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Containment Testing for Occupied and Unoccupied Laboratory Chemical Hoods

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ABSTRACT

Containment of hazards in a laboratory chemical hood is based on the principle that air drawn through the face area of the hood is sufficient to overcome the many challenges at or near the opening. Challenges to overcome include, but are not limited to, air velocities near the hood, movement of the researcher, people walking past the hood, location of equipment inside the hood, size of the sash opening, and the shape and configuration of entrance conditions. To overcome these challenges, a sufficient face velocity must be maintained. Determining that proper face velocity for a given hood should be resolved by the system designer, facility safety officer, and researcher with these and other issues in mind.

This research tests for containment at 100 feet per minute (fpm) face velocity on occupied hoods and tests the same hoods for containment at the reduced velocity of 60 fpm when unoccupied. Three laboratory chemical hoods of different sizes with several sash positions are used. The test results show that under ideal conditions in a test laboratory, an unoccupied hood (without a manikin) at 60 fpm contains as good as, if not better than, an occupied hood (with a manikin) at 100 fpm, as measured by the tracer gas tests specified in ANSI/ASHRAE 110-1995, Method of Testing Performance of Laboratory Fume Hoods *(ASHRAE 1995). Further testing is needed to determine if this relationship is the same under conditions of actual use, i.e., cluttered hoods and presence of cross-drafts.*

INTRODUCTION

Containment of gaseous fumes in a laboratory chemical hood is commonly defined by maintaining a proper face velocity through the hood opening (e.g., 100 fpm). Previous research has indicated that lower velocities may provide containment, especially with low external challenges such as a person's movement and sash movement. Ljungquist (1991) published evidence showing the safety and good capture of a hood with the combination of a still operator and low face velocities. Haugen (1995) published data showing containment at low face velocities with no operator walk-by or sash movement but higher velocity requirements with rapid sash movement or walk-by. Caplan and Knutson (1977) concluded that the effect of room air challenge is significant and is of the same order of magnitude as the effect of face velocity.

One underlying principle behind this previous research is that higher face velocities are needed to contain when external forces such as operator presence, sash movement, and turbulence exist. Without these external challenges, containment may be possible with lower face velocity control.

A common problem in laboratories is the failure to close sashes when the operator is not using the hood. In the event that a sash is left open and the operators vacate the space, one may conclude from the previous research that the operating face velocity is higher than necessary, creating a waste of conditioned air. This research is designed to test for containment under two different operating conditions of a laboratory chemical hood:

- an occupied hood at 100 fpm face velocity;
- an unoccupied hood at reduced face velocity of 60 fpm.

The purpose of testing these modes was to determine the viability of reducing face velocity control during unoccupied periods.

The tracer gas tests specified in *ANSI/ASHRAE 110-1995* (ASHRAE 1995) were conducted on a 5 ft, a 6 ft, and an 8 ft laboratory hood using a variety of sash positions. A total of 42

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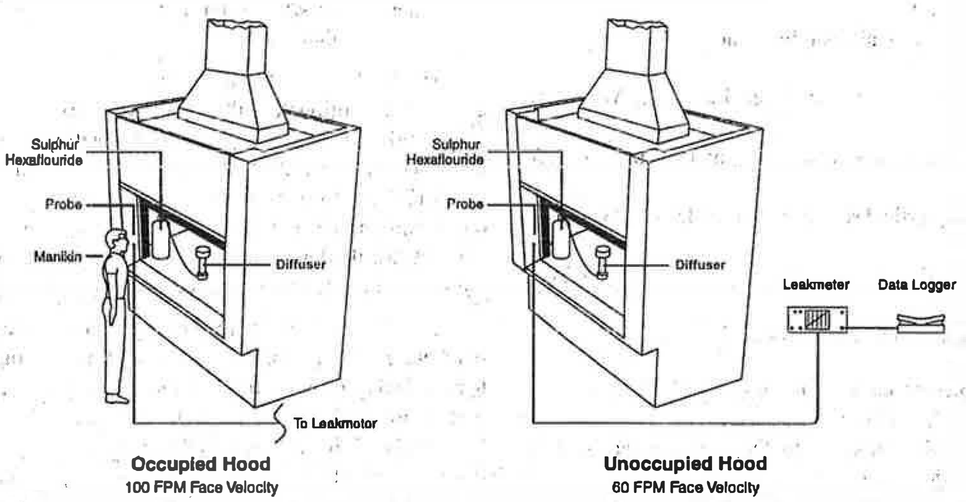

Figure 1 *Schematic of test setup.*

containment tests were conducted, including replicate tests. Sash movement effects were not tested.

TEST PROCEDURES

General

Prior to tracer gas testing, face velocity measurements were taken with an 8-point grid velometer. Each hood face was traversed and the exhaust rate was adjusted to get a measured average face velocity within 5% of the target value (either 100 fpm or 60 fpm). All hoods had the bypass blocked off. Figure 1 shows a schematic of the test setup.

Tracer gas containment tests were conducted according to the ASHRAE 110-1995 (ASHRAE 1995) test protocol. The diffuser was always placed in front of the manikin. When no manikin was used, the leakmeter intake probe was positioned in the same place as if the manikin were present—3 in. in front of the sash and 26 in. above the work surface.

One hundred percent sulfur hexafluoride was used in the ASHRAE 110 containment tests. A flow rate of 4 liters per minute through an ASHRAE diffuser was used to challenge the hoods. The flow rate was controlled with a calibrated pressure gauge and a flow-limiting orifice. The diffuser was located 6 in. behind the sash in all cases.

A leakmeter was used to detect the sulfur hexafluoride. The leakmeter was calibrated over the range of 10 ppb to 10 ppm. The breathing zone sampling point was fixed by connecting the sampling probe to a piece of tubing running from the back of the manikin's head to the front, just under the nose. The manikin was always positioned so the end of the tubing was 3 in. in front of the sash.

All containment data were collected on a datalogger recording four times per second. A spreadsheet was used to convert voltages to ppm based on calibration data. Five-minute averages of sulfur hexafluoride concentrations were calculated.

Hood Testing

Definitions

Occupied Mode: Face velocity set at 100 fpm; a manikin located in front of the sash opening.

Unoccupied Mode: Face velocity set at 60 fpm; a sensing probe located in front of the sash opening.

Five Foot Hood

Full-open vertical sash dimension: 52 in. W × 28.5 in. H (10.3 ft^2)

Half-open vertical sash dimension: 52 in. W × 14.0 in. H (5.1 ft^2)

Containment tests were conducted (9 total)

- in the occupied mode with the vertical sash full open and then half open;
- in the unoccupied mode with the vertical sash full open and then half open.

Six Foot Hood

Full-open vertical sash dimension: 63 in. W × 28.5 in. H (12.5 ft^2)

Half-open vertical sash dimension: 63 in. W × 14.0 in. H (6.1 ft^2)

Center-open horizontal sash dimension: 27 in. W × 24.5 in. H (4.6 ft^2)

Containment tests were conducted (13 total)

- in the occupied mode with the vertical sash full open and then half open;
- in the unoccupied mode with the vertical sash full open and then half open;
- in the occupied mode with the center horizontal sash open;
- in the unoccupied mode with the center horizontal sash open.

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Eight Foot Hood

Full-open dual vertical sash dimension: 87 in. W × 28.5 in. H (17.2 ft^2)

Half-open dual vertical sash dimension: 87 in. W × 14.0 in. H (8.5 ft^2)

One full-open vertical sash dimension: 43.5 in. W × 28.5 in. H (8.6 ft^2)

One half-open vertical sash dimension: 43.5 in. W × 14.0 in. H (4.2 ft^2)

Center-open horizontal sash dimension: 36.0 in. W × 24.5 in. H (6.1 ft^2)

Containment tests were conducted (20 total)

- in the occupied mode with the dual vertical sashes full open and then half open;
- in the unoccupied mode with the dual vertical sashes full open and then half open;
- in the occupied mode with one vertical sash full open and then half open;
- in the unoccupied mode with one vertical sash full open and then half open;
- in the occupied mode with the center horizontal sash open;
- in the unoccupied mode with the center horizontal sash open.

Replicate Testing

Containment testing was conducted on two separate occasions. When results were significantly different, a third test was conducted. All test data are shown in Table 1.

RESULTS

Table 1 lists the results for all three hoods both with and without a manikin. For a reference point, ANSI Z9.5-1992 recommends a pass/fail criteria of 0.1 ppm at a challenge rate of 4 liters per minute.

The 5 ft hood passed the containment criteria tests for all occupied conditions at 100 fpm and all original unoccupied tests at 60 fpm. In the full-open sash position, the concentrations were 0.01 and <0.01 for the occupied test, and 0.01, 0.09, and 0.17 for the unoccupied test (note that only the third test out of three failed for this condition). Very low leakage was detected for the half-open sash position (<0.01 for the occupied test and 0.02 and <0.01 for the unoccupied test).

The 6 ft hood passed the containment criteria tests for all unoccupied conditions at 60 fpm and all original occupied tests at 100 fpm. In the full-open sash position, the concentrations were 0.03 and <0.01 for the unoccupied test and 0.02, 0.42, and 0.39 for the occupied test (note that the second and third tests out of three failed for this condition). Very low leakage was detected for the half-open sash position (0.01 and <0.01 for the occupied test and <0.01 for the unoccupied test). Very low leakage was detected for the center horizontal-open sash position (<0.01 and 0.03 for the occupied test and <0.01 and 0.02 for unoccupied).

The 8 ft hood passed the containment criteria tests for all unoccupied conditions at 60 fpm but not for all occupied conditions at 100 fpm. With both sashes in the full-open position, the concentrations were 0.04 for the unoccupied test and 0.96 and 0.42 for the occupied test. Likewise, in the vertical right sash full-open position, the concentrations were <0.01 for the unoccupied test and 0.13 and 0.10 for the occupied test. Very low leakage was detected for both the sashes' half-open position (<0.01 for the occupied test and 0.04 and <0.01 for the unoccupied test). Finally, no leakage was detected in either mode for the vertical right sash half-open and horizontal right center sash full-open positions.

TABLE 1
ASHRAE 110 Containment Test Results

Hood Type	Sash Position	No Manikin 60 fpm			Manikin 100 fpm		
5 ft Hood	Full Open	0.01	0.09	0.17	0.01	<0.01	
	Half Open	0.02	<0.01		<0.01	<0.01	
6 ft Hood	Vertical Full Open	0.03	<0.01		0.02	0.42	0.39
	Vertical Half Open	<0.01	<0.01		0.01	<0.01	
	Center Horizontal Full Open	<0.01	0.02		<0.01	0.03	
8 ft Hood	Both Verticals Full Open	0.04	0.04		0.92	0.42	
	Both Verticals Half Open	<0.01	0.04		<0.01	<0.01	
	Right Vertical Full Open	<0.01	<0.01		0.13	0.10	
	Right Vertical Half Open	<0.01	<0.01		<0.01	<0.01	
	Right Center Horizontal Full Open	<0.01	<0.01		<0.01	<0.01	

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Ranking concentration measured in the breathing zone from highest to lowest is as follows:

8 ft hood occupied with 100 fpm (original test), both vertical sashes full open, 0.92 ppm (fail)

8 ft hood occupied with 100 fpm (replicate test), both vertical sashes full open, 0.42 ppm (fail)

6 ft hood occupied with 100 fpm (replicate #1), vertical sash full open, 0.42 ppm (fail)

6 ft hood occupied with 100 fpm (replicate #2), vertical sash full open, 0.39 ppm (fail)

5 ft hood unoccupied with 60 fpm (replicate #2), vertical sash full open, 0.17 ppm (fail)

8 ft hood, occupied with 100 fpm (original test), right vertical sash full open, 0.13 ppm (fail)

8 ft hood, occupied with 100 fpm (replicate test), right vertical sash full open, 0.10 ppm (fail)

5 ft hood unoccupied with 60 fpm (replicate #2), vertical sash full open, 0.09 ppm (pass)

8 ft hood, unoccupied with 60 fpm (original & replicate), both vertical sashes full open, 0.04 ppm (pass)

8 ft hood, unoccupied with 60 fpm (replicate test), both vertical sashes half open, 0.04 ppm (pass)

6 ft hood, occupied with 100 fpm (replicate test), center horizontal sash full open, 0.03 ppm (pass)

6 ft hood, unoccupied with 60 fpm (original test), vertical sash full open, 0.03 ppm (pass)

6 ft hood occupied with 100 fpm (original test), vertical sash full open, 0.02 ppm (pass)

5 ft hood, unoccupied with 60 fpm (replicate test), vertical sash half open, 0.02 ppm (pass)

6 ft hood, unoccupied with 60 fpm (replicate test), center horizontal sash full open, 0.02 ppm (pass)

All other tests were at or below the detection level of 0.01 ppm (pass).

DISCUSSION AND CONCLUSIONS

While face velocity control is a tangible means to operate hoods, proper containment may not always be accomplished with one universal face velocity set point. These tests show that higher face velocity does not categorically translate to greater containment. Six of the seven containment failures occurred during tests with a manikin at 100 fpm.

The containment test results may be classified as follows:

- Full-open vertical sash(es), 67% failure rate at 100 fpm, 11% failure rate at 60 fpm.
- Half-open vertical sash(es), no failures at either 100 or 60 fpm.
- Full-open horizontal sash(es), no failures at either 100 or 60 fpm.

Other conditions that can affect containment may include the following:

- The presence of an operator or other obstruction creating turbulence at the open sash. This could decrease the capture efficiency. Challenges can exist that even a face velocity of 100 fpm may not overcome. This may dictate face velocity setpoints, which are based on hood conditions.
- A reduction in face velocity. This will result in lower air turbulence surrounding the open sash, which will increase the capture efficiency.

In reviewing the tests, there is no clear advantage to using 100 fpm face velocity when the hood is unoccupied. Twenty out of 21 unoccupied tests showed containment at 60 fpm, while just 15 out of 21 occupied tests contained at 100 fpm. From these tests, it is reasonable to conclude that

- under ideal conditions, an unoccupied hood (without a manikin) at 60 fpm contains more often than an occupied hood (with a manikin) at 100 fpm;
- for the same hood and face velocity, a hood with the sash half open contains better than with the sash full open;
- for the same hood and face velocity, a hood with a horizontal sash fully open contains better than with the vertical fully open.

There are many factors that affect hood containment including room airflow patterns and airflow rates, traffic patterns, operator presence, operator movements, hood size, hood sash configuration, sash positions, face velocity settings, and face velocity control. To be certain of maintaining containment and protecting operators, it is important to review design parameters and then actual field conditions of fume hood installations. Determining face velocity control parameters is typically done during the design phase of a project. However, actual field conditions may offer possible reductions or may dictate increases in actual face velocity requirements for a given hood. These test results indicate that lower face velocities may provide adequate containment when there is no one at the hood. Before this can be said conclusively, the effects of cross-drafts and hood clutter under similar conditions need to be investigated.

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