Using Ceiling Radiant Cooling Panels

Tempering Cold Outdoor Air

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When dedicated outdoor air systems (DOAS) are used in parallel with ceiling radiant cooling panels (CRCP), the volume of air moving in any space often is less than 20% of that moving in a conventional variable air volume (VAV) system.

This reduces the system's ability to use an airside economizer. So, a waterside economizer often is used in conjunction with the CRCPs to achieve the economizer function.

However, at low outdoor air temperatures (OAT), the outdoor air (OA) alone can be used to satisfy the cooling load, thus avoiding the expense of operating a cooling tower and its potential for freezing problems.

Introducing air cooler than 30°F (–1°C) directly into the space, even through high induction diffusers (induction ratios of 30:1) designed to handle air as cold as 40°F (4°C), can cause cold drafts.

Nevertheless, the system discussed here was operated that way for the prior two winters. And, some complaints of cold drafts were received, which occurred when the enthalpy wheel (EW) was turned off (at times for 10–12 hours) to provide airside economizer cooling.

At least two options are available to prevent the winter DOAS supply air temperature (SAT) from ever dropping to OATs, thus avoiding cold drafts. One is to modulate the speed of the EW whenever the OAT is below 40°F (4°C) to maintain a SAT that will avoid cold drafts. If the space needs cooling at the elevated SATs, CRCPs served with a cooling tower could provide that cooling.

The second option is to activate the CRCP pump, thereby extracting heat from the space via the CRCPs and releasing that heat via the DOAS cooling coil to temper the incoming OA. This option allows achieving airside economizer performance at low OATs without sending that air into the space at a low temperature.

The central thrust here is to report field experience with the second option of tempering the supply air, and compare it with the baseline winter performance of the system before using the panel pump in this way.

Facility Used for Field Tests

This is the same facility discussed in previous columns by the author. It is a single zone 3,200 ft^2 (298 m^2) facility serving an academic space housing 40 senior-level architecture students around the clock.

The OA is preconditioned with an enthalpy wheel for exchanging energy with the exhaust air. (A schematic of the system is presented in *Figure 1*.)

A cooling coil is used for much of the year to cool and dehumidify the supply air. The balance of the space sensible cooling is achieved with the CRCPs. During mild OA conditions, the cooling coil and CRCPs receive chilled water from a chiller.

The original winter system design approach was to temper the OA with the enthalpy wheel as needed to prevent over-cooling. The enthalpy wheel operates in an on or off mode, without wheel speed modulation capabilities.

Use of Web-based controls with excellent trending capability led to the concept of tempering the OA with the CRCPs during the winter.

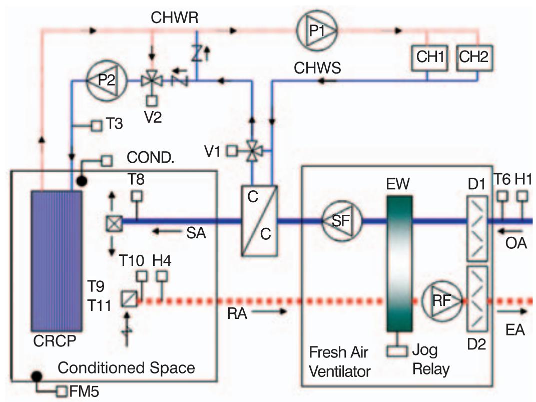

Figure 1: Schematic of the system used for field tests. The building houses architecture students.

Baseline Winter Performance

The space has a high interior sensible load year-round, so even in the winter cooling is required nearly all the time. The air-cooled chiller is deactivated during the winter months, so all cooling must be achieved using OA.

As the temperature drops, the EW is cycled on and off by the direct digital controls (DDC) to keep the space temperature between 73°F and 74°F (23°C and 24°C). When the temperature drops low enough, the EW remains on for extended periods to maintain a comfortable temperature in the space. Cold air can cause unpleasant drafts whenever the EW is off.

Figure 2 is a trend plot of the SAT (T8) along with the concurrent OAT (T6) and the space temperature (T11).

The SAT is essentially equal to the OAT from 6 p.m. until about 10:30 p.m. After 10:30 p.m., the SAT starts cycling between 30°F and 59°F (–1°C and 15°C) as the EW is cycled on and off. As the internal generation is reduced after midnight (as some of the students leave the space), the EW on time grows progressively with each cycle.

The status of the panel pump, off, is shown in the lower trend plot in *Figure 2*. Also on the lower trend plot is the EW trend. Apparent in the EW trend plot is the hourly on spikes where the cleaning cycle is activated. The cleaning cycle is only a few minutes per hour (when the EW is otherwise off), and its influence on the SAT is apparent by the approximately 2°F (1°C) spikes of the SAT (T8). For the data presented in *Figure 2*, it is apparent that the space is receiving air at below 40°F (4°C) for many hours.

Figure 3 is a trend plot of the space temperature (T11) cycling between 73°F and 74°F (23°C and 24°C) as the EW (trend in the lower plot) is cycled on and off. For the time period illustrated, the space temperature stayed within the dead band settings. There are times when room temperature is either warmer or colder than the 1°F (0.6°C) dead band.

Figure 4 illustrates how the cooling capacity of the SA changes as the EW is cycled on and off. The cooling done by the SA exceeds 3 tons (10.5 kW) between 6 p.m. and 10:30 p.m., then is reduced to about +1 ton (+3.5 kW) when the EW cycles on. Clearly the load in the space drops from +3 tons (+10.5 kW) to nearly 1 ton (3.5 kW) by 6 a.m., when the EW is operating continually.

Tempering Supply Air With Heat Exchanged Between Ceiling Radiant Cooling Panels and Cooling Coil

In the previous section, it was demonstrated that with a DOAS-CRCP cooling system, extended winter periods exist

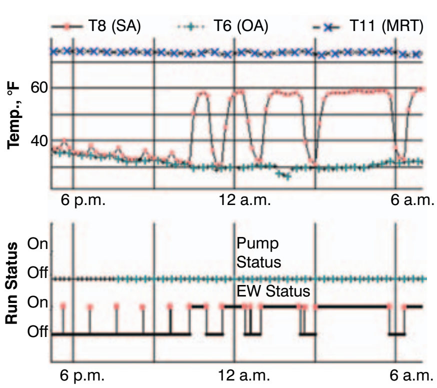

Figure 2: Trend plot of DOAS supply air temperature (T8) with panel pump off.

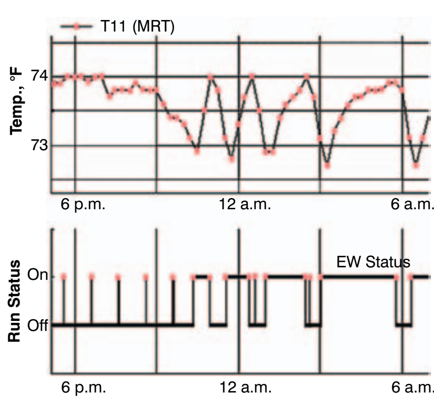

Figure 3: Trend plot of space temperature (T11) with panel pump off.

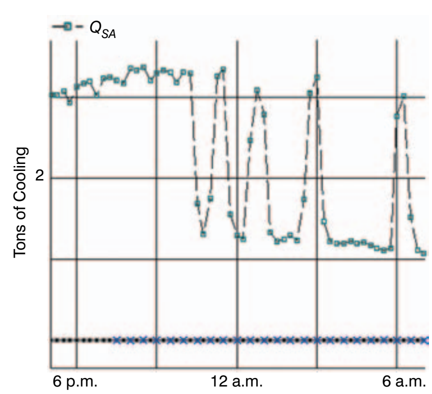

Figure 4: Trend plot of DOAS cooling parameters (Q_{SA}) with panel pump off.

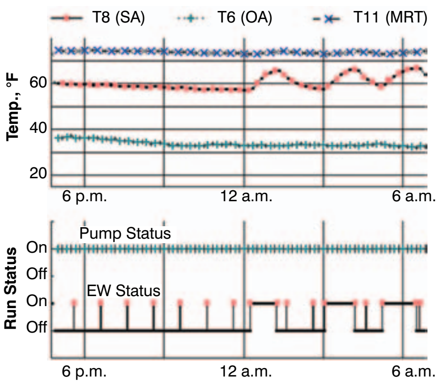

Figure 5: Trend plot of DOAS supply air temperature (T8) with panel pump on.

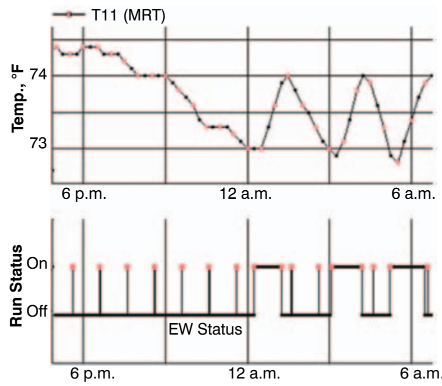

Figure 6: Trend plot of space temperature (T11) with panel pump on.

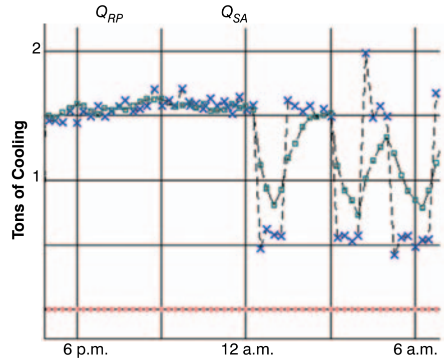

Figure 7: Trend plot of DOAS cooling parameters (Q_{SA}, Q_{RP}) with panel pump on.

when the SAT equals the OAT because of the low supply air quantities compared to all air systems (low flow means large temperature difference to achieve the same cooling capacity). It has been discovered that by activating the panel pump, and opening the control valves V1 and V2 fully, heat extracted at the CRCPs is transported by the pumped hydronic system around to the cooling coil. As a result, the OA is tempered by the cooling coil in the winter.

A typical operating period in this mode of operation is illustrated in *Figure 5*. The upper trend plot shows that the SAT, when the OAT was about 32°F (0°C), cycled between 58°F and 66°F (14°C and 19°C) as the EW was cycled on and off.

The space temperature was held within the dead band in this case (*Figure 6*). However the cycle period of about three hours is twice as long as that illustrated by the base case (*Figure 3*). This longer cycle leads to more stable space temperatures, in addition to the cold draft reduction. The longer cycle is caused by the introduction of the chilled water loop and the CRCP capacitances active participation.

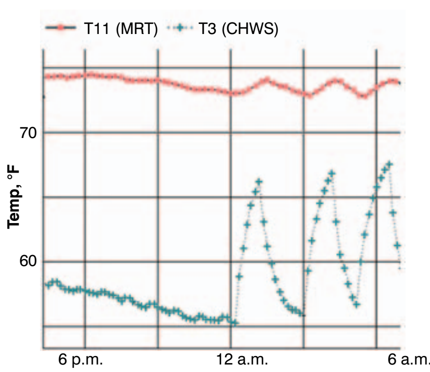

Figure 8: Trend plot of panel inlet water temperature (T3) with panel pump on.

The relative contribution and dynamics of both the SA component and the CRCP component of space cooling are illustrated by *Figure 7*.

Between 6 p.m. and midnight, the contribution of both the SA and the CRCP were each about equal at +1.5 tons (5.3 kW) (+3 tons [+10.5 kW] combined) during the period that the EW was off. This is very similar to the load removed by the OA alone in the base case *Figure 4* with the EW off. After midnight when the EW began to cycle on and off, the CRCP cooling dropped to about 0.5 tons (1.8 kW), and the SA dropped to a low of about 0.75 tons (2.6 kW).

Dynamically, the CRCP capacity responded in an almost step function as the EW cycled between on and off. This is typical of the very short CRCP time constants. By contrast, the SAT changed much slower.

The cooling done by the CRCPs is made possible by the chilled water loop temperatures leaving the cooling coil and entering the CRCP (T3). The panel inlet water temperature trend plot is illustrated in *Figure 8*. The panel inlet water temperature cycled between about 56°F to 67°F (13°C to 19°C).

Energy Consequences

Tempering the OA with heat removed from the space via the CRCPs increases the operating costs over the baseline case due the panel pump operation. However, of the alternatives for tempering the OA to avoid cold drafts, it is the least expensive alternative to operate. Tempering the OA with the EW and then cooling with either a chiller or via a cooling tower requires more energy-consuming equipment to be activated.

Conclusions

Tempering the OA with the cooling coil in the winter, using heat removed from the space at the CRCPs greatly extends the number of hours the system can operate without producing cold drafts. And this mode of operation allows the tempering to occur without the need for supplemental cooling by alternative means, such as a waterside economizer. Not using the cooling tower in the winter prevents potential freezing complications.

While the experimental results presented in this column apply only to a single zone, the approach easily could be expanded to include multiple space facilities. The heat removed by the CRCPs in each space can be regulated by the space temperature control system, and the sum of the system-wide heat removal dissipated through the common DOAS cooling coil.

The approach to winter cold draft reduction, while simple, represents an energy efficient step toward improving the indoor thermal environment of DOAS-CRCP systems.

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