Preconditioning Dedicated OA for Improved IAQ — Part 2

The central thrust is to develop a fundamental engineering understanding of the thermodynamic performance of each of the individual components of the system … as well as their integrated operation together.

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In the Spring 2001 issue of *IAQ Applications,* the author's column provided a discussion of the components used in outdoor air preconditioning equipment to meet ANSI/ASHRAE Standard 90.1-1999, *Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings,* and ANSI/ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*.

In this column, the central thrust is to develop a fundamental engineering understanding of the thermodynamic performance of each of the individual components of the system (preheat coil, enthalpy wheel, cooling coil and sensible wheel), as well as their integrated operation.

The performance of each component and the entire dedicated outdoor air system (DOAS) are presented for all outdoor air thermodynamic conditions that fall into any of the four distinct operating regions of the psychrometric chart.

Psychrometric Analysis

The operation of the DOAS,[1] *Figure 1,* is best understood with the help of a psychrometric chart. The psychrometric chart in *Figure 2* (the shaded area contains all of the typical weather data points) presents the four regions A, B, C, and D into which OA may fall. For this column, the following conditions are assumed (see *Figure 1* for the physical location of the state points):

- State 3, 45°F (7°C) and saturated;
- State 4, 55°F (13°C) dry-bulb temperature and 45°F (7°C) dew-point temperature;
- State 5, 80°F (27°C) dry-bulb temperature and 55°F (13°C) dew-point temperature; and
- State 6, 70°F (21°C) dry-bulb temperature and 55°F (13°C) dew-point temperature;
- Supply and return mass flow rates equal;
- Maximum enthalpy wheel effectiveness 85%.

The horizontal line containing State points 3 and 4 on *Figure 2* is the required supply air dew-point temperature necessary to decouple the space sensible and latent loads, or 45°F (7°C) dew-point temperature in this illustration. When the outside air conditions are above that line (denoted as wet area), the air must be cooled and dehumidified to State 3 (45°F [7°C] and saturated) and then reheated to State 4 (55°F [13°C] in this illustration) with the sensible wheel.

The sensible cooling of the relief air from State 5 to State 6 is a result of energy extraction from the return air by the sensible wheel. An identical rate of energy is added to the supply air leaving the deep cooling coil (CC) at State 3, reheating it to State 4.

A line of constant enthalpy passing through State 6 (h_6) separates the "wet" area above the 45°F (7°C) dew-point temperature line into Regions A and B. In Region A, full use of the enthalpy wheel dramatically reduces the CC load. In Region B, any use of the enthalpy wheel increases the CC load. Therefore, the enthalpy wheel must be off.

Another boundary is formed below the required supply air dew-point temperature, or "dry" area by the extension of a line through the return condition State 5 and the supply condition State 4. The solid line, which first appears at State 4 and proceeds to a humidity ratio of 0 gr./lb (0 g/g), divides the "dry" area where humidification is required into Regions C and D. In Region C, sensible cooling is required. In Region D, no sensible cooling is required.

Since no preheat is required in Regions A, B, C, and much of D, State 0 (before the preheat coil) and State 1 (after the preheat coil) are the same thermodynamically. Therefore, in the discussion that follows, State 1 will be used to refer to the OA condition when in these regions.

Figure 3 illustrates how the DOAS works when the OA conditions fall in either Region A or B. When the outdoor conditions fall in Region A, as illustrated by State A1, the enthalpy wheel (required by Standard 90.1-1999 as discussed in Part 1) operates at full effectiveness (along the blue line of *Figure 3*). The OA is cooled and dehumidified to State A2 without the expenditure of chiller energy.

Further, since the effectiveness of the enthalpy wheel is assumed to be 85% in this illustration, State A2 is within 15% of State 6. The CC control valve modulates the coil capacity, cooling the air from State A2 to 45°F (7°C) at State 3 (along the upper dark-gray path of *Figure 3*).

Without the enthalpy wheel, the CC would have been required to cool and dehumidify the higher energy content air from State A1. Finally, the sensible wheel speed is modulated to reheat the 45°F (7°C) air at State 3 to the desired 55°F (13°C) State 4 condition (horizontal

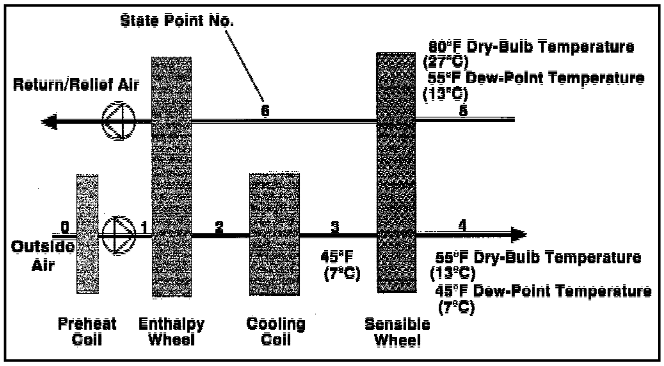

Figure 1: General arrangement of the DOAS with state points identified.

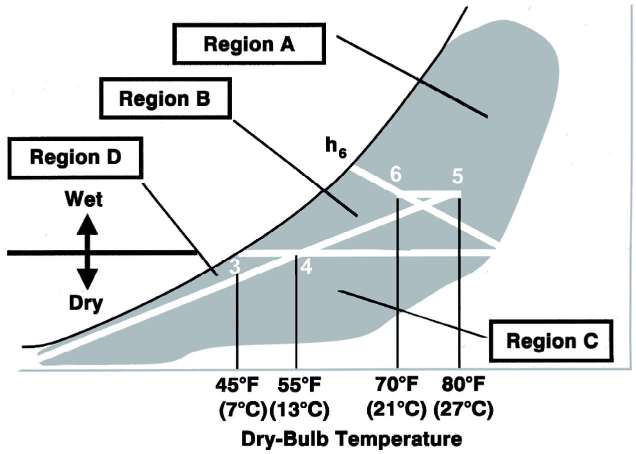

Figure 2: OA Regions A, B, C and D identified on the psychrometric chart.

white line on the 45°F dew-point temperature line) without the expenditure of reheat energy (in compliance with Standard 90.1-1999 as discussed in Part 1).

When the outdoor conditions fall into Region B, use of the enthalpy wheel operating between the OA State B1 and State 6 would increase the enthalpy of the air entering the CC. Therefore, the enthalpy wheel must be shut off when the OA conditions fall in Region B. Where the OA is assumed to be in Region B, State B1 & 2 are equal. The CC control valve modulates the coil capacity, cooling the air from State B1 (State 2 is the same as State B1 in this case) to 45°F (7°C) at State 3 (along the lower dark-grey path of *Figure 3*). The sensible wheel speed is again modulated to reheat the 45°F (7°C) air to the desired 55°F (13°C) State 4 condition without the expenditure of heating energy.

Figure 4 illustrates the DOAS performance when the OA conditions fall in Regions C and D. For outdoor conditions in Region C, State C1 in this illustration, preheat is never required to prevent enthalpy wheel frosting. In Region C, there will never be a need for the use of the sensible wheel since the deep CC setpoint is reset to the required supply air temperature of 55°F (13°C). In this “dry” outdoor air area, the air is already below the required dew-point temperature. Therefore, it is unnecessary to cool the air to 45°F (7°C) for dehumidification.

The enthalpy wheel speed is modulated to bring the air up to the desired dew-point temperature for comfort (45°F [7°C] in this illustration). The resulting State C2 lies at the intersection of the enthalpy wheel process line (right blue line in *Figure 4*) between State C1 and State 5 and C6 (State C6 is equal to State 5 since no reheat is required when the OA is in Region C) and the 45°F (7°C) dew-point temperature line. In this illustration, the enthalpy wheel speed is reduced so that its effectiveness is reduced to about 50%. From State C2, the air is sensibly cooled (the gray horizontal line) by the deep CC to 55°F (13°C), and supplied to the building (State C3 and 4 are equal since no reheat).

In Region D, preheat is never needed if the OA temperature is above 32°F (0°C). Such a case is illustrated in *Figure 4*. In Region D, both the enthalpy wheel and the sensible wheel speeds are modulated. The enthalpy wheel is used to heat and humidify the OA (the left blue line in *Figure 4*) from State D1 to the desired 45°F (7°C) dew-point temperature at D2, which is al-

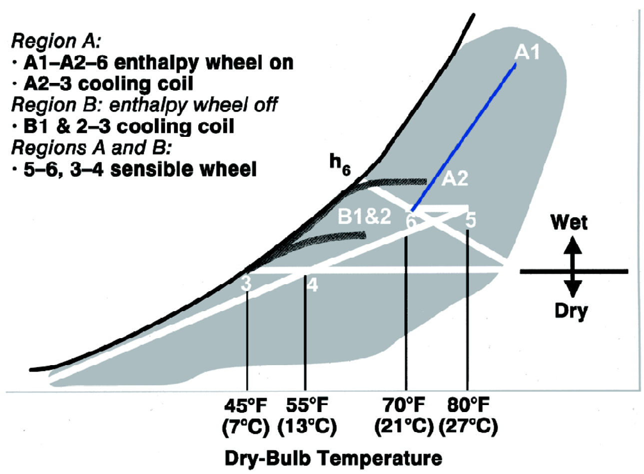

Figure 3: Cooling and dehumidification processes in wet Regions A and B.

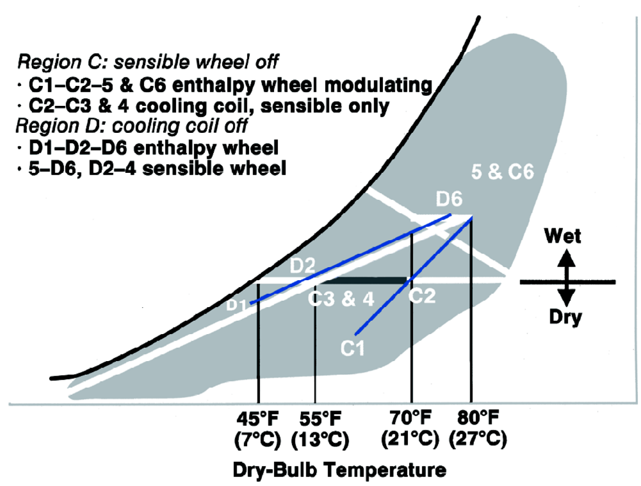

Figure 4: Humidification and cooling/heating in the dry Regions C and D.

ways below the desired 55°F (13°C) at State 4. Therefore, the sensible wheel speed is modulated so the required energy is removed from the return air and added to the supply air to bring its temperature up to 55°F (13°C).

In this illustration, the temperature difference between States 5 and D6 equals the temperature difference between States D2 and 4 (note this is less than 10°F [6°C]). If the OA conditions are sufficiently low and dry that the line connecting D1 and D6 crosses the saturation curve, condensation and wheel frosting may result. To avoid this, preheat is required. Details of this process and the necessary controls (preheat and entire system) are presented in *ASHRAE Transactions*.[2]

Conclusions

The energy recovery equipment required by Standard 90.1-1999 makes the DOAS equipment very energy efficient. However, energy savings alone will not drive the migration to dedicated OA units. Instead, it will be the superior comfort and human productivity that accompanies systems that can separate the sensible and latent loads. Next, is the system's ability to ensure the proper ventilation to every zone in the building, something that cannot be ensured with a single all-air system. Also, these systems have lower first and operating costs. In conclusion, a DOAS as discussed in this column is highly recommended to precondition dedicated OA for improved indoor air quality.

References

1. Mumma, S. A., K. Shank, 2001. "Achieving dry outside air in an energy efficient manner." *ASHRAE Transactions* 107(1).

2. Mumma, S. A. 2001. "Dedicated outdoor air-dual wheel system control requirements." *ASHRAE Transactions* 107(1).

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