SECTION III

MODELING

SECTION III - TABLE of CONTENTS

3. MODELING

This section describes the primary features of the laboratories, the laboratory hood, and configuration variations as modeled in this project. As well as this general information, other specific variations are detailed (for example, the presence of a scientist in front of the laboratory hood). In particular, one of the key variations is associated with the diffuser type and position.

A summary of the different configurations is provided here with a full database of the simulations, their configuration changes, and summary results given in the appendix.

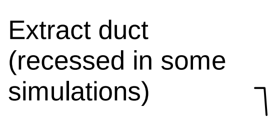
3.1 Laboratory

Two basic laboratory modules are defined in order to investigate the effect of air flow within the laboratory on the containment efficiency of the hood. The two sizes chosen are representative of large (33 ft x 22 ft) and small (22 ft x 11 ft) laboratories.

3.1.1 Large Laboratory

The large laboratory (figure 3.01) occupies a floor area of 33 ft (10.06 m) by 22 ft (6.70 m). The ceiling height is 10 ft (3.05 m). There are three doors and two windows in the walls of the laboratory. Working space is provided within the laboratory in the form of three benches; one along each of the longer walls and one down the center of the room. A number of tall cupboards and five desks are also provided in the laboratory area.

For all but the displacement ventilation simulations, air is introduced through ceiling mounted diffusers. All the air exits the laboratory through the general laboratory exhaust and/or the fume hood(s). In line with common practice more air is exhausted than supplied. As a result, for most simulations, make up air is allowed to enter through a crack under the main door placed in the shorter wall.



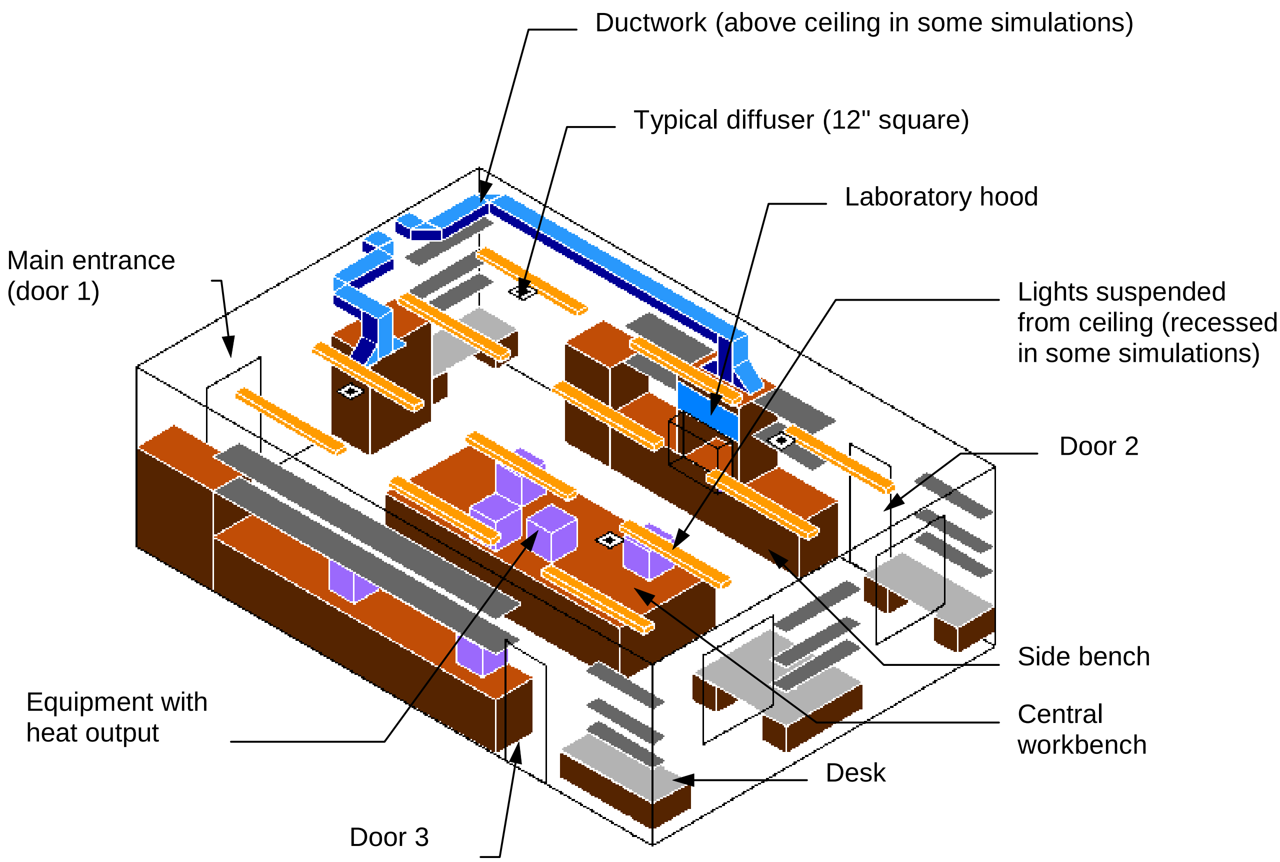


Figure 3.01 Layout of large laboratory

The majority of simulations have a total heat load of 8 W/ft^2, a lower or higher heat load is applied in selected simulations to determine sensitivity. Included in this is lighting (2.3 W/ft^2) in the form of fluorescent tubes suspended from, or recessed into, the ceiling. The remaining heat load is distributed around the laboratory. A source of heat, distributed over an appropriate volume, is placed upon each desk to represent equipment such as computers. In some simulations a scientist is modeled working in front of the fume hood, with their chest either 4" or 6" away from the sash of the hood, and their arms extending through the sash opening.

3.1.2 Small Laboratory

The small laboratory (figure 3.02) has dimensions 22 ft (6.7 m) by 11 ft (3.35 m) with a ceiling height of 10 ft (3.05 m). There are two doors and one window in this laboratory. The conceptual layout and heat gains for this laboratory are basically the same as for the larger laboratory. Of course, due to more limited space there is no central bench and only one desk.

Air is introduced at the ceiling level and is removed through the laboratory hood. In many of the simulations the imbalance is such that a make - up air grille is required, normally in addition to the crack under the door. This make - up air grille is placed above the main door placed in the short wall.

3.2 Hood

The laboratory hood is modeled by describing the physical surfaces and objects with any associated flow and heat transfer (figure 3.03). The following describes the representation used for the simulations undertaken in this project.

It is well known that the design of the laboratory hood can significantly affect the containment performance, hence for this research a generic 4 foot (total width, 1.22 m) hood is selected. Since this project is not intended to address the effect of actual laboratory hood design or the dynamics of the associated hood ventilation system, the model simulates the flow from the laboratory only as far as the slots in the rear baffle. The flow rate through each of these slots and the slot sizes and their positions are prescribed on the basis of previously determined experimental data (Memarzadeh, 1989). This approach should ensure that the performance in practice is at least as good as than that predicted, since an aerodynamically designed hood would be expected to perform as well as or better than the generic hood modeled here.

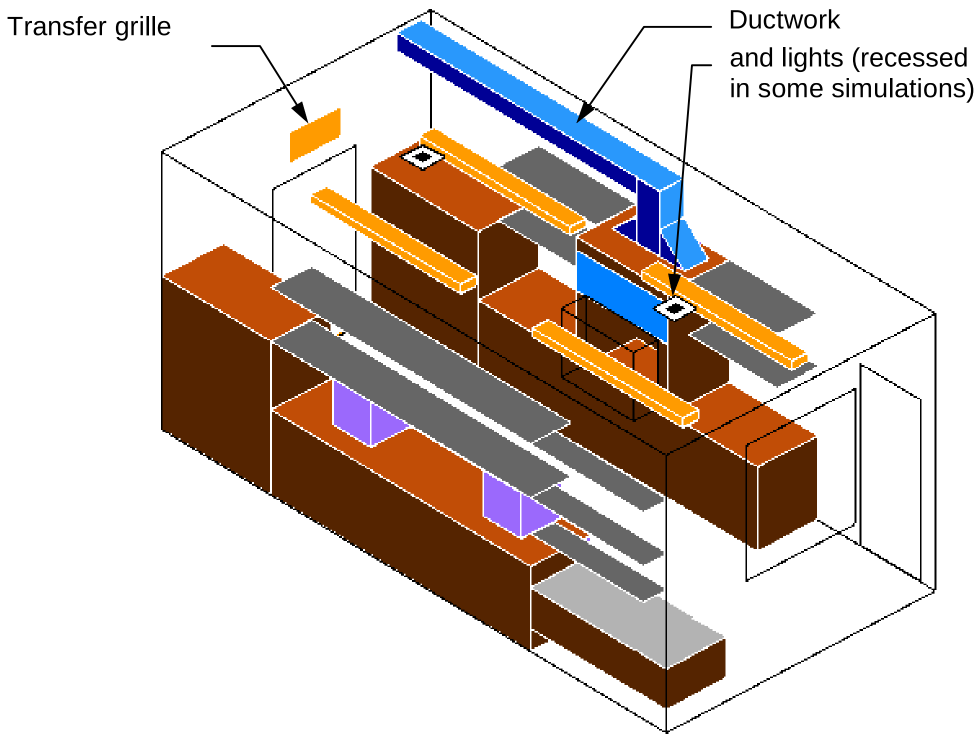
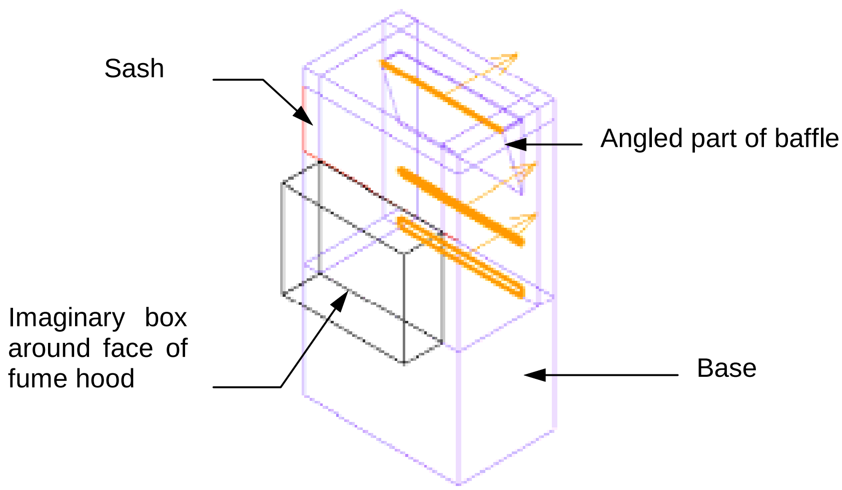
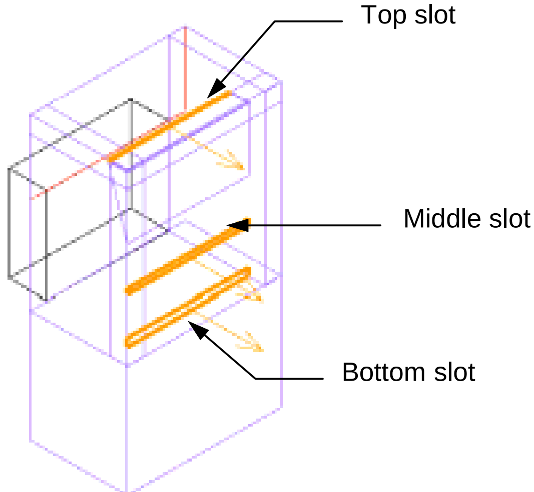


Figure 3.02 Layout of small laboratory.



Front view of fume hood



Back view of fume hood

Figure 3.03 General layout of fume hood models

The sash is assumed to be at its maximum opening position (30 in, 0.76 m) for the majority of simulations, however, some simulations are conducted with the sash at 25% opening. The width of the open region of the hood is 3 ft 2 in (0.96 m). The total flow - rate through the hood for the majority of the simulations is set so that the average face velocity is 100 fpm (0.507 m/s). Some of the simulations are undertaken with an average face velocity of 50 fpm (0.254 m/s), thus allowing comparison of the two standards.

For some simulations, a bulkhead was included above the hood (figure 3.04) so the cabinet of the hood extends all the way to the ceiling.

In practice, the hood leakage rate is directly related to the rate of the contamination source inside the hood, representing an infinite number of conditions. In order to determine the relative leakage rate of the hood in different laboratory configurations, the sash opening is filled with contamination to represent a worst case scenario. Thus any leakage from the hood can be observed and quantified. The leakage predicted by the simulation can be considered as a factor that can be applied to a known concentration inside the hood. Thus the leakage from within the laboratory hood through the sash opening into the working zone, and, from the working zone into the laboratory can be predicted for any given source. Diagrams showing concentration distributions can be similarly scaled by multiplying the predicted concentrations by the actual concentrations in the laboratory hood.

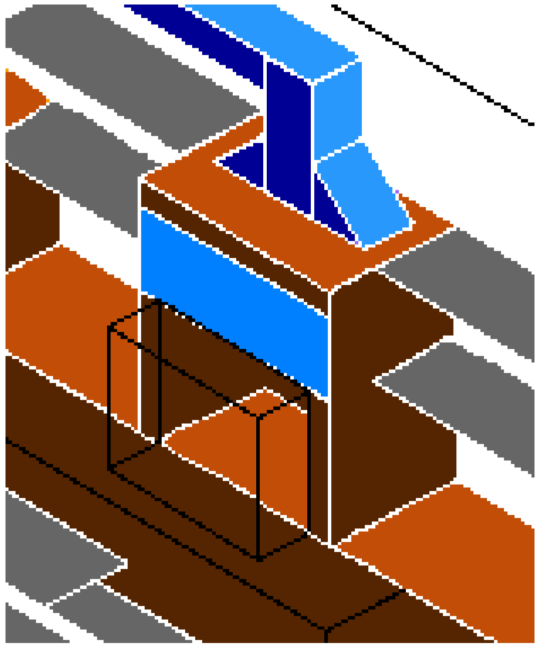
3.3 Laboratory Configurations

To investigate a wide range of parameters, the basic models described in section 3.1 are modified. Where possible, only one parameter is changed in order to fully assess the effect. However, in some instances several parameters are directly linked, and therefore more than one needs to be altered. For example, the supply flow - rate and temperature are linked to maintain a constant cooling load. Three tables are provided at the end of this section (tables 3.4-3.6) as a summary of the simulations modeled and to allow relevant data selection.

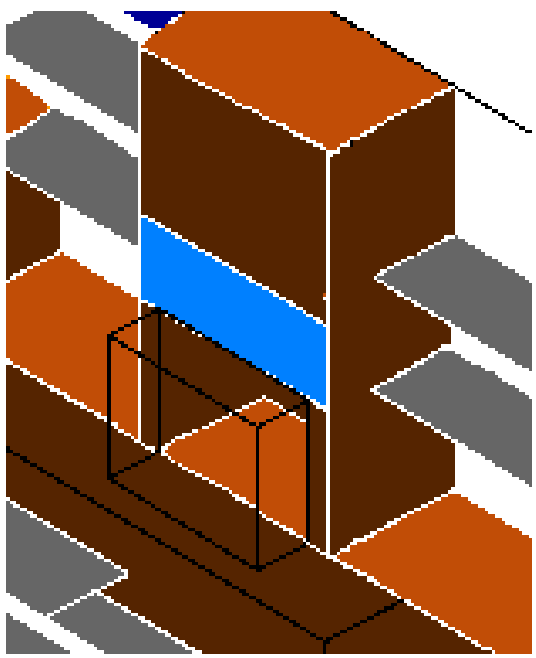
3.3.1 Hood Position

Hood position is important for two reasons :

does the position in the laboratory protect or expose the laboratory hood in regard to the room air movement?
does one hood position compared with another significantly impair hood containment performance?



Hood without bulkhead



Hood with bulkhead

Figure 3.04 Hood with and without bulkhead.

3.3.1.1 Single hood positions

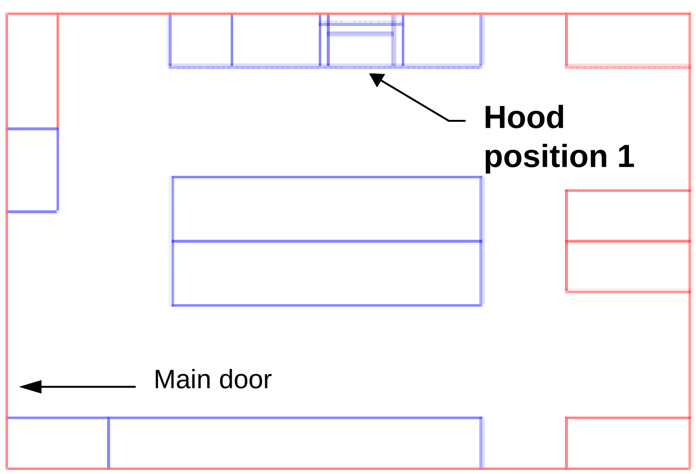
To investigate the first question, simulations address a single hood in the open on the long or the short wall as well as a single hood placed in a corner. The three hood positions modeled for the single laboratory hood in both the small and large laboratories are listed in table 3.01. To accommodate this variation the laboratories were re - arranged. A plan view of the layout is shown for large laboratory and small laboratory models in figures 3.05 and 3.06 respectively.

Table 3.01 Description of single hood positions

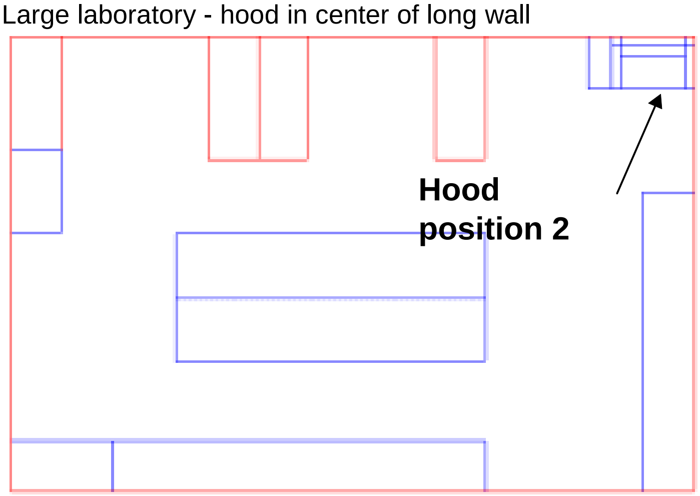
Hood Position	Description
1	Center of long wall
2	Sited on long wall close to corner
3	Center of short wall

3.3.1.2 Double hood positions

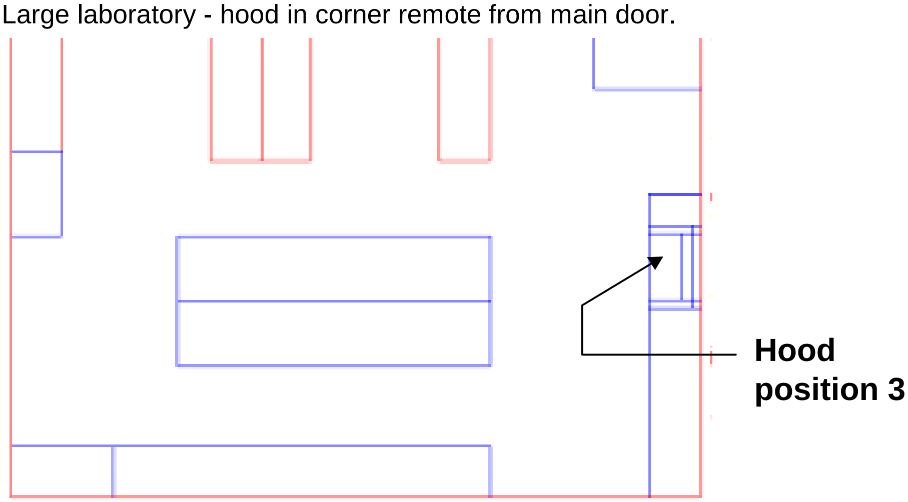
To answer the question about hood interaction, for the small laboratory, simulations are also undertaken for a number of configurations with two laboratory hoods (figures 3.07 to 3.11, table 3.02).



Large laboratory - hood in center of long wall

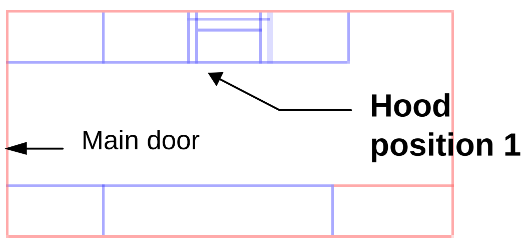


Large laboratory - hood in corner remote from main door.



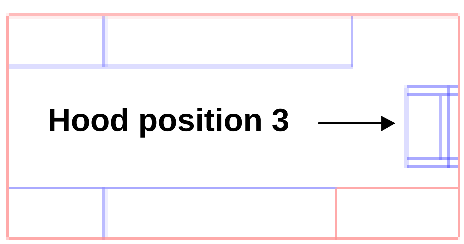
Large laboratory - hood in center of short wall opposite main door.

Figure 3.05 Hood positions in large laboratory.



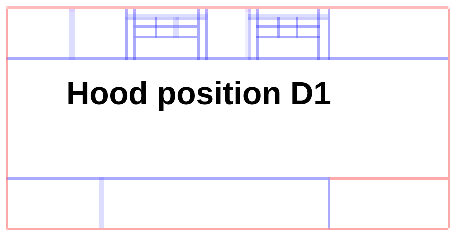
Small laboratory - hood in centre of long wall.

Small laboratory - hood in corner near main door.

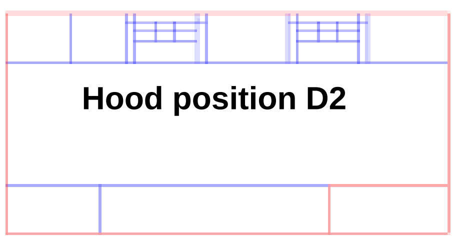


Small laboratory - hood in center of long wall.

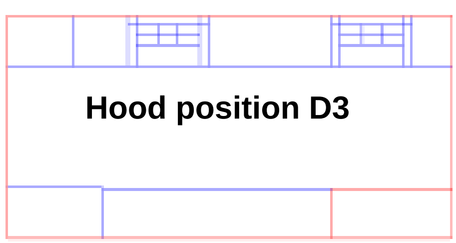
Figure 3.06 Hood positions in small laboratory.



Small laboratory - two hoods on same wall (2 ft apart).

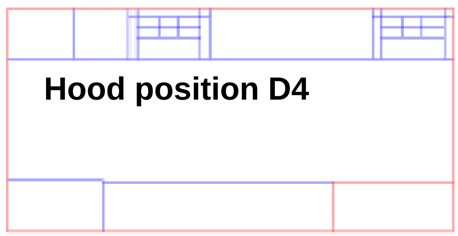


Small laboratory - two hoods on same wall (4 ft apart)

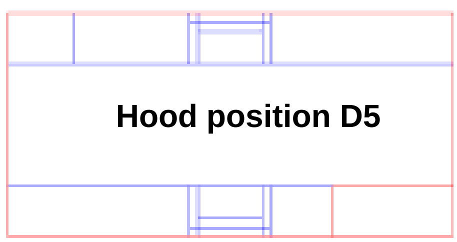


Small laboratory - two hoods on same wall (6 ft apart)

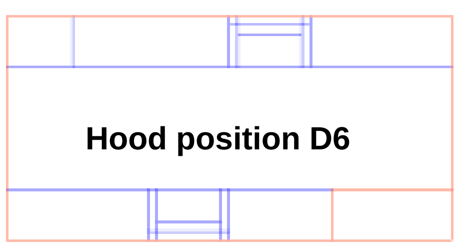
Figure 3.07 Double hood layout.



Small laboratory - two hoods on same wall (8 ft apart).

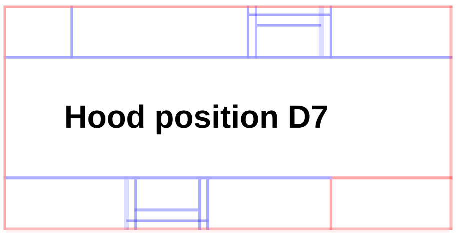


Small laboratory - two hoods on opposite walls.

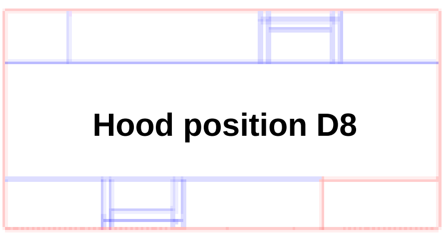


Small laboratory - two hoods on opposite walls (no gaps between sides)

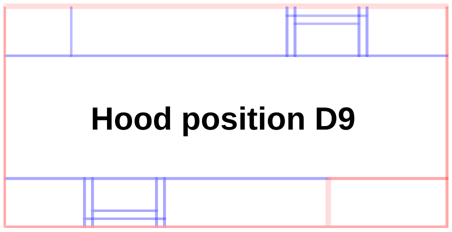
Figure 3.08 Double hood layout**.**



Small laboratory - two hoods on opposite walls (2 ft apart).

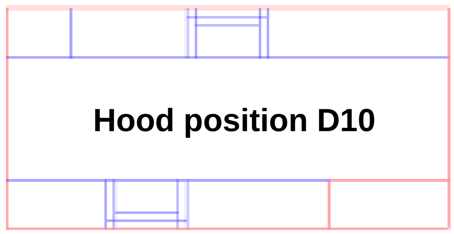


Small laboratory - two hoods on opposite walls (4 ft apart).



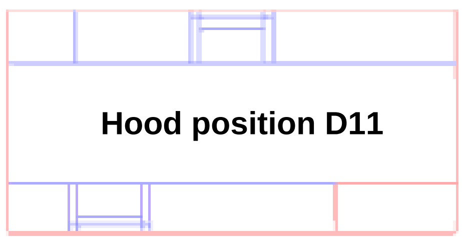
Small laboratory - two hoods on opposite walls (6 ft apart)

Figure 3.09 Double hood layout**.**

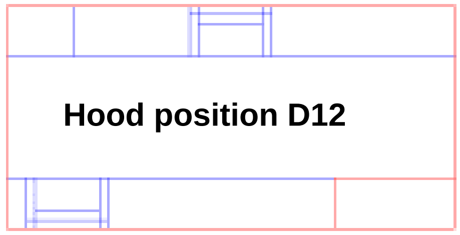


Position D10 - D12 only one hood moves.

Small laboratory - two hoods on opposite walls (no gap between sides.



Small laboratory - two hoods on opposite walls (2 ft apart).



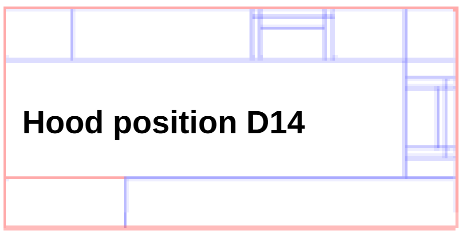
Small laboratory - two hoods on opposite walls (4 ft apart)

Figure 3.10 Double hood layout.

Hood 4 ft from corner

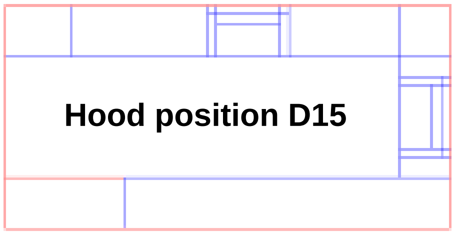
Small laboratory - hoods on adjacent perpendicular walls.

Hood 6 ft from corner



Small laboratory - hoods on adjacent perpendicular walls.

Hood 8 ft from corner



Small laboratory - hoods on adjacent perpendicular walls.

Figure 3.11 Double hood layouts

Table 3.02 Description of double hood positions

Hood Position	Description
D1	Two hoods on same wall, 2 feet apart
D2	Two hoods on same wall, 4 feet apart
D3	Two hoods on same wall, 6 feet apart
D4	Two hoods on same wall, 8 feet apart
D5	Two hoods on opposite walls, directly opposite
D6	Two hoods on opposite walls, both moved, 0 feet apart
D7	Two hoods on opposite walls, both moved, 2 feet apart
D8	Two hoods on opposite walls, both moved, 4 feet apart
D9	Two hoods on opposite walls, both moved, 6 feet apart
D10	Two hoods on opposite walls, one moved, 0 feet apart
D11	Two hoods on opposite walls, one moved, 2 feet apart
D12	Two hoods on opposite walls, one moved, 4 feet apart
D13	Two hoods on perpendicular walls. One center of 11 ft wall, second nearest edge 4 ft from corner.
D14	Two hoods on perpendicular walls. One center of 11 ft wall, second nearest edge 6 ft from corner.
D15	Two hoods on perpendicular walls. One center of 11 ft wall, second nearest edge 8 ft from corner.

3.3.2 Diffuser Types

A number of different types of supply diffusers are modeled (table 3.03). These were selected from catalog data with respect to acceptable flow rates through each diffuser while maintaining a noise level in the range of 35 to 40 dB. In some of the tests the velocity flow rate was significantly altered. For comparison, the basic diffusers were utilized but with the realization that noise criteria, etc., would be exceeded. Before use in the laboratory models each diffuser was tested and compared with manufacturer's throw data by constructing a numerical test module. It was intended that a model as accurate as possible was achieved.

Table 3. 03 Diffuser types

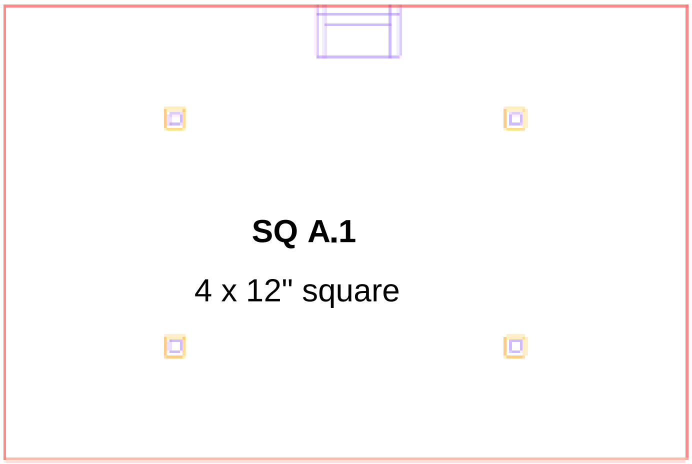
Name	Description
SQ A	four, 12 inch square diffusers
SQ B	two, 24 inch square diffusers
SQ C	four, 24 inch square diffusers
TAD A	two, 48 inch by 24 inch radial diffusers
TAD B	two, 24 inch by 24 inch radial diffusers
TAD C	four, 24 inch by 24 inch radial diffusers
LAM A	six, 48 inch by 12 inch down - flow diffusers
LAM B	four, 48 inch by 24 inch down - flow diffusers
DOWN A	four, 24 inch by 24 inch down - flow diffusers
DOWN B	four, 24 inch by 48 inch down - flow diffusers
PERF A	four, 12 inch by 12 inch perforated diffusers, horizontal throw
DISP 1	fourteen, 24 inch square floor grilles
DISP 2	four, wall displacement units
SM SQ A	two, 12 inch square diffusers
SM SQ B	one, 24 inch square diffuser
SM TAD A	one, 24 inch by 24 inch radial diffuser
SM LAM A	two, 48 inch by 12 inch down - flow
SM PERF A	two, 12 inch square perforated diffusers, horizontal throw

The diffuser types were also used in different layouts. A complete list giving all the diffuser layouts is presented (tables 3.04 and 3.05) along with plan views of the diffuser configurations (figures 3.12-3.31). Included in the table are the simulation numbers relating to the particular diffuser layout (see also section 3.3.5).

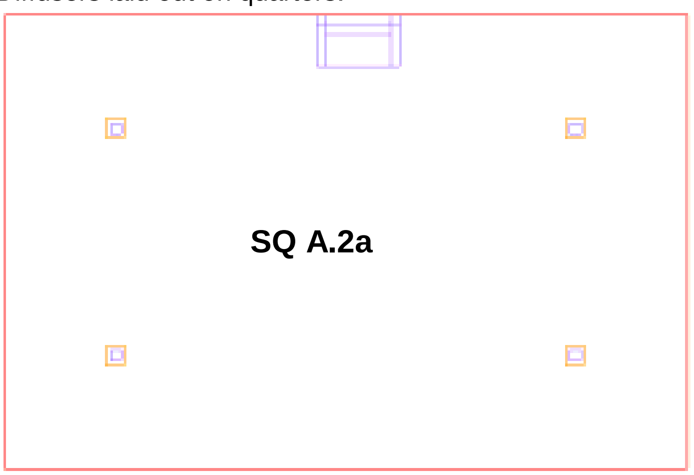
Table 3.04 Diffuser positions - large laboratory (33ft x 22ft)
(figures 3.12 to 3.23)

Layout Name	No. / Type / Size	Description	Simulation Nos.
SQ A.1	4 / Square / 12”	Laid out on quarters	41,43,44,52-58, 76-9,122,142
SQ A.2a	4 / Square / 12”	Spaced close to end walls	61
SQ A.2b	4 / Square / 12”	Spaced close to end walls, quadrants towards walls blanked	62
SQ A.3	4 / Square / 12”	Diffusers staggered	63
SQ B.1	2 / Square / 24”	Staggered spacing	42,45,46,106, 107,123,143
SQ B.2	2 / Square / 24”	Along centerline	64,86-88
SQ B.3	2 / Square / 24”	In line in front if hood, quadrant towards hood blanked	65
SQ C.1	4 / Square / 24”	Spaced close to end walls	2,10,18
SQ C.2	4 / Square / 24”	Laid out on quarters	3,15,19,25,28,31,33
SQ C.3	4 / Square / 24”	Diffusers staggered	4,11
PERF A.1	4 / 12” x 12”	Laid out on quarters	41b,54b-56b,125, 145
PERF A.2a	4 / 12” x 12”	Spaced close to end walls	61b
PERF A.3	4 / 12” x 12”	Diffusers staggered	63b
DOWN A.1	4 / Square 24”	Spaced close to end walls	7,21,27,30
DOWN A.2	4 / Square 24”	Diffusers staggered	8,14
DOWN B.1	4 / 24” x 48”	Spaced close to end walls	22,24
DOWN B.2	4 / 24” x 48”	Diffusers staggered	23
LAM A.1	6 / Down-flow / 48”x12”	Aligned short edge in lines of 3, long edges in direction of long walls	47,80
LAM A.2	6 / Down-flow / 48”x12”	Aligned long edge in lines of 3, long edges in direction of long walls	66
LAM B.1	4 / Down-flow / 48”x12”	Laid out on quarters, long edges	48,89-91

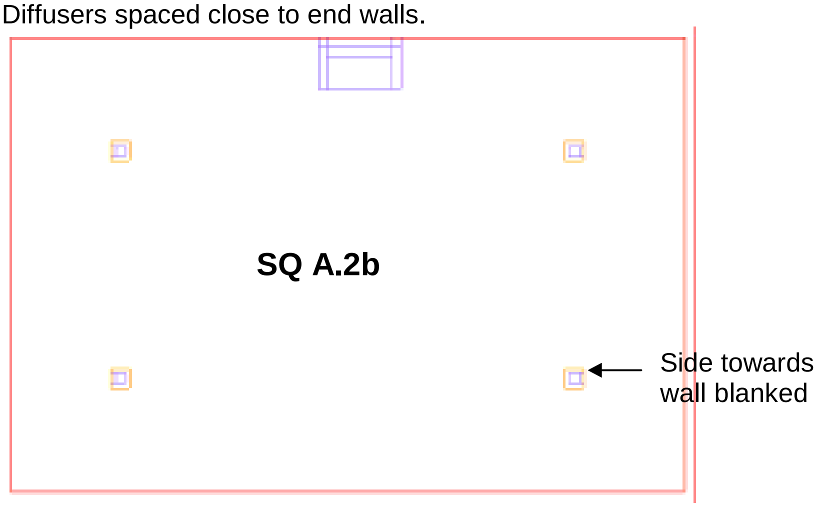
Layout Name	No. / Type / Size	Description	Simulation Nos.
		in line with long walls	
LAM B.2	4 / Down-flow / 48”x12”	Spaced close to end walls, long edges in line with long walls	67
LAM B.3	4 / Down-flow / 48”x12”	Diffusers staggered, long edges in line with long walls	68
TAD A.1	2 / Radial / 48”x24”	Along centerline, radial spread across laboratory	16,17,20,26,29,32,34,49,49c, 92-94
TAD A.2	2 / Radial / 48”x24”	Staggered array, radial spread across laboratory	5,12, 69,69c
TAD A.3	2 / Radial / 48”x24”	Staggered array, diffusers close to hood, radial spread across laboratory	6,13, 70,70c
TAD B.1	2 / Radial / 24”x24”	Along centerline, radial spread across laboratory	50,50c,81,124, 144,147
TAD B.2	2 / Radial / 24”x24”	Staggered array, radial spread across laboratory	71,71c
TAD B.3a	2 / Radial / 24”x24”	Staggered array, diffusers close to hood, radial spread across laboratory	72,146
TAD B.3b	2 / Radial / 24”x24”	Staggered array, diffusers close to hood, radial spread along laboratory	73
TAD C.1a	4 / Radial / 24”x24”	Laid out on quarters, radial spread across laboratory	51
TAD C.1b	4 / Radial / 24”x24”	Laid out on quarters, radial spread along laboratory	74
TAD C.2	4 / Radial / 24”x24”	Staggered array, radial spread across laboratory	75,75c
DISP 1		14 off 24” floor grilles	59
DISP 2		4 off standing displacement units	60
NONE	3 Free stream	3 open sides to the hood in isolation model	**0,35-40**



Diffusers laid out on quarters.



Diffusers spaced close to end walls.



Diffusers close to walls - quadrants towards short walls blanked.

Figure 3.12 Diffuser layout - large laboratory.

SQA.3

Diffusers staqqered.

SQB.1

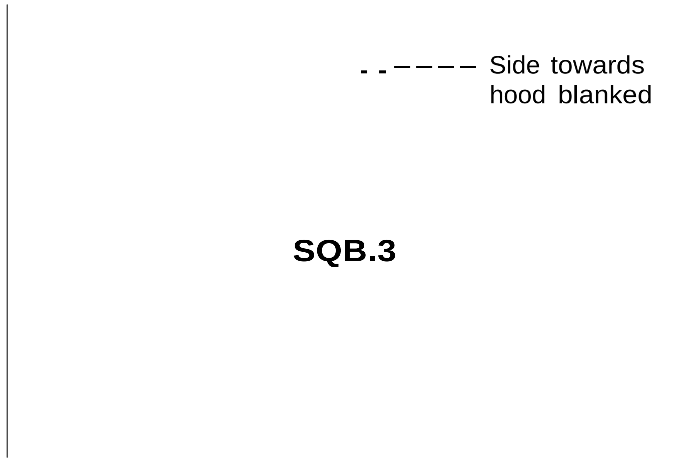
2 x 24" square

Staqqered spacinq of diffusers.

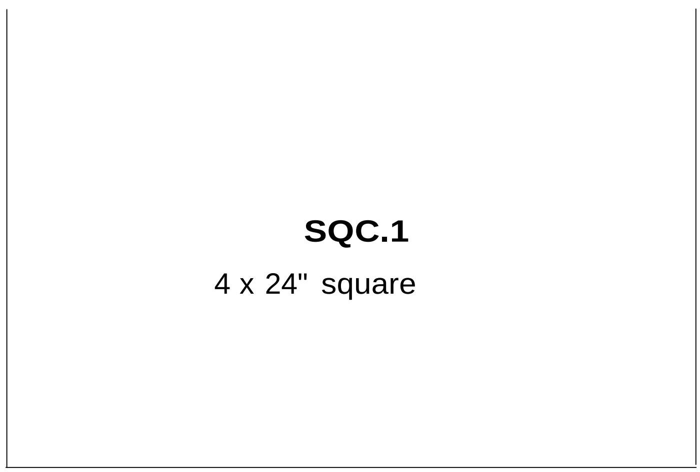
SQB.2

Diffuser along centerline.

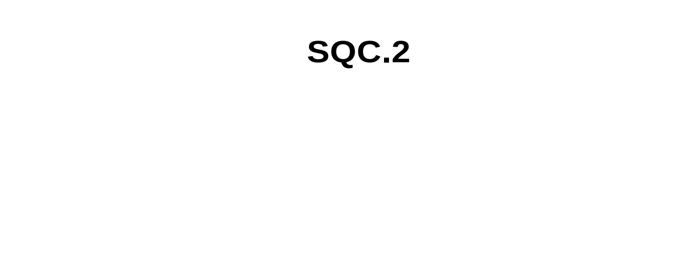
Figure 3.13 *Diffuser layout -large laboratory.*



Diffusers in line in front of hood. Quadrant towards hood blanked.

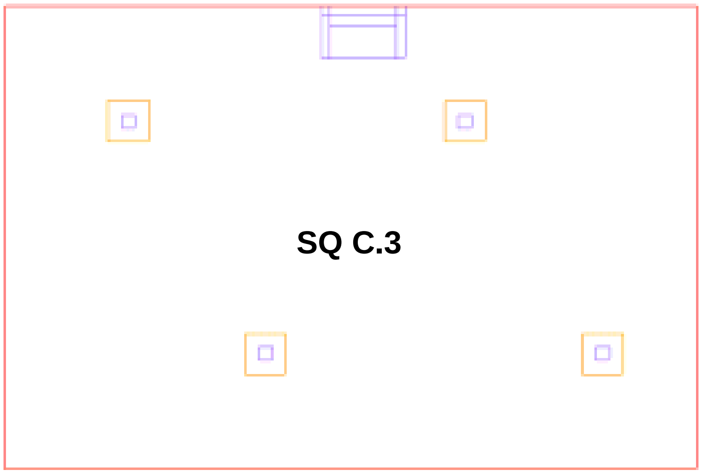


Diffusers spaced close to end walls.

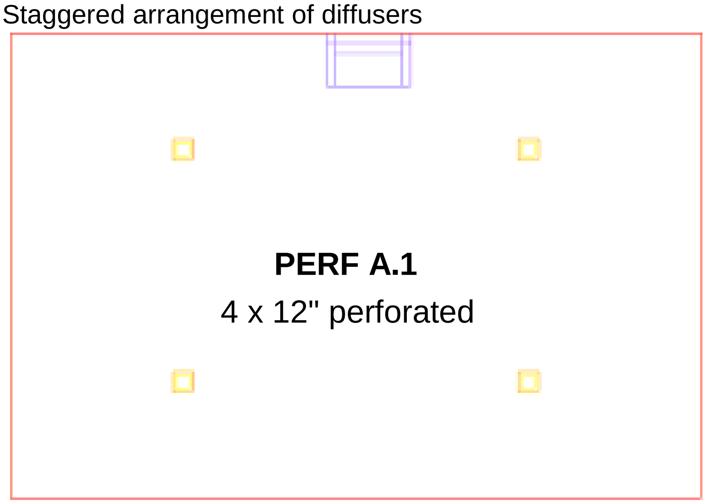


Diffusers laid out on quarters.

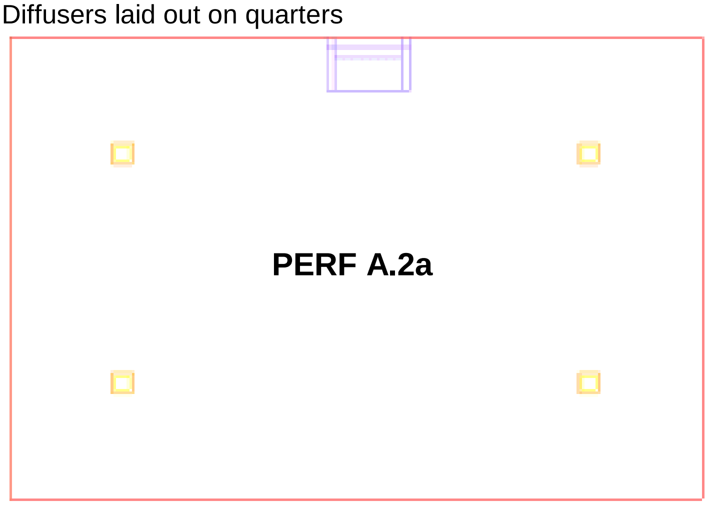
Figure 3.14 *Diffuser layout -large laboratory.*



Staggered arrangement of diffusers

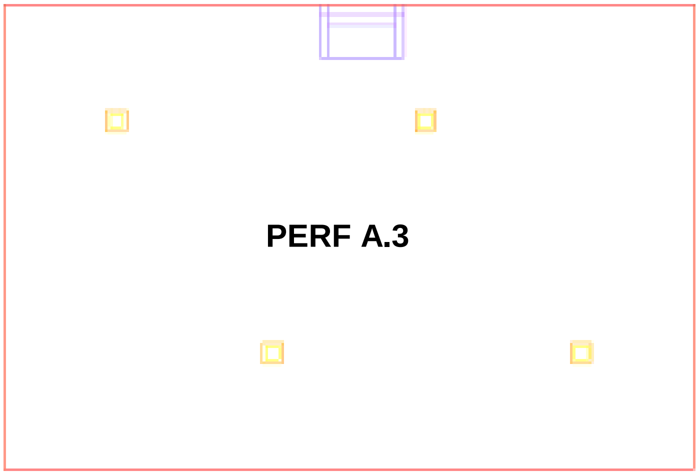


Diffusers laid out on quarters

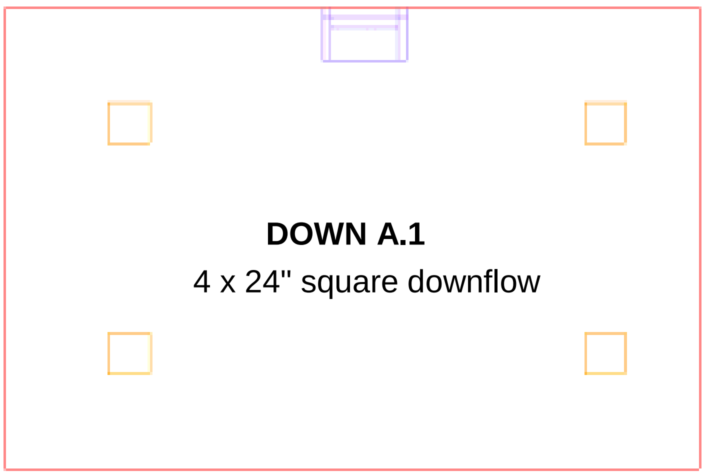


Diffusers spaced close to end walls

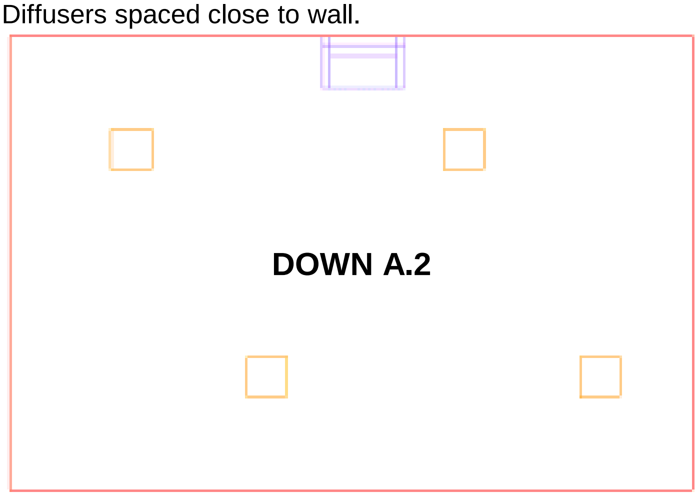
Figure 3.15 Diffuser layout - large laboratory



Diffusers with staggered arrangement.

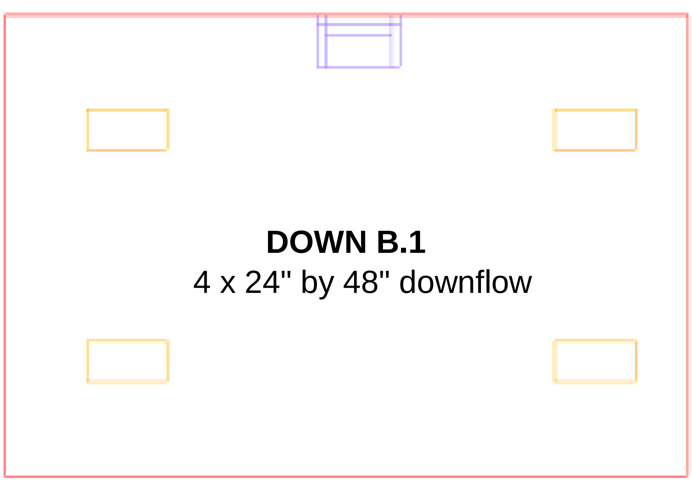


Diffusers spaced close to wall.

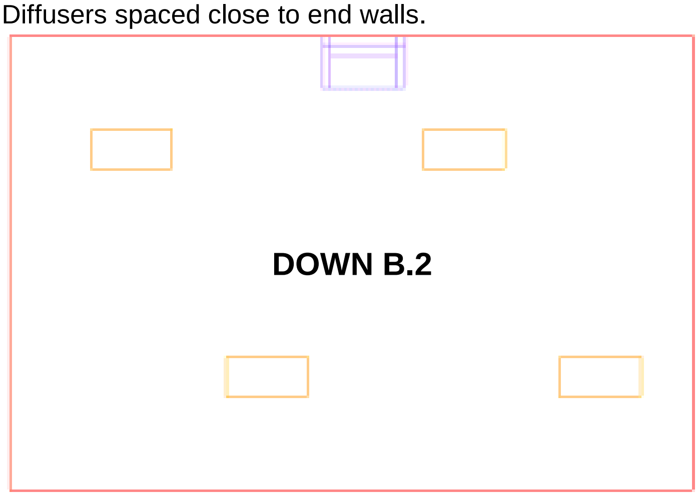


Staggered arrangement of diffusers.

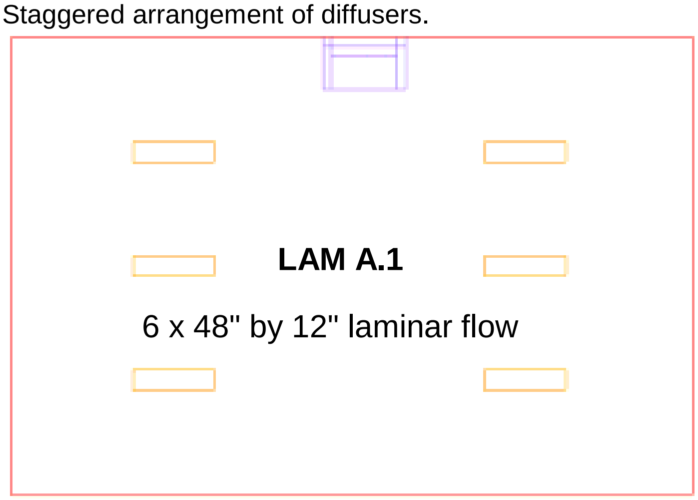
Figure 3.16 Diffuser layout - large laboratory.



Diffusers spaced close to end walls.

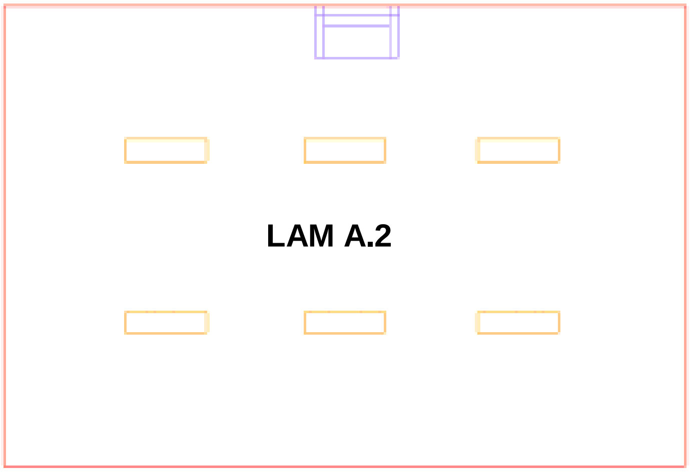


Staggered arrangement of diffusers.

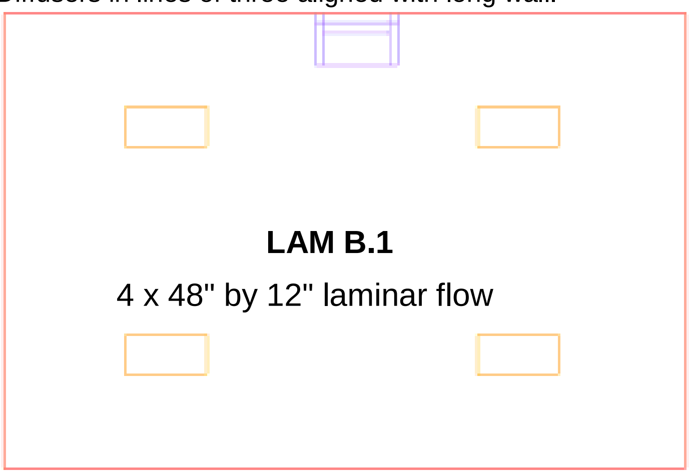


Diffusers in lines of three aligned with short wall.

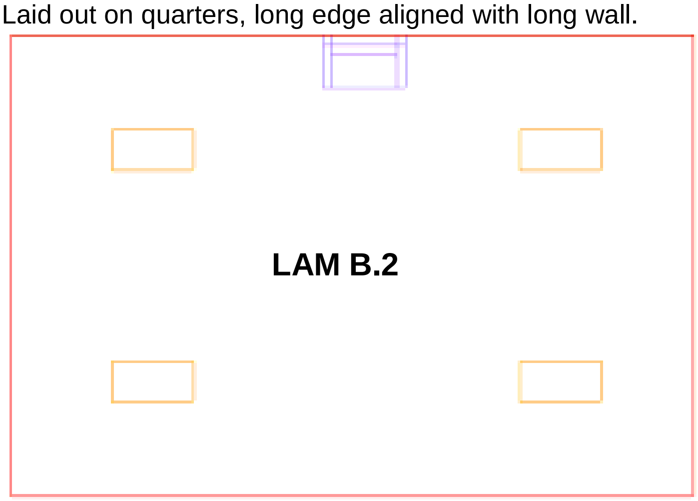
Figure 3.17 Diffuser layout - large laboratory**.**



Diffusers in lines of three aligned with long wall.

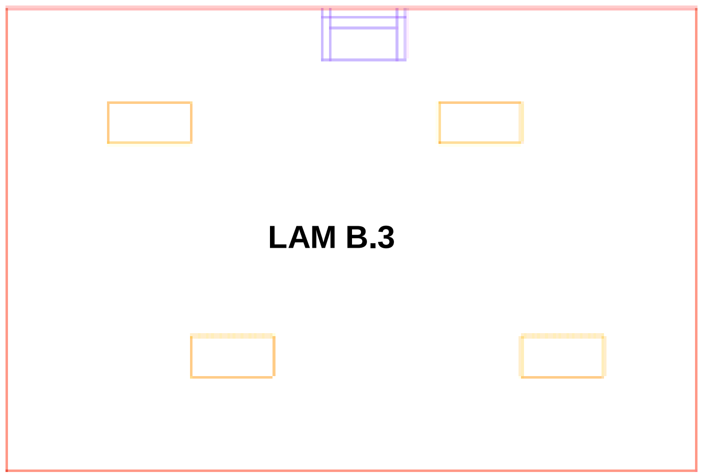


Laid out on quarters, long edge aligned with long wall.

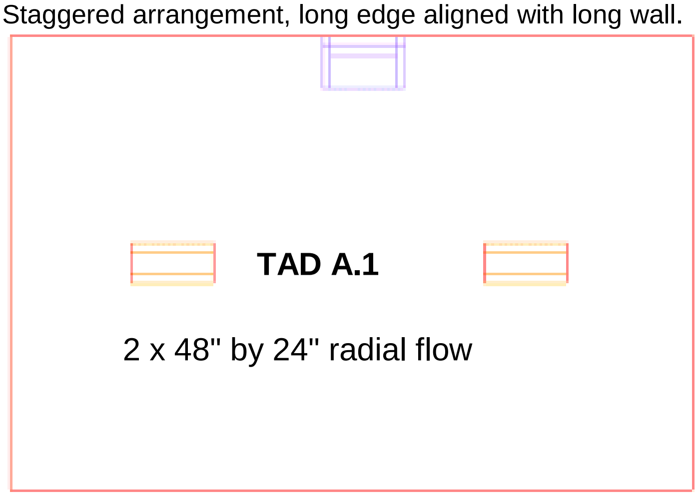


Close to end walls. Long edge aligned with long wall.

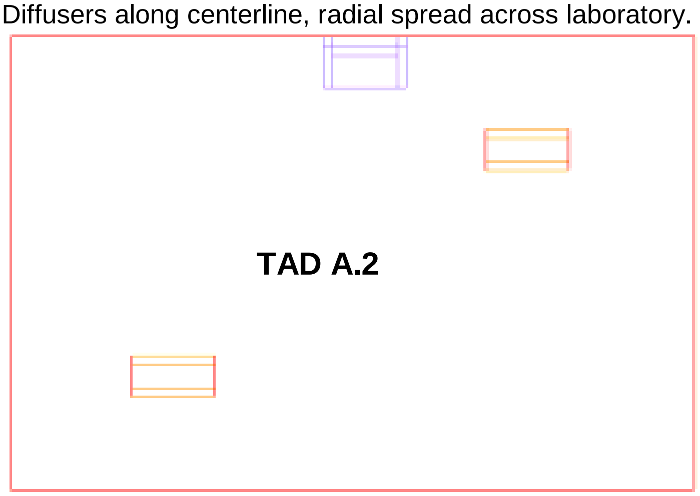
Figure 3.18 Diffuser layout - large laboratory**.**



Staggered arrangement, long edge aligned with long wall.

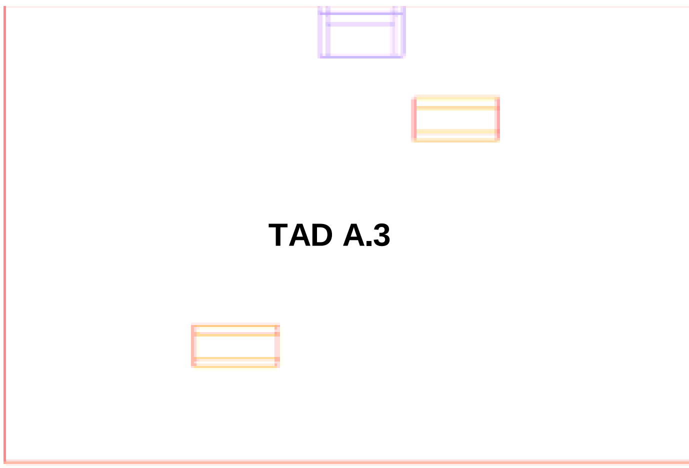


Diffusers along centerline, radial spread across laboratory.

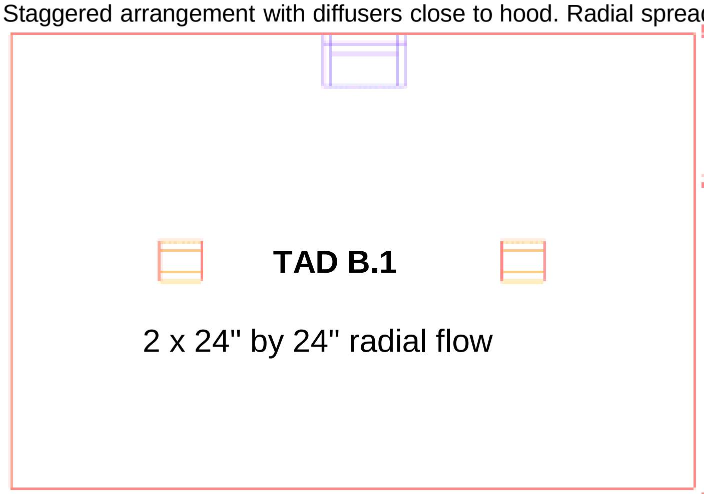


Staggered arrangement of diffusers.

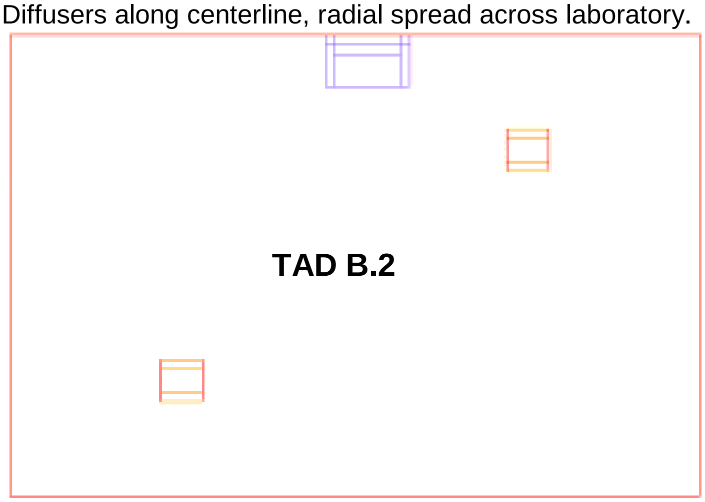
Figure 3.19 Diffuser layout - large laboratory**.**



Staggered arrangement with diffusers close to hood. Radial spread across laboratory.

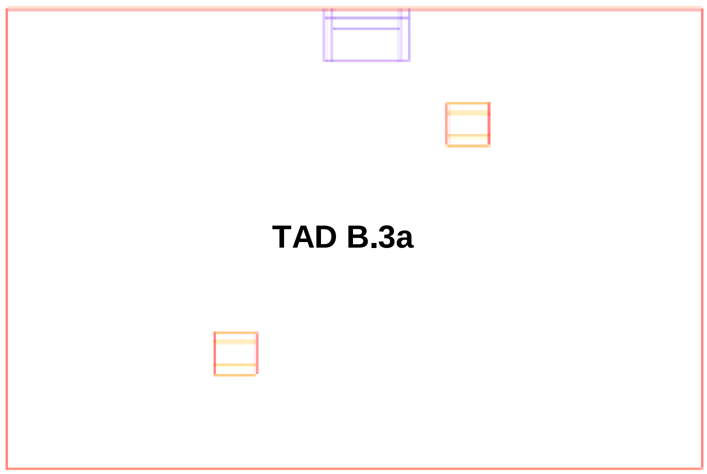


Diffusers along centerline, radial spread across laboratory.

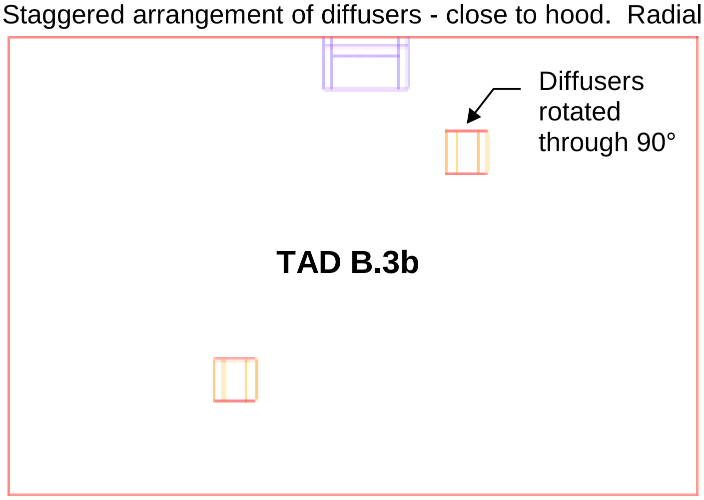


Staggered array, radial spread across laboratory.

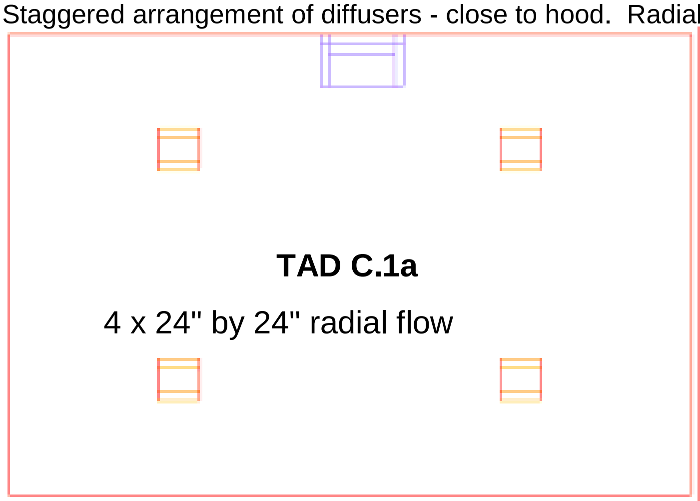
Figures 3.20 Diffuser layout - large laboratory**.**



Staggered arrangement of diffusers - close to hood. Radial spread across laboratory.

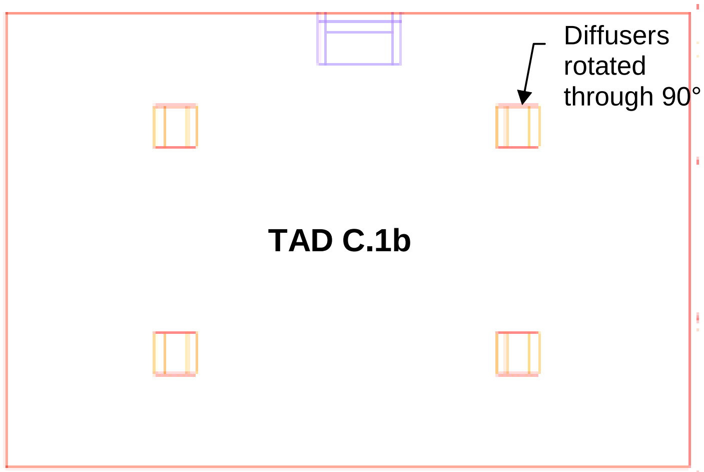


Staggered arrangement of diffusers - close to hood. Radial spread along laboratory.

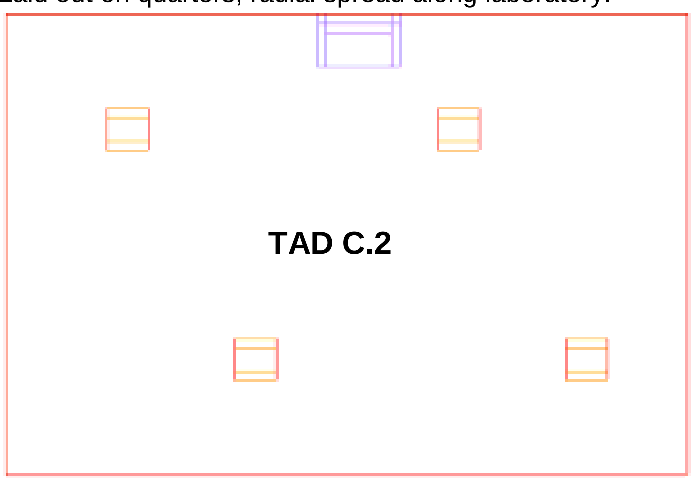


Diffusers laid out on quarters, radial spread across laboratory.

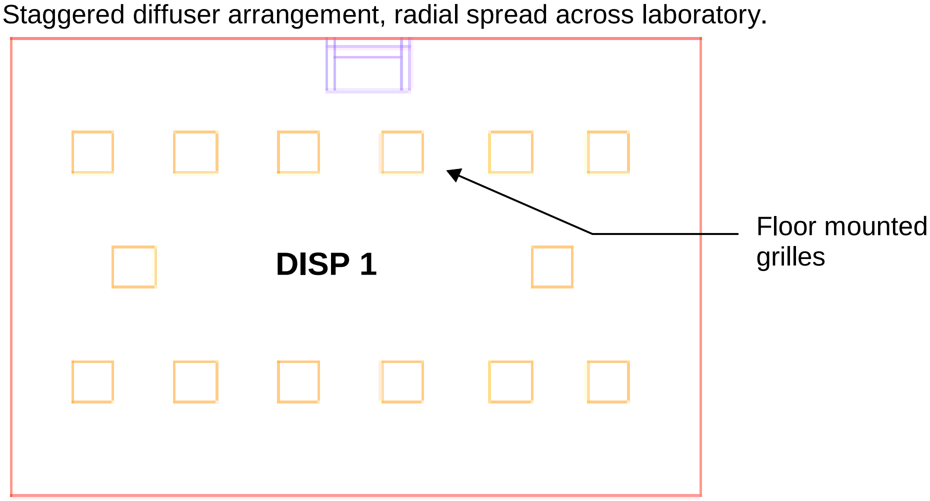
Figure 3.21 Diffuser layout - large laboratory.



Laid out on quarters, radial spread along laboratory.

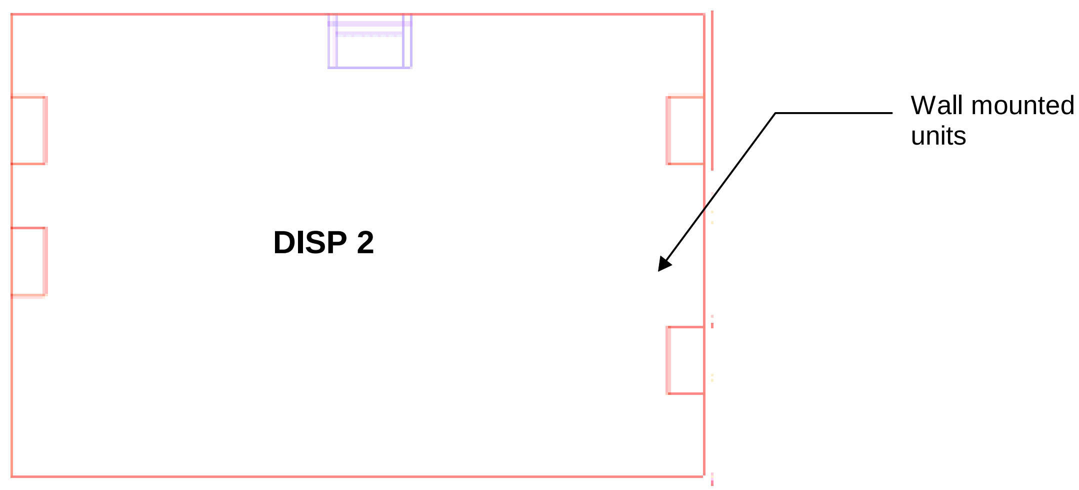


Staggered diffuser arrangement, radial spread across laboratory.



Fourteen 24" square floor grilles.

Figure 3.22 Diffuser layouts - large laboratory.



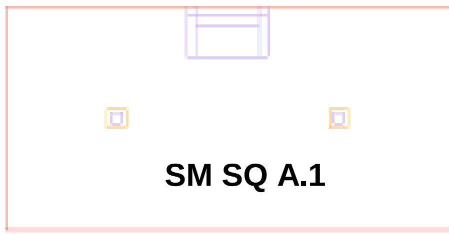
Four floor standing displacement units.

Figure 3.23 Diffuser layout - large laboratory**.**

Table 3.05 Diffuser positions - small laboratory (22ft x 11ft)
(figures 3.24 to 3.31)

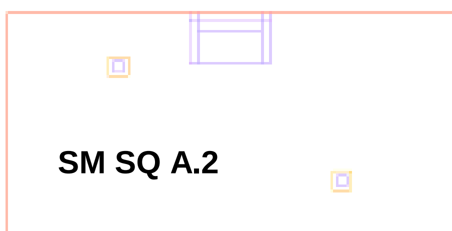
Layout Name	No. / Type / Size	Description	Simulation Nos.
SM SQ A.1	2 / Square / 12”	Even jet throw along centerline	82,82c,110,110c,118,118c, 126,126c,130,130c,134,138, 139,139c,148,153,155,183, 184,193
SM SQ A.2a	2 / Square / 12”	Staggered	102,102c,103, 148,149
SM SQ B.1	1 / Square / 24	On center line, away from main door	83,83c,119,119c,127,127c, 131,131c,135,135c,139,140, 140c,150,179,185
SM SQ B.2	1 / Square / 24	On centerline, close to main door	104,104c
SM SQ B.3	1 / Square / 24	On centerline, in front of hood	112,113,113c,189,190
SM SQ B.3b	1 / Square / 24	On centerline, in front of hood, quadrant towards hood blanked	105,105c,111,111c,151
SM SQ B3c	1 / Square / 24	1 foot further away from hood than SM SQ B3	191
SM SQ B3d	1 / Square / 24	1 foot nearer to hood than SM SQ B3	192

Layout Name	No. / Type / Size	Description	Simulation Nos.
SM SQ B4	2 / Square / 24	Between SM SQ B.1 and SM SQ B.3	188
SM LAM A.1	2 / Down-flow / 48”x12”	Arranged either side of hood, long edge across laboratory	84,84c
SM LAM A.2	2 / Down-flow / 48”x12”	Along centerline, long edge along laboratory	98,98c
SM LAM A.3	2 / Down-flow / 48”x12”	Staggered, long edge along laboratory	99,99c
SM LAM A.4	2 / Down-flow / 48”x12”	In line in front of hood, long edge along laboratory	100,100c
SM LAM A.5	2 / Down-flow / 48”x12”	Close to hood sides, long edge across laboratory	101,101c
SM TAD A.1a	1 / Radial / 24”x24”	On centerline away from main door, radial spread across laboratory	85,85c,108,108c,109,109c, 181
SM TAD A.1b	1 / Radial / 24”x24”	On centerline away from main door, radial spread along laboratory	97,97c,114,115,154
SM TAD A.2a	1 / Radial / 24”x24”	On centerline close to main door, radial spread across laboratory	95,95c,180
SM TAD A.2b	1 / Radial / 24”x24”	On centerline close to main door, radial spread along laboratory	96,96c
SM TAD A.3	1 / Radial / 24”x24”	Centered in front of the hood	116,116c,117,117c,120,120c, 128,128c,132,132c,136,136c, 152,186
SM PERF A.1	2 / Perforated / 12”x12”	On centerline along laboratory at ¼ and ¾	84b,121,129,133,133c,137, 141,182,187
SM PERF A.2	2 / Perforated / 12”x12”	Staggered at ¼ and ¾ along length of laboratory	99b
SM PERF A.3	2 / Perforated / 12”x12”	Staggered close to hood sides	101b

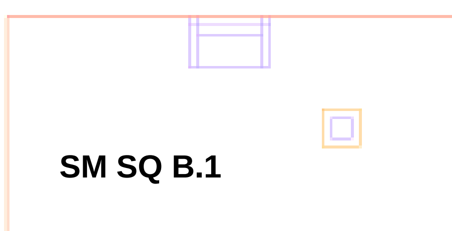


2 x 12" square

Diffusers along centerline



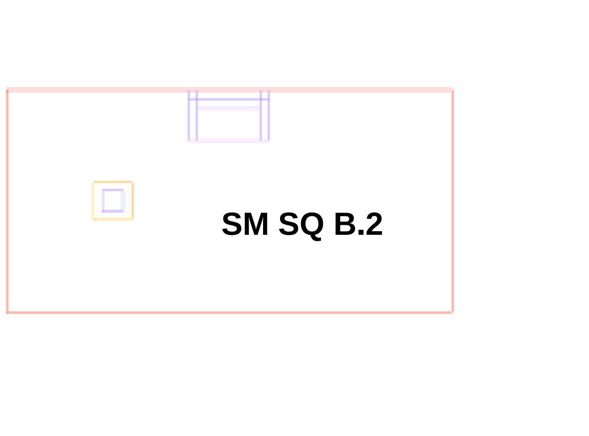
Staggered arrangement of diffusers



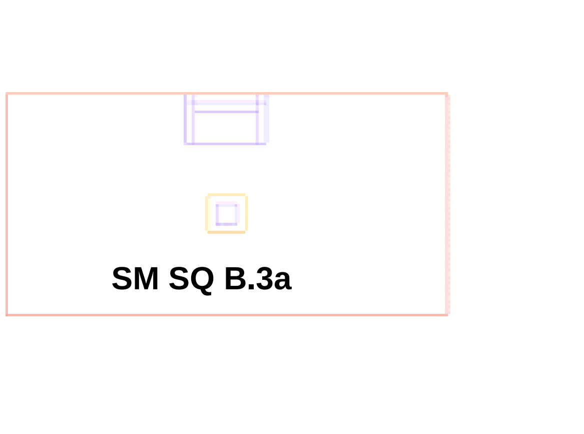
1 x 24" square

Diffuser on centerline away from main door

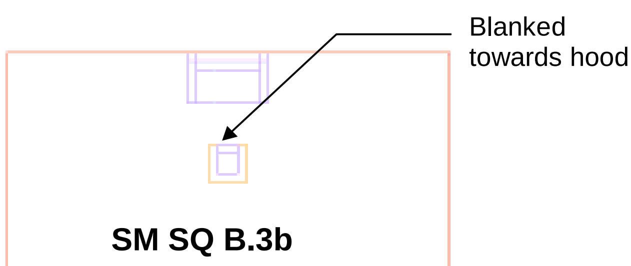
Figure 3.24 Diffuser layout - small laboratory**.**



Diffuser on centerline close to main door.

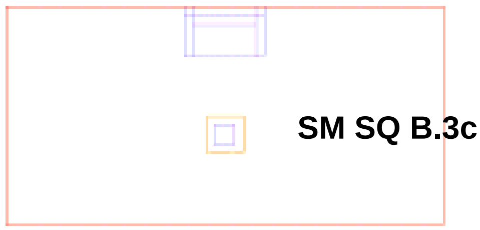


Diffuser on centerline in front of hood.

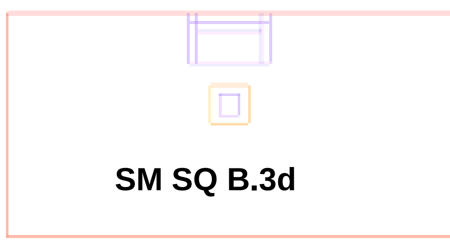


Diffuser on centerline in front of hood, quadrant towards hood blanked.

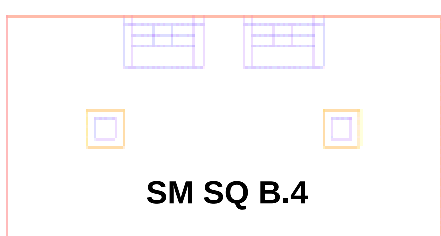
Figure 3.25 Diffuser layout - small laboratory**.**



1 foot further away from hood than SM SQ B.3

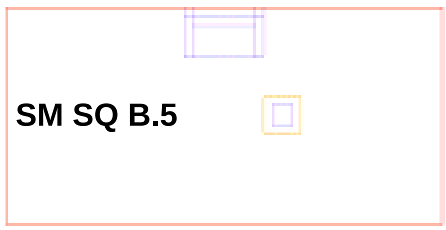


1 foot closer to hood than SM SQ B.3

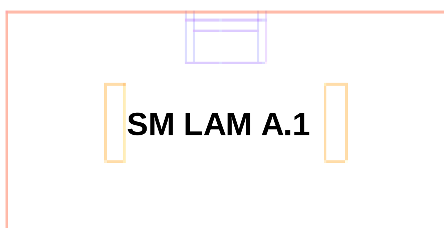


Two diffusers on centerline (to facilitate use of two hoods)

Figure 3.26 Diffuser layout - small laboratory**.**

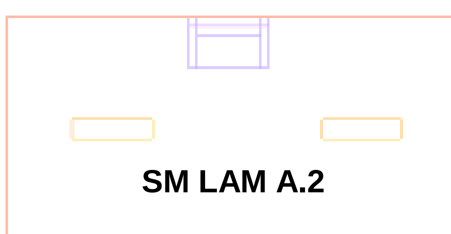


Diffuser on centerline, just to one side of hood.



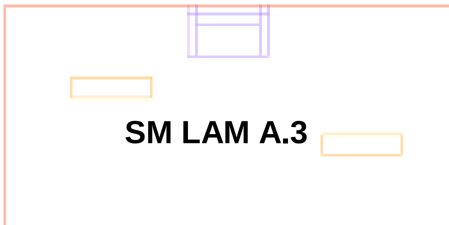
2 x 48" x 12" laminar flow

Diffuser each side of hood, long side across laboratory.

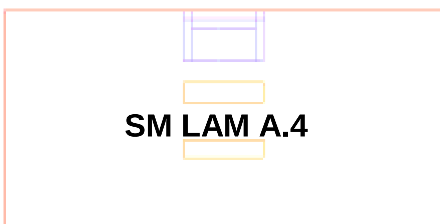


Diffusers each side of hood, long side along laboratory.

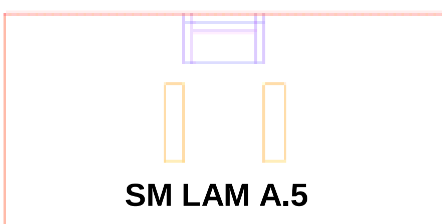
Figure 3.27 Diffuser layout - small laboratory**.**



Staggered arrangement, long side along laboratory.

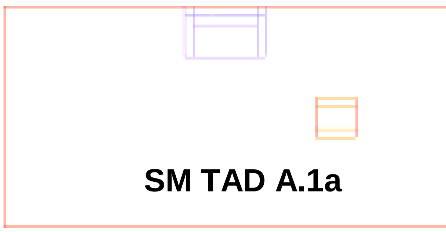


Diffusers both in line in front of hood.



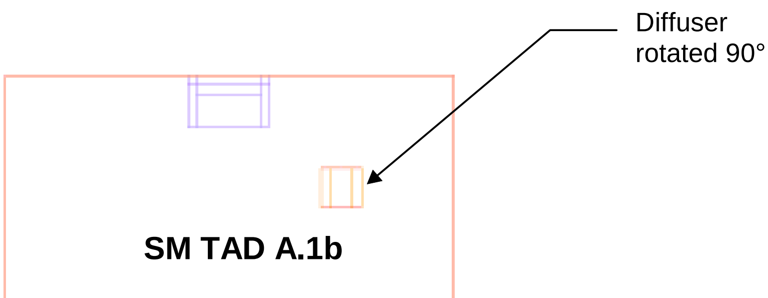
Diffusers close to hood sides, long sides across laboratory.

Figure 3.28 Diffuser layout - small laboratory**.**

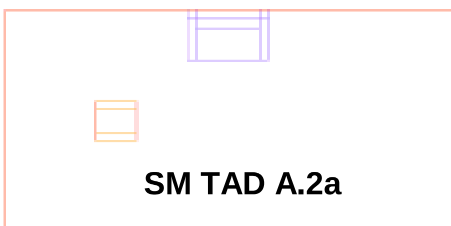


1 x 24" by 24" radial flow

On centerline, remote from main door, radial spread across laboratory

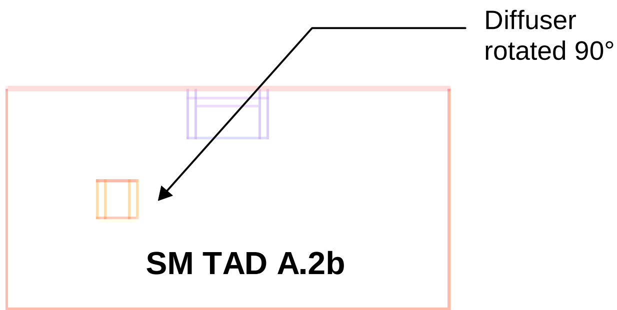


As SM TAD A.1a with diffuser rotated 90°

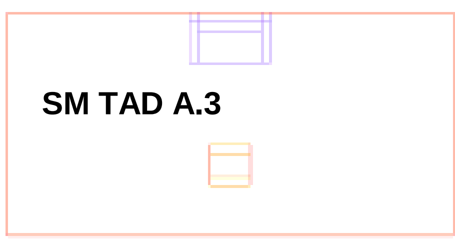


On centerline, near to main door, radial spread across laboratory.

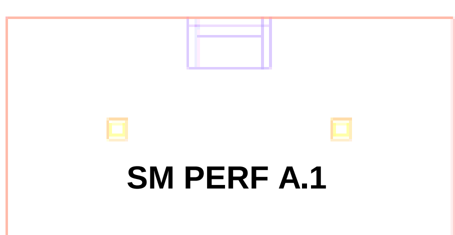
Figure 3.29 Diffuser layout - small laboratory.



As SM TAD A.2a with diffuser rotated 90°.



Diffuser centered in front of hood, radial spread across laboratory.

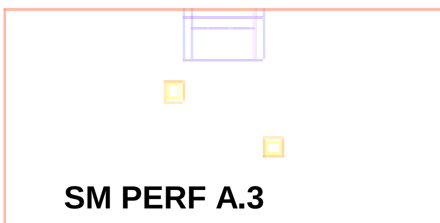


2 x 12" square perforated

Diffusers on centerline of laboratory.

Figure 3.30 Diffuser layout - small laboratory.

Staggered arrangement of diffusers.



Staggered arrangement with diffusers close to hood.

Figure 3.31 Diffuser layout - small laboratory.

3.3.3 Heating, Ventilating, and Air Conditioning

As well as changing the diffuser type, many of the HVAC parameters were modified to assess sensitivity. The changes relating to effects on the ventilation system can be summarized as follows :

The ventilation rate through the supply air diffusers varies between 6.0 and 34.7 air changes per hour (ACH).
Supply air temperature varies between 50^{o}F (10.0^{o}C) and 63.5^{o}F (17.5^{o}C).
Heat load varies between 5.16 W/sq. ft and 12 W/sq. ft.

Make up air is introduced through door crack(s) and / or a transfer grille and is assumed to be at the ambient temperature of the adjacent space of 72^{o}F (22.2^{o}C) with a variation in quantity from none to 542 cfm.

3.3.4 Scientist in Front of the Hood

In a number of the simulations, a scientist is present in front of the laboratory hood. In particular, all the simulations with the letter “c” after the name (for example run049c) simulate a scientist in front of the hood. Additionally, the duct - work from the fume hood and the lighting are recessed into a false ceiling. The other details, (such as heat load, ventilation rate, etc.) match those of the original run without the additional letter (for example run049)

3.3.5 Simulations Performed

The hundreds of simulations performed represent different parametric changes in order to compare performance. The tables presented are to describe the differences between the individual cases:

Tables 3.04 and 3.05. These tables, presented previously in this section, detail the diffuser layouts for the large and small laboratories respectively. For each layout the simulations numbers using that layout are given.

Table 3.06. This table details in numerical order every simulation performed. The table gives the general parameters used and difference to the base - line model for each diffuser type. This table matches the appendix where input data and results are presented in numerical order for every simulation undertaken.

Table 3.07. For a number of global parameters (for example supply temperature) this table gives the associated simulation numbers for the large or small laboratory. This table helps the reader to find cases that match a particular parameter. Full details of the cases can then be found in the appendix, which is presented with the simulations in numerical order.

Table 3.06 Simulations

Unless otherwise stated in table 3.06, the simulations use the following common parameters:

Hood face velocity is 100 fpm

Diffuser layouts prefixed by “SM” refer to simulations using the small laboratory model

The notes column in table 3.06 represents changes from a ‘base - line’ model for that diffuser type.

Simulations (runs) marked with the letter "b" (for example run054b) are for a perforated diffuser (configured to blow horizontally across the ceiling in four distinct jets) replacing the original diffuser type. In the case of run054b the perforated diffusers replace the square diffusers of run054.

Simulations (runs) marked with the letter "c" (for example run049c) have a representation of a scientist four inches in front of the sash opening. In addition the ductwork from the fume hood and the lighting units are assumed to be recessed into a false ceiling. In the basic case (say for example run049) the entry to the hood is unrestricted and the lights are suspended below the ceiling. The duct removing air from the fume hood is below ceiling level.

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
000	na	isol.	na	na	Hood in isolation; basic reference case used in analysis, hood face velocity 100 fpm
001	na	1	8.1	53	Ventilation system over whole ceiling. Hood face velocity 50 fpm
002	SQ C.1	1	8.1	53	4 off square 24” diffusers. Hood face velocity 50 fpm
003	SQ C.2	1	8.1	53	4 off square diffusers (placed so that distance from end wall to diffuser center line = one quarter length of room). Hood 50 fpm
004	SQ C.3	1	8.1	53	4 off square diffusers (placed such that a diffuser is close to the fume hood).Hood 50 fpm
005	TAD A.2	1	8.1	53	2 off 2' x 4' TAD radial diffusers placed asymmetrically so that diffuser to hood dimension large. Hood 50 fpm
006	TAD A.3	1	8.1	53	2 off 2' x 4' TAD radial diffusers placed asymmetrically so that diffuser to hood dimension relatively small. Hood 50 fpm
007	DOWN A.1	1	8.1	53	4 off downward air flow from 24" square ceiling grilles

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
008	DOWN A.2	1	8.1	53	4 off downward air flow from 24" square ceiling grilles
009	na	1	8.1	53	Run 001 hood velocity 100 fpm
010	SQ C.1	1	8.1	53	Fume hood face velocity increased to100 fpm
011	SQ C.3	1	8.1	53	Fume hood face velocity increased to100 fpm
012	TAD A.2	1	8.1	53	Run 005 hood velocity 100 fpm
013	TAD A.3	1	8.1	53	Run 006 hood velocity 100 fpm
014	DOWN A.2	1	8.1	53	Hood velocity 100 fpm, downward air flow from one of the positions in runs 007 and 008
015	SQ C.2	1	10.0	58.8	As run003 increase flow rate to 10 ACH and increase supply air temperature. Hood 50 fpm
016	TAD A.1	1	8.1	53	2 off TAD diffusers on centerline. Hood 50 fpm
017	TAD A.1	1	8.1	53	Run 16 - hood face velocity 100 fpm
018	SQ C.1	1	8.1	53	Close door and set such that room supply is exactly matched with exhaust and fume hood. Hood 50 fpm.
019	SQ C.2	1	8.1	53	Close door and set such that room supply is exactly matched with exhaust and fume hood. Hood 50 fpm
020	TAD A.1	1	8.1	53	Close door and set such that room supply is exactly matched with exhaust and fume hood. Hood 50 fpm
021	DOWN A.1	1	8.1	53	Close door and set such that room supply is exactly matched with exhaust and fume hood. Hood 50 fpm
022	DOWN B.1	1	8.1	53	Double size of down-flow grilles (2' x 4'), hood 50 fpm (as Run 007)
023	DOWN B.2	1	8.1	53	Double size of down-flow grilles (2' x 4'), hood 50 fpm (as Run 008)
024	DOWN B.1	1	8.1	53	Double size of down-flow grilles (2' x 4'), hood 100 fpm (as Run 014)
025	SQ C.2	1	8.1	53	Reduce hood opening to 25%, maintain hood face velocity of 50 fpm via bypass
026	TAD A.1	1	8.1	53	Reduce hood opening to 25%, maintain hood face velocity of 50 fpm via bypass
027	DOWN A.1	1	8.1	53	Reduce hood opening to 25%, maintain hood face velocity of 50 fpm via bypass
028	SQ C.2	1	8.1	62.3	Reduce equipment gain to a half and increase supply air temperature
029	TAD A.1	1	8.1	62.3	Reduce equipment gain to a half and increase supply air temperature
030	DOWN A.1	1	8.1	62.3	Reduce equipment gain to a half and increase supply air temperature
031	SQ C.2	1	8.1	53	Add person (as physical obstruction) in front of hood. Hood 50 fpm

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
032	TAD A.1	1	8.1	53	Add person (as physical obstruction) in front of hood. Hood 50 fpm
033	SQ C.2	1	8.1	53	Add person + trolley & equipment in front of hood. 1 run with square diffuser. Hood 50 fpm
034	TAD A.1	1	8.1	53	Add person + trolley & equipment in front of hood. 1 run with square diffuser. Hood 50 fpm
035	na	na	na	na	Investigation on fume hood air flow Exhaust from back baffle position, and various positions up duct system to investigate effect on face air flow distribution. Runs carried out without thermal effects in a simple test cell. Hood face velocity 50 fpm
036	na	na	na	na	
037	na	na	na	na	
038	na	na	na	na	Fume hood in isolation, isothermal. 25% open with by pass as large hole. Hood 50 fpm
039	na	na	na	na	Fume hood in isolation, isothermal. 25% open with by pass (different pressure loss to represent a grille over the by pass). Hood 50 fpm
040	na	na	na	na	Fume hood in isolation, isothermal. 100% open person in front. Hood 50 fpm
041	SQ A.1	1	9.1	55	Base-line model
041b	PERF A.1	1	9.1	55	Base-line model
042	SQ B.1	1	9.1	55	Base-line model
043	SQ A.1	1	9.1	55	Person 4 inches in front of hood
044	SQ A.1	1	9.1	55	Person 6 inches in front of hood
045	SQ B.1	1	9.1	55	Person 4 inches in front of hood
046	SQ B.1	1	9.1	55	Person 6 inches in front of hood
047	LAM A.1	1	9.1	55	Base-line model
048	LAM B.1	1	9.1	55	Base-line model
049	TAD A.1	1	9.1	55	Base-line model
049c	TAD A.1	1	9.1	55	As run049: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
050	TAD B.1	1	9.1	55	Base-line model
050c	TAD B.1	1	9.1	55	As run050: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
051	TAD C.1a	1	9.1	55	Base-line model
052	SQ A.1	1	9.1	55	Decrease jet thickness such that initial jet velocity doubled
053	SQ A.1	1	9.1	55	Increase initial jet thickness such that initial jet velocity halved
054	SQ A.1	1.2	9.1	55	Completely box in region above hood - bulkhead
054b	PERF A.1	1.2	9.1	55	Completely box in region above hood - bulkhead

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
055	SQ A.1	2	9.1	55	Move hood and re-arrange laboratory
055b	PERF A.1	2	9.1	55	Move hood and re-arrange laboratory
056	SQ A.1	3	9.1	55	Move hood and re-arrange laboratory
056b	PERF A.1	3	9.1	55	Move hood and re-arrange laboratory
057	SQ A.1	1	13.6	55	Increase heat load to 12 W/ft^2. Maintain supply temperature mass flow rate increases
058	SQ A.1	1	18.1	63.5	Increase supply temperature - mass flow rate will also increase
059	DISP 1	1	18.1	63.5	“Displacement system”; lower temperature difference, mass flow rate increased.
060	DISP 2	1	18.1	63.5	“Displacement system”; lower temperature difference, mass flow rate increased.
061	SQ A.2a	1	9.1	55	Base-line model
061b	PERF A.2a	1	9.1	55	Base-line model
062	SQ A.2b	1	9.1	55	Part of diffuser blanked off (towards wall)
063	SQ A.3	1	9.1	55	Base-line model
063b	PERF A.3	1	9.1	55	Base-line model
064	SQ B.2	1	9.1	55	Base-line model
065	SQ B.3	1	9.1	55	Part of diffuser pointing towards hood blanked off
066	LAM A.2	1	9.1	55	Base-line model
067	LAM B.2	1	9.1	55	Base-line model
068	LAM B.3	1	9.1	55	Base-line model
069	TAD A.2	1	9.1	55	Base-line model
069c	TAD A.2	1	9.1	55	As run069: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
070	TAD A.3	1	9.1	55	Base-line model
070c	TAD A.3	1	9.1	55	As run070: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
071	TAD B.2	1	9.1	55	Base-line model
071c	TAD B.2	1	9.1	55	As run071: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
072	TAD B.3a	1	9.1	55	Base-line model
072c	TAD B.3a	1	9.1	55	As run072: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
073	TAD B.3b	1	9.1	55	Diffusers rotated through 90° compared to layout TAD B.3a
073c	TAD B.3b	1	9.1	55	As run073: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
074	TAD C.1b	1	9.1	55	Diffusers rotated through 90° compared to layout TAD C.1a
074c	TAD C.1b	1	9.1	55	As run074: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
075	TAD C.2	1	9.1	55	Base-line model

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
075c	TAD C.2	1	9.1	55	As run075: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
076	SQ A.1	1	9.1	55	Door cracks under all doors
077	SQ A.1	1	9.1	55	Door crack sealed, transfer grille above main door
078	SQ A.1	1	9.1	55	Door crack sealed, transfer grille above door nearest hood
079	SQ A.1	1	9.1	55	Door crack sealed, transfer grille above door. Increase exhaust through dropper to increase flow through transfer to 200 cfm
080	LAM A.1	1	9.1	55	Door crack sealed, transfer grille above main door
081	TAD B.1	1	9.1	55	Door crack sealed, transfer grille above main door
082	SM SQ A.1	1	9.1	55	Base-line model
082c	SM SQ A.1	1	9.1	55	As run082: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
083	SM SQ B.1	1	9.1	55	Base-line model
083c	SM SQ B.1	1	9.1	55	As run083: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
084	SM LAM A.1	1	9.1	55	Base-line model
084b	SM PERF A.1	1	9.1	55	Base-line model
084c	SM LAM A.1	1	9.1	55	As run084: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
085	SM TAD A.1a	1	9.1	55	Base-line model
085c	SM TAD A.1a	1	9.1	55	As run085: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
086	SQ B.2	1.2	9.1	55	Completely box in region above hood - bulkhead
087	SQ B.2	2	9.1	55	Move hood and re-arrange laboratory
088	SQ B.2	3	9.1	55	Move hood and re-arrange laboratory
089	LAM B.1	1.2	9.1	55	Completely box in region above hood - bulkhead
090	LAM B.1	2	9.1	55	Move hood and re-arrange laboratory
091	LAM B.1	3	9.1	55	Move hood and re-arrange laboratory
092	TAD A.1	1.2	9.1	55	Completely box in region above hood - bulkhead
093	TAD A.1	2	9.1	55	Move hood and re-arrange laboratory
094	TAD A.1	3	9.1	55	Move hood and re-arrange laboratory
095	SM TAD A.2a	1	9.1	55	Base-line model
095c	SM TAD A.2a	1	9.1	55	As run095: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
096	SM TAD A.2b	1	9.1	55	Base-line model
096c	SM TAD A.2b	1	9.1	55	As run096: person 4 inches in front of hood,

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
					ductwork and lighting recessed into ceiling
097	SM TAD A.1b	1	9.1	55	Base-line model
097c	SM TAD A.1b	1	9.1	55	As run097: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
098	SM LAM A.2	1.2	9.1	55	Base-line model
098c	SM LAM A.2	1.2	9.1	55	As run098: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
099	SM LAM A.3	1	9.1	55	Base-line model
099b	SM PERF A.2	1	9.1	55	Base-line model
099c	SM LAM A.3	1	9.1	55	As run099: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
100	SM LAM A.4	1	9.1	55	Base-line model
100c	SM LAM A.4	1	9.1	55	As run100: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
101	SM LAM A.5	1	9.1	55	Base-line model
101b	SM PERFA.3	1	9.1	55	Base-line model
101c	SM LAM A.5	1	9.1	55	As run101: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
102	SM SQ A.2	1	9.1	55	Base-line model
102c	SM SQ A.2	1	9.1	55	As run102: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
103	SM SQ A.2	1.2	9.1	55	Bulkhead fitted above hood
103c	SM SQ A.2	1.2	9.1	55	As run103: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
104	SM SQ B.2	1	9.1	55	Base-line model
104c	SM SQ B.2	1	9.1	55	As run104: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
105	SM SQ B.3b	1	9.1	55	Side towards hood blanked off
105c	SM SQ B.3b	1	9.1	55	As run105: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
106	SQ B.1	3	9.1	55	Double module, hood position 3, transfer grilles above side door near hood (supply velocity 1.3 m/s)
107	SQ B.1	1	9.1	55	Double module, hood position 1. Door with transfer grille moved closer to wall with hood.
108	SM TAD A.1a	1	9.1	55	Move transfer grille along current wall away from hood
108c	SM TAD A.1a	1	9.1	55	As run108: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
109	SM TAD A.1a	1	10.0	57	Increase supply flow compensating the supply temperature accordingly. Reduce air flow through transfer grille
109c	SM TAD A.1a	1	10.0	57	As run109: person 4 inches in front of hood, ductwork and lighting recessed into ceiling

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
110	SM SQ A.1	1	10.0	57	Increase supply flow compensating the supply temperature accordingly. Reduce air flow through transfer grille (supply velocity 1.5 m/s)
110c	SM SQ A.1	1	10.0	57	As run110: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
111	SM SQ B.3b	1	9.1	55	Supply velocity 0.9 m/s. Side towards hood blanked
111c	SM SQ B.3b	1	9.1	55	As run111: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
112	SM SQ B.3a	1	9.1	55	As 111, but with all four sides active
112c	SM SQ B.3a	1	9.1	55	As run112: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
113	SM SQ B.3a	1	9.1	55	As 112, but with bulkhead above hood
113c	SM SQ B.3a	1	9.1	55	As run113: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
114	SM TAD A.1b	2	9.1	55	Hood moved towards door
115	SM TAD A.1b	3	9.1	55	Hood moved to end wall opposite door
116	SM TAD A.3	1	9.1	55	Radial diffuser in front of hood - blowing towards hood
116c	SM TAD A.3	1	9.1	55	As run116: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
117	SM TAD A.3	1	9.1	55	As 116 with bulkhead above hood
117c	SM TAD A.3	1	9.1	55	As run117: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
118	SM SQ A.1	1	17.0	63	Transfer grille closed and extra air supplied through diffusers. Supply temperature calculated based on standard heat gains
118c	SM SQ A.1	1	17.0	63	As run118: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
119	SM SQ B.1	1	17.0	63	Transfer grille closed and extra air supplied through diffusers. Supply temperature calculated based on standard heat gains
119c	SM SQ B.1	1	17.0	63	As run119: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
120	SM TAD A.3	1	17.0	63	Transfer grille closed and extra air supplied through diffusers. Supply temperature calculated based on standard heat gains
120c	SM TAD A.3	1	17.0	63	As run120: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
121	SM PERF A.1	1	17.0	63	Transfer grille closed and extra air supplied through diffusers. Supply temperature calculated based on standard heat gains

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
121c	SM PERF A.1	1	17.0	63	As run121: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
122	SQ A.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature
123	SQ B.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature
124	TAD B.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature
125	PERF A.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature
126	SM SQ A.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
126c	SM SQ A.1	1	6.0	55	As run126: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
127	SM SQ B.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
127c	SM SQ B.1	1	6.0	55	As run127: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
128	SM TAD A.3	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
128c	SM TAD A.3	1	6.0	55	As run128: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
129	SM PERF A.1	1	6.0	55	Heat load reduced so that SUPPLY air change rate = 6 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
129c	SM PERF A.1	1	6.0	55	As run129: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
130	SM SQ A.1	1	12.0	55	Heat load increased so that SUPPLY air change rate = 12 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
130c	SM SQ A.1	1	12.0	55	As run130: person 4 inches in front of hood,

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
					ductwork and lighting recessed into ceiling
131	SM SQ B.1	1	12.0	55	Heat load increased so that SUPPLY air change rate = 12 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
131c	SM SQ B.1	1	12.0	55	As run131: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
132	SM TAD A.3	1	12.0	55	Heat load increased so that SUPPLY air change rate = 12 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
132c	SM TAD A.3	1	12.0	55	As run132: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
133	SM PERF A.1	1	12.0	55	Heat load increased so that SUPPLY air change rate = 12 ACH while maintaining same supply temperature. Make up air through transfer grille at ambient temperature
133c	SM PERF A.1	1	12.0	55	As run133: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
134	SM SQ A.1	1	9.1	50	Supply temperature reduced - load calculated based upon 9.1 ACH. Make up air through transfer grille at ambient temperature
134c	SM SQ A.1	1	9.1	50	As run134: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
135	SM SQ B.1	1	9.1	50	Supply temperature reduced - load calculated based upon 9.1 ACH. Make up air through transfer grille at ambient temperature
135c	SM SQ B.1	1	9.1	50	As run135: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
136	SM TAD A.3	1	9.1	50	Supply temperature reduced - load calculated based upon 9.1 ACH. Make up air through transfer grille at ambient temperature
136c	SM TAD A.3	1	9.1	50	As run136: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
137	SM PERF A.1	1	9.1	50	Supply temperature reduced - load calculated based upon 9.1 ACH. Make up air through transfer grille at ambient temperature
137c	SM PERF A.1	1	9.1	50	As run137: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
138	SM SQ A.1	3	9.1	55	Move hood, re-arrange laboratory
139	SM SQ A.1	1.2	9.1	55	Bulkhead fitted above hood
139c	SM SQ A.1	1.2	9.1	55	As run139: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
140	SM SQ B.1	1.2	9.1	55	Bulkhead fitted above hood
140c	SM SQ B.1	1.2	9.1	55	As run140: person 4 inches in front of hood, ductwork and lighting recessed into ceiling

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
141	SM PERF A.1	1.2	9.1	55	Bulkhead fitted above hood
141c	SM PERF A.1	1.2	9.1	55	As run141: person 4 inches in front of hood, ductwork and lighting recessed into ceiling
142	SQ A.1	1.4	9.1	55	Trunk exhaust moved to opposite end of room
143	SQ B.1	1.4	9.1	55	Trunk exhaust moved to opposite end of room
144	TAD B.1	1.4	9.1	55	Trunk exhaust moved to opposite end of room
145	PERF A.1	1.4	9.1	55	Trunk exhaust moved to opposite end of room
146	TAD B.3a	1	9.1	55	Person 4 inches from hood face
147	TAD B.1	1	9.1	55	Person 4 inches from hood face
148	SM SQ A.1	1	9.1	55	Person 4 inches from hood face
149	SM SQ A.2	1	9.1	55	Person 4 inches from hood face
150	SM SQ B.1	1	9.1	55	Person 4 inches from hood face
151	SM SQ B.3b	1	9.1	55	Person 4 inches from hood face
152	SM TAD A.3	1	9.1	55	Person 4 inches from hood face
153	SM SQ A.1	2	9.1	55	Person 4 inches from hood face
154	SM TAD A.1b	3	9.1	55	Person 4 inches from hood face
155	SM SQ A.1	3	9.1	55	Person 4 inches from hood face
156	SM SQ B.4		27.3	60.8	Two hoods on same wall, 2 foot apart
157	SM SQ B.4		34.7	63.1	Two hoods on same wall, 2 foot apart
158	SM SQ B.4		27.3	60.8	Two hoods on same wall, 4 foot apart
159	SM SQ B.4		27.3	60.8	Two hoods on same wall, 4 foot apart Diffuser blowing towards hood - side blanked
160	SM SQ B.4		34.7	63.1	Two hoods on same wall, 4 foot apart
161	SM SQ B.4		34.7	63.1	Two hoods on same wall, 4 foot apart Diffuser blowing towards hood side blanked
162	SM SQ B.4		27.3	60.8	Two hoods on same wall, 6 foot apart
163	SM SQ B.4		27.3	60.8	Two hoods on same wall, 6 foot apart Diffuser blowing towards hood - side blanked
164	SM SQ B.4		34.7	63.1	Two hoods on same wall, 6 foot apart
165	SM SQ B.4		34.7	63.1	Two hoods on same wall, 6 foot apart Diffuser blowing towards hood - side blanked
166	SM SQ B.4		27.3	60.8	Two hoods on same wall, 8 foot apart
167	SM SQ B.4		34.7	63.1	Two hoods on same wall, 8 foot apart
168	SM SQ B.4		34.7	63.1	Two hood directly opposite across width of laboratory
169	SM SQ B.4		34.7	63.1	Two hoods opposite, both moved, edges line up
170	SM SQ B.4		34.7	63.1	Two hoods opposite, both moved, gap 2 ft
171	SM SQ B.4		34.7	63.1	Two hoods opposite, both moved, gap 4 ft
172	SM SQ B.4		34.7	63.1	Two hoods opposite, both moved, gap 6 ft
173	SM SQ B.4		34.7	63.1	Two hoods opposite, one moved, edges line up
174	SM SQ B.4		34.7	63.1	Two hoods opposite, one moved, gap 2 ft
175	SM SQ B.4		34.7	63.1	Two hoods opposite, one moved, gap 4 ft
176	SM SQ B.4		34.7	63.1	Two hoods on perpendicular walls. One center

Run no.	Diffuser Layout	Hood Posn	Supp ACH	Supp temp (°F)	Notes
					of 11 ft wall, second nearest edge 4 ft from corner
177	SM SQ B.4		34.7	63.1	Two hoods on perpendicular walls. One center of 11 ft wall, second nearest edge 6 ft from corner
178	SM SQ B.4		34.7	63.1	Two hoods on perpendicular walls. One center of 11 ft wall, second nearest edge 8 ft from corner
179	SM SQ B.1	2	9.1	55	All parameters except hood position are the same as in run083
180	SM TAD A.2a	2	9.1	55	All parameters except hood position are the same as in run095
181	SM TAD A.1a	2	9.1	55	All parameters except hood position are the same as in run085
182	SM PERF A.1	2	9.1	55	All parameters except hood position are the same as in run084b
183	SM SQ A.1	2	9.1	55	All parameters except hood position are the same as in run082
184	SM SQ A.1	2	17.0	63	All parameters except hood position are the same as in run118
185	SM SQ B.1	2	17.0	63	All parameters except hood position are the same as in run119
186	SM TAD A.3	2	17.0	63	All parameters except hood position are the same as in run120
187	SM PERF A.1	2	17.0	63	All parameters except hood position are the same as in run121
188	SM SQ B.5	1	17.0	63	Transfer grille shut, diffuser in position between SM SQ B.1 & SM SQ B.3
189	SM SQ B.3a	1	17.0	63	Transfer grille shut - diffuser in front of hood, no blanking
190	SM SQ B.3a	1.2	17.0	63	The same as run189 except bulkhead fitted
191	SM SQ B.3c	1.2	17.0	63	Diffuser moved 1 ft away from hood (c.f. SM SQ B.3), bulkhead fitted above hood
192	SM SQ B.3d	1.2	17.0	63	Diffuser moved 1 ft nearer to hood (c.f. SM SQ B.3), bulkhead fitted above hood
193	SM SQ A.1	1	15.2	61.9	Single hood with modified supply rates for double hood comparison

Table 3.07 Reference configurations

Simulations	Large Laboratory 33ft x 22ft	Small Laboratory 22ft x 11ft
Diffuser :		
Conventional	2-4,10,11,15,18,19,25,28,31,33,41-46,52-58,61-65,76-79,86-88,106-107,122,123,142-143	82,82c,83,83c,102-105,102c-105c,110-113,110c-113c,118-119,118c-119c,126,126c,127,127c,130-131,130c-131c,134-135,134c-135c,138-140,139c-140c,148-151,153,156-179,183-185,188-193
Perforated (horizontal throw)	41b,54b-56b61b,63b,125,145	84b,99b,101b,121,121c,129,129c,133,133c,137,137c,182,187
Perforated (downward throw)	7,8,14,21-24,27,30	
Laminar	1[2], 9[2],47,48,66-68, 80,84,84c,89-91	84,84c,98-101,98c-101c
Radial (TAD)	5,6,12,13,16,17,20,26,29,32,34,49-51,49c,50c,69-75,69c-75c,81,92-94,124,144,146,147	85,85c,95-97,95c-97c,108-109,108c-109c,114-117,116c,117c,120,120c,128,128c,132,132c,136,136c,152,154,180,181,186
Displacement	59,60	
None	0,35-40	0,35-40
Temperature :		
50.0 ^{o}F/10.0 ^{o}C		134-137,134-137c
53.0 ^{o}F/11.7 ^{o}C	1-14,16-27,31-34	
55.0 ^{o}F/12.7 ^{o}C	41-57,41b,49c,50c,54b,55b,61-81,61b,63b,69c-75c,86-94,106-107,122-125,142-147	82-85,84b,82c-85c,95,105,99b,101b, 95c-105c,108,108c,111-117,126-133,126c-133c,138-141, 139c-141c,148-155
57.0^{o}F/13.9 ^{o}C		109,109c,110,110c
58.8 ^{o}F/14.9 ^{o}C	15	
60.8 ^{o}F/16.0 ^{o}C		156,158,159,162,163,166
61.9 ^{o}F/16.6 ^{o}C		193
62.3 ^{o}F/16.8 ^{o}C	28-30	
63.0 ^{o}F/17.2 ^{o}C		118-121,118c-121c,157,160,161,164,165,167-178,184-192
63.5 ^{o}F/17.5 ^{o}C	58-60	

Simulations	Large Laboratory 33ft x 22ft	Small Laboratory 22ft x 11ft
Ventilation Rate :		
6.0 ach	122-125	126-129,126c-129c
8.1 ach	1-14,16-34	
10.0 ach	15	
9.1 ach	41-56,41b,49c,50c,54b-56b,61-81, 61b,63b,69c-75c,86-94,106-107,142-147	82-85,82c-85c,95-105,95c-105c,108, 111-117,111c-113c,116c-117c,134-141,134c-137c,139c-141c,148-155, 179-183
10.0 ach	15	
12.0 ach		130-133,130c-133c
13.6 ach	57	
15.2 ach		193
17.0 ach		118-121,118c-121c,184-192
18.1 ach	58-60	
27.3 ach		156,158,159,162,163,166
34.7ach		157,160,161,164,165,167-178
Hood Face Velocity :		
50 fpm, 25% open	25-27	
50 fpm	1-8,15,16,18-23,27-40	
100 fpm	0,9-14,17,24,41-81,41b,49c,50c,54b-56b,61b,63b,69c-75c,86-94,106-107, 122-125,142-147	82-85,82c-85c,95-105,95c-105c,108-121,108c-113c,116c-118c,126-141, 126c-137c,139c-141c,148-193
Hood Position :		
Hood in Isolation	0,35-40	0,35-40
Long Wall	1-34,41-53,41b,49c,50c,57-81,61b,63b, 69c-75c,107,122-125,142-147	82-85,82c-85c,95-97,95c-97c,99-102,99b,99c-102c,101b,104,104c, 105,105c,108-113,108c-113c,116-121, 116c-121c,126-141,126c-137c, 139c-141c,148-152,188-189,193
Long Wall - Corner	55,55b,87,90,93	114,153,179-187

Simulations	**Large Laboratory 33ft x 22ft**	**Small Laboratory 22ft x 11ft**
Short Wall	56,56b,88,91,94,106	115,154,155
Under bulkhead	54,54b,86,89,92	98,98c,103,103c,139-141,139c-141c,190-192
Two - Same Wall		156-167
Two - Opposite Walls		167-175
Two - Perpendicular		176-178
Person in Front of Hood:		
No	0-30, 35-42,41b,47-81,86-94,106-107,122-125, 142-145	82-85,95-105,108-121,126-141,179-193
Yes 4”	43,45,49c,50c,69c-75c,146-147	82c-85c,95c-105c108c-113c,116c-121c,126c-141c,148-178
Yes 6”	44,46	
In front	31,32	
In front with equipment	33,34	
Heat Source :		
None	0,35-40	0,35-40
5.16/5.3 W/sq ft	28-30,122-125	126-129
7.75 W/sq ft	1,2,4-11,13-15,18,19,31-34	
8.0 W/sq ft	3,12,16,17,20-27,41-56,41b,49c,50c, 54b-56b, 58-81,61b, 63b,69c-75c,86-94,106-107,142-147	82-85,82c-85c,95-105,95c-105c,108-121,108c-113c,116c-121c,138-141, 139c-141c,148-193
10.3/10.4 W/sq ft		130-137
12 W/sq ft	57	
Make-up Air Position :		
None	18-21	
Under Door 1[1]	1-17, 22-34,41-75,41b,49c,50c,54b-56b,61b,63b,69c-75c,86-94,122-125, 142-147	82-85, 84b,82c-85c ,95-05,99b,95105c,108[3],108c[3],126-141,126c-137c,139c-141c.148-193
Under All Doors[1]	76	

Simulations	Large Laboratory 33ft x 22ft	Small Laboratory 22ft x 11ft
Transfer Grille Door 1[1]	77,79-81,107[3]	82-85,84b,82c-85c,95-105, 99b,95c-105c,108[3],108c[3],109-121,109c-113c, 116c-117c, 126-141,126c-137c, 139c-141c,148-183
Transfer Grille Door 2[1]	78,106	
All - Hood in Isolation	0,35-40	0,35-40
Make-up Air Quantity[4] :		
None	18-21	
56 cfm	122-125	
100 cfm	1-17,22-34,41-78,41b,49c,50c,54b-56b,61b,63b,69c-75c,80,81, 86-94,106,107,118-121	118-121,118c-121c,184-192
166 cfm		157,160,161,164,165,167-178,193
200 cfm	79	
300 cfm		130-133,130c-133c
381 cfm		109,109c,110,110c
419 cfm		82-85,82c-85c,95-105,95c-105c,108, 108c,111-117,111c-113c,116c-117c, 134-141,134c-137c,139c-141c,148-155,179-183
467 cfm		156,158,159,162,163,166
513 cfm	142-147	
542 cfm		126-129,126c-129c
All	0,35-40	0,35-40

Notes for Table 3.07

1. Make-up Air Locations

Door 1 is the main door into the laboratory through one of the short walls. Doors 2 and 3 are ‘corridor’ doors at the opposite end of the laboratory but on the long walls. For a door, when leakage is allowed it is defined as coming through a crack under the appropriate door. Where transfer grilles have been included they measure 12” x 24” and are placed above the stated door with a 50% free area ratio and a loss coefficient of 1.5.

2. Down-flow from whole ceiling

Simulations of down - flow from the whole ceiling were intended to provide a good environment for the hood. However, it was found that the very low velocity resulting from the distributed momentum source allowed the heat sources to dominate the flow and the desired effect was not achieved. This approach was therefore abandoned.

3. Main door moved

These simulations are with the main door moved closer or farther away relative to the hood wall. This means that the make - up air position moves relative to the door.

3.4 Grid Selection

Although CFD is a well tested and established technique, there is a further level of testing required to ensure that the simulations are predicting performance as accurately as possible. This testing is often termed ‘grid selection’ or ‘grid sensitivity studies’. The testing is so termed because the grid needs to be sufficiently refined to minimize numerical error. The number of grid cells significantly affects the calculation time for each simulation, and so it is necessary to identify the minimum number of grid cells that allow prediction of the solution with sufficient accuracy. This is particularly critical around the sash opening where variations in velocity, turbulence, and concentration are very high. The grid selected has to be sufficient to capture these high gradients, if not, then, in particular, excessive numerical diffusion of the concentration may occur.

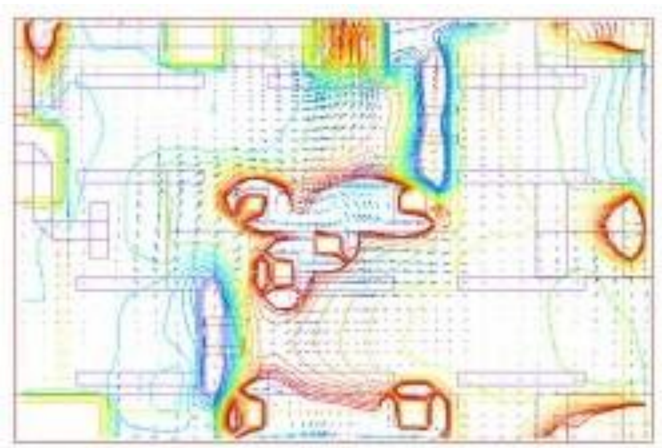
Two levels of grid dependency tests are performed. The first checks that the general flows and temperature predictions within the laboratory do not change when the number of grid cells is changed, and the second investigates the contaminant diffusion from the face of the hood.

The general flow is assessed using one of the large laboratory simulations (run072 - table 3.08), with the results from two different calculation grids being compared.

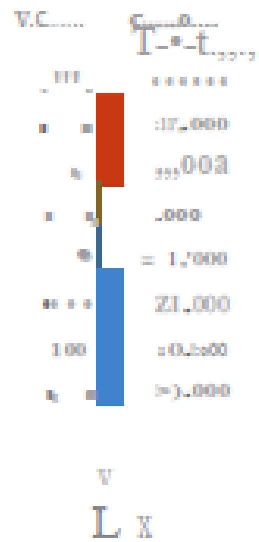
Table 3.08 Comparison of grid in run072.

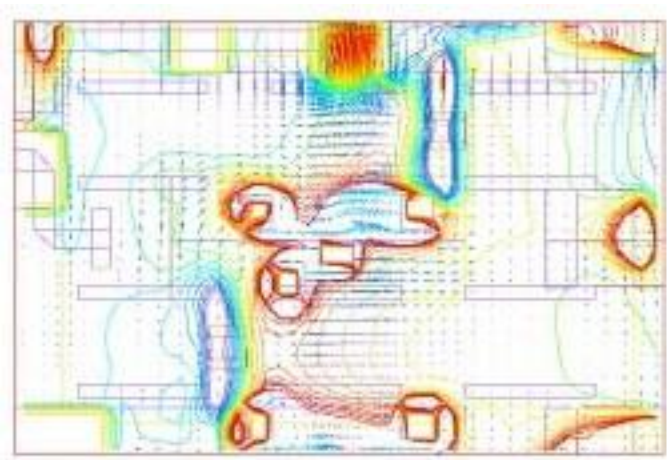
	Number of grid cells in each direction			Total number of grid cells
	x	y	z	
Fine grid - whole lab	54	56	39	117 936
Fine grid - box region	14	9	12	1 512
Coarse grid - whole lab	45	43	33	63 855
Coarse grid - box region	8	4	7	224

The results show no significant deviation from one simulation to another. Figure 3.32 shows the flow and temperature distribution, in a section at a height of 4 ft 4 in (1.3 m) above the floor for the two calculations for a qualitative comparison. The flow in the critical area around the hood is assessed further in a quantitative manner. An imaginary box is drawn around the sash opening to a distance of 12" in front of the hood. The air flow and temperature through each face is recorded (tables 3.09 and 3.10) and is found to closely match. The sides of the box are referred to by their position relative to the hood along a particular axis. For example the low x side is to the side of the hood closer to the origin (x = 0.0) and high x the side further from the origin. Hence, with a fine grid, and to the side of the hood closer to the origin 0.0727 kg/s of air flows towards the hood. This is at a temperature of 21.66°C. This compares to a flow rate of 0.0742 kg/s at a temperature of 21.63°C obtained using a coarse grid, which is an acceptable error.



Coarse Grid





Refined Grid

Figure 3.32 Visval comparison of resv/ls from grid sensitivity.

Table 3.09 Air flow comparison.

Case	Air flow through imaginary box (kg/s)				
	low x	high x	low y	low z	high z
Fine	0.0727[1]	-0.0575	0.1766	0.0552 -0.0028	-0.0878
Coarse	0.0742	-0.0604	0.1689	0.0551 -0.0033	-0.0847

1 Sign indicates direction of flow relative to axis direction

Table 3.10 Temperature comparison.

Case	Temperature of air passing through sides of box (°C)				
	low x	high x	low y	low z	high z
Fine	21.66	21.66	22.10	21.23 21.57	23.14
Coarse	21.63	21.69	22.07	21.19 21.55	23.12

The second part of the grid dependency testing focuses on the diffusion of the tracer from the sash opening. Three grids are tested (table 3.11). Use is made of a grid distribution facility that enables non uniform grid spacing across selected regions, refining the cell distribution towards the edges of the opening. In this way, small calculation cells are present at the edges where the high gradients of velocity, turbulence, and concentration can be expected. This can be done most easily by specifying a power law distribution that stipulates that the cell sizes increase and decrease according to the factor (power) and the type. There are three types :

If the cell size gets bigger as the coordinate increases, this is denoted an increasing type.
If the cell size gets smaller as the coordinate decreases, this is denoted a decreasing type.
If the cells get bigger and then get smaller again, this is denoted symmetric type.

The sash opening is considered to be full of concentration (kg species / kg air).

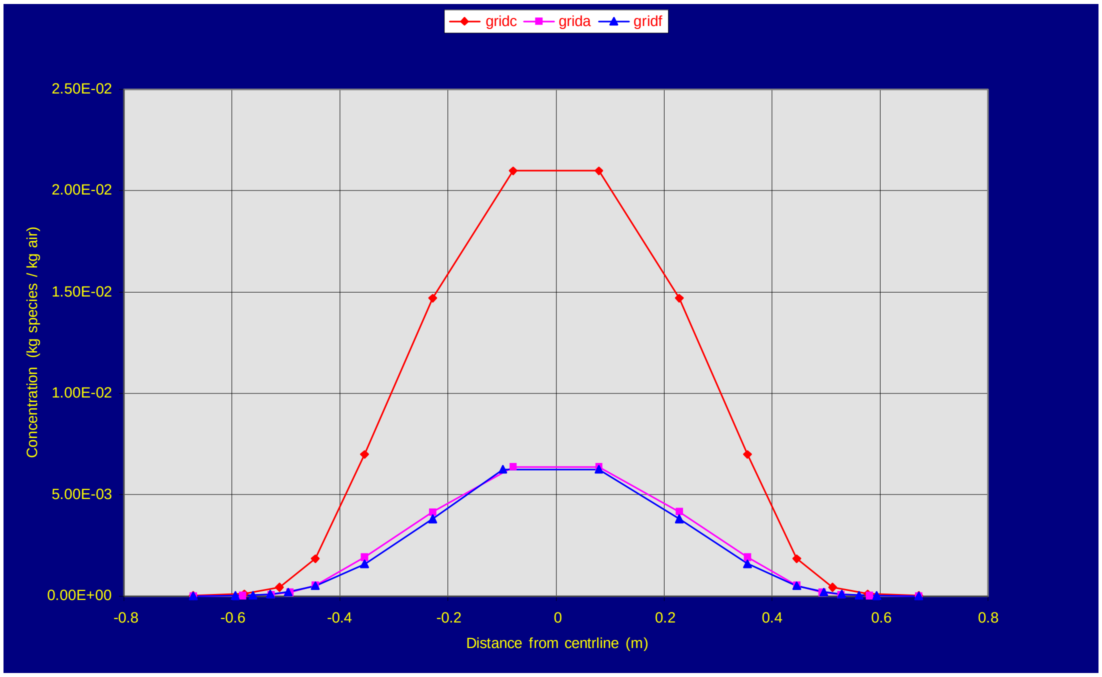
The grid is specified in regions. These regions are set relative to a distance from the origin of the coordinate system for the model. In this model the x axis ran across the hood face and the y axis was perpendicular to the hood face. The hood face was set at a position y = 2.24 m from the origin of the model.

Table 3.11 Comparison of grids

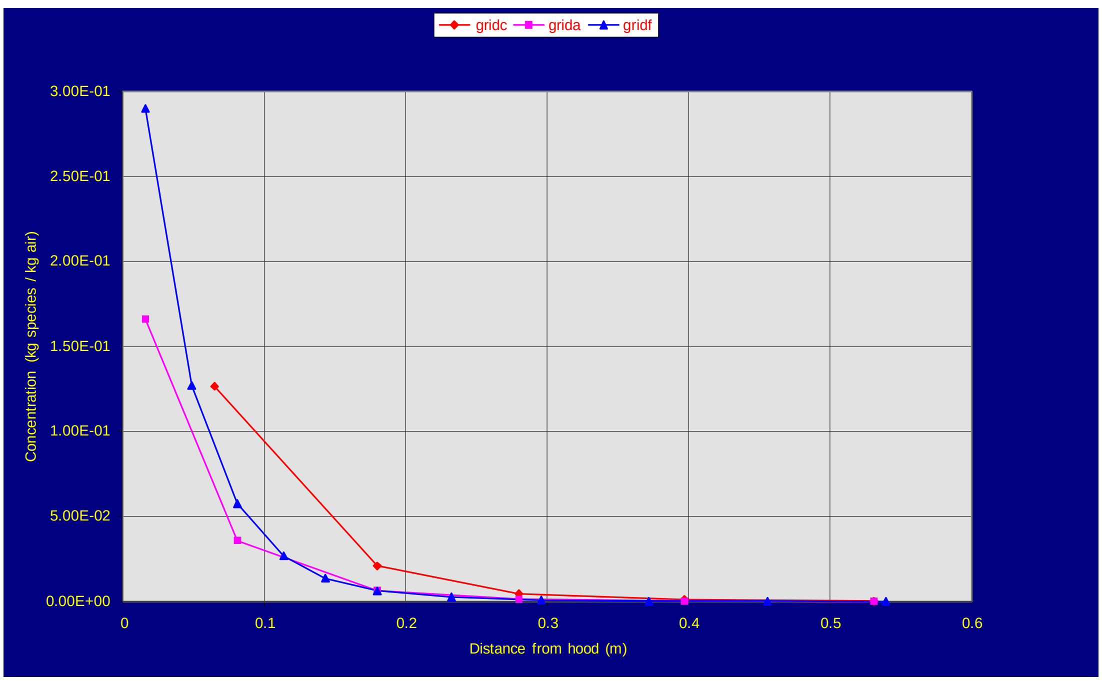
File name	Grid across face (x axis)		
	Side (low x)	**Across face**	**Side (high x)**
Coarse grid	2 cells uniform spacing	8 cells, symmetric factor 1.4	2 cell uniform spacing
Intermediate grid	3 cells decreasing factor 1.5	8 cells, symmetric factor 1.4	3 cells increasing factor 1.5
Fine grid	4 cells uniform	8 cells, symmetric factor 1.4	4 cells uniform

File name	Grid perpendicular to face (y axis)			
	from y = 0.0 to y = 1.24	**from y = 1.24 to y = 1.91**	**from y = 1.24 to y = 2.11**	**from y = 2.11 to y = 2.24**
Coarse grid	6 cells uniform spacing	5 cells uniform spacing	2 cells uniform spacing	1 cell uniform spacing
Intermediate grid	6 cells uniform spacing	5 cells uniform spacing	2 cells uniform spacing	2 cells decreasing factor 2.0
Fine grid	6 cells uniform spacing	8 cells uniform spacing	4 cells decreasing factor 1.45	4 cells uniform spacing

Figure 3.33 shows the concentration plotted along two lines. The first is a line parallel to the sash opening, 7 in (0.18 m) from the opening, and 12 in. (0.30 m) above the working surface. The second, again 12 in above the surface, is perpendicular to the sash opening near the center. Comparison of the results shows a considerable difference between the coarse and fine grids. However, the results with the intermediate grid (and the one that is used in the main simulations) compared well with the fine grid.



Across face.



Perpendicular to face.

Figure 3.33 Comparison of concentration around hood with different grids.

3.5 Assumptions

Several modeling assumptions are taken throughout the project. While many laboratory configurations are considered, these modeling assumptions are necessary to focus the scope of this research.

A solar load is not modeled through the windows and walls.

Floor, ceiling, and walls are assumed to have no heat transfer; that is the surrounding areas are assumed to be at the same temperature.

Shelving is specified as thin plates, ignoring any effect of thickness but still providing a barrier to airflow and surface friction on the horizontal surfaces. In a typical laboratory these shelves contain books, equipment, and supplies. In order to make the representation as generic as possible individual items are not modeled. Rather the effect of these items are represented by a defining a resistance to air flow creating a pressure drop and thus restricting the flow into and along the shelves. Other equipment is modeled as solid obstructions placed around the laboratory on the work benches. All surfaces are considered to be smooth when calculating surface friction.

All cases with double hoods have a person 4" away from the faces of the hood and all lighting and duct work recessed in the ceiling cavity.

The person modeled has a prescribed heat gain of 75 W distributed non - uniformly over the body. No account of body motion is taken.

In large labs, with the ductwork exposed, a general laboratory exhaust is mounted just below the ceiling level and exiting the laboratory through a short wall.

Lighting throughout the labs is 2.3 W/ft^2 in the form of fluorescent tubes suspended from, or recessed into, the ceiling. A split of approximately 50/50 is assumed in the convective / radiative components of the lighting heat gain.

The hood is modeled without any special aerodynamic (airfoil) design around the entry. The geometry of the hood is formed from a number of rectangular objects representing the base and the walls, with wedge shaped objects for sloping surfaces. The sash itself is represented as a thin plate preventing flow through it. The sash is assumed to be at its maximum opening position (30 in, 0.76 m) for the majority of simulations. Some simulations are conducted with the sash open at 25%.

The total flow - rate through the hood is set so that the average face velocity was 100 fpm (0.507 m/s). Several simulations are conducted with an average face velocity of 50 fpm (0.254 m/s).

At 100 fpm (0.507 m/s) the total flow rate through the hood is 784 cfm (0.44 kg/s). Table 3.12 describes the details of flow thorough different hood slots. This assumed that the hood is correctly installed and balanced.

Table 3.12 Hood slot flow rates

Slot Location	Width of slot		Flow - rate through slot	
	inches	meters	cfm	kg/s
Bottom Slot	2.5	0.064	470	0.264
Middle Slot	1.5	0.038	157	0.088
Top Slot	0.5	0.013	157	0.088
Total			784	0.440

Just inside, the hood sash opening is filled with the contamination to represent the worst case scenario of leakage. The tracer gas has the same density as the ambient air.

The laboratory temperature is kept at 72°F (22.2°C) throughout all simulations except 0 - 40 inclusive, where the laboratory temperature is 71°F (21.6°C).

No leakage occurs in to or out of the laboratory other than that specified through crack(s) under the door or a transfer grille.

The crack under the door provides 100 cfm (0.06 kg/s) to maintain -0.008” of water pressure (-2 Pascal) in the lab.

Supply diffusers are formed from a number of boundary conditions so that the jet velocity and direction are specified.

Supply diffusers are selected from manufacturers data to provide the required flow rates whilst keeping within the noise criteria of between 35 and 40 dB.

Equipment is represented as either a heat input over a volume, or, a solid object with heat output over the surface. The former simply puts heat into the air, while the latter represents blockage effects.

Density variations due to temperature are negligible. Density is therefore ignored in all terms apart from the buoyancy source term in the momentum equation. This is known as the Boussinesq approximation.

In practice, the contaminant is so diluted that variation of the mixture density due to differing molecular weights is negligible.