

**TASK SHEET 1C**  
**LABORATORY AIRFLOW DISTRIBUTION**

Rowan Williams Davies & Irwin, Inc.



Exposure Control Technologies, Inc.



July 14, 2009

## Introduction

Proper airflow distribution in laboratories is important to laboratory occupants as it helps ensure a healthy, productive and energy efficient environment for research and development. The process of designing, specifying, and testing the air distribution systems and components for laboratories is a critical function of the architects, engineers, test and balance firms, and facility commissioning agents. Laboratory air distribution systems need to minimize energy consumption, distribute sufficient quantities of air to meet indoor air quality (IAQ) standards, provide occupants with a comfortable work environment, and most importantly, effectively distribute air that will support the operation of exposure control devices. Furthermore, proper airflow distribution improves energy efficiency by ensuring proper mixing and maximum utility of expensive conditioned air.

Air distribution systems must be dynamic, providing the facility owner with an efficient, yet effective system. Distribution systems should be capable of delivering air based on an operational demand rather than arbitrarily selected fixed volumes (*reference: Task Sheet 1A, Determination of Laboratory Airflow Rates*,

Heating, cooling, and fan energy consumption of laboratory buildings are several times higher than a typical commercial building. Ill-advised application of energy conservation measures, without careful consideration of all laboratory design requirements must be avoided, as their implementation can adversely affect the safety and health of laboratory and building occupants.

With the advent of Variable Air Volume (VAV) systems, Usage Based Controls (UBC), Occupied/Un-Occupied modes, and Energy Recovery Units (ERU), the control of air distribution becomes very complex due to the inter-dependency of the system components and variable operating conditions. Components of the air distribution system consist of (but are not limited to) Air Handling Units (AHU), the distribution ductwork, supply air flow control devices, supply air diffusers or grilles, return air grilles, exposure control devices (ECD), exhaust air flow control devices, exhaust ductwork, exhaust fans (EF), and exhaust discharge stacks. The harmonious integration of the air distribution components with ECDs becomes a challenge to the laboratory designer. The performance of many ECDs especially chemical fume hoods are dependent on the lab environment and the air supply conditions near the opening face of a laboratory hood.

## Task Sheet Scope

The focus of this Task Sheet-1C is to provide guidance for the selection and placement of supply air diffusers and grilles within the boundaries of the lab space. The placement, operation, and containment capabilities of laboratory fume hoods and other ECDs are directly related to the selection and placement of the supply air diffusers and exhaust grilles. Guidelines contained herein relate primarily to laboratory fume hoods, but may be applicable to other ECDs as well.

The design and construction of new facilities affords the designer the ability to meet all operational specifications by specifying the requisite lab area and separation distance requirements for equipment and air distribution components. Retrofitting or modification of existing laboratory spaces becomes a greater challenge due to constraints of existing air distribution system and/or components and the physical boundaries of the laboratory space and location of existing equipment.

The following bullet items must be considered jointly during the laboratory design process:

- Fume Hood Placement
- Fume Hood Density
- Operating Mode of the Air Distribution System
- Air Distribution Effectiveness
- Air Diffuser Selection

## Fume Hood Placement

The placement of single or multiple fume hoods within a laboratory is critical to their safe and efficient operation. Placing fume hoods in locations in close proximity of the air supply sources (diffusers and transfer air openings) may create cross drafts or temperature gradients at the sash plane causing turbulence and potential for escape. In addition, the position of fume hoods, with respect to each other, can also cause undesirable airflow patterns that could affect the ability of the fume hoods to perform properly.

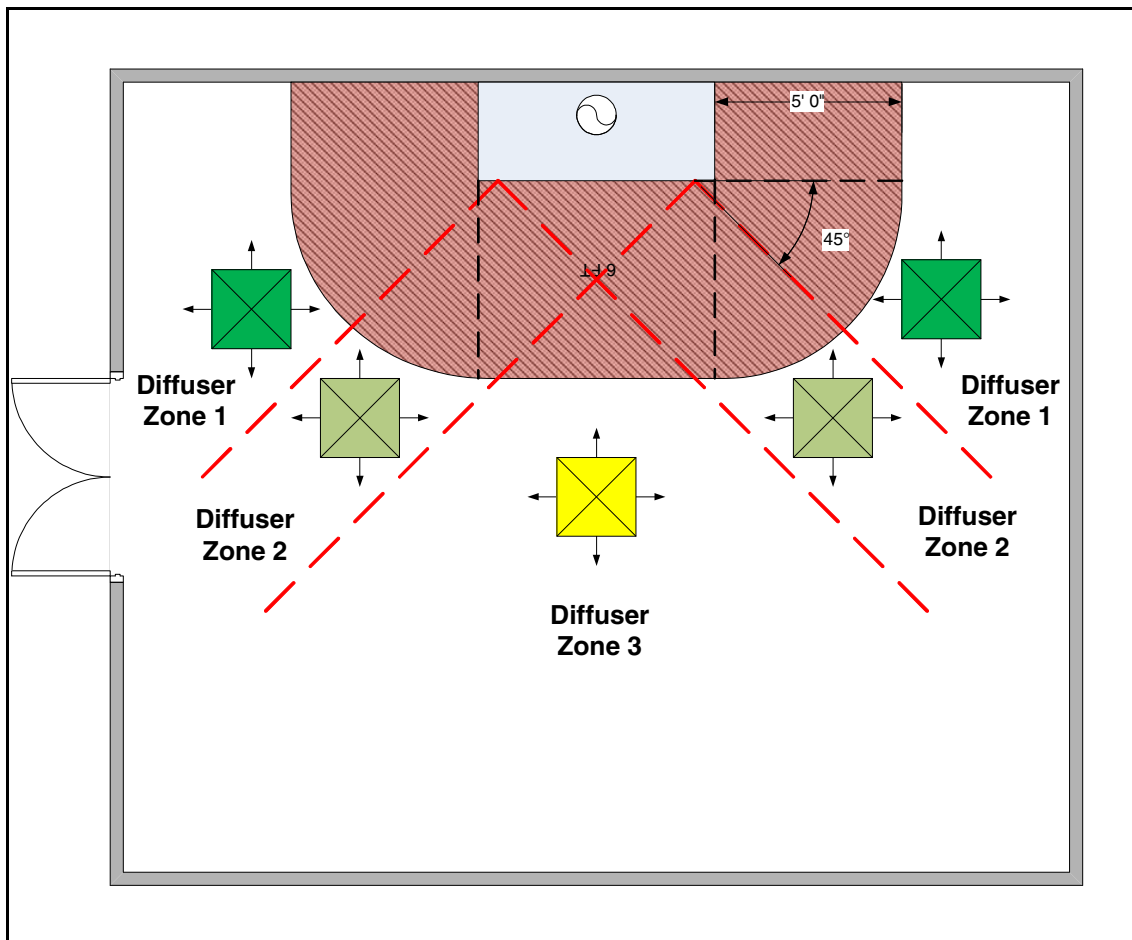
Adherence to the following guidelines for the placement of fume hoods within a laboratory will minimize the adverse affects caused by supply air terminal velocities and personnel traffic patterns. See **Figure 1** for distance relationships for hood placements.

- A. Locate fume hoods at the back of labs or in alcoves .
- B. There should be at least a 4 feet distance between fume hoods and adjacent doors.
- C. Fume hoods should have a distance of at least 8 feet from doorways when facing the doorways.
- D. Fume Hoods should not be located within 3 feet of obstructions that cause undesirable airflow patterns at the plane of the sash including large equipment ( refrigerators, freezers, and incubators).
- E. A fume hood should be located at least 4 feet from a main traffic aisle.
- F. Fume hoods should be located at least 4 inches from adjacent walls unless the design of the hood prevents spatial variations in face velocity from wall effects.
- G. Fume hoods should not face each other within distances of less than the minimum hood width or not less than 5 feet from sash plane to sash plane.
- H. There is no recommendation for distances that separate adjacent fume hoods unless the average face velocities vary by more than 20%.



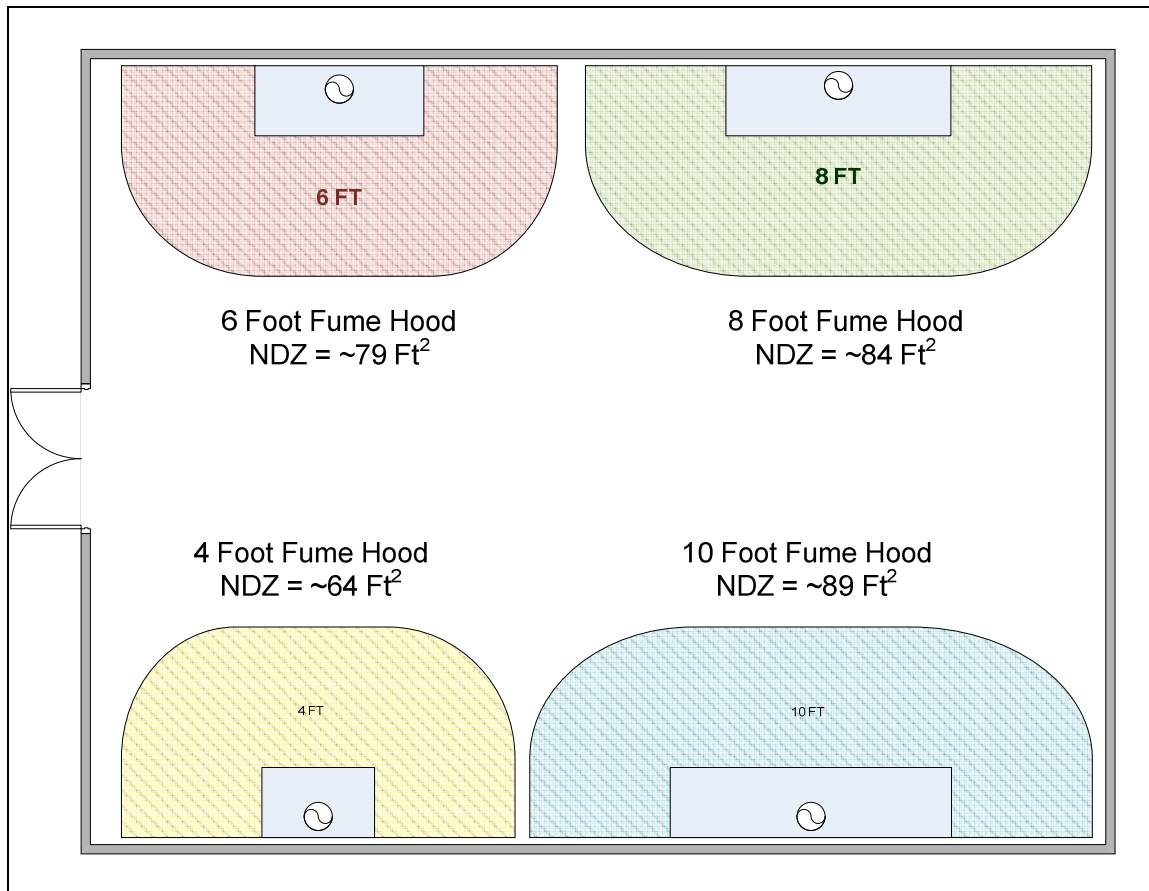
fume hoods reduces hood turbulence due to cross drafts and variations in air supply temperature. The distance of 5 feet from the front and sides of the fume hood defines a zone (*No Diffuser Zone, NDZ*), in which lab designers should avoid placing air supply diffusers. Placement of any diffuser within the NDZ should be avoided unless the diffuser is required for room air circulation and air supply from the diffuser does not impact fume hood performance. High velocity diffusers should be avoided near laboratory fume hoods.

Additionally, when the placement of diffusers is to be close to this zone, certain locations may be preferred as shown in Figure 2. Three zones are identified surrounding the NDZ that include Diffuser Zone 3 as a good location, Diffuser Zone 2 as a better location and Diffuser Zone 1 as the best location. Lab designers should use caution when locating diffusers in Zone 3 in front of a hood opening as air directed perpendicular to the plane of the sash can be more detrimental to hood performance than cross drafts of similar velocity directed parallel to the opening. Where diffusers must be located near or within the NDZ, CFD may be advantageous to evaluate potential problems or ASHRAE 110 performance tests may be necessary identify and alleviate problems during commissioning.



**Figure 2** Diagram showing good, better and best locations for supply diffusers with respect to hood opening.

As the NDZ extends five feet from the front and sides of the hood, the size or area of the NDZ is a function of the size of the fume hood (the larger the fume hood, the larger the NDZ). **Figure 3** below illustrates this sizing relationship:



**Figure 3** Diagram showing No Diffuser Zones (NDZ) as a function of hood size.

To minimize restrictions caused by the size of the NDZ, fume hoods may be placed such that the NDZs overlap or extend outside the laboratory envelope. This recommendation is compliant with the guidelines for placement of adjacent fume hoods established previously. See **Figures 4 and 5** below:

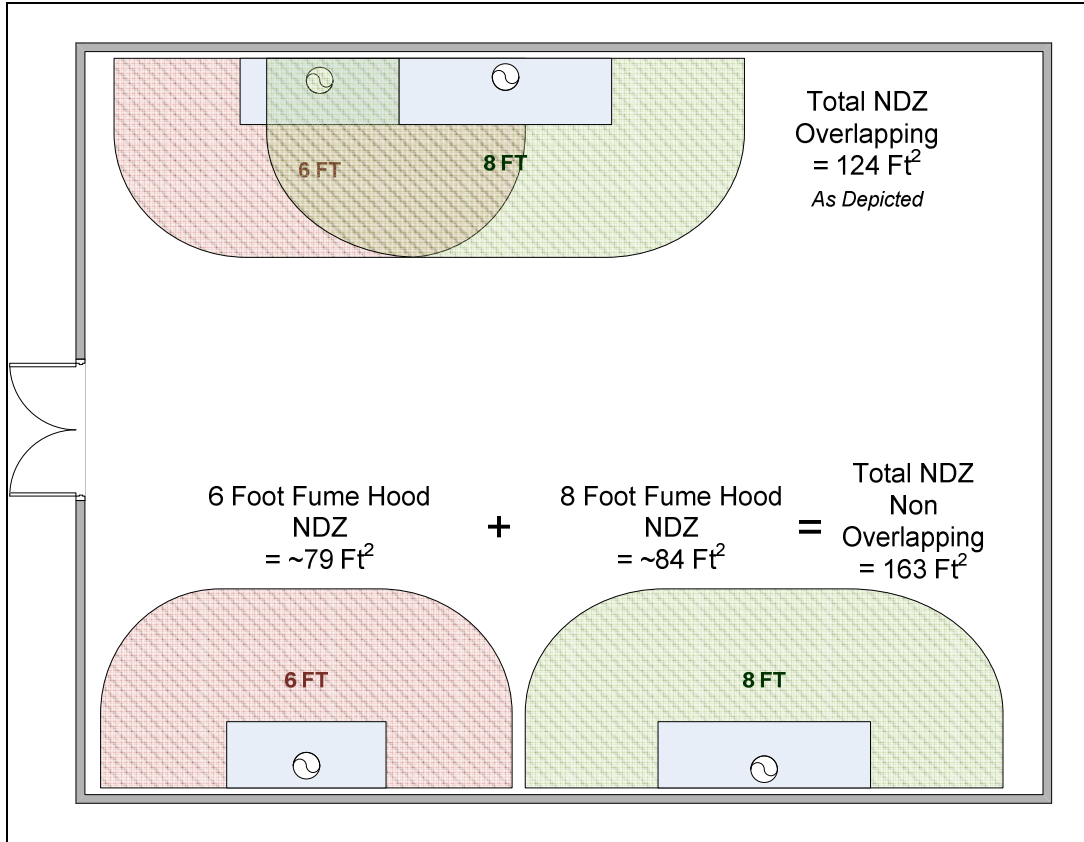


Figure 4 Diagram of laboratory hoods showing adjacent and overlapping NDZs.

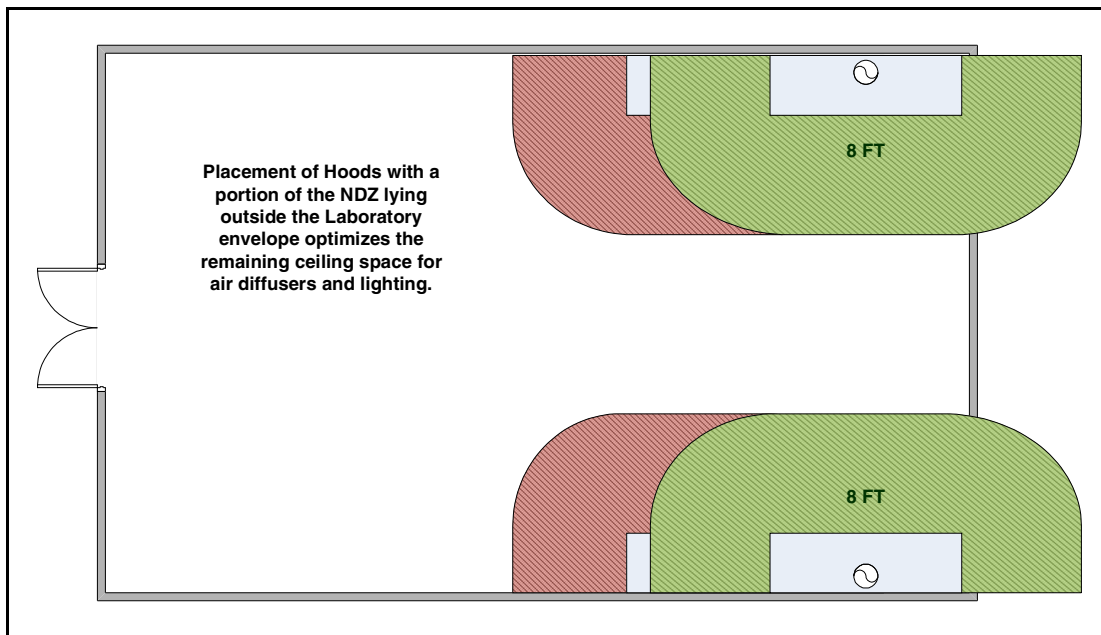
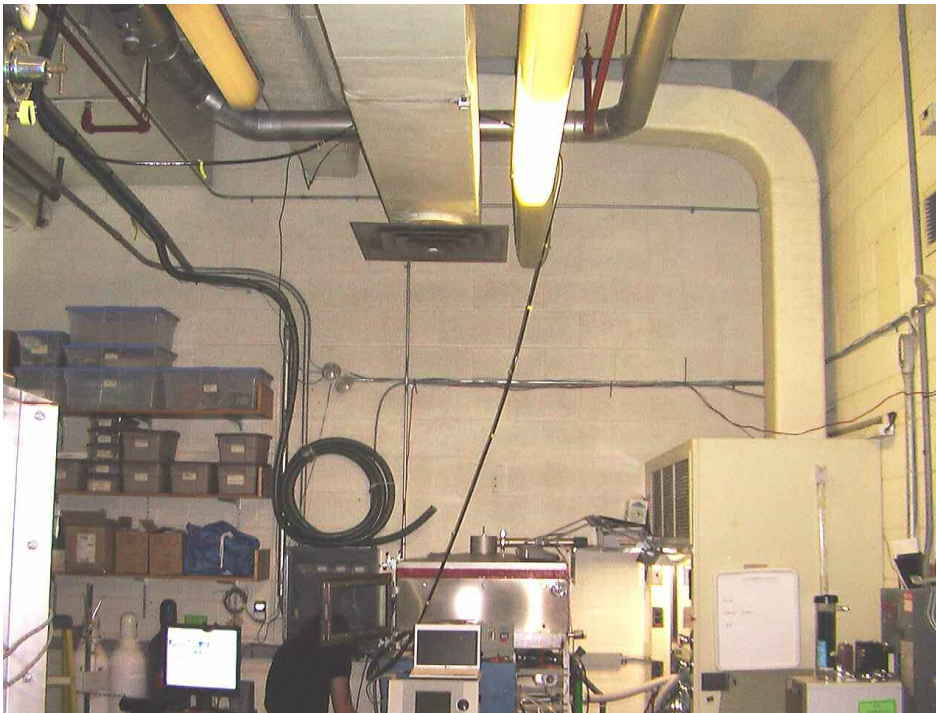


Figure 5 Diagram of adjacent laboratory hoods showing overlapping NDZs.

As the fume hood density in a lab space increases, the effective area of the combined NDZ(s) also increases. As such, the amount of ceiling space available for the installation of diffusers, lighting fixtures, or other furnishings decreases accordingly.

Once the fume hoods have been selected, the air flow requirements must be specified and the lab designer must select air diffusers that have performance characteristics capable of delivering the required air volume, provide adequate mixing for space conditioning and minimize affects on fume hood performance. Ideally cross drafts at the plane of the sash should be limited to a maximum of 50% of the fume hoods design face velocity.

Air diffusers create airflow patterns with velocities that are directly proportional to the volume of air that they are delivering. As the air is distributed into the space, the supply velocities will degrade due to expansion of the discharge plume. The degradation of the velocity is expressed by the term, Terminal Velocity (*TV*). Additionally the characteristic length (*L*) or distance from the diffuser for achieving the *TV* places constraints on the placement of diffusers. The discharge characteristics are particularly important when diffusers are not mounted flush to the ceiling or free standing in labs with high ceilings (see Figure 6).

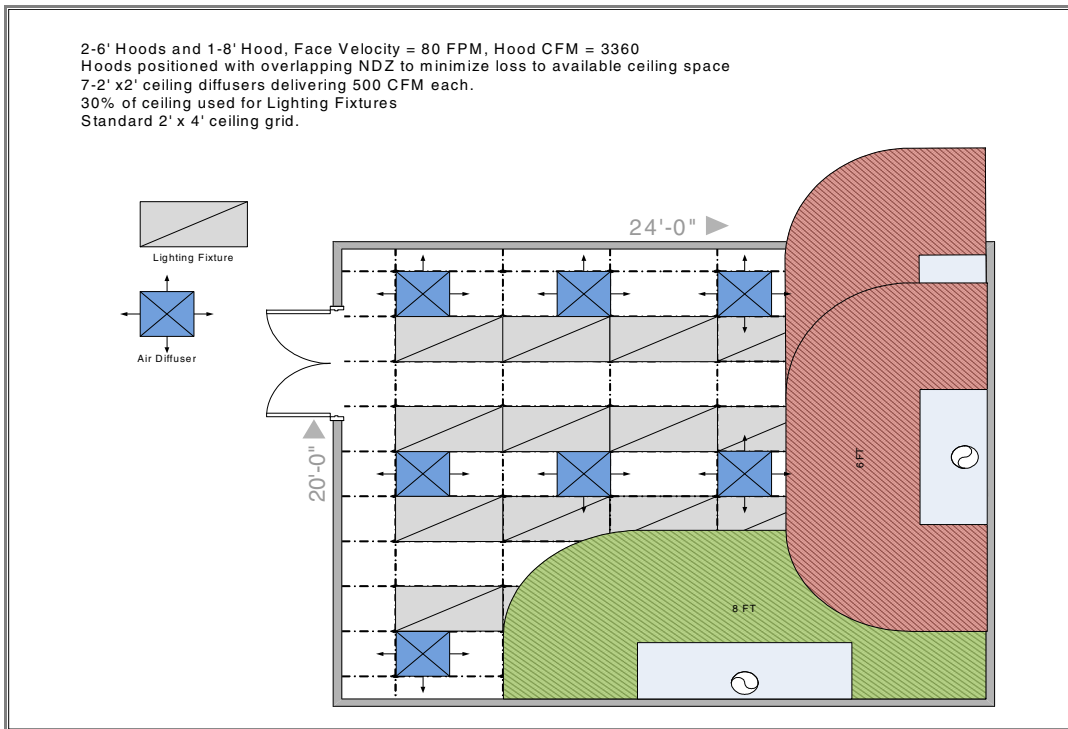


**Figure 6 Lab with high ceiling and free mounted diffuser above fume hood.**

Air diffusers should be selected and placed that can deliver the maximum volume of air while minimizing the distance from the diffuser for achievement of the maximum *TV*. In addition to locating diffusers at least 5 feet from laboratory hoods, the discharge area of the diffuser should be sufficient (approximately 2 times the area of the fume hood design openings). The 2:1 ratio can help determine the number of diffusers required to provide adequate make-up air to the lab. The number and size of the diffusers together with the area of the NDZ provides a natural limit

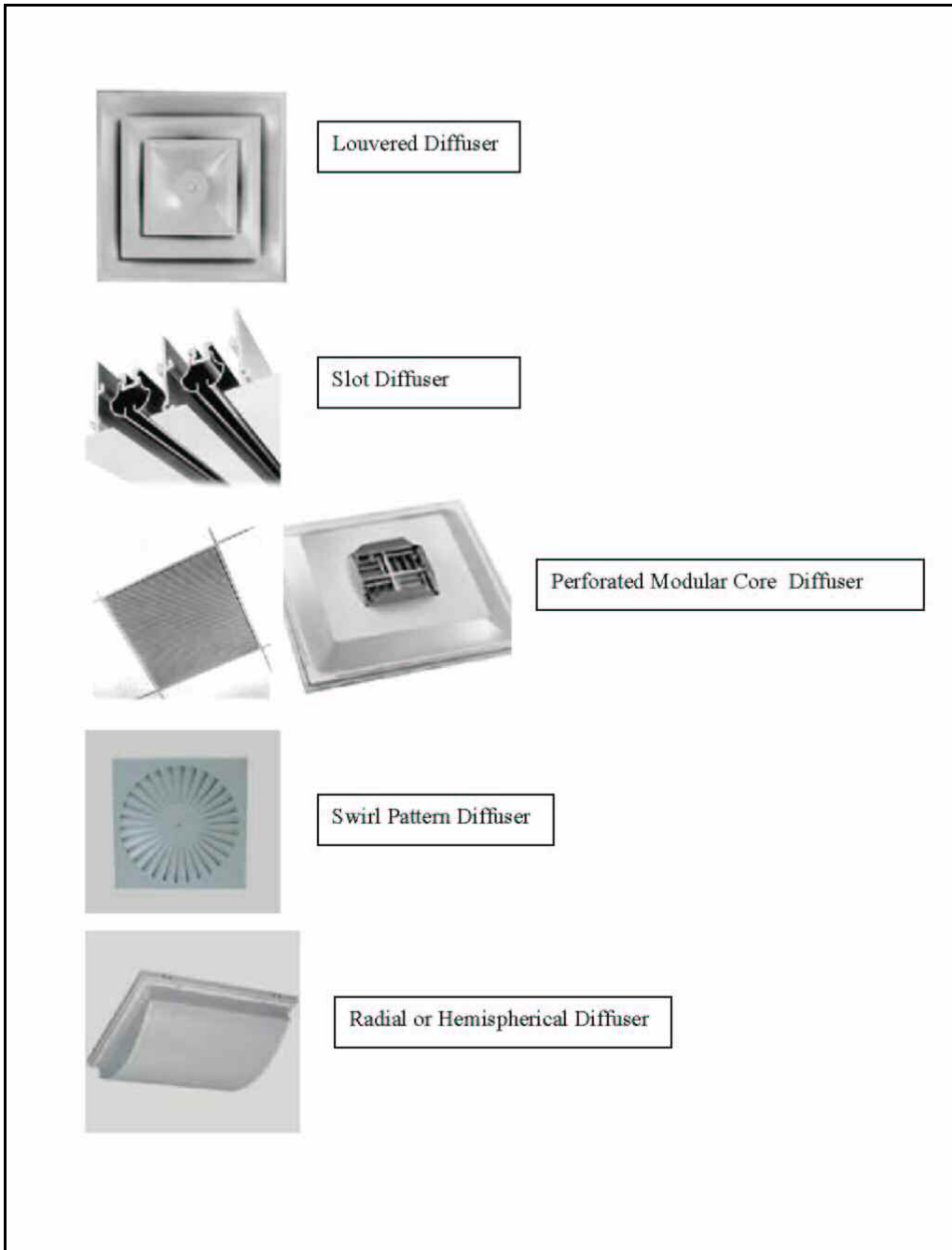


to the allowable fume hood density. The relationships between the size of the fume hoods, hood opening size, average face velocity (exhaust flow), the area of the resultant NDZs, and the remaining area in the lab for locating diffusers determines the maximum number of fume hoods that can be installed in a lab. In general, the lab area should be at least 10 times the design opening area of the fume hoods and ideally approximately 20 times the sash opening area. Refer to Figure 7 for a diagram of a laboratory showing the space available for supply diffusers outside the NDZ and ceiling space required for lights and other services. Lights and other services can occupy 15% to 20% of the ceiling space.



**Figure 7 Diagram showing location of supply diffusers outside NDZ.**

## Selected Diffuser Styles



**Figure 8** Sample of different air supply diffusers.

**Louvered Diffuser** – These diffusers are generally high velocity diffusers routinely used in office or commercial buildings where larger volumes of air and terminal velocities are a not a

primary concern. Horizontal throw from this type of diffuser will range from 16-28 ft. to achieve a terminal velocity of 50 FPM with air volumes ranging from 300-500 CFM.

**Slot Diffuser** - These diffusers are routinely used to provide an air curtain which will provide a thermal barrier adjacent to windowed exterior walls. Horizontal throw of this type of diffuser will range from 16-28 ft. to achieve a terminal velocity of 50 FPM with air volumes ranging from 300-500 CFM.

**Perforated Diffuser with Modular Core** – This type of diffuser is routinely used in laboratory and office spaces. The modular core can be specified to deliver air in 1, 2, 3, or 4 directions. Directional flow characteristics allow placement of diffusers near walls and corners of the space. Horizontal throw of this type of diffuser will range from 9-13 Ft. to achieve a terminal velocity of 50 FPM with air volumes ranging from 300-500 CFM.

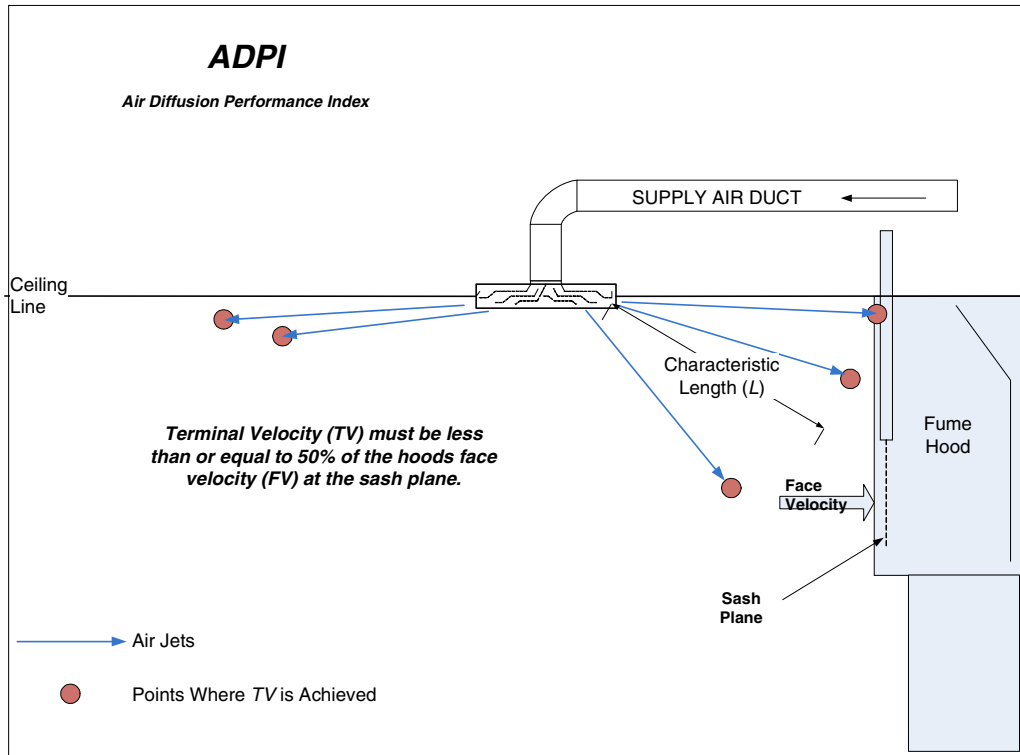
**Swirl Pattern Diffuser** – This type of diffuser is relatively new and has earned a place in applications requiring reduced horizontal throws. Horizontal throw of this type of diffuser will range from 5-13 Ft. to achieve a terminal velocity of 50 FPM with air volumes ranging from 300-500 CFM.

**Radial Diffuser or Hemispherical Diffuser** – This style of diffuser was designed for critical space applications and laboratories where turbulence due to air jets must be minimized. Horizontal throw of this type of diffuser will range from 4-8 Ft. and vertical throws of 6-7 Ft. to achieve a terminal velocity of 50 FPM with air volumes ranging from 300-500 CFM.

Radial and Hemispherical diffusers are most appropriate for laboratories with fume hoods.

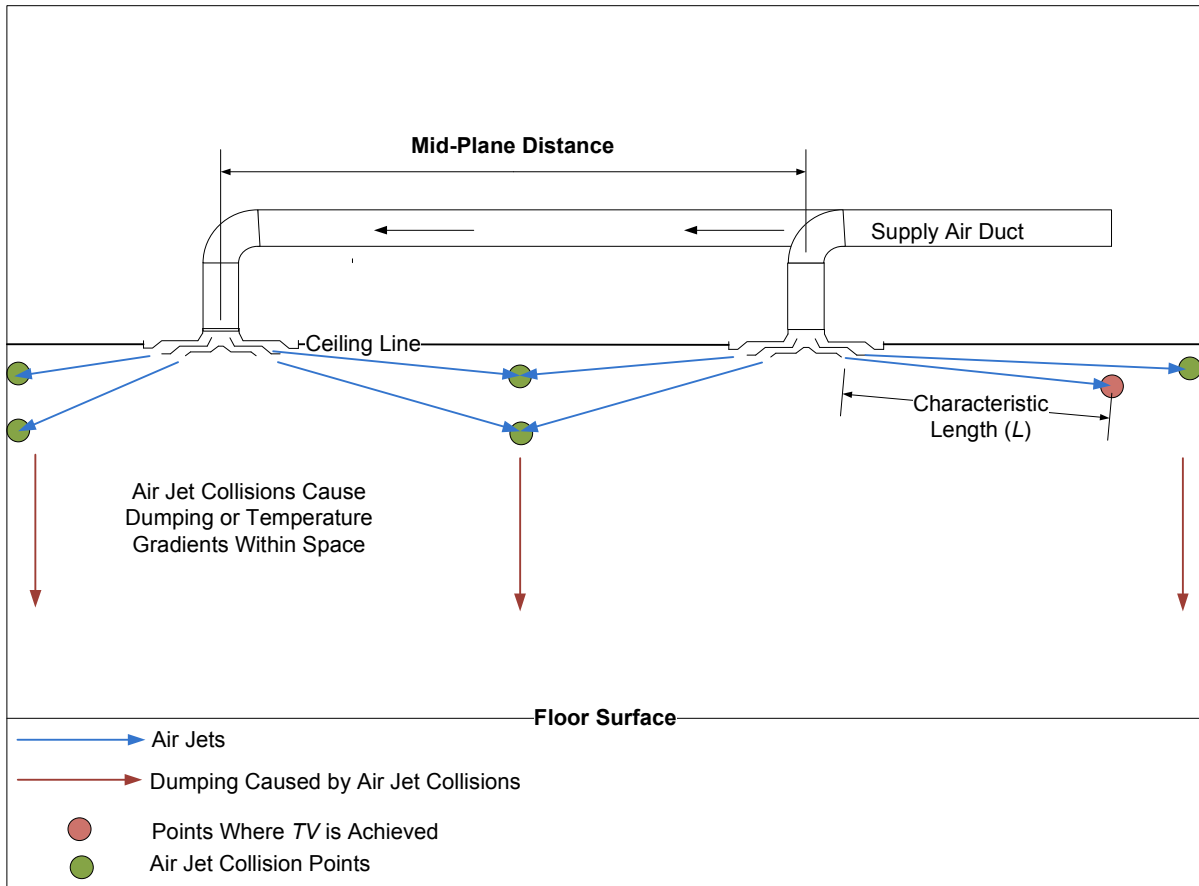
## Supply Diffuser Performance Index

The location, size, type, supply volume and discharge temperatures must be evaluated to ensure proper selection and location of supply diffusers. **Figure 9** below illustrates Terminal Velocity ( $TV$ ) and Characteristic Length ( $L$ ) for air diffusers. Diffuser manufacturers can provide **Air Diffusion Performance Index** (ADPI) ratings for their diffusers where the higher the rating the better the diffuser should perform to provide space conditioning. The ADPI for a diffuser involves the ability of the diffuser to mix the supply air with room air to provide a comfortable working condition within the space. From an energy perspective and to maximize utility of conditioned air, it is desirable to ensure proper mixing over the range of potential supply volumes. However, the ADPI does not indicate the effect on hood performance and the diffuser must not negatively impact performance of a laboratory hood over the range of supply volumes and discharge temperatures. Diffusers listed as critical environment or laminar flow type are considered most appropriate for use in laboratories.



**Figure 9** Diagram showing supply diffuser and characteristic length from diffuser for a TV.

Designers must consider limiting hood density due to the resultant increase in air diffuser density. As the density of diffusers increase airflow from the diffusers will collide with walls and with each other causing temperature gradients within the space. During cooling cycles, dumping of cold air may occur when air jets collide. This effect will render the space uncomfortable for occupants and is caused when the mid-plane distance between diffusers is too short or diffusers are located too close to walls or other obstructions.



**Figure 10** Diagram of diffusers in close proximity showing interaction of airflow from two diffusers with colliding jets.

### System Operating Modes

The system operating mode will also impact the design of the air distribution system. Laboratories operating CAV hoods are uniquely different from laboratories operating VAV hoods. CAV hoods should operate continuously at full volume because there is no feedback to the control system for hood sash position, therefore air diffusers must operate at maximum volumes. VAV hoods modulate exhaust volumes based on sash position; therefore the air diffusers modulate supply air proportionately to the sash position. Diffusers for VAV laboratories must be capable of providing effective room air distribution over the range of operating flow volume set points and discharge temperatures.

**Table 1**

<b>CAV vs. VAV Supply Air Volume Requirement</b>							
<b>800 Ft<sup>2</sup> Lab Space w/ 10' Ceiling Height</b>							
<b>6' Hoods Operating at Maximum Sash Opening(28")</b>							
<b>80 Ft/Min Face Velocity</b>							
<b>CAV<sup>(1)</sup></b>				<b>VAV<sup>(2)</sup> (250 CFM Min/Hood)</b>			
<b># Hoods</b>	<b>Supply Volume Required (CFM)</b>	<b>Exhaust ACH Rate (Hood Only)</b>	<b>Floor Space to Hood Opening Ratio</b>	<b># Hoods</b>	<b>Supply Volume Required (CFM)</b>	<b>Exhaust ACH Rate (Hood Only)</b>	<b>Floor Space to Hood Opening Ratio</b>
1	964	7	64:1	1	250 - 964	2 - 7	64:1
2	1928	14	32:1	2	500 - 1928	4 - 14	32:1
3	2892	22	21:1	3	750 - 2892	6 - 22	21:1
4	3856	29	16:1	4	1000 - 3856	8 - 29	16:1
5	4820	36	13:1	5	1250 - 4820	10-36	13:1

<sup>1</sup> CAV hoods with local on/off control for the hoods require the lab space to be equipped with a general exhaust grille capable of maintaining minimum air exchange rates for the laboratory, down to the space offset requirement during un-occupied times and the general exhaust grille's operation must be interfaced with hood(s) operation. CAV hoods that can be shut down locally lose the capability to maintain the capture of any contaminants within the hoods during the hood "off-time" periods.

<sup>2</sup> VAV hoods operate continuously and modulate down to the minimum exhaust airflow requirement.

As demonstrated above, as the density of fume hoods increase in a lab space the air supply requirement also increases. This constraint requires an increase in the density of supply air diffusers or increases the *TV* and *L* of selected air diffusers in order to meet the demand for higher supply air volume.

The natural limit for air supply diffuser density would be to incorporate the entire ceiling space as the air diffuser; this is impractical due to space required for lighting, general exhaust grilles, and other fixtures or furnishings that may consume a percentage of the ceiling area. Therefore; a metric needs to be adopted to limit hood density based of the summation of fume hood openings in relation to the square footage of the laboratory space. As a general guideline, the available lab area should be approximately 20 times the design summation of the opening area of the laboratory hoods. Highlighted rows in **Table 1** above indicate that hood density is too great and will require an excessive amount of supply air for the given space.

### **Air Distribution Effectiveness**

The effectiveness of the air distribution system can be judged by several factors:

- Utilizing the maximum percentage of air to condition the space versus short circuited with little or no utility.
- Causing minimal or no effect on the operation of exposure control devices.

- Maintaining IAQ.
- Providing minimal “First Cost” and subsequent operational costs.
- Maintaining differential pressure relationship to adjoining spaces.

Distribution effectiveness can be affected by people, movement within the room, location of obstructions and equipment, heat sources, and system operating modes. The design of the air distribution systems must take into account all of these factors for maximum effectiveness. Selection of diffusers for VAV laboratories is particularly challenging due to the changing supply volume and discharge temperatures. In VAV labs, the air supply from supply diffusers must not affect operation of the fume hoods when the sashes are open regardless of the discharge temperature and must provide adequate room air mixing at low volumes when the sashes are closed. As such, the air distribution systems must properly condition the space, compliment hood performance at all operating modes and minimize installation and operating costs.