

Acumen

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Using A Constant Air Volume Controller To Insulate A Class II Biosafety Cabinet From Negative Effects Of A Variable Air Volume Exhaust System

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ABSTRACT

Variable air volume (VAV) systems are often used to exhaust air from chemical fume hoods. VAV controls reduce the exhaust air flow in proportion to the actual need. Consequently the system uses less fan power, and less energy is used to condition the replacement air.

Unlike fume hoods, however, biosafety cabinets require a constant flow of air to contain contamination and to protect products in the cabinet. When variable volume fume hoods are connected to the same exhaust system as a biosafety cabinet, the variation in total system exhaust flow can disturb the critical pressure relationships between air flows in the cabinet. Such pressure changes can allow contaminants to escape the cabinet, or allow lab contaminants to enter the cabinet.

To avoid these problems, biosafety cabinets can be equipped with constant air volume (CAV) controllers. Such controllers sense flow changes in the cabinet exhaust system. To keep that flow constant, the controller opens or closes a damper located in the cabinet exhaust duct.

This research shows that CAV controllers can be effective in maintaining constant air flow. However, increases in room supply air can cause local flow turbulence which adversely affect cabinet containment. The test results show that keeping the cabinet air flow constant does not necessarily guarantee that the cabinet will perform properly.

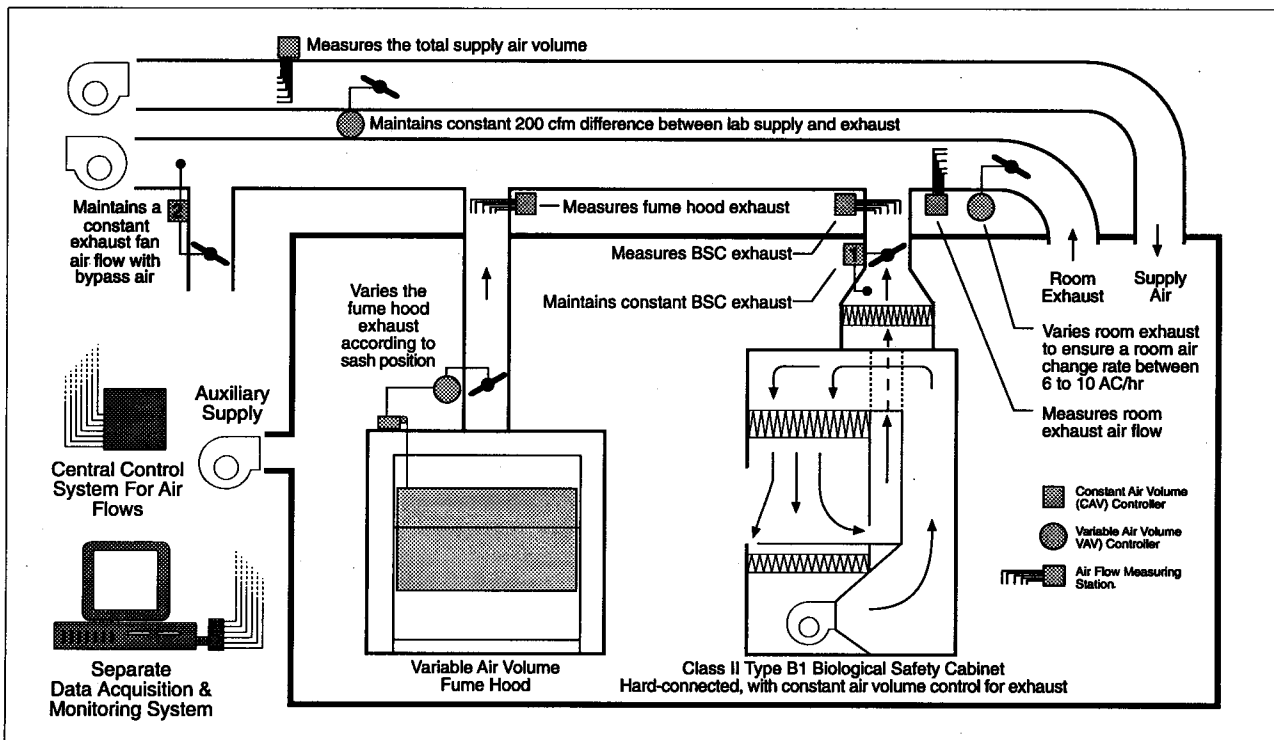


Figure 1. Laboratory and equipment arranged to test the effectiveness of a CAV controller in maintaining both BSC air flow and containment effectiveness when connected to a central exhaust with wide air flow variations.

Connecting Class II Biosafety Cabinets To Variable Volume Exhaust Systems

In volume 2, no.1 of the ACUMEN series, we noted that "thimbles" can be used to isolate Class II Type A and Type B3 biosafety cabinets from air flow changes caused by variable air volume exhaust systems. But that option is not possible for Type B1 and Type B2 cabinets. The exhaust from these cabinets must always be "hard-connected" to the building exhaust duct work.

In most buildings, combined exhaust systems are the rule, because separate exhausts for each device are often impractical for economic and physical reasons. Since variable volume chemical fume hoods often share exhaust duct work with biosafety cabinets, combined systems generally have pressure and air flow fluctuations as fume hood sashes are raised and lowered. These fluctuations can cause containment or isolation problems in BSC's.

Consequently, when a Class II Type B1 or Type B2 cabinet is exhausted to a central system, a constant volume controller is often used to regulate the cabinet exhaust air flow. Figure 1 shows such a system. When controller #1 senses increased flow in the cabinet exhaust duct (too much air being exhausted from the cabinet), the controller closes a damper in the cabinet exhaust. If the cabinet controller senses a flow reduction (too little air being pulled from the cabinet), the cabinet exhaust damper opens so more air is pulled from the cabinet.

Other systems use different devices such as variable-speed fans rather than dampers, and different air flow sensing devices such as calibrated orifices or thermal anemometers. But the goal is the same: vary some other parameter so the cabinet air flow stays within the $\pm 5\%$ limit required by NSF Standard 49. The assumption behind the $\pm 5\%$ tolerance is that if air flow remains constant, the cabinet will continue to contain and protect the product as it did during its original NSF biological certification test.

RESEARCH GOALS

Given the popularity of central VAV exhaust systems, and the frequency of Class II biosafety cabinets being connected to these systems, it is important to understand the behavior and limits of performance of constant volume controllers. This research was conducted to answer three principal questions:

1. Can a CAV controller on a Class II, Type B1 BSC respond to changes in fume hood exhaust quickly enough to maintain the cabinet air flow within the $\pm 5\%$ specification of NSF Standard 49?
2. What effect does room pressurization or depressurization have on the controller's ability to maintain air flow within $\pm 5\%$?
3. Apart from maintaining the NSF-required air flow tolerance of $\pm 5\%$, does the CAV-equipped cabinet in fact contain contaminants under typical VAV exhaust conditions?

EXPERIMENTAL DESIGN

A test laboratory was equipped with an exhaust system connected to both a four-foot chemical fume hood and a Class II, Type B1 biological safety cabinet as shown in figure 1. Air flow controls, all of which were provided by a single vendor, were installed at key points throughout the system. These points are shown in figure 1 and described by the text below.

The *fume hood* was equipped with a VAV controller which automatically adjusted a damper to maintain a constant hood face velocity regardless of the changes in sash position.

The *BSC* was equipped with a CAV controller which measured air flow leaving the cabinet, and automatically modulated a damper in the exhaust duct to maintain a constant exhaust flow from the cabinet.

The *central exhaust* fan was also equipped with its own CAV controller (#2) so the fan could operate at constant speed and pressure. That system consisted of a pressure sensor connected to an automatic modulating damper in a bypass duct. When necessary, the damper allowed extra air from outside the room to enter the exhaust duct to compensate for air flow reductions caused by lowering the fume hood sash.

All air flow controllers were networked with the room exhaust and supply controls, so the required fresh air flow rate of six air changes per hour could be maintained in the lab space. The controls were also arranged to supply a constant 200 cfm beyond the room exhaust quantity when a positive room pressure was required, or 200 cfm less than the exhaust when a negative pressure was needed.

In addition to the air flow controls, a separate data acquisition system was installed to monitor and record the performance of the control system. The monitoring points and devices connected to this system are described below.

To measure *cabinet and fume hood exhaust air* flows, averaging Pitot tube arrays were placed in the ducts leaving this equipment. The average velocity pressure in these arrays was measured by a transducer which was accurate to 0.07% of its full scale, which was 0.25" WC. The transducer output was conditioned with a square root extractor, which output a voltage signal that was directly proportional to air flow. Output voltages were scaled and recorded with the computerized data acquisition system. The *cabinet intake air flow* (air flowing from the lab into the cabinet) was assumed to be the same as the cabinet exhaust air flow.

To *establish a reference for air flow inside the BSC*, a single-point, hot-wire anemometer was placed in the downflow air stream inside the cabinet. The hot-wire signal was also sent to the data acquisition system where it was scaled and recorded.

Air flow readings were taken from the measurement points at a rate of 16 times per second. These 16 readings were averaged and recorded at a rate of one per second.

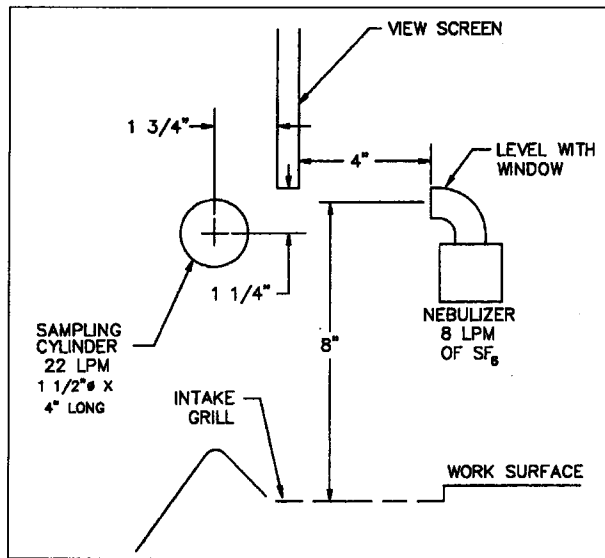


Figure 2. Procedure and equipment for containment challenge (similar to NSF Standard 49).

To test the containment performance of the cabinet, the experiment used a tracer gas procedure to simulate the biological tests described by NSF Standard 49. This procedure was developed and validated in a separate series of experiments. The advantage of this technique is that it allows data collection in real time. A biological test requires a two-day incubation period to obtain results. The tracer gas method used here provides a reasonable indication of cabinet performance in real time. Sulfur hexafluoride (SF_6) was released from a nebulizer located inside the cabinet at a rate of 8 l/min. An infrared gas analyzer sampling at a rate of 20 l/min was positioned

outside the cabinet, and arranged so that trace amounts of SF_6 gas could be detected continuously. Variations in tracer gas concentration were used to quantify cabinet containment performance.

To test cabinet performance and the effectiveness of the CAV controller in maintaining a constant cabinet exhaust air flow, the fume hood sash was raised and lowered in a two-second period between a 10-inch height and its 30-inch maximum. These changes in sash height varied the fume hood exhaust between 319 cfm and 806 cfm. The BSC exhaust was set to 275 cfm and the CAV controller modulated a damper to keep that value constant.

The base line test started at the 30" sash height with the lab under negative pressure. After 7 minutes, the sash was lowered to 20", and at 11 minutes, lowered to the minimum 10" height. Another raise-lower cycle was completed before the lab pressure was changed from negative to positive. Then two cycles were repeated with the lab under positive pressure.

RESULTS

Figure 3 shows the test results, which include:

1. **Constant BSC flow rate.** The CAV controller did an excellent job of keeping the flow rates of the cabinet constant in spite of wide swings in fume hood exhaust.
2. **No measurable effect of room pressure.** The CAV controller kept cabinet air flow constant when the room went from negative to positive air pressure with respect to the surrounding corridors.
3. **Inconsistent containment.** The SF_6 tracer gas tests show that there was a wide variation in containment performance even though the cabinet air flows were held within the $\pm 5\%$ range specified by NSF. The

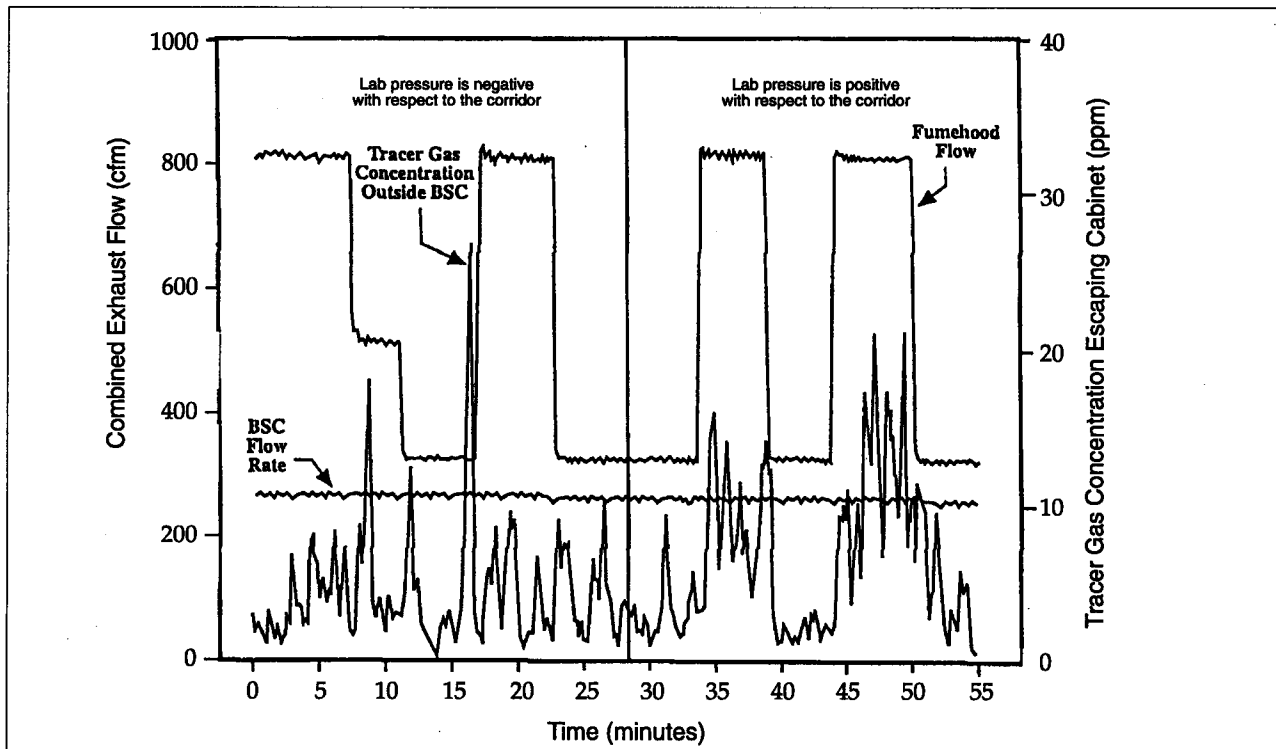


Figure 3. Test results show that the constant air volume controller maintained the cabinet air flow within NSF specification, yet there was leakage of contaminants from the cabinet at several points during the test.

tracer gas escaped the cabinet more frequently when the supply air flow was larger—when the fume hood sash was at 30" and when the lab was being maintained under positive air pressure.

DISCUSSION

The CAV controller kept the cabinet intake air flow essentially constant, and therefore the system satisfies the requirement of NSF Standard 49 to keep air flows within a $\pm 5\%$ range.¹ However, in this case, the constant air flow failed to ensure that the cabinet contains its contaminants. At times, the sulfur hexafluoride tracer gas escaped the cabinet in concentrations up to 25 parts per million—far greater than the initial, baseline escape rate of 2 to 8 ppm.

Figure 3 also shows that escaping concentrations were higher on average when the sash was at its maximum 30" height and when the lab was under positive pressure. The authors speculate this phenomenon may result from room air turbulence. Supply air volume increases to keep the room under positive pressure and to meet the flow requirement of the fume hood when it is fully open. All other things being equal, more air flowing through a given space creates more turbulence. Turbulence could create brief, localized pressure fluctuations which can pull air (and contaminants) out of the cabinet. It may be that if detailed velocity measurements could be taken at the cabinet opening instead of in the exhaust duct, such turbulence could be detected and correlated with the increased leak rates that were seen in this experiment.

CONCLUSIONS AND IMPLICATIONS FOR THE SYSTEM DESIGNER

The NSF Standard 49 air flow tolerance of $\pm 5\%$ may be a useful predictor for cabinet performance under some conditions. However, at high supply air flow rates, there seem to be turbulent effects which make cabinet air flow consistency less reliable as an indicator of containment performance.

It is important to note that the results obtained in this case are specific to the equipment and the controllers used for the experiment. The mechanisms explaining the containment failures are not clear from this work. Further research will be needed to establish a better understanding

why the tracer gas escaped and the parameters which influence the phenomenon. However, the results of this experiment do suggest some useful cautions.

Ideally, biosafety cabinets should be exhausted by constant-volume exhaust systems, and not connected to the same system as variable-volume equipment. But when that ideal cannot be achieved, a designer of a variable volume exhaust system for combinations of fume hoods and BSC's may wish to consider that:

1. CAV controllers can effectively assist in maintaining BSC air flows within NSF specifications.
2. Holding the cabinet intake air within the $\pm 5\%$ range specified by NSF does not by itself guarantee cabinet performance.
3. The adverse effect of excess supply air flow in the lab is not unique to VAV exhaust systems. When rooms are small in relation to the air flow volumes moving through them, precautions beyond just CAV controllers may be necessary to ensure that BSC's contain contaminants properly. Minimum air change rates may be best for small, densely-packed labs if that can be done without negative effects on personnel comfort. Lower air flows reduce air turbulence and therefore reduce the potential for containment and isolation problems with a BSC.

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