Chilled Ceiling Condensation Control Experience
In A Movable Sash Building

Introduction:

A dedicated outdoor air system (DOAS) with a parallel sensible cooling chilled ceiling, or ceiling radiant cooling panel (CRCP) system (Jong, Mumma, Bahnfleth) has been in operation on campus for over a year. The design intent was to use the DOAS to meet the ventilation requirements and remove the entire space latent load (Shank, Mumma) and meet the space sensible loads with the CRCP without condensation concerns (Mumma, 2001a). In spite of the design intent, and subsequent condensation free operation to date, the university physical facilities personnel have remained skeptical of the systems ability to avoid condensation problems, a common concern expressed almost universally. Their primary skepticism seems to be based upon the fact that the CRCP is in an old building with a large area of movable sash, and is occupied by undergraduate students on an around the clock basis. Their concern is that condensation will form and drop onto valuable objects below. In addition, while not an explicit concern expressed by the personnel, condensation on a continual basis would lead to mold growth and potential IAQ problems. The intent of this column is to help alleviate the concerns and skepticism on the part of engineers, contractors, operational personnel (including the university facility personnel), investors/owners, and building occupants.

Controls For CRCP 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 (Mumma 2001b), or a constant flow variable temperature inlet water conditions (Conroy, Mumma) the CRCP capacity can be modulated. In either case, the CRCP inlet water temperature must not drop below the space DPT—typically 55 to 60F 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 dew point temperature (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 employed. Under muggy summer conditions, if a window or door is opened, the space DPT
will rise and the CRCP inlet water temperature will be 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 multi-zone 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 under a closed windows condition. 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 (may be a row of perimeter offices for example or a single space) must close to avoid condensation. Should all of the doors and windows return to their closed positions, the CRCP control valve may be permitted to modulate again following a suitable time delay that would allow the DOAS system to restore the space DPT to design.

Field Experience With CRCP Condensation Control In A Movable Sash Building.

The Architecture (not Engineering) students in the DOAS-CRCP space were briefly instructed the first week of fall semester a year ago concerning the system operation. Regarding window operation, they were informed that they were free to open the windows, as they desired, but that space temperature and comfort would be compromised. At no time did the students choose to open the windows. It is speculated that they behaved in this fashion since the DOAS, providing 100% fresh OA, maintained the space RH relatively uniform at around 50% while the CRCP maintained the space dry bulb temperature at set point. Apparently, because the controlled indoor environment was always to be favored over the outdoor conditions, there was no incentive to open the windows.

Since the students did not create a situation to test the facilities personnel’s open window concerns, such a test was conducted by the author. All of the
windows were opened, Figure 1, and the two exterior doors were opened at a time when the space DPT was 57.5F and the outside air DPT was 66F.

A trend plot of the data is presented in Figure 2. The space DPT (DPT_{st4} on Figure 2) rose exponentially and approached a quasi-steady value of 65F, just 1F below the outdoor air DPT. And it rose rapidly, exhibiting a time constant of 5 minutes. The rapidly rising space DPT caused the control to close the CRCP control valve, denoted V_{2pos} on Figure 3, 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 4 minutes of the window and door opening. The delayed valve response caused a delay in the response of the CRCP inlet water temperature, denoted T_{3(CHWS)} on Figure 2. The closed CRCP control valve caused the inlet water temperature to rise quickly, a time constant of 12 minutes following a 3 minute delay, as heat from the space was added to the CRCP while the CRCP pump continued to run.

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 5F or less. In prior research (Mumma, 2002), it was shown that the visible condensation is small, when a surface is held 5F below the space DPT for 8.5 hours. There was absolutely no condensation visible on the CRCP surface, Figure 4, and essentially none on the uninsulated chilled water supply piping Figure 5 (on a shiny copper surface, condensation is noticed when the reflection becomes even slightly diffuse). 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. So sensible cooling was not completely lost 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:

Condensation prevention control, in a historic building with large movable sash, was easily achieved even when the inside DPT was suddenly elevated
by opening all of the doors and windows. The test was repeated many times, with similar results and never a condensation problem.

A future IAQ column will address another concern of the university facilities personnel: Can the passive fail safe condensate sensor prevent damaging condensation should the automatic temperature and humidity control system fail to cause the CRCP control valve to respond when the doors and windows are opened?

References:


Figure 1, Picture of the exterior wall with the windows open
Figure 2, Trend plot of the important temperatures
Figure 3, Trend plot with control valve position
Figure 4, CRCP after opening windows, no condensation
Figure 5, Chilled water pipe with slight condensation visible after opening windows.