# Chilled Ceiling Condensation Control

*In a historic building with a large area of movable sash, condensation control was achieved easily, even when the inside dew-point temperature was suddenly elevated by opening all of the doors and windows.*

**By Stanley A. Mumma, Ph.D., P.E.,**
Fellow ASHRAE

IAQ professionals are concerned about indoor condensation for good reasons. Condensation forming on a continual basis leads to mold growth and potential IAQ problems.

University personnel voiced their concerns about condensation when a dedicated outdoor air system (DOAS) with a parallel sensible cooling chilled ceiling, or ceiling radiant cooling panel (CRCP) system[1] was installed on campus.

***Mumma***

The design intent was to use the DOAS to meet the ventilation requirements, remove the entire space latent load,[2] and meet the space sensible loads with the CRCP without condensation concerns.[3]

The skepticism appeared to be based on the CRCP's location, an old building with a large area of movable sash that is occupied by undergraduate students around-the-clock. Personnel worried that condensation would form and drop onto valuable objects below.

Data presented here shows that condensation control is easily achievable in a historic building with a large area of movable sash.

## Capacity and Condensation Control

Capacity control can be achieved in two ways, much as capacity control can be achieved in an all-air system. Using either a constant temperature variable flow,[4] or a constant flow variable temperature inlet water conditions[5] the CRCP capacity can be modulated. In either case, the CRCP inlet water temperature must not drop below the space dew-point temperature (DPT) — typically 55°F to 60°F (13°C to 15.5°C) when the sash and doors are closed.

For small- or single-zone applications where a constant flow and variable temperature control is used to avoid condensation, the zone DPT is monitored and the CRCP water inlet temperature is controlled by mixing CRCP return water with low temperature chilled water. As a backup, a passive fail-safe condensation sensor is used. If a window or door is opened during muggy summer conditions, the space DPT rises and the CRCP inlet water temperature is controlled at or above the space DPT. CRCP cooling capacity may decrease below that required, but condensation will be avoided. In the worst-case limit, all of the windows and exterior doors are opened. This column will present data for such an occurrence with this control approach.

For large multizone applications, a variable flow and constant temperature control would result in the lowest first-cost installation. In this case, the controls would attempt to maintain the desired space DPT with the DOAS, and modulate the CRCP water flow to meet the required sensible load with closed windows. In the event that a window or exterior door is opened longer than momentarily as detected by proximity switches (rather than individual space DPT to limit the project first cost), the CRCP flow control valve may need to close to prevent condensation. A decision on closure would be based upon a comparison of the design space DPT and the current outside DPT. If the outside DPT exceeds the design space DPT (a worst-case scenario), the CRCP control valve serving the zone (e.g., a row of perimeter offices or a single space) must close to avoid condensation. Should all of the doors and windows return to closed positions, the CRCP control valve may be permitted to modulate again following a suitable time delay, thus allowing the DOAS system to restore the space DPT to design.

## Field Experience

The students in the DOAS-CRCP space were informed about the system operation and invited to open the windows. However, they were told that space temperature and comfort would be compromised. No student chose to open a window, probably because the DOAS provided 100% fresh OA, maintained the space RH at around 50%, and the CRCP maintained the space dry-bulb temperature at setpoint. The controlled indoor environment always was favored over outdoor conditions, so there was no incentive to open windows.

Since the students did not create a situation to test the facilities personnel's open-window concerns, such a test was

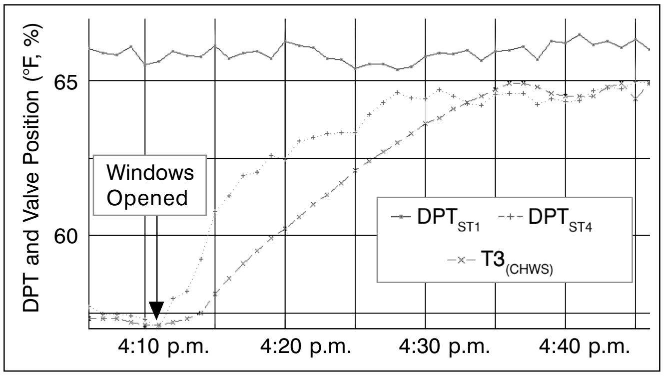


**Figure 1: Trend plot of important temperatures.**

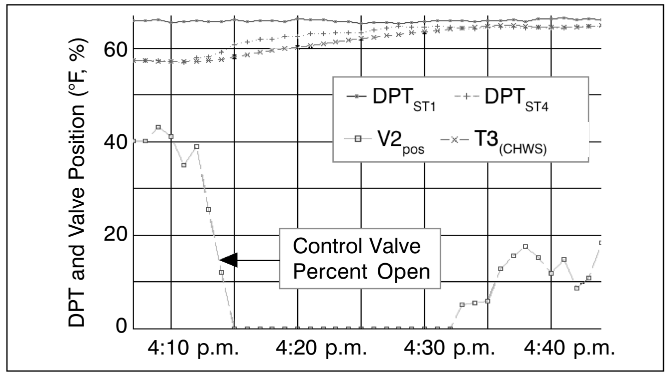


**Figure 2: Trend plot with control valve position.**

conducted by the author. All of the windows and two exterior doors were opened when the space DPT was 57.5°F (14.2°C) and the outside air DPT was 66°F (19°C).

A trend plot of the data is presented in *Figure 1*. The space DPT ($DPT_{ST4}$ on *Figure 1*) rose exponentially and approached a quasi-steady value of 65°F (18°C), just 1°F (0.6°C) below the outdoor air DPT. It rose rapidly, exhibiting a time constant of five minutes. The rapidly rising space DPT caused the control to close the CRCP control valve, denoted $V2_{pos}$ in *Figure 2,* since the CRCP inlet fluid temperature was well below that of the space DPT. The valve response was delayed no more than one minute, and was completely closed within four minutes of the window and door opening. The delayed valve response caused a delay in the response of the CRCP inlet water temperature, denoted $T3_{(CHWS)}$ in *Figure 1*. The closed CRCP control valve caused the inlet water temperature to rise quickly, a time constant of 12 minutes following a three-minute delay, as heat from the space was added to the CRCP while the CRCP pump continued to run.

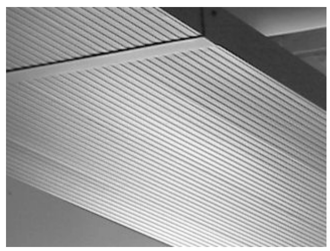

**Figure 3: No condensation is seen on the CRCP after opening windows.**

**Figure 4: Chilled water pipe with slight condensation visible after opening windows.**

Twenty-two minutes after the windows and doors were opened, the CRCP inlet water temperature and the space DPT curves crossed again, and the danger of condensation no longer existed. During the 22 minutes, the difference between the space DPT and the CRCP inlet water temperature was 5°F (3°C) or less.

In prior research,[6] it was shown that the visible condensation is minimal when a surface is held 5°F (3°C) below the space DPT for 8.5 hours.

No condensation was visible on the CRCP surface (*Figure 3*) and essentially none on the uninsulated chilled water supply piping (*Figure 4*). Any condensation on the supply pipe quickly dissipated after the CRCP inlet fluid temperature reached the space DPT.

As expected, 23 minutes after the CRCP fluid temperature reached the space DPT, the control valve began to modulate. Sensible cooling was not lost completely, even with the doors and windows fully open to the outside. However, both sensible and latent comfort control was not adequately maintained with the doors and windows open.

## Conclusion

In a historic building with a large area of movable sash, condensation control was achieved easily, even when the space DPT was suddenly elevated by opening all of the doors and windows. The test was repeated many times, with similar results and without a condensation problem.

## References

1. Jeong, J., S. A. Mumma and W. P. Bahnfleth. 2003. "Energy conservation benefits of a dedicated outdoor air system with parallel sensible cooling by ceiling radiant panels." *ASHRAE Transactions* 109(2).

2. Shank, K. and S.A. Mumma. 2001. "Selecting the supply air conditions for a dedicated outdoor air system working in parallel with distributed sensible cooling terminal equipment." *ASHRAE Transactions* 107(1):562–570.

3. Mumma, S.A. 2001. "Ceiling panel cooling systems." *ASHRAE Journal* 43(11):28–32.

4. Mumma, S.A. 2001. "Dedicated outdoor air in parallel with chilled ceiling systems." *Engineered Systems* 18(11):56–66.

5. Conroy, C. and S.A. Mumma. 2001. "Ceiling radiant cooling panels as a viable distributed parallel sensible cooling technology integrated with dedicated outdoor-air systems." *ASHRAE Transactions* 107(1):571–579.

6. Mumma, S.A. 2002. "Chilled ceilings in parallel with dedicated outdoor air systems: Addressing the concerns of condensation, capacity, and cost." *ASHRAE Transactions* 108(2):220–231.

*S.A. Mumma, Ph.D., P.E., is a professor of architectural engineering at Penn State University, University Park, Pa. He is an ASHRAE Learning Institute Trustee, ASHRAE Distinguished Lecturer, and serves on Technical Activities Committees, Integrated Building Design and Solar Energy Utilization. He can be reached at sam11@psu.edu.*