Displacement Ventilation Engineering Information

INTRODUCTION

Fully stratified air distribution systems have been used in industrial applications for many years. In the 1980s, they became a popular alternative for office and classroom HVAC in Europe, and their popularity has recently spread to North America because of their high contaminant removal efficiencies and their potential energy savings, especially in relatively mild climates.

Thermal displacement ventilation (TDV) systems are the most widely used variant of these systems. The main objective of a mixed-air system is to create a homogenous mixture of supply and room air throughout the space. Contaminants and heat are diluted and then extracted through the return inlet. TDV systems do not attempt to mix heat and contaminants; instead, they allow them to escape into the upper uninhabited zone, from which they are extracted. With a TDV system, supply air is introduced directly into the occupied zone at low velocity and a temperature lower than that of room air. Contaminants and heat in the space are carried by convective flows (created by space heat sources) into the upper part of the room. Warm air in the upper zone does not recirculate into the occupied zone, so the temperature and concentration of most impurities at the exhaust inlet exceed those in the occupied zone and at the breathing level.

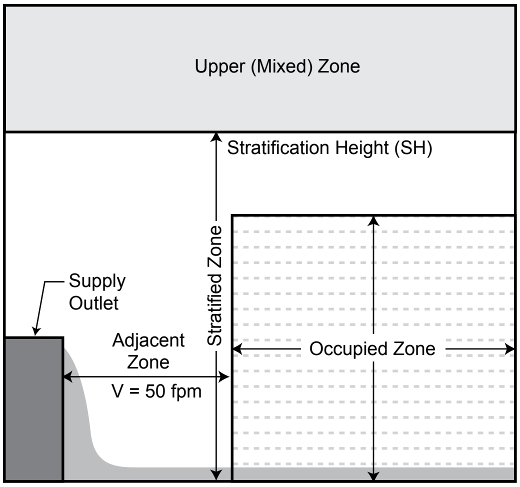
TDV systems offer increased ventilation effectiveness and may reduce HVAC energy consumption. Applications include classrooms, conference rooms, theaters, restaurants, supermarkets, and spaces with high ceilings (10 ft and above) It has been suggested that the maximum convective cooling load in office buildings with TDV should not exceed about 8 Btu/h•ft^2, so that the maximum vertical temperature gradient in the occupied zone is not greater than 5°F. It has been demonstrated, however, that cooling loads up to 40 Btu/h•ft^2 can be handled in the office environment if the ventilation rate is increased.

CONVECTIVE FLOWS & HEAT SOURCES

Convective heat flows in the space are the driving forces behind TDV systems. When the surface temperature of a heat source exceeds that of the air surrounding it, heat is transferred to ambient air by convection. This transfer warms the air and causes it to rise because of buoyancy. These rising plumes grow as they entrain room air. Radiant heat transfer does not directly affect heat plume formation, but may indirectly influence development of other heat source plumes by raising the surface temperature of the source.

TDV ZONES

Spaces conditioned by TDV systems can be categorized into 4 basic zones. The adjacent zone (sometimes referred to as the near or clear zone) is the portion of the space near the air outlet where horizontal velocities in excess of 50 fpm may be found. This zone is defined as the room volume bordered horizontally by the outlet and the vertical plane corresponding to the furthest extent of an isovel of 50 fpm. Stationary occupants should not normally be located in this zone, because local velocities and supply air temperatures are likely to cause draft sensations. Once the supply air is reduced to a terminal velocity of 50 fpm or less when measured 4" above the floor, its temperature has usually increased to a level not likely to produce draft sensation.



Once the conditioned air mixture has passed through the adjacent zone, it pools out across the floor and only moves vertically when entrained by a convective plume associated with a space heat source. The plume rises through the naturally stratified environment (the stratification zone) to a level where it encounters equally warm air. The plume then dissipates horizontally across the space.

The level at which this occurs is called the stratification height (SH; sometimes also called the shift height). Displaced heat and contaminants (whose buoyancy exceeds that of room air) pool in the space above the stratification height. This is referred to as the upper zone.

OUTLET SELECTION AND LOCATION

TDV outlets should be selected and located so that stationary space occupants are not located within their adjacent zone where draft risks are high. The low discharge velocities of TDV terminals create very little noise and thus are only of concern in very sensitive acoustical applications. System noise (noise from fans, dampers, ductwork, etc.) should be considered because it is transmitted with the supply airflow.

RETURN INLET SELECTION AND LOCATION

TDV return air inlets used should conform to the same requirements as those for mixed-air systems. They should always be located above the occupied zone, and should be provided within any confined space served by a TDV supply air terminal.

SYSTEM PERFORMANCE EVALUATION

The primary comfort criterion of TDV systems is maintaining the design room air temperature (usually specified at the head level of the predominant space occupants) while limiting the vertical temperature difference between occupants' ankle and head levels to no more than 5.4°F. Because velocities in the occupied zone are very low, they are of minimal concern. Additional information may be found in ASHRAE Standard 113.

ADPI should not be used to evaluate fully stratified systems, because it essentially measures the degree of mixing achieved by the room air distribution system. A fully mixed environment would have the highest ADPI rating.

NOTE: Excerpts adapted from ASHRAE Handbook 2008.