am to 4:30 pm)
San Francisco--PEC

http://www.pge.com/mybusiness/edusafety/training/pec/classes/

Implementing Energy Efficiency Projects

Attendees will learn how to do a basic audit and determine if new equipment is worth the investment.

April 17 (Tuesday, 8:30 am to 3:30 pm)
Irvine City Hall

http://www.sce.com/b-sb/energy-centers/workshops-classes.htm