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Continuous-Flow Bypass For Improved Fume Hood Performance

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ABSTRACT

The "roll" of air which forms inside a fume hood immediately behind the sash can be a reservoir for contaminants. Air recirculates at that location rather than exiting the hood immediately. So contaminant concentrations may be higher in the "roll" than at other points inside the hood.

The matter is of some concern, because the roll is close to the breathing zone of the scientist performing the work. The current project investigated a means of reducing the concentration of contaminants directly behind the sash. If this concentration is reduced, any leakage would be less hazardous to workers in the lab.

The method, called the continuous-flow bypass, introduces a constant stream of air into the hood above the sash, delivering dilution air directly to the roll. The method reduced contaminant concentration by 50 to 90%, which significantly reduces the hazard potential of any leakage.

INTRODUCTION

A chemical fume hood contains gases and particulates, so that lab workers will not inhale such contaminants. The hood encloses the experimental apparatus on five sides with a physical barrier. The sixth side is equipped with a moveable sash, so workers can access the apparatus inside the hood. To form a barrier against the escape of contaminants on the sixth side, the hood pulls in lab air. If that air has sufficient velocity and the turbulence intensity is low, contaminants are less likely to escape.

However, contaminants can and do regularly escape such hoods. Leakage is caused by intermittent, local disturbances in the smooth flow of air into the hood. Those disturbances are caused by workers adjusting apparatus inside the hood, or by air turbulence caused by people walking near the face of the hood, or by doors near the hood being quickly opened or closed. For these and other reasons, leakage occurs in the "as-used" mode that would not occur in the "as manufactured" mode.(1,2) Given that intermittent escape is a probability, a well-designed fume hood should limit the exposure hazard from such leakage.

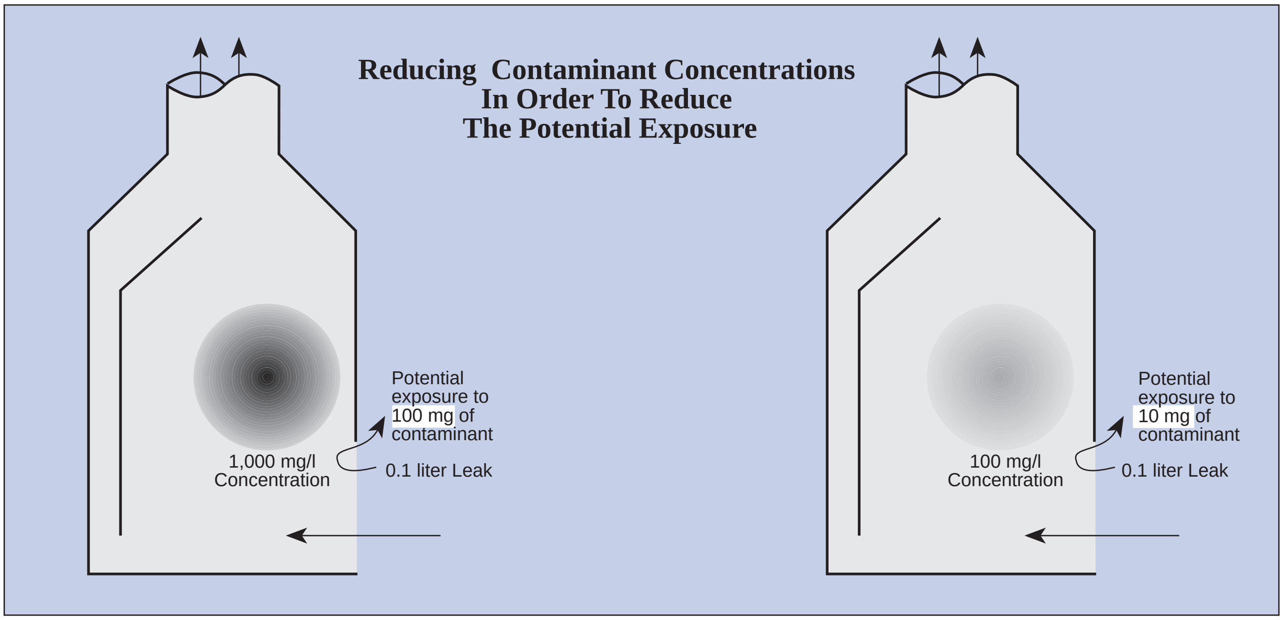
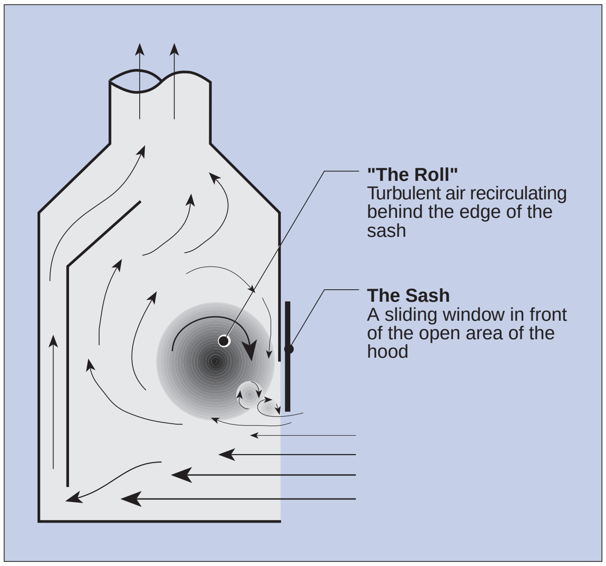


Figure 1. Potential Exposure is proportional to: Concentration (ppm) x Leakage (liters per sec.)



"The Roll"
Turbulent air recirculating behind the edge of the sash

The Sash
A sliding window in front of the open area of the hood

Figure 2. "The Roll"

Potential exposure is a function of the concentration in the roll. It is proportional to the volume of leakage (liters) multiplied by the concentration of the contaminant in that leaking air. This is shown by the diagram in figure 1. Exposure can be reduced by limiting the volume of leakage, or by reducing the concentration of the contaminant, or reducing both. The current project was intended to focus on the concentration of the contaminant.

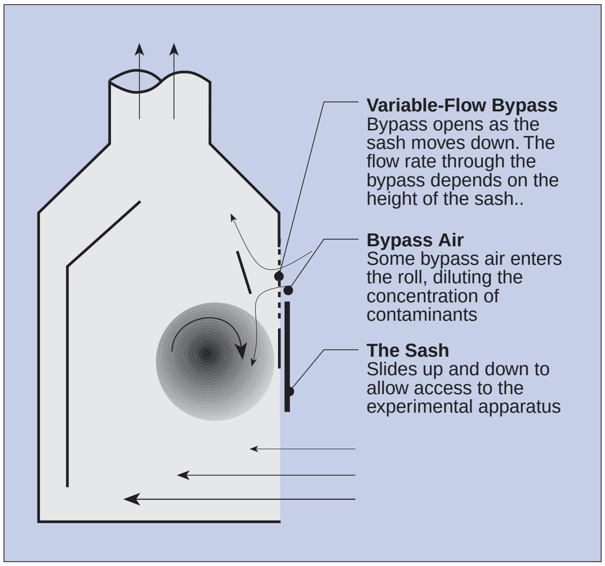
Within a fume hood, contaminant concentration varies widely. The concentration is greatest at the source of the contamination. For example, the air immediately above a boiling beaker of acid may be nearly saturated with acid vapor. But five or six inches (125 to 150mm) away from the edge of the beaker, air flowing through the hood dilutes the vapor concentration considerably, due to molecular and eddy diffusion.[3,4] Near the front edge of the work surface, the concentration will be especially low, because contaminant sources are usually well inside the hood, and fresh air is flowing into the hood at a high rate.

However, above the work surface, the concentration may be higher, especially just behind the hood sash. As shown in figure 2, the air inside the hood has some degree of turbulence, and at that particular location, the air tumbles in a circular pattern known in the trade as "the roll".(5) In the roll, air is recirculating inside the hood, rather than being quickly flushed out the hood exhaust. Because the roll air remains inside the hood for a longer period, contaminant concentration is likely to be higher there than at any other location apart from the contaminant source itself. This is unfortunate for two reasons. First, roll air is likely to be the air which is pulled out of the hood if outside turbulence disturbs the smooth flow of air into the hood, because the roll is located near the front of the hood. Secondly, leakage from the roll is likely to reach the breathing zone of workers standing near the front of the hood. So the current research tests a hood modification designed to reduce the concentration within the roll, which would reduce the exposure hazard from any air leakage into the laboratory.

"BYPASS" FUME HOODS

In a laboratory exhaust system, there are many reasons for keeping the total exhaust flow constant. For example, if the total flow is reduced, the air may not exit the roof line with enough momentum to be propelled above the fresh air intakes. Also, exhaust cleaning equipment like wet scrubbers functions best if the air velocity through the contact bed is constant. So fume hoods are designed with controls to keep the exhaust air flow constant, in spite of changes in the height of the sash.

One method of keeping the total flow constant is a bypass grill arranged as shown in figure 3. As the sash is lowered, it exposes the bypass grill so that air can flow into the hood above the sash, keeping air flow relatively

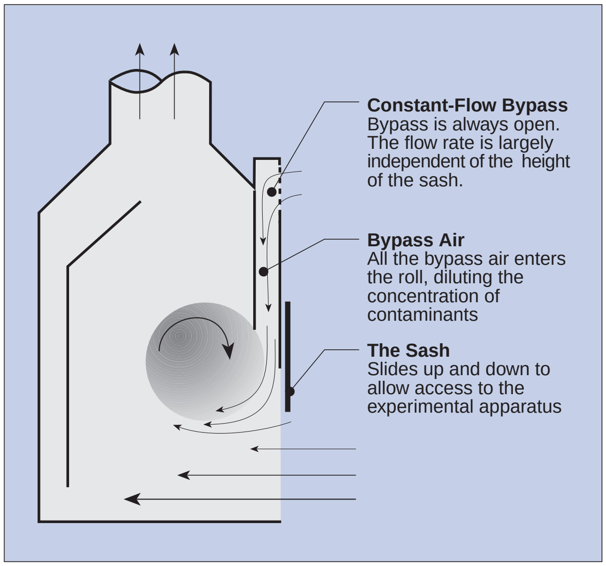


Variable-Flow Bypass
Bypass opens as the sash moves down. The flow rate through the bypass depends on the height of the sash..

Bypass Air
Some bypass air enters the roll, diluting the concentration of contaminants

The Sash
Slides up and down to allow access to the experimental apparatus

Figure 3. Variable-Flow Bypass



Constant-Flow Bypass
Bypass is always open. The flow rate is largely independent of the height of the sash.

Bypass Air
All the bypass air enters the roll, diluting the concentration of contaminants

The Sash
Slides up and down to allow access to the experimental apparatus

Figure 4. Continuous-Flow Bypass

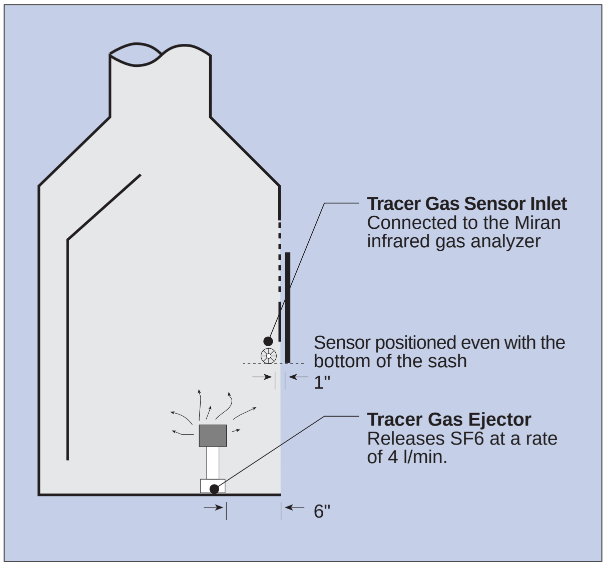


Figure 5. Experimental Arrangement - Vertical Sash

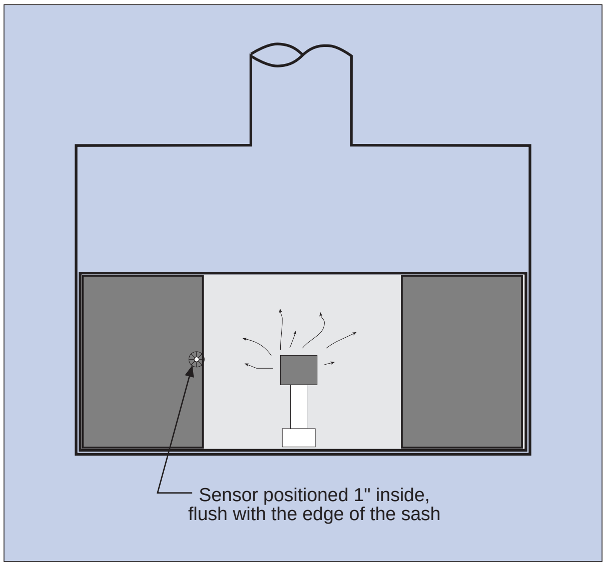


Figure 6. Sensor position for the horizontal sash

constant into the hood and limiting how high the entering velocity can become. Without the bypass or some other control, the air velocity through the remaining open area of the hood would increase greatly as the sash was lowered. High air velocity could disturb experiments within the hood. Containment could also be adversely affected, because turbulence increases as more air flows around the operator on its way into the hood. Such turbulence can pull contaminated air out of the hood and into the operator's breathing zone.

If the bypass is equipped with a baffle as shown in figure 3, air flows partly into the exhaust, but also partly into the roll. That is beneficial, because the additional air dilutes the contaminants within the roll. However, if such a sash is fully-raised, there is no air flowing through the bypass, so therefore there is no dilution of the concentration in the roll.

An alternate arrangement is a continuous-flow bypass, as shown in figure four.(6) This design was developed to ensure that air flows through the bypass at all times. The amount increases or decreases slightly based on changes in sash height, but there is always air flowing directly into the roll zone, so that contaminant concentrations are reduced. The current research was designed to quantify the effect of such a bypass on the contaminant concentration in the roll zone.

A continuous bypass can also be helpful for hoods which use a third approach to controlling air velocity at the hood face. Some hood controls vary the exhaust flow rate in direct proportion to the open area under the sash (variable air volume system). As the sash opens, a controller increases exhaust flow and vice-versa. Such systems do not use a variable bypass, but a continuous bypass is still appropriate. The continuous bypass can provide roll dilution when the sash is open, and provide a beneficial flow beneath the airfoil when the sash is closed.

EXPERIMENTAL PROCEDURE

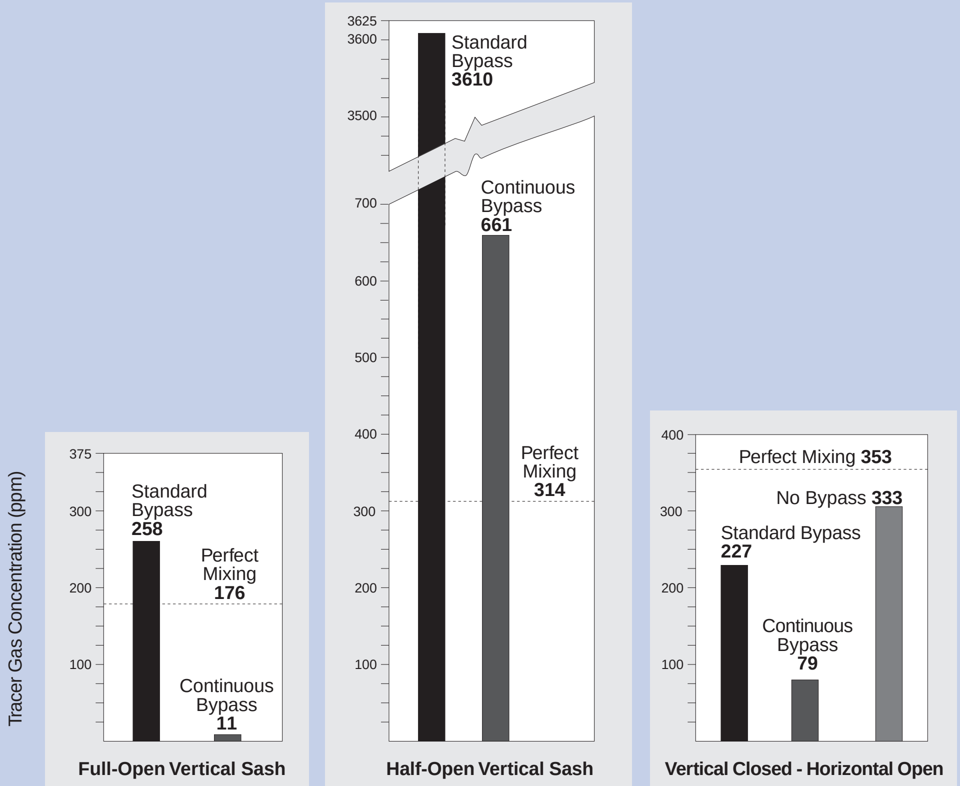
A tracer gas technique was used to quantify concentration in the roll. The tracer gas used was sulfur hexafluoride (SF_6). The gas was released inside the hood near the work surface, and the concentration was measured in the roll zone, while the sash height was changed. Two different sash types were tested: vertical-opening and vertical-frame with horizontal-opening windows.

The tracer gas ejector was identical to that described by the ANSI /ASHRAE Standard 110-1985 test procedure.(7) The gas was released as shown in figure 5, at a rate of 4 liters per minute. The tracer gas concentration was measured by a Miran Model 1A infrared gas analyzer. The instrument sampled the air near the bottom of the sash at a rate of 20 liters per minute through a probe measuring 4" long by 1.75" in diameter. Other details of probe location are shown in figure 6. The sampling probe was located near the edge of the sash—in the air which would be leaked, if any leaking were to occur. A common hood was modified to create three hood designs for testing. These designs included:

1. Non-bypass (Figure 2)
   Standard hood with a vertical sash with no provision to allow air to enter by bypassing the sash.

2. Standard Bypass Hood (Figure 3)
   A traditional bypass arrangement, where the view screen blocks the bypass until the sash is lowered. Then air enters the hood through a bypass above the sash.

3. Continuous-Flow Bypass (Figure 4)
   In this design, air enters the hood through the bypass continuously, although the amount of air flowing through the bypass is somewhat affected by the position of the sash.



	Full-Open Vertical Sash		Half-Open Vertical Sash		Vertical Closed - Horizontal Open	
Perfect Mixing Value	176 ppm		314 ppm		353 ppm	
Research Results	Replicates	**Average**	Replicates	**Average**	Replicates	**Average**
Standard Bypass (ppm)	238 239 298	**258**	3480 3390 3960	**3610**	279 127 276	**227**
Continuous Bypass (ppm)	6 12 13	**11**	660 635 687	**661**	83 65 89	**79**
No Bypass (ppm)	---------- Not Tested ---------		---------- Not Tested ---------		349 290 359	**333**

Figure 7. Test Results

The bypass hoods were tested in three sash positions:

- Vertical full open (28")—Horizontal windows closed
- Vertical half open (15")—Horizontal windows closed
- Vertical closed—Horizontal windows full open

The non-bypass hood was only tested in the last position—vertical closed, horizontal windows fully opened. In the other sash positions, its airflow pattern is identical to that of the standard bypass—the bypass is blocked when the sash is in either the full-open or half-open positions.

Each hood was tested at each position for three replicate runs. The results shown in figure 7 are the average of the results from the three replicate runs. During all test runs, the total exhaust flow rate (cfm) for the hoods was set by establishing 100 fpm as the inlet face velocity in the standard bypass hood. The air flow was set using procedures outlined in ANSI/ASHRAE Standard 110-1985. Then the exhaust flow was held constant for the standard bypass hood, and for the other two hoods as well. This meant that the inlet face velocity for the other hoods varied slightly from the 100 fpm velocity of the standard bypass hood. The range of this variation was between 90 and 110 fpm. The air flow rate (cfm) was held constant rather than the face velocity (fpm). That way, differences in measured concentration could be attributed to differences in hood geometry rather being confused by the increased dilution effect of a larger air flow.

In each of the replicate runs, the concentration data were collected over a three minute time period. The final results reflect the average of the values collected during that 3-minute period.

RESULTS & DISCUSSION

The average of the three replicate runs is shown in figure 7 and compared to a "perfect mixing" base line concentration. That is, the concentration which would be achieved if all of the air entering the hood were perfectly mixed with the tracer gas. Note the difference in concentration between the continuous-flow bypass, and both other types of hoods.

Consider, for example, the runs performed with hoods in the fully-open, vertical sash position. Theoretically-perfect mixing(8) would yield a concentration of 176 ppm. ($Q_{sf6} \div Q_{air} \times 10^6$) At 258 ppm, the variable bypass design permits much higher-than-perfect-mixing concentrations. The continuous-flow bypass, in contrast, reduces concentration to 11ppm; in other words: more than a 96% reduction from the variable bypass design.

This pattern continues for the runs performed in the half-open/half closed vertical sash position. Since air flow is reduced as the sash is lowered, perfect mixing would result in a slightly higher concentration of 314 ppm. The equipment with a variable bypass greatly exceeds that concentration, with a value of 3,610 ppm. In contrast, the continuous-flow bypass drops the concentration to 661 ppm, or more than an 80% reduction from the variable bypass design.

The authors note that in this sash position, both designs considerably exceed the value expected with theoretical perfect mixing. One explanation could be that in the half-open position, the gas sensor is much closer to the tracer gas ejector than when the vertical sash is either fully open or fully closed. Another factor may be that with the sash in the half-open position, the air has a more direct path to the back of the hood and into the exhaust, with less flushing of the air in the roll and less dilution of the air above the ejector, so concentrations could build to higher levels with the sash in this low position. The authors also suggest that the continuous-flow design may not actually reduce concentration within the roll. The effect of the bypass air may be to push the roll further back into the hood, away from the edge of the sash.

Regardless of the mechanism, the net result is that, compared to other designs, the continuous-flow bypass considerably reduces concentrations where air is most likely to leak.

In the third set of runs, the vertical sash has been fully-closed, but the horizontal windows in the sash are fully-open. Once again, at 79 ppm, the continuous-flow bypass provides much lower concentrations than other designs, and also lower than the perfect-mixing value.

SUMMARY AND CONCLUSIONS

Potential exposure for fume hood operators can be reduced three ways. First, the aerodynamics of the inlet can be changed to reduce turbulence and therefore reduce leakage.(5,9) Second, the operator's procedures can be modified to reduce turbulence and leakage. Finally, the contaminant concentration in the leakage zone behind the sash can be reduced to limit exposure if air should leak from the hood. This paper focuses on the last approach.

Information provided here shows that the air bypass design can have a significant effect on the concentration in the "roll", or primary leak zone, located immediately behind the sash.

Specifically, the authors conclude that:

1. The continuous-flow bypass design tested here reduces contaminant concentrations near the edge of the hood sash. In that way, the design allows a considerable reduction in the potential exposure hazard to workers who use the fume hood.
2. In contrast, the standard bypass tested here (in the horizontal-open position) only marginally improves on the performance of a hood with no bypass air in the design.

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