TECH TIPS | Overhead Air Distribution Systems

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When a designer selects overhead air distribution as the basis for designing a building space, there are several design considerations. Overhead air distribution is characterized by an injection of conditioned air (typically a mixture of fresh air and re-circulated air) into a region of the building space that will not directly enter the occupied zone. The occupied zone is described as one foot from the walls and six feet above the floor in the building space (see Figure 1). Ideal overhead air distribution is characterized by uniform mixing throughout the entire building space, even where there are no occupants. See Figure 2 for a computational fluid dynamics (CFD) image of this mixing.

Most buildings use variable air volume (VAV) systems which vary the supply air volume based on demand. In heating mode, the supply volume is usually significantly lower than the cooling supply volume. In most places, the normal turn down ratio of cooling air volume to heating air volume is around 30%.

ASHRAE Standard 62.1 defines Zone Air Distribution Effectiveness (Ez) as a measure of how effectively the zone air distribution uses the supply air to maintain acceptable air quality in the occupied zone (also known as the breathing zone). The zone air distribution effectiveness is described by Table 1 in ASHRAE Standard 62.1. For overhead cooling, the Ez is 1.0. For overhead heating, the Ez is only 0.8, unless the warm air is distributed down the walls in the unoccupied zone to at least 4.5 ft above the floor. This proves to be a challenge for designers as VAV systems usually have the highest airflow rate in cooling mode and a lower airflow rate in heating mode. Making this even more interesting is the buoyancy effect of warm and cold air. Cold air

seeks to fall downward as it is denser than the room air, and warm air tends to rise due to its lower density than the room air.

There is a solution that will help satisfy both cooling and heating and provide an Ez of 1.0 for both cases. Use a diffuser that changes the distribution pattern of the discharge air, such as the TBDI6-HC. It operates with a horizontal discharge pattern in cooling mode and uses an internal thermally operated actuator to change the discharge pattern to a vertical discharge when the supply air rises above 81°F.

As an example, consider an office that is 30 ft wide by 20 ft long and has a 9 ft ceiling. During cooling operation, the air volume is 690 CFM. During heating mode the room will have 210 CFM of warm air supplied. Three diffusers will be used to supply this zone.

From the catalog, the performance of the TBDI6-HC diffuser is thus:

Size 24", 8" inlet at 230 CFM has isothermal horizontal throw values of 19-24-34 (150 fpm, 100 fpm and 50fpm) with an NC value of 35. When the horizontal throw is corrected for the actual supply air temperature — 55°F supply air temperature (Ts), 75°F room air temperature (Tr) for every 1 degree lower the throw is reduced by approximately 1% — the 50 fpm throw is determined to be: 34 x 0.8= 27 ft. Since the room is 30 ft long in the discharge direction, the throw distance of 27 ft is considered adequate. The throw would be an issue if it were to exceed the horizontal distance of 30 ft plus the vertical distance of 9 ft (the air path will follow surfaces until the air velocity falls below 50 fpm).

Size 24", 8" inlet at 70 CFM vertical discharge throw values are 7-9-12 with an NC of less than
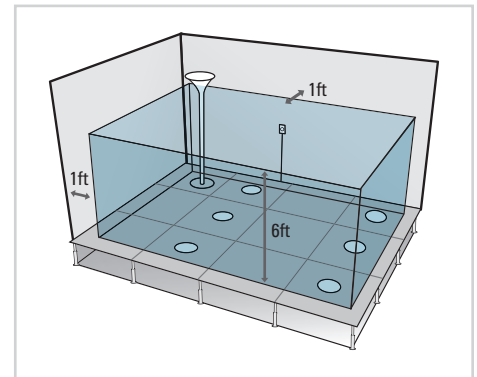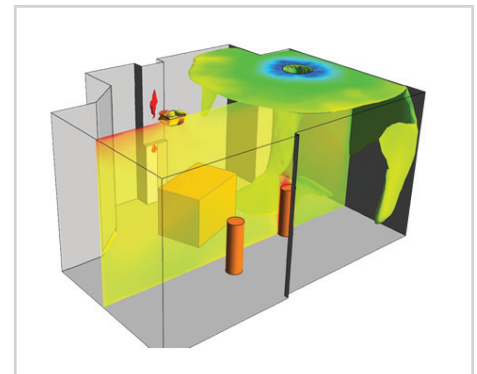

Figure 1: Occupied Zone

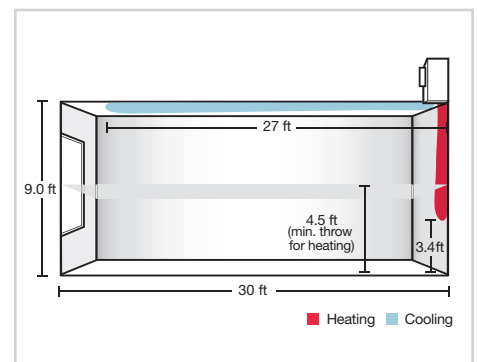

Figure 2: CFD velocity profile for overhead mixing

Figure 3: Throw pattern for heating and cooling

15. Correcting for temperature effects (Ts=95F, Tr=75F) involves lowering the throw by 1% per degree of temperature difference and the 150 fpm throw is determined to be 7 x .8=5.6 ft. Vertical downward throw for 150 fpm is 9 ft – 5.6 ft = 3.4 ft. See Figure 3.

Since ASHRAE 62.1 requires the warm air to penetrate to at least the 4.5 ft level above the floor, this diffuser is a good selection, and in both heating and cooling modes the Ez is a 1.0.

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. Note: For lower velocity supply air, $E_z = 0.8$	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply reaches 4.5 ft (1.4 m) or more above the floor. Note: Most underfloor air distribution systems comply with this proviso	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Make up supply drawn in on the opposite side of the room from the exhaust and/or return	0.8
Make up supply drawn in near to the exhaust and/or return location	0.5
1. "Cool air" is air cooler than space temperature 2. "Warm air" is air warmer than space temperature 3. "Ceiling" includes any point above the breathing zone 4. "Floor" includes any point below the breathing zone 5. As an alternative to using the above values, E_z may be regarded as equal to air change effectiveness determined in accordance with ASHRAE Standard 129[16] for all air distribution configuration except unidirectional flow.	

Table 1: Zone Air Distribution Effectiveness