Dedicated Outdoor Air Systems

Meeting Air Change Criteria

The Standard 62 air change per hour design criteria in no way inhibits the use of DOAS from either a ventilation perspective or a thermal comfort perspective. In fact, they are strong benefits of DOAS.

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Can dedicated outdoor air systems meet ASHRAE's air change per hour design criteria?

Since it is difficult to verify that Standard 62 is constantly met with an all-air system, a separate constant volume ventilation air system (DOAS) is used to deliver the required design OA to each occupied space. The OA is preconditioned with the aid of a total energy recovery device as specified in ANSI/ASHRAE/IESNA Standard 90.1-2001, *Energy Standard for Buildings Except Low-Rise Residential Buildings.*

Mumma

The OA can be conditioned to decouple the space sensible and latent loads, if desired. Finally, a number of parallel systems including VAV, fan coil, unitary equipment, and ceiling radiant cooling panels can be used to handle space loads not met with the DOAS units. Placing the entire latent load on the DOAS unit allows the last three parallel system choices to operate with dry surfaces, eliminating septic amplifiers at the cooling surfaces and condensation formation on the ceiling cooling panels.

Air Changes/Hour Criteria

The *1999 ASHRAE Handbook—Applications* presents general design criteria for most comfort applications. Circulation air changes per hour are specified for only two building types: commercial/public and health-care facilities. For example, Table 1, Pages 3.2 and 3.3, calls for offices to have 4 to 10 circulation air changes per hour (ACH) (0.6 to 1.5 cfm/ft² [3 to 7.6 L/s per m²] for a space with a 9 ft [2.75 m] ceiling). Since the minimum ventilation air required by Standard 62 is about 1.3 ACH (0.2 cfm/ft² [1 L/s per m²] for a space with a 9 ft [2.75 m] ceiling), the design criteria calls for considerable recirculated air to meet the thermal and air motion requirements of the space.

Air Exchange Rate

Page 26.3 of the *2001 ASHRAE Handbook—Fundamentals* defines air exchange rate (AER) as the ratio of the volumetric flow rate of air into the space to the interior volume of the space. When expressed in hours, AER is called air changes per hour. The general equation for AER is: $I=Q/\nu$, units of 1/time. The section deals with two forms of AER. One is for OA brought into the building or space and is called the nominal AER. It is represented by the equation: $I_N = Q_{OA}/\nu$. This formulation does not describe recirculation or distribution of ventilation air to each space. The other is the space AER and is represented by the equation: $I_S = Q_{SA}/\nu$. The Q_{SA} is the total supply airflow rate including both OA and recirculated air. This space AER often is used to describe diffuser performance and space air mixing.

Diffusers Mixing

The diffuser performance and space air mixing govern the space air temperature distribution and air speed. These two factors are used to define the occupant's thermal comfort in the form of the effective draft temperature:

$$\theta = (t_x - t_c) - 0.07 \times (v_x - 30)$$

where

θ = effective draft temperature
t_x = local airstream dry-bulb temperature
t_c = average room dry-bulb temperature
v_x = local air stream center line velocity

A high percentage of people in sedentary occupations are comfortable when $-3°F < \theta < +2°F$ and $v_x < 70$ fpm. Air Diffusion Performance Index (ADPI) is the statistic used to define the percentage of locations, during cooling, in the occupied space with effective draft temperatures between –3°F to 2°F (–1.6°C to 1.1°C). When ADPI approaches 100%, the most desirable conditions are achieved. ADPI does not consider space relative humidity or mean radiant temperature.

Most diffuser types, their range of ADPI performance characteristics, and induction ratios are presented in *Table 1*.

High Induction Diffusers

To entrain large quantities of room air (greater than 10:1), the diffusers must:

- Introduce the injected air with high momentum;
- Provide maximum contact surface between the injected air and the room air;
- Establish nonturbulent linear flow within the nozzles;

• Space the nozzles for maximum contact between the jets and the room air;

• Direct the jets at a specific angle away from the ceiling creating a negative pressure region enhancing room air entrainment above the jet.

Diffusers that embody these five qualities were originally designed for low-temperature applications and are readily available today.

Research has shown that the high induction diffusers provide complete air mixing, resulting in even temperature gradients throughout the space. More importantly, they eliminate short-circuiting of the primary supply air to the return air system. This increases the "ventilation effectiveness factor" and optimizes the effectiveness of outdoor ventilation air in achieving acceptable indoor air quality. The research also reveals that superior heating performance from overhead air distribution is achieved, contrary to the performance of standard diffusers (and the reason ADPI applies only to cooling conditions).

In practice, high induction diffusers supplying 40°F (4°C) air at the rate of 0.28 cfm/ft^2 (1.4 L/s per m^2) is achieving effective draft temperature profiles of $-1.5°F < \theta < 1.5°F$ with room secondary minimum velocity of 25 fpm (0.13 m/s), resulting in an ADPI of 100%. Even when the airflow rate is reduced to 0.12 cfm/ft^2 (0.6 L/s per m^2), the room secondary minimum velocity is 18 fpm (0.09 m/s) and the ADPI is 98%.

Diffuser Type	Range Of ADPI	Induction Ratio
High Sidewall Grille	68 – 85%	4:1 to 10:1
Ceiling Round	76 – 93%	4:1 to 10:1
Ceiling Slots	85 – 92%	4:1 to 10:1
Ceiling Troffers	86 – 95%	4:1 to 10:1
Ceiling Four-Way	86 – 95%	4:1 to 10:1
Ceiling High Induction	95 – 100%	18:1 to 36:1

Table 1: Diffuser types and ADPI potential.

Can DOAS Meet Air Change/Hour Criteria?

Since two ways exist to define the air exchange rate (AER) or air change per hour, each will be explored separately.

Nominal Air Exchange Rate

Since DOAS always meets the minimum OA required by Standard 62, it always meets the nominal AER. This is not easily achieved by most all-air systems, regardless of the air changes per hour.

Space Air Exchange Rate

Remember, this characteristic is frequently used to evaluate the supply air diffuser performance and space air mixing. From this perspective, it is important to consider the induction ratio of the diffuser. If an office space had an all-air VAV system capable of supplying 1 cfm/ft^2 (5 L/s per m^2), used ceiling diffusers with an induction ratio of 4:1, and had a 9 ft (2.75 m) ceiling, the *effective* space AER (includes the air moving performance of the diffuser) would be:

$$AER = [(4 \times 1)/9] \times 60 = 27$$

A DOAS system supplying 0.2 cfm/ft^2 (0.1 L/s per m^2), used ceiling diffusers with an induction ratio of 36:1, and had a 9 ft (2.75 m) ceiling, the *effective* space AER would be:

$$AER = [(36 \times 0.2)/9] \times 60 = 48$$

Conclusion

Clearly, the DOAS with high induction diffusers can meet or exceed the performance of a conventional all-air VAV system under design conditions from a diffuser performance, space air mixing, and ADPI perspective. At off-design conditions, there is no change in the constant volume DOAS system performance. The Standard 62 air change per hour design criteria in no way inhibits the use of DOAS from either a ventilation perspective or a thermal comfort perspective. In fact, they are strong benefits of DOAS.

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