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CONTINUOUS MONITORING OF FUME HOOD FACE VELOCITY WITH A SIDE WALL SENSOR

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ABSTRACT

A face velocity monitor was used in a study to indicate average fume hood face velocity on a continuous basis. The monitor consists of a thermal-type sensor mounted on the side wall of the hood and a display unit mounted on the front of the hood. This report describes a systematic study conducted to investigate the distribution of fume hood face velocity and the factors that influence the accuracy of the face velocity monitor. The study included a four-foot bypass hood, a four-foot nonbypass hood, a six-foot bypass hood, and an eight-foot combination sash hood. All are commercially available models. Results showed that the center velocity, the velocity at the center of the sash opening, adequately represents the average face velocity. Also, with a properly chosen location for the sensor, the air velocity measured by a side wall sensor correlated well with the average face velocity for various sash openings. All face velocities were measured by a thermal-type portable air velocity meter.

INTRODUCTION

To effectively contain hazardous substances in the fume hood, it is important that the velocity at the face of the hood (face velocity) is maintained above a certain minimum level, usually between 60 and 100 fpm (0.3 to 0.5 m/s) (OSHA 1990; Fuller and Etchells 1979). On the other hand, it is desirable to operate fume hoods at a minimum face velocity level, as a higher face velocity means larger consumption of conditioned air and, therefore, higher operating costs (Saunders 1991).

One of the existing general practices is to check the fume hood face velocity at commissioning and at regular intervals thereafter. Even though this practice is adequate in some cases, it does not ensure safety at all times. In particular, in modern buildings where many hoods are connected to common exhaust blowers, the face velocity of one hood can be affected by the opening and closing of the sash of another hood. One of the best ways to obtain maximum safety is to continuously monitor the fume hood face velocity.

The new OSHA (1990) regulations suggest continuous monitoring of fume hood face velocity for confirmation of adequate hood performance before use. In addition, according to the NFPA (1990) regulations, a face velocity monitor, or an airflow indicator, must be installed on all new and modified fume hoods. Because of these regulations, the interest in continuous monitoring of fume hood face velocity has significantly increased in recent years.

There are a few different approaches for monitoring the fume hood face velocity. One of the traditional methods is to hang a ribbon on the bottom of the sash. The movement of the ribbon is used as the indicator of airflow. This method is qualitative and cannot be used to confirm the actual face velocity. In another approach, a flow sensor is mounted in the exhaust duct and a sash sensor is used to measure the position of the sash. The face velocity is determined from the exhaust flow and the sash position. A critical shortcoming of this method is the indirect measurement of the face velocity. Since the face velocity is determined indirectly from the duct flow, the measurement can be biased by factors such as leakage in the duct, blockage of the sash opening, and flow disturbances in the duct. The duct flow measurement is also subject to other limitations. For instance, since the sensor is located in the exhaust duct, it can become contaminated or damaged by corrosive gases. In addition, the sensor has to be placed a specific distance from the hood or any bend in the duct to avoid the effects of flow disturbances.

In contrast to the methods previously discussed, the side wall sensor technique, a direct measurement method, appears to be a better approach (Koenigsberg 1991). To measure the air velocity across the face of a hood in the side wall sensor approach, a through-the-wall air velocity sensor (side wall sensor) is mounted on the side wall of the fume hood. The specific sensor used in this study consists of a platinum resistance temperature device (RTD) velocity sensor and a temperature sensor. The side wall sensor is connected to a display unit mounted on the front of the fume hood. The output of the monitor is proportional to the air velocity past the velocity sensor and is independent of the air temperature. Since the airflow across the face of the hood and the airflow through the side wall sensor are driven

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by the same differential pressure, the velocity measured by the side wall sensor correlates to the face velocity of the fume hood. However, there have been some unanswered questions regarding side wall sensor technology. The typical questions are:

1. Does the side wall measurement correlate well to the true face velocity?
2. Is the side wall measurement affected by the sensor location?
3. What is the effect of sash position on the side wall sensor output?

The objective of this study was to characterize the performance of the side wall technique and to try to answer these questions. In this paper, we will discuss the results of three tests that evaluate the performance of a side-wall-sensor-type face velocity monitor in different types of fume hoods. The objectives of these tests were as follows.

The first objective was to determine how well the velocity at the center of the sash opening represents the average face velocity at different sash openings. Ideally, the fume hood face velocity should be uniform for all sash openings, and the fume hood face velocity monitor should indicate this velocity at all times. However, it is known that the face velocity profile is usually somewhat nonuniform (Knutson 1984). The velocity profile also changes with the sash opening. Under these circumstances, the face velocity monitor can only be expected to approximately represent average face velocities for all sash openings.

Second, an effort was made to develop a technique for determining the optimum location for the side wall sensor.

Finally, we concentrated on our main objective, collecting extensive test data to evaluate the correlation between the reading of the face velocity monitor and the average face velocity for various sash openings. The study included both variable-air-volume (VAV) hoods as well as constant-air-volume (CAV) hoods. Also, the effect of baffle position on the correlation was studied.

AVERAGE FACE VELOCITY AND CENTER VELOCITY

The face velocity profiles over the sash opening were measured using a thermal-type portable air velocity meter. The meter consists of an antenna probe and a display unit and uses a platinum RTD velocity sensor that is maintained at a constant temperature above the ambient temperature. Another RTD senses the ambient temperature. The meter provides a direct digital reading in feet per minute. The fume hood openings were divided into nine subregions (see Figure 1), and the air velocity at the center of each subregion was measured. Each velocity reading was averaged over 60 seconds. The average face velocity, V_a, was then calculated as follows:

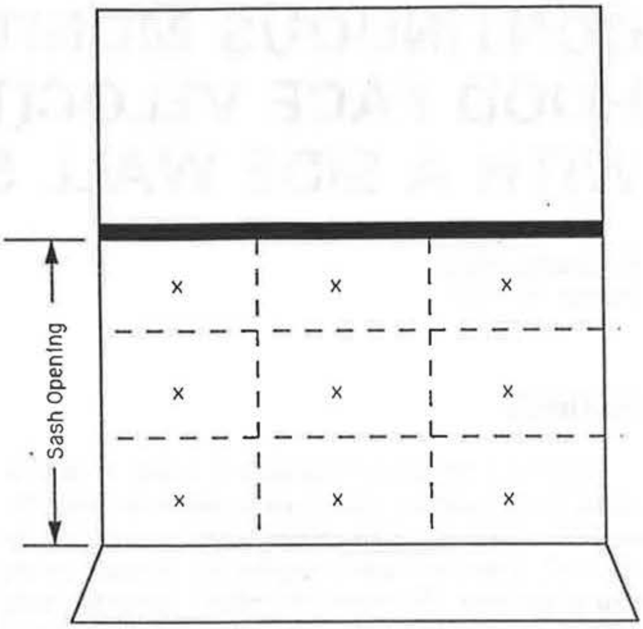


Figure 1 *Face velocity profile measurement.*

$$V_a = \frac{\Sigma(V_i \times A_i)}{\Sigma A_i} \tag{1}$$

where V_i is the velocity at the center of each subregion and A_i is the area of each subregion. This process was repeated for other sash openings.

Table 1 shows the face velocity distribution of a four-foot bypass hood at sash openings of 15%, 25%, 50%, 75%, and 100%. These tests were conducted when the baffle of the fume hood was set to the open position and the fume hood was operating in a VAV mode.

The test results revealed an interesting characteristic of the fume hood. As shown in Table 1, at the 100% open position, the face velocity was higher near the edges and lower at the center. However, the difference between the highest velocity and lowest velocity was small, especially at the 750° sash opening. As the sash opening was reduced, the face velocity gradient increased. The highest velocities were observed near the base of the hood. This general characteristic was demonstrated by all fume hoods tested. However, the velocity gradient was smaller for larger hoods.

From Table 1, it is also seen that the face velocity at the center, V_c, was close to the average face velocity for all sash openings. This is graphically shown in Figure 2 with the center velocity, V_c, normalized to the average face velocity, V_a. The four operating modes were baffle open/VAV, baffle open/CAV, baffle closed/VAV, and baffle closed/CAV. Figure 3 shows similar data. Figure 4 shows the results for a six-foot hood operating in VAV and CAV modes (the baffles were fixed in this hood). For all three cases, the center velocity is slightly higher than the average velocity at smaller sash openings and slightly lower at larger sash openings. Because of the good uniformity of

TABLE 1
Face Velocity Distribution of a 4-ft Bypass Hood
(Open Baffle/VAV Mode)

Sash Opening	Face Velocity, fpm (at 9 locations of the face of the hood)		
100%	102 92 96	102 93 98	100 94 97
75%	98 95 98	99 92 96	100 94 97
50%	100 104 113	100 103 110	101 104 113
25%	99 116 138	101 112 137	101 119 135
15%	103 119 130	102 120 134	102 123 132

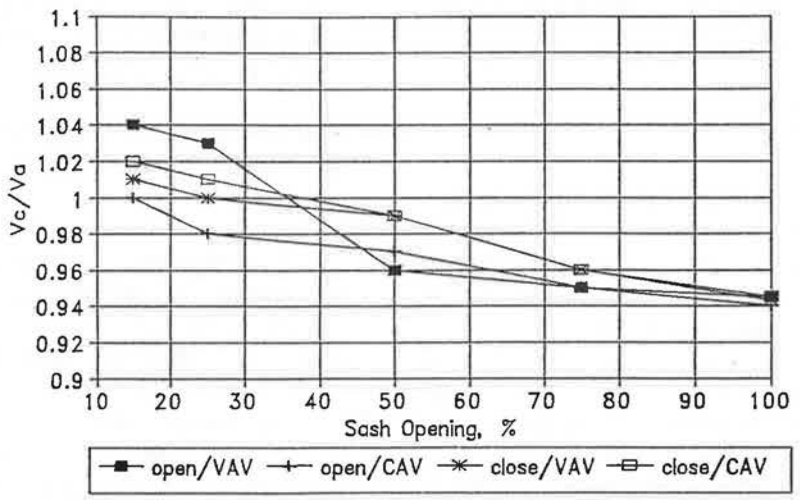


Figure 2 *Variation of center velocity with sash opening (four-foot bypass hood).*

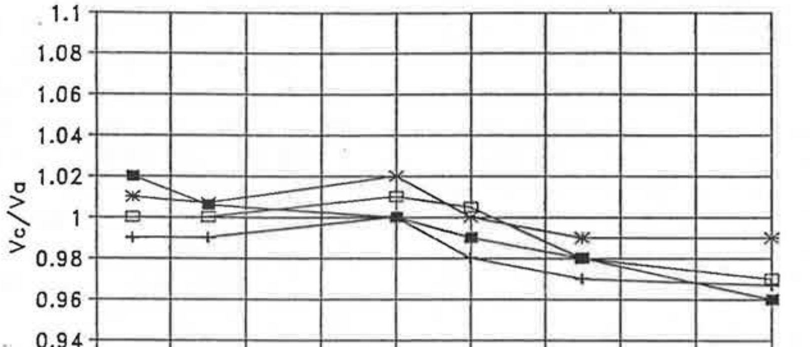


Figure 3 *Variation of center velocity with sash opening (four-foot nonbypass hood).*

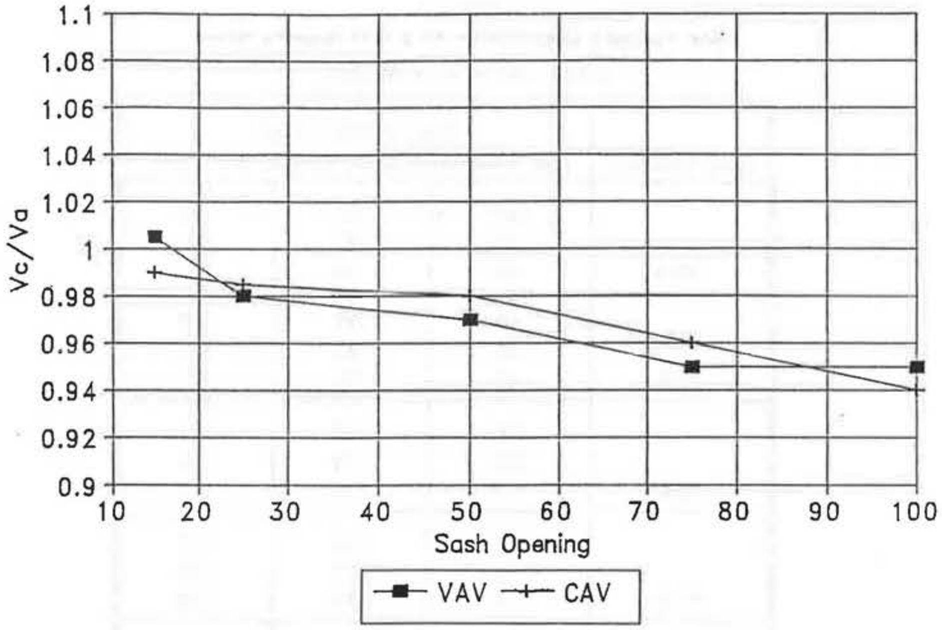


Figure 4 *Variation of center velocity with sash opening (six-foot bypass hood).*

face velocity, these fume hoods were selected to test the performance of the side wall sensor.

OPTIMUM LOCATION FOR THE SIDE WALL SENSOR

As mentioned earlier, in the present approach, the face velocity is determined by measuring the velocity of air through a side wall sensor. Due to the complexity of airflow in the hood, the velocity of air through the side wall sensor may be affected by the localized differential pressures across the side wall. For best results, the side wall sensor should be located where the localized differential pressure is not only dependent on the face velocity but also independent of the sash position. To determine the best sensor position, a sensitive differential pressure transducer was used to measure the localized differential pressure across the side wall of the fume hood. The procedure was as follows: Two pieces of clear flexible plastic tube were connected to the differential pressure transducer. The high-pressure side was held stationary near the side wall outside the hood. The low-pressure side was held stationary near the side wall inside the hood. The pressure transducer reading indicated the localized differential pressure. The side wall surface was divided into a grid pattern consisting of 15 points (see Figure 5). The localized differential pressure was then measured at each grid point for sash openings of 15%, 25%, 50%, 75%, and 100%. The location where the localized differential pressure was least affected by the sash position was chosen as the optimum sensor location.

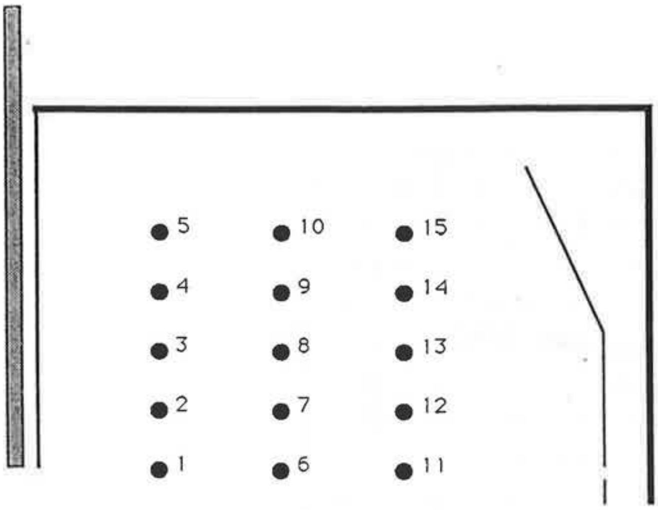
Figure 5 shows the typical pressure distributions on the side wall at different sash openings. As shown in the figure, the pressure variations at location 2 were minimal as the sash opening varied. This location was chosen as the optimum sensor location. It was also found that for all fume hoods tested, the pressure distributions were similar, indicating that a single optimum sensor location can be used in different types of hoods.

INFLUENCE OF SASH POSITION ON MONITOR READING

Once the side wall sensor was mounted, the face velocity monitor was calibrated to correlate to the average face velocity. To calibrate the face velocity monitor, the sash was raised until it hit the stops. This sash position is usually the normal working position for most fume hoods. The probe of the portable air velocity meter was taped to the sash hanging downward. The antenna probe was adjusted so that the velocity sensor was at the center of the sash opening. Since the center velocity at the sash opening is very close to the average face velocity, the face velocity monitor was calibrated to give the same reading as the portable air velocity meter.

To study the effect of sash opening on the face velocity monitor reading, the following procedure was followed. The sash position was varied from 15% to 100% open. The antenna probe of the portable velocity meter was readjusted to read the center velocity for each sash opening. Using the data presented in Figures 2 through 4, corrections were applied to the headings of the portable air velocity meter to arrive at the average face velocities.

The relationship between the monitor reading, V_m, and the average face velocity, V_a, are shown in Figures 6 through 8. In general, the ratio V_m/V_a decreased with increasing sash opening, reaching a minimum at 50% open, then increased with further opening of the sash. Although the monitor reading was found to be somewhat different from the average face velocity at some sash positions, the difference between the two velocities was generally less than 10%.



Location Index	Differential Pressure (x10^{-2} mm Hg) Opening=33%	Opening=66%	Opening=100%
1	0.228	0.296	0.236
2	0.228	0.278	0.248
3	0.225	0.330	0.333
4	0.227	0.358	0.450
5	0.226	0.380	0.701
6	0.228	0.297	0.236
7	0.226	0.306	0.333
8	0.226	0.335	0.435
9	0.225	0.368	0.720
10	0.225	0.380	0.712
11	0.228	0.302	0.242
12	0.227	0.315	0.400
13	0.226	0.340	0.542
14	0.227	0.367	0.800
15	0.227	0.400	0.890

Figure 5 ***Distribution of different pressures on the side wall at different sash openings. Face velocity = 100 fpm (0.5 m/s) for all sash openings.***

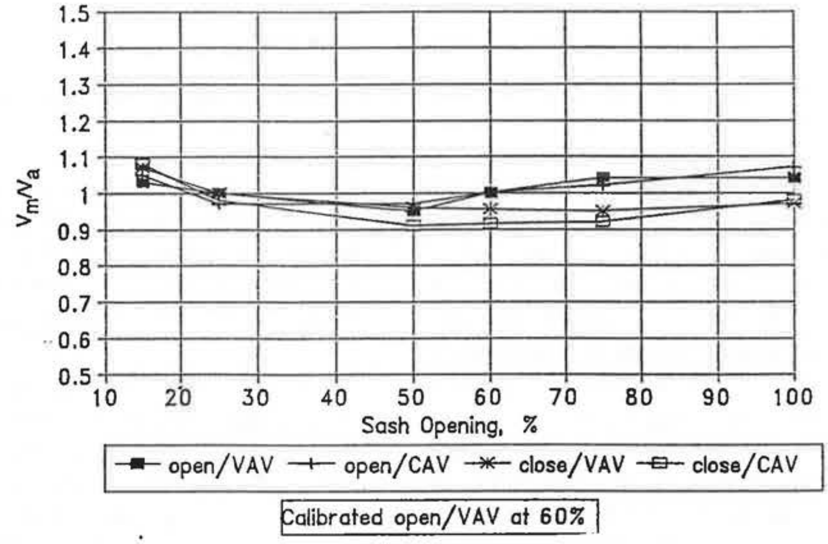


Figure 6 ***Effect of sash opening on face velocity monitor reading (four-foot bypass hood).***

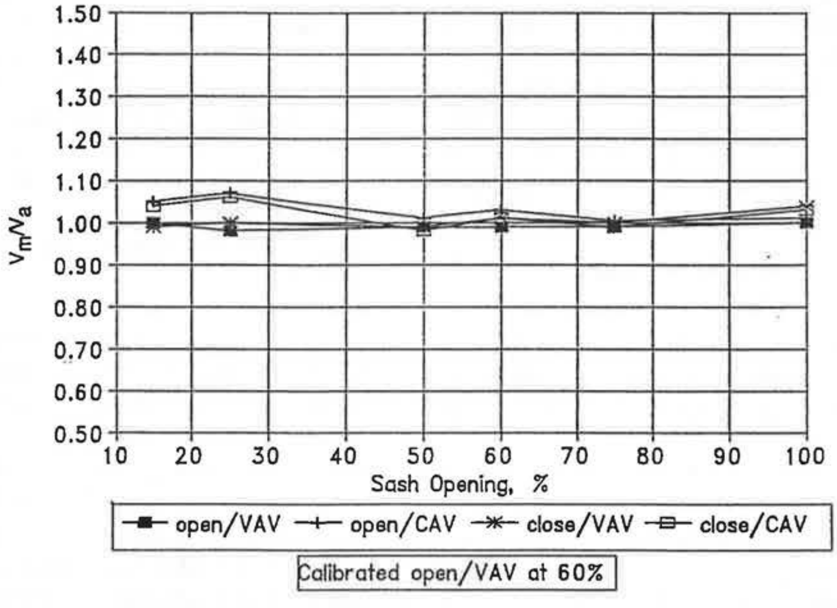


Figure 7 ***Effect of sash opening on face velocity monitor reading (four-foot nonbypass hood).***

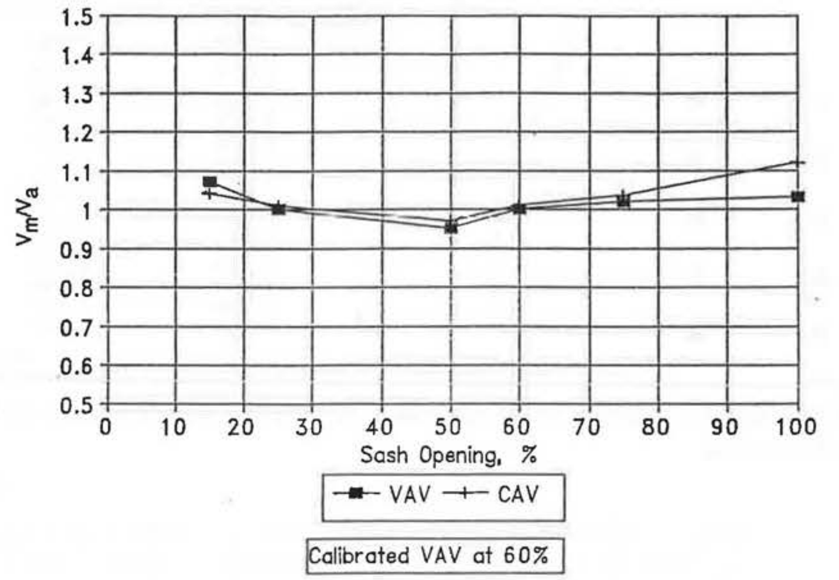


Figure 8 ***Effect of sash opening on face velocity monitor reading (six-foot bypass hood).***

Experiments were also conducted to evaluate the performance of the face velocity monitor on an eight-foot hood with combination sashes. This hood has two vertical sashes. Each vertical sash consists of three horizontal sashes. The uniformity of the face velocity was first investigated. It was found that for various sash openings the center velocity agreed with the average face velocity within ±5%. Experiments were then conducted to find the optimum location for the side wall sensor using the method described above. To calibrate the face velocity monitor, the vertical sashes were closed and the horizontal sashes were fully opened, which was assumed to be the most often used configuration for setups.

After calibration, the performance of the face velocity monitor was verified by comparing the reading of the face velocity monitor, V_m, with the face velocity measured at the center of the sash opening, V_c. For each sash opening, 15 measurements were made for V_c and V_m. The average face velocity monitor reading, $<V_m>$, and average center velocity, $<V_c>$, were then calculated. The errors in the face velocity monitor reading were determined using the following equation:

$$\text{Error} = \frac{\langle V_m \rangle - \langle V_c \rangle}{\langle V_c \rangle} \times 100\%. \qquad (2)$$

The results obtained at various combinations of the sash openings are shown in Figures 9 through 11. To keep this paper concise, only the average velocities and the errors are given in the figures.

CONCLUSIONS

1. The face velocity profile was found to vary with sash opening. For sash openings greater than 75%, air velocities near the sash edge and near the sill are higher than those at the center. For smaller sash openings, the face velocity is lower near the sash edge and higher near the sill. However, over the sash opening range of 15% to 100%, the difference between the average face velocity and the velocity at the center was less than 6%.

2. For good results, the side wall sensor of the face velocity monitor must be installed in the proper location. The optimum sensor location can be determined by measuring distributions of the side wall differential pressures for different sash openings. The experimental results also showed that the optimum sensor location is similar for all hoods tested in this study.

3. It is recommended that the face velocity monitor be calibrated with the sash opened to the normal working position. Many hood manufacturers recommend the normal working sash position by providing stops for the sash. These hoods should be calibrated with the sash open to the stops. If the hood is provided with adjustable sash stops, then it should be calibrated with the sash stops adjusted to the most frequently used position. A fume hood with no stops should be calibrated with its sash raised to the 60% open position.

4. Experiments were performed on a four-foot nonbypass hood, a four-foot bypass hood, a six-foot bypass hood, and an eight-foot combination sash hood. The face velocity monitor readings on those hoods were compared with the average face velocity. It was found that the difference between the monitor reading and the average face velocity was generally less than 10% for different sash openings and various sash combinations. Therefore, it was concluded that this method is adequate for continuous monitoring of the fume hood face velocity.

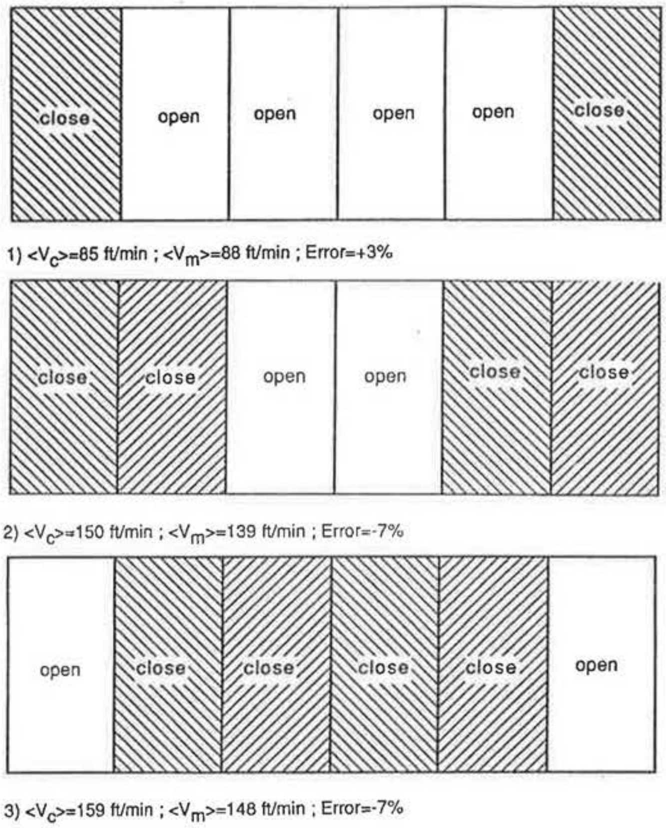


Figure 9 *Accuracy of face velocity monitor on an eight-foot combination sash hood, case 1 through case 3.*

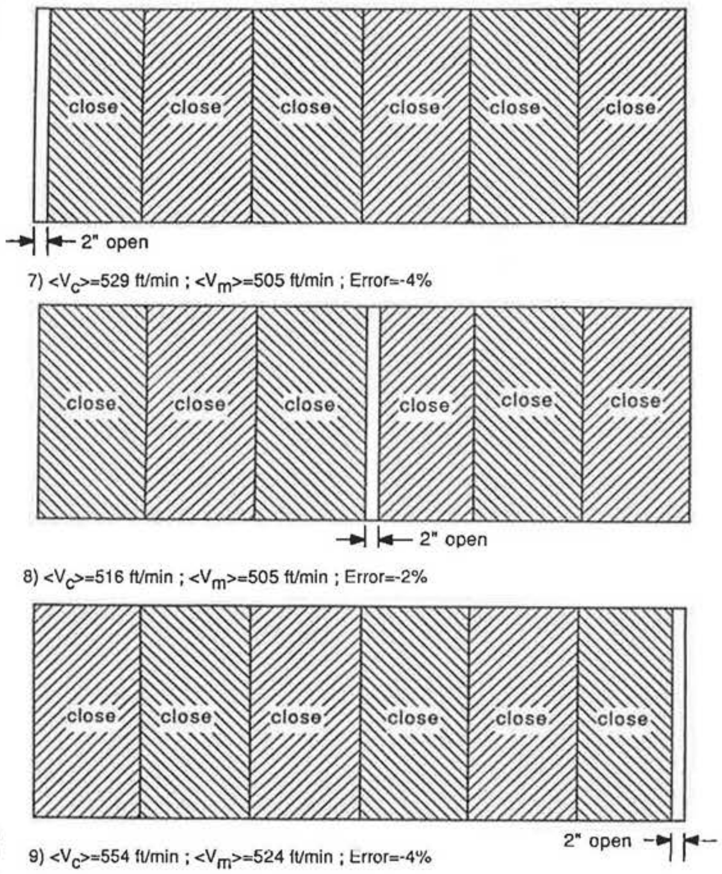


Figure 11 *Accuracy of face velocity monitor on an eight-foot combination sash hood, case 7 through case 9.*

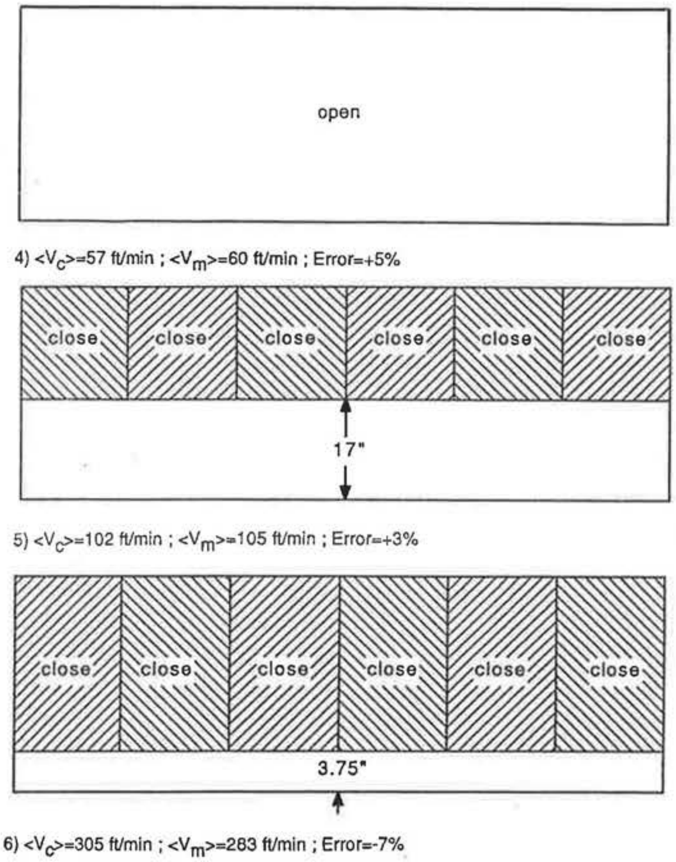


Figure 10 *Accuracy of face velocity monitor on an eight-foot combination sash hood, case 4 through case 6.*

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