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Safety and Comfort Using DOAS

Radiant Cooling Panel Systems

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Recent cases of workers exposed to anthrax have caused the building industry to reevaluate the way building HVAC systems are designed. First, let us explore the issue of indoor environmental safety in buildings served by the Dedicated Outdoor Air System (DOAS)/radiant approach compared to all-air systems.

Naturally occurring microbes grow within building materials and the mechanical system due to moisture. The microbes contribute to sick building problems and reduced worker productivity. Generally, moisture is the result of either water leaks or condensation in high humidity spaces. The DOAS decouples the space-sensible and latent loads, which eliminates damp spots such as ceiling tiles, insulation, carpets and behind vapor barriers where biocontaminants can breed.

The DOAS/radiant approach does not use recirculated air. Consequently, any biological or chemical agents released inside the building are not transported to other parts of the building by the mechanical system. They are diluted and exhausted from each space.

The enthalpy wheel in the DOAS has the potential for a slight carryover, but this is infinitesimal compared to the nearly 80% carryover by recirculated air in conventional all-air systems.

Consider biological agents released in the vicinity of the fresh air intakes. Commercial filters, with dust spot efficiencies greater than 40% will remove more than 90% of 1 – 5 μm spore-sized particles (such as anthrax).¹ In new designs, better filters could be used (with a first and operating cost penalty) capable of par-

ticle filtration efficiencies up to or greater than 99.999%. A percentage of the biological agents not removed by the filters could be killed with ultraviolet lamps. The quantity of air that must be treated with the DOAS/radiant approach is generally less than 20% of conventional all-air systems.

Ventilation is required to dilute indoor-generated contaminants. Owners and operators must not close the OA openings, which could lead to sick building problems.

Thermal Comfort

Thermal comfort is governed by variables that influence the energy balance on human occupants. The primary variables include clothing, activity level, mixed air temperature, mean radiant temperature, vertical air temperature gradients, radiant asymmetry, air motion and air moisture content.



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With ceiling radiant cooling panels (radiant panels), the heat rejection, from the human body by radiation is increased from about 35% without radiant panels to 50% with radiant panels.² Likewise, the heat loss due to convection decreases from about 40% without the radiant panels to about 30% with. The net effect is that less heat is rejected by perspiration in the presence of the radiant cooling field.

The human head, which emits much of the body's heat, can more effectively emit that energy with the cool ceiling above.³ The result of the cooled ceiling is a radiatively cool face and temperate feet for increased comfort.

As a result of these two impacts, it is possible to maintain the space dry-bulb temperature higher with radiant panels and achieve the desired thermal comfort.

A space at 78°F (25.6°C) with radiant cooling gives the perception of a space at about 75°F (23.9°C) without radiant panels.⁴ This results in a reduction in the building skin and ventilation air-cooling loads. It also means that the conditioned ventilation supply air can remove more sensible cooling load since there is about a 3°F (1.7°C) larger temperature rise as the air passes through the space.

Another issue is the radiant asymmetry experienced by the occupant with radiant panels. With most of the enclosure at 78°F (25.6°C) or below and the radiant panels at approximately 60°F (15.6°C), up to 18°F (10°C) radiant asymmetry temperature differential exists. The archival literature^{5,6} indicates that the predicted percent of dissatisfied occupancy is less than 6% as a result of a 14°F (8°C) or less radiant asymmetry, well below the percent dissatisfied level accepted by ASHRAE standards. Further, for most cases, only about 50% of the ceiling is chilled, so the effective mean radiant ceiling temperature of the two nearly equal areas is close to 69°F (20.6°C), resulting in a radiant asymmetry of only about 9°F (5°C)—much too small for radiant asymmetry discomfort.

The remaining three major variables influencing thermal comfort, air motion, vertical air temperature gradients, and air moisture content, are influenced by the design of the DOAS. Air is introduced at constant volume (no possibility of cold air dumping out of the diffusers as may occur in VAV systems under turn down conditions) into the space at about 45°F (7°C) via high aspiration ceiling diffusers capable of creating a secondary flow to primary airflow ratio of approximately 20:1. This high mixing ratio causes the cold primary air to be warmed to room temperature in about 12 to 15 in. (305 to 380 mm), eliminating the possibility of cold drafts. It also creates sufficient

air motion in the space to achieve satisfactory air diffuser performance index (ADPI) values, effectively eliminating vertical air temperature gradients.

Displacement ventilation and underfloor air-distribution systems (referred to as floor delivery systems) have received attention from engineers in Europe for some time, and there is growing interest in them in the United States. Consequently, it is logical to consider how floor delivery systems might impact the environmental performance of a DOAS/radiant system.

Keep in mind that with the DOAS/radiant system, the only air introduced into the space is ventilation air. The low DOAS supply air temperature means that floor level air delivery systems cannot even be considered with radiant cooling for comfort reasons. If the supply air temperature were increased to accommodate floor delivery, the added sensible load that the radiant system must bear would increase the required panel area and first cost by about 50%. Published European literature⁷ makes a case for using displacement ventilation, introduced at floor level at about 65°F to 70°F (18.3°C to 21°C) with radiant panels. Supplying the ventilation air 20°F to 25°F (11°C to 14°C) warmer than available with the DOAS requires the radiant panels to absorb more sensible load than necessary, introducing a first-cost penalty as noted earlier.

Another reason for not using floor delivery systems is that they do little to enhance the convective heat transfer to the radiant panels. However, by supplying the DOAS air to the space via high aspiration ceiling diffusers, the convective heat transfer to the radiant panels can be increased. The overall increase in heat transfer is about 15% greater than when the panels are operating in still air, and 10% greater than when the panels are operating with displacement ventilation. The enhanced convective heat transfer performance further reduces the ceiling area devoted to radiant panels, and hence first cost. Therefore, floor delivery systems should not be used with radiant panels. Rather, the 45°F (7°C) air should be supplied to the space via high aspiration diffusers located in the ceiling. The diffuser throw needs to parallel the longitudinal pattern of the radiant panels.

Floor delivery systems are a poor choice for all-air systems (consisting of ventilation air and return air) because of the following reasons:

- The elevated supply air temperatures require high flow rates. As a result a great quantity of air must be recirculated, eliminating the advertised IAQ benefits, which suggests that there is minimal mixing of the air with room contaminants. The high flow rates also increase the fan energy use and demand. Finally, the high flow rates stir up the irritants tracked into the space on the shoes of the occupants and place them in the occupant's zone.
- The OA is mixed with recirculated room air. Hence, verifiable fresh air distribution is difficult, which is similar to other all-air systems.
- The high supply air temperatures mean that the potential for serious high humidity problems exists.
- Vertical air temperature concerns.

Acoustical Comfort

The DOAS is quieter because of the lower airflow and the

ability to select high aspiration diffusers with less than a NC 20 rating. Since the air is constant volume, there is no variation in the acoustical quality of the space as the loads change. The radiant panel cooling is mechanically silent. Drop-in radiant panels are available with excellent acoustical qualities, comparable to traditional dropped ceiling panels.

Conclusions

The author considers the DOAS/radiant approach to be superior to all-air systems in the area of environmental safety for three reasons. First, no air is recirculated, so building-wide contamination from localized release will not occur. Second, since such a small quantity of air is delivered, the first and operating cost of using superior filters and other air treatment equipment would be less than that of all-air systems. Third, since the sensible and latent loads are decoupled, biological contaminant generation in the building elements is minimized or eliminated.

It is the author's opinion that the DOAS/radiant approach provides a superior thermal environment to conventional all-air systems by removing more heat from the occupant's head and less at the feet. Drafts are minimized, and dumping from diffusers in minimum airflow never occurs. The space-relative humidity is controlled independently of the space sensible load, thus avoiding the discomfort, associated with most all-air systems, of high humidity at low space sensible loads. The DOAS/radiant approach is quieter compared to conventional all-air systems.

Editor's Note: An overview of the DOAS system and the associated thermodynamics were presented in the first three issues of 2001 IAQ Applications. Panel cooling and condensation concerns were presented in the Fall 2001 issue.

References

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