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A Study of How Sash Movement Affects Performance of Fume Hoods

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ABSTRACT

This study was conducted to determine how sash movements affect the performance of fume hoods. The performance of two fume hoods was studied as the sashes were moved from closed to open position at speeds of 2 ft/s, 1.5 ft/s, and 1 ft/s. The tests were conducted with fume hoods operated at both constant volume and variable air volume. The tests indicate that sash movements can disturb airflow patterns at the face of the hood and potentially affect the performance of the hood. The effect of the sash movement varied with hood type and speed of sash movement. The faster sash movements of 2 ft/s and 1.5 ft/s had a greater effect on the performance of the hoods than the slower movement of 1 ft/s. Constant-volume hoods and variable-air-volume hoods were both affected by sash movements. Constant-volume hoods set to a full open face velocity of 60 ft/min were more susceptible to the sash movement than at 100 ft/min full open face velocity. The performance of variable-air-volume hoods is affected not only by sash movement speed but also by the response time of the controller. The drop in face velocity that occurs when the sash is moved is determined by the speed of the VAV controller. The required response time for containment depends on the fume hood design and the speed of the sash movement.

INTRODUCTION

ANSI/ASHRAE 110-1995, Method of Testing Performance of Laboratory Fume Hoods includes a dynamic test that tests fume hood performance when the sash is moved. Standard 110 and earlier studies suggest a relationship between sash movement and the performance of fume hoods (Ahmed and Bradley 1990).

Testing was undertaken to study fume hood performance when the sash is moved. The performance of two variable-air-volume (VAV) fume hoods was studied by moving the sash at different speeds and by varying VAV controller response times. The results were then compared to the results of tests run on the same hoods without VAV (with constant volume) controls. The goal of the study was to determine how sash speed and controller speed of response affect the performance of fume hoods. This study does not define what is acceptable performance for fume hoods.

TEST EQUIPMENT

Performance tests were conducted on two laboratory fume hoods installed in a test laboratory. Hood A was a 4-foot hood with a vertical rising sash. Hood B was an 8-foot hood with two 4-foot combination horizontal and vertical sashes. Both hoods are commercially available models from two leading fume hood manufacturers. The hoods were connected to a manifold exhaust system.

The hoods were equipped with a through-the-wall (TTW), thermal anemometry-based, face velocity controller. The TTW controller maintained the fume hood face velocity by modulating a butterfly damper with an electric actuator. A TTW sensor was chosen because it provides an accurate measurement of the face velocity (Zhang and Agarwal 1993). The controller modulated the damper to maintain a constant face velocity of 100 ft/min (0.51m/s), which is considered adequate to contain chemicals in a fume hood (AIHA 1992). In order to provide repeatable and accurate speed control of the sash movements, an electric motor was installed on the sashes to automatically open them during the tests.

The test equipment followed the guidelines set by Standard 110. Figure 1 shows the complete test setup. An infrared gas analyzer connected to the standard ASHRAE mannequin was used to measure tracer gas concentration in the breathing zone. The measurement range of the analyzer was 0-1 parts per million (ppm).

The test procedure and data collection were automated by a computer equipped with an analog-to-digital converter card. The face velocity, gas concentration, and elapsed time were

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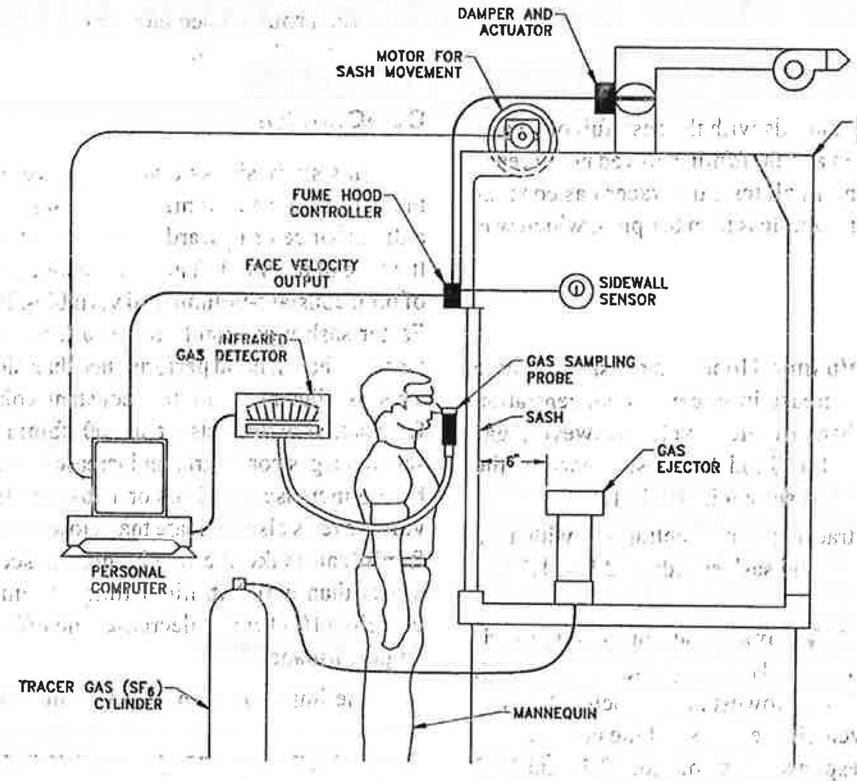

Figure 1 *Test setup.*

recorded by the computer during each test. The computer also provided the control signal for the motorized sash movement.

TEST PROCEDURE

The tests were performed on both hoods. Hood A was a 4-foot hood with a single vertical rising sash that was raised during the test. Hood B was an 8-foot hood with a combination horizontal and vertical sash that was divided into two 4-foot vertical rising sashes. During the test on Hood B, only one of the 4-foot sashes was raised. The test was divided into two parts: a static test and a dynamic test.

Static Test

The static test followed the procedure described in Standard 110. Tests were performed on both hoods with sashes full open at face velocities of 100 ft/min (0.51 m/s) and 60 ft/min (0.30 m/s). Sulfur hexafluoride (SF_6) was injected into the fume hood at a rate of 4 liters per minute (L/min). The computer recorded the fume hood face velocity and the SF_6 concentration in the breathing zone for 10 minutes.

Dynamic Test

The dynamic test was divided into two sections: constant volume and variable volume.

Dynamic Constant-Volume During the constant-volume dynamic test, the control damper was locked in a single position, allowing the hood to be balanced as a constant-volume system. Two tests were run on both hoods with the hoods balanced so the face velocities were maintained at 100 ft/min and 60 ft/min at sash full open.

Dynamic Variable Air Volume During the variable-air-volume dynamic tests, the control dampers were modulated to maintain a constant face velocity of 100 ft/min. The test was repeated for sash movement speeds of 1 ft/s, 1.5 ft/s, and 2 ft/s with response times on the controllers ranging from about 2 seconds to 20 seconds. Response time is defined as the time from the start of the sash movement until the face velocity is within 90% of the control setpoint. This definition is consistent with Standard 110.

Dynamic Test Procedure Dynamic tests were run under both constant-volume and variable-air-volume conditions. The sash movement speeds were 1 ft/s, 1.5 ft/s, and 2 ft/s. The following procedure was repeated for the different constant-volume face velocity settings and controller response times in the variable-air-volume system.

1. Set up control configuration for fume hood.
2. Close the fume hood sash.
3. Release tracer gas (SF_6) at 4 L/min into the fume hood for 20 seconds.
4. Begin recording data. Record the face velocity and tracer gas concentration for five seconds.
5. Move the sash from a closed to 100% open position at the specified rate.
6. Continue recording face velocity and tracer gas concentration for a total of one minute.
7. Shut off the tracer gas and stop recording data.

TEST RESULTS

Static Test

The static tests on both hoods with the sash full open and face velocities of 100 ft/min and 60 ft/min showed no increase in tracer gas concentration. In all tests the tracer gas concentration in the breathing zone was less than 0.1 ppm, which was the background level.

Dynamic Test

Dynamic Constant Volume Hood A's constant-volume dynamic test showed no increase in tracer gas concentration when compared to the background level. However, gas concentration did increase for Hood B. A summary of the constant-volume test results is shown in Table 1.

Figure 2 shows the tracer gas concentrations with face velocity settings of 60 ft/min and sash speeds of 2 ft/s, 1.5 ft/s, and 1 ft/s for Hood B.

Dynamic Variable Air Volume A summary of the variable-air-volume dynamic tests on Hood A is shown in Table 2. "Minimum Face Velocity" is the lowest face velocity observed during the test. The face velocity response of the controller to sash speed of 2 ft/s and response times of 2.6, 10.1, and 20.7 seconds is shown in Figure 3, which illustrates the interaction between face velocity and response time for fast sash movements (2 ft/s) for Hood A. Figure 4 shows the breathing zone tracer gas concentrations when the controller response time was around 20 seconds and the sash was moved at 2 ft/s, 1.5 ft/s, and 1 ft/s.

Hood B

A summary of the variable-air-volume tests on Hood B is shown in Table 3. Figure 5 shows the gas concentration in the breathing zone when the controller response time was around 7 seconds and the sash was moved at 1.5 ft/s and 1 ft/for Hood B.

CONCLUSION

This study shows that sash movement speed does affect the performance of fume hoods. Sash movements can create a disturbance or upward movement to the airflow patterns at the face of the hood. This disturbance affects the performance of both constant-volume and variable-air-volume fume hoods. Faster sash movement creates a larger disturbance, hence, a larger effect on hood performance than slower sash movements. This is illustrated in the constant-volume tests (Table 1). Constant-volume tests at a 100 ft/min face velocity setting showed a gas concentration increase greater than 1 ppm at 2 ft/s but no increase at 1.5 ft/s or 1 ft/s for Hood B. The constant-volume tests also indicate that a low face velocity setting of 60 ft/min can make the hoods more susceptible to sash movements than a 100 ft/min setting. Maintaining a higher face velocity (100 ft/min) decreases the effect sash movement has on performance.

The importance that VAV control response time had on

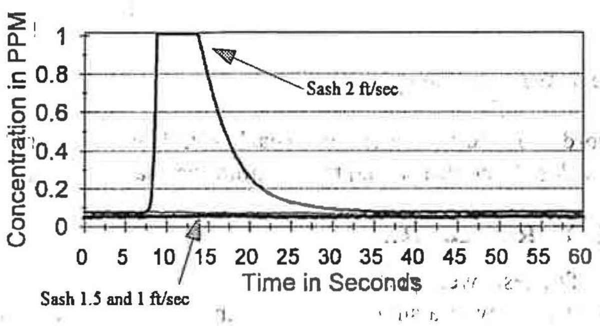

Figure 2 Dynamic containment test, constant volume 100 ft/min, Hood B.

TABLE 1
Constant-Volume Dynamic Test

Mode	Sash Speed	Peak Gas Concentration Hood A	Peak Gas Concentration Hood B
Constant Volume 100 ft/min	2 ft/s	No Increase	> 1 ppm *
Constant Volume 100 ft/min	1.5 ft/s	No Increase	No Increase
Constant Volume 100 ft/min	1 ft/s	No Increase	No Increase
Constant Volume 60 ft/min	2 ft/s	No Increase	> 1 ppm *
Constant Volume 60 ft/min	1.5 ft/s	No Increase	>1 ppm *
Constant Volume 60 ft/min	1 ft/s	No Increase	>1 ppm *

* Note: 1 ppm was the maximum value on the gas analyzer. The actual concentration value was greater than 1 ppm.

TABLE 2
Hood A VAV Dynamic Tests

Sash Movement Speed	VAV Response Time	Minimum Face Velocity	Peak Gas Concentration
2 ft/sec	2.6 seconds	63 ft/min (0.32 m/s)	No Increase
2 ft/sec	2.9 seconds	62 ft/min (0.31 m/s)	No Increase
2 ft/sec	3.4 seconds	60 ft/min (0.30 m/s)	No Increase
2 ft/sec	3.5 seconds	66 ft/min (0.34 m/s)	No Increase
2 ft/sec	4.0 seconds	61 ft/min (0.31 m/s)	No Increase
2 ft/sec	4.5 seconds	56 ft/min (0.28 m/s)	No Increase
2 ft/sec	5.4 seconds	50 ft/min (0.25 m/s)	No Increase
2 ft/sec	7.6 seconds	50 ft/min (0.25 m/s)	No Increase
2 ft/sec	10.1 seconds	49 ft/min (0.25 m/s)	0.48 ppm
2 ft/sec	20.7 seconds	40 ft/min (0.20 m/s)	> 1 ppm
1.5 ft/sec	3.1 seconds	70 ft/min (0.36 m/s)	No Increase
1.5 ft/sec	3.2 seconds	70 ft/min (0.36 m/s)	No Increase
1.5 ft/sec	3.5 seconds	65 ft/min (0.33 m/s)	No Increase
1.5 ft/sec	4.1 seconds	63 ft/min (0.32 m/s)	No Increase
1.5 ft/sec	4.3 seconds	61 ft/min (0.31 m/s)	No Increase
1.5 ft/sec	4.6 seconds	56 ft/min (0.28 m/s)	No Increase
1.5 ft/sec	5.4 seconds	51 ft/min (0.26 m/s)	No Increase
1.5 ft/sec	7.5 seconds	50 ft/min (0.25 m/s)	No Increase
1.5 ft/sec	10.1 seconds	50 ft/min (0.25 m/s)	No Increase
1.5 ft/sec	20.9 seconds	36 ft/min (0.18 m/s)	0.66 ppm
1 ft/sec	3.3 seconds	71 ft/min (0.36 m/s)	No Increase
1 ft/sec	3.6 seconds	69 ft/min (0.35 m/s)	No Increase
1 ft/sec	4.0 seconds	69 ft/min (0.35 m/s)	No Increase
1 ft/sec	4.1 seconds	65 ft/min (0.33 m/s)	No Increase
1 ft/sec	4.5 seconds	64 ft/min (0.33 m/s)	No Increase
1 ft/sec	4.8 seconds	60 ft/min (0.30 m/s)	No Increase
1 ft/sec	5.8 seconds	54 ft/min (0.27 m/s)	No Increase
1 ft/sec	7.8 seconds	49 ft/min (0.25 m/s)	No Increase
1 ft/sec	11.4 seconds	46 ft/min (0.23 m/s)	No Increase
1 ft/sec	22.4 seconds	36 ft/min (0.18 m/s)	No Increase

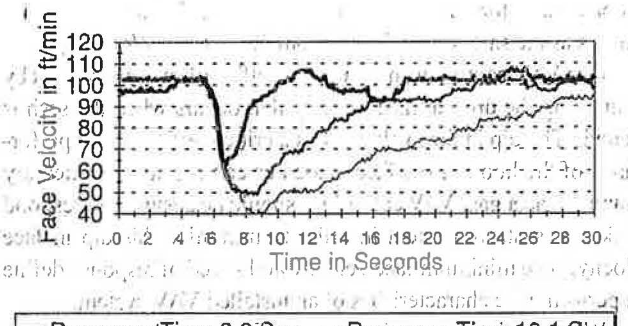

Figure 3 Dynamic containment test, VAV response, sash, 2 ft/s, Hood A.

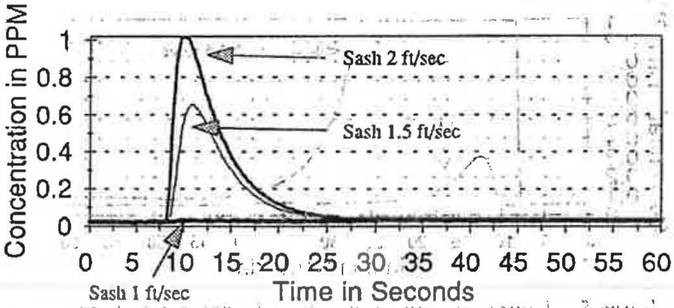

Figure 4 Dynamic containment test, response time 20 seconds, Hood A.

TABLE 3
Hood B VAV Dynamic Test

Sash Movement Speed	VAV Response Time	Minimum Face Velocity	Peak Concentration
2 ft/sec	2.5 seconds	75 ft/min (0.38 m/s)	> 1 ppm
*			
1.5 ft/sec	2.7 seconds	77 ft/min (0.39 m/s)	No Increase
1.5 ft/sec	2.8 seconds	74 ft/min (0.38 m/s)	No Increase
1.5 ft/sec	3.0 seconds	70 ft/min (0.36 m/s)	No Increase
1.5 ft/sec	3.1 seconds	66 ft/min (0.34 m/s)	0.316 ppm
1.5 ft/sec	3.4 seconds	65 ft/min (0.33 m/s)	0.207 ppm
1.5 ft/sec	3.9 seconds	66 ft/min (0.34 m/s)	0.43 ppm
1.5 ft/sec	4.7 seconds	64 ft/min (0.33 m/s)	> 1 ppm
1.5 ft/sec	7.1 seconds	56 ft/min (0.28 m/s)	> 1 ppm
1 ft/sec	2.9 seconds	83 ft/min (0.42 m/s)	No Increase
1 ft/sec	3.0 seconds	81 ft/min (0.41 m/s)	No Increase
1 ft/sec	3.1 seconds	78 ft/min (0.40 m/s)	No Increase
1 ft/sec	3.2 seconds	73 ft/min (0.37 m/s)	No Increase
1 ft/sec	3.4 seconds	69 ft/min (0.35 m/s)	No Increase
1 ft/sec	3.5 seconds	67 ft/min (0.34 m/s)	No Increase
1 ft/sec	4.6 seconds	66 ft/min (0.34 m/s)	No Increase
1 ft/sec	4.7 seconds	65 ft/min (0.33 m/s)	No Increase
1 ft/sec	6.6 seconds	57 ft/min (0.29 m/s)	0.3 ppm
1 ft/sec	12.1 seconds	47 ft/min (0.24 m/s)	> 1 ppm

* Note: All 2 ft/s sash movements during the VAV test on Hood B resulted in a concentration increase greater than 1 ppm.

performance varied between hoods. The differences between the tests on Hood A and Hood B indicate there is a difference in performance requirements for different hood designs (Table 2 and Table 3). A sash movement of 1.5 ft/s showed an increase in tracer gas concentration when the response time was greater than 10.1 seconds in Hood A and greater than 3.0 seconds in Hood B.

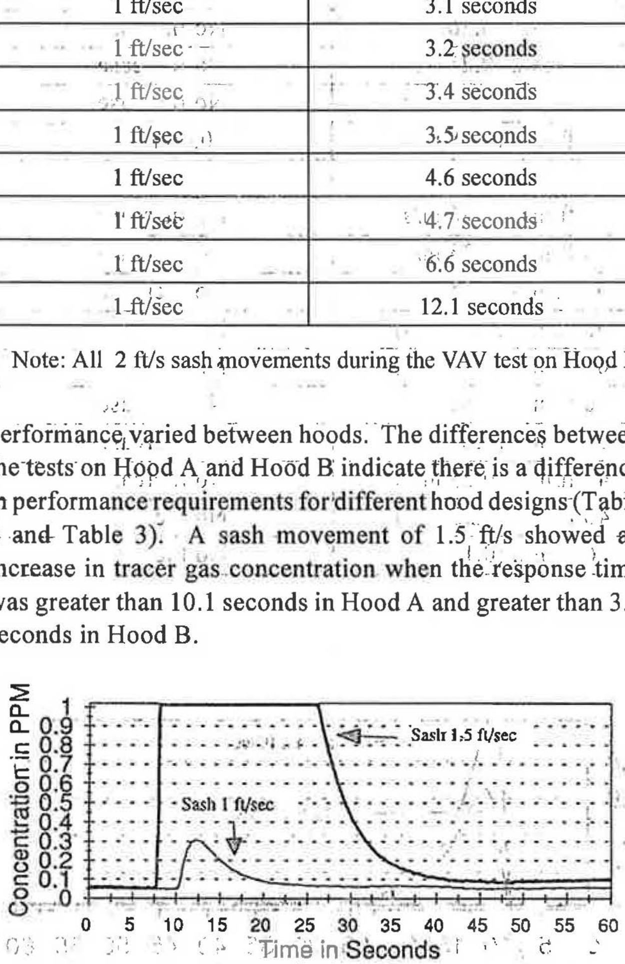

Figure 5 *Dynamic containment test, response time 7 seconds, Hood B.*

The response time required for a VAV controller varies depending on the speed of the sash movement. Slow (1 ft/s) sash movements showed less increase in tracer gas concentration than the fast (2 ft/s) sash movements. On Hood A, the required response time for containment increased from 10.2 seconds to 22 seconds as the sash speed slowed from 2 ft/s to 1.5 ft/s. On Hood B, the required response time for containment increased from 3.0 seconds to 4.7 seconds as the sash speed slowed from 1.5 ft/s to 1 ft/s.

Fast VAV controllers minimize the effect of sash movement by minimizing the drop in face velocity that occurs when the sash is opened. The dip in face velocity has a critical effect on the performance of the hood. Low face velocities can result in momentary escape of tracer gas. VAV controllers should be designed to respond quickly to sash movement in order to minimize this dip in face velocity. The minimum face velocity and speed of response define the performance characteristics of an installed VAV system.

When testing the performance of fume hoods as the sash is moved, it is important to keep sash speed constant. An inconsistent sash speed will change the results that are obtained. Tests should be done on both VAV hoods and constant-volume hoods to ensure that the performance of the hood meets the necessary performance requirements.

This study showed that sash movements can jeopardize hood containment. The study did not indicate when a hood system is unsafe or what are unsafe levels of tracer gas concentration. Determining acceptable tracer gas concentration levels is the responsibility of industrial hygienists, users, and owners of the facility.

REFERENCES

Ahmed, O., and S.A. Bradley. 1990. An approach to detemining the required response time for a VAV fume hood control system. *ASHRAE Transactions* 96 (2).

AIHA. 1992. *ANSI/AIHA Z9.5-1992, American national standard for laboratory ventilation.* American Industrial Hygiene Association.

ASHRAE. 1995. *ANSI/ASHRAE 110-1995, Method of testing performance of laboratory fume hoods.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Zhang, Z., and J.K. Agarwal. 1993. Continuous monitoring of fume hood face velocity with a side wall sensor. *ASHRAE Transactions* 99 (1).