Displacement Ventilation Diffuser Selection

Air outlets are typically selected in order to satisfy occupant comfort as well as additional functionality, defined by the space type (such as patient isolation, automation, etc.). In a displacement ventilation system air is introduced at low velocity in order to minimize mixing, creating a layer of fresh, cool air at floor level, which is then pulled into the thermal plumes that develop around heat sources. As a result, the primary functionality of a displacement diffuser is to supply air into the room in such a way that minimizes induction and maximizes occupant comfort.

Occupant comfort, as defined by ASHRAE Standard 55, requires that conditions be created that promote whole body comfort and limit the occurrence of local discomfort. The local discomfort factors that are uniquely affected by a DV system are draft and stratification. Chen and Glicksman's (1999) procedure for determining the air volume already accounts for stratification, so the primary selection criterion for displacement diffusers is draft. Draft is a function of velocity, v, temperature, t, and turbulence intensity, Tu:

$$Draft = (93.2 - t)(0.00004vTu + 0.066)(v - 10)^{0.062}$$

The performance of displacement diffusers is commonly presented as either adjacent zone (AZ), or throw. The AZ is the region around the outlet where the velocity is 40 fpm [0.2 m/s], measured at both 1 in. and 2 in. [25 mm and 50 mm] above the floor. Throw is typically measured in accordance with ASHRAE Standard 70, which provides the air pattern created by a diffuser under isothermal conditions in a standard room, bounded by 50 fpm. Both of these ignore the effect of temperature (and turbulence), thereby making it difficult to get a sense of how this data translates to the thermal comfort of occupants. The room air flow characteristics of a DV system are such that they make concepts of throw, spread and drop meaningless. It is the heat sources in the room that drive the air diffusion, not the momentum from the air outlet.

A more appropriate metric is the draft ratio (DR) from ASHRAE Standard 55-2004 and ISO 7730-2005. DR identifies the percentage of people dissatisfied based on a combination of temperature, velocity and turbulence intensity. Performance data, when presented in this form, gives the engineer useful information about thermal conditions around a displacement diffuser. In both ASHRAE Standard 55-2004 and ISO 7730-2005, the range of acceptable DR is between 0 and 20.

The discomfort due to draft, DR, is highest in areas closest to the diffuser, where the lowest temperatures and often the highest velocity exist. Because of this, higher supply air temperatures and lower diffuser face velocities are desirable in order to minimize draft. Moving away from the outlet, the velocity decreases and the supply air temperature increases due to entrainment of room air and drag on the floor, occupants and equipment, as well as convective heat transfer from surrounding surfaces. These all translate to a decay of DR, shown in the figure below.

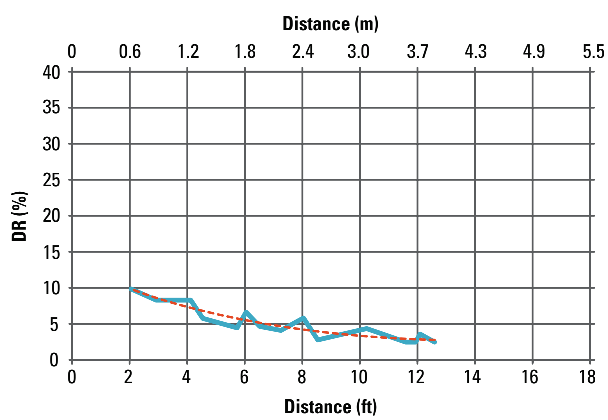

FIGURE 1: DR vs. distance, 40 fpm [0.2 m/s] face velocity, supply air 10°F[5.5°C] below t_{room}

The face velocity will have an impact on the size of the selected diffuser. For example, 200 cfm out of a diffuser with a face velocity of 40 fpm will require 5 ft^2 of diffuser face, whereas a face velocity of 50 fpm only requires 4 ft^2 of diffuser face.

ASHRAE (Chen & Glicksman, 2003) recommends a maximum face velocity of 40 fpm [0.2 m/s] for regularly occupied commercial spaces. In practice, this number seems to be a good compromise between draft and diffuser size. Depending on the application, some adjustment to the face velocity is possible. If people are seated adjacent to the outlet, such as in a theater with diffusers in risers behind the seats, a lower face velocity is preferred. In transient spaces such as lobbies or airports, shown in the figure below, the engineer may be able to select higher face velocities, perhaps as high as 50 - 55 fpm [0.25 - 0.275 m/s]. In areas where draft is less of a concern, such as in a machine shop, significantly higher face velocities may be appropriate. It is not unusual to have a face velocity as high as 100 fpm [0.5 m/s] in industrial spaces.

These typical face velocities are rules of thumb and have been determined to be acceptable for most spaces. A more accurate method for determining an appropriate diffuser face velocity is to evaluate the draft, or DR, around the diffuser. The diffuser face velocity directly impacts the air velocity at the floor level, thereby affecting the draft. Laboratory testing can compare the diffuser face velocity and supply air temperature to the DR in a room, illustrating their relationships. Other factors that affect comfort with a given velocity and temperature include:

- Occupant's metabolic rate
- Occupant's clothing level
- Occupant density
- Room loads

Due to these complex relationships, referencing supplier DR data with these values stipulated, conducting a CFD study or using selection software will help the designer to refine the diffuser size and face velocity based on a specific application.

FIGURE 2: Displacement diffusers located in large transit spaces, such as airports, can have a higher face velocity