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Biological Safety Canopy Exhaust Connection Saves Energy and Improves Overall Safety Performance

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ABSTRACT

With environmental resources becoming more and more limited and energy costs on the rise, reducing energy consumption is an important consideration for every laboratory. It is especially important in light of an analysis published by the US Environmental Protection Agency concluded that laboratories consume five to 10 times more energy per square foot than typical office buildings.[1]

As one of the most frequently used devices in the laboratory, biological safety cabinets (BSCs) provide the primary source of containment for microbiological research. BSCs are critical for the protection of personnel from exposure to airborne biohazards and other potentially harmful particulates within the cabinet. BSCs also provide product protection from contaminants outside the cabinet environment through the use of a HEPA-filtered airflow that is contained within the BSC. This vertical unidirectional downflow air combined with suction below the intake grille prevents outside airborne contaminants from entering the cabinet's workspace.

Class II Type A2 BSCs can either exhaust HEPA-filtered air back into the laboratory or outside through a canopy exhaust connection (CEC). When vented to the building exhaust system, a BSC becomes the first piece of system ductwork, and the facility's HVAC design must accommodate duct static pressure and exhaust flow values. Exhausted air must be replaced by a laboratory's air supply system and typically needs to be conditioned (either heated or cooled). BSCs are often operated continuously, so conditioned air can add considerable operating costs to a laboratory over time.

The Baker Company (Baker) has developed a patent-pending CEC, FlexAIR™ that can provide significant savings for laboratories by reducing the amount of exhaust required to operate a BSC. The FlexAIR also allows a cabinet to maintain product and personnel protection standards over a wide range of exhaust system fluctuations, even if a building's exhaust system fails. The following paper demonstrates how the FlexAIR reduces both total exhaust flow and the amount of conditioned air required, while providing a higher level of protection than traditional canopy connections.

INTRODUCTION

Baker's Class II Type A2 biosafety cabinet, the SterilGARD® e3, provides personnel, product and environmental protection at a high efficiency level while maintaining optimum performance.[2] Use of volatile chemicals within an A2 cabinet typically requires it to be vented to the outdoors for removal of gases. A cabinet is connected to a facility's exhaust system through a canopy exhaust connection (CEC), which provides an air gap that protects the cabinet from potential variations of airflow in the facility exhaust system.

Typically, a "thimble" connection is used, which utilizes fixed openings that allow air to be drawn in from the room (Figure 1). CECs with fixed openings have limitations that increase energy requirements and impact the performance of the cabinet. During normal exhaust system operation, these openings continually draw air from the room, and can increase the amount of air exhausted by as much as 20%.[3] Exhausting additional conditioned air increases the energy costs of operating the cabinet.

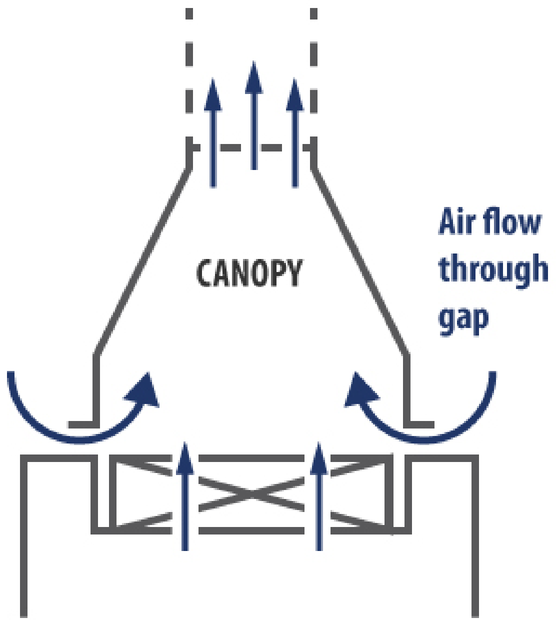

Figure 1: Traditional canopy exhaust.

The openings of a thimble CEC must be large enough to maintain correct airflow through a cabinet in the event of building exhaust system fluctuations or failure. When this occurs, cabinet performance may be compromised. If an exhaust system fails or is not pulling enough air, cabinet intake airflow velocity may be reduced, which means that personnel protection may be compromised. Baker has found that when a building exhaust system fails, traditional canopies cause cabinet intake air to drop to around 80 FPM.[4] If exhaust system flow is too high (for example, if a neighboring cabinet connected to the same exhaust system is turned off), cabinet intake air flow may increase to a point where product protection is compromised.

Baker's patent-pending CEC, FlexAIR, has none of these limitations. Because of its design, the FlexAIR reduces the volume of room air taken into the canopy when the exhaust system is operating normally. It also allows the BSC to maintain the appropriate airflow intake velocity to ensure personnel and product protection during building exhaust system fluctuations or failures.

FlexAIR Canopy Exhaust Connection Design

When an exhaust system is operating normally, the gaps or openings in conventional canopies always remain open, and conditioned air is removed from the laboratory. The FlexAIR incorporates a plurality of openings covered by air dampers that open and close as needed. This reduces the overall volume of air required during normal cabinet operation, resulting in less air exhausted and reduced energy requirements. The air dampers are entirely controlled by the air pressure naturally present in the system. They do not require any mechanical or electrical device to operate them.

If a building exhaust system does not exhaust a sufficient amount of air from a cabinet, or if it fails, the outlet damper on the front will open and let cabinet exhaust air escape through this outlet port (Figure 2). The cabinet will maintain standard operating conditions and an alarm on the cabinet will sound, notifying the worker.

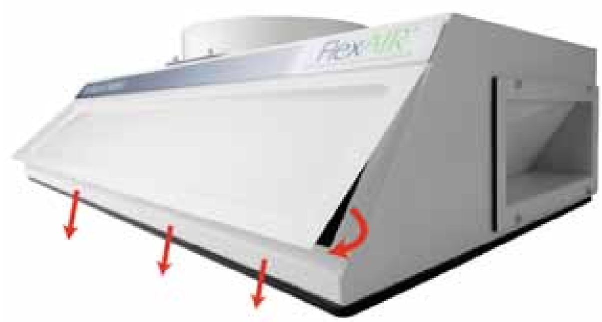

Figure 2: When exhaust system does not exhaust sufficient air flow, the FlexAIR front will open.

If a building exhaust system attempts to pull in more air than is exhausted by a cabinet, the two intake dampers on the sides of the FlexAIR will open to allow room air in through those intake ports. This enables the cabinet to maintain the required intake airflow at its front access opening (Figure 3).

Figure 3: When exhaust system creates too much air flow, the FlexAIR side dampers opens to accommodate.

PURPOSE

To show how energy requirements differ, the volume of air exhausted was measured from a SterilGARD e3 connected to a standard CEC and then a FlexAIR. Tests were also performed to verify that gas was not lost through the FlexAIR ports and to determine the minimum amount of exhaust flow required to maintain containment. Finally, the SterilGARD with FlexAIR was tested to ensure that the system maintains adequate personnel and product protection during fluctuations in exhaust system airflow, including failures.

METHODS

Energy Savings Test

Three sizes of the SterilGARD e3 cabinet (4-foot model SG403, 5-foot model SG503 and 6-foot model SG603) were connected to an exhaust system using a traditional canopy exhaust connection and exhaust was measured using a calibrated orifice with an inclined manometer. The same cabinets were then connected using the FlexAIR, and exhaust was measured and recorded for each.

FlexAIR Gas Containment Test

Since there is no quantitative test in the NSF International 49 Standard.[5] for exhaust canopy performance, a new test was developed to ensure that gas would be contained within the FlexAIR so it could be appropriately exhausted through the facility's exhaust system.

Figure 4: ASHRAE gas ejector positioned in center of cabinet

An ASHRAE gas ejector[6] was used to introduce helium gas into the cabinet (Figure 4). The ejector was placed in the center of the work surface inside the cabinet and the helium gas pressure was set at 30 psi. This ejector flow rate resulted in the cabinet exhaust air containing 1129 parts per million (ppm) of helium.

Each test began by turning on the helium gas, which passed through the ejector to flood the cabinet. An Alcatel helium leak detector capable of detecting 6 ppm was used to scan the FlexAIR for leaks by passing the helium leak detector's sniffer probe around the air dampers (Figure 5).

To determine the minimum amount of exhaust flow needed to contain gas, the FlexAIR was scanned for gas leaks while the external exhaust system airflow was reduced slowly. The minimum exhaust airflow value was recorded before gas was detected for each test sample.

Figure 5: An Alcatel helium leak detector scans the FlexAIR for leaks.

Cabinet Performance Test

This following test method was developed to show that a cabinet using the FlexAIR can maintain the intake airflow velocity required by NSF Standard 49 to ensure product and personnel protection during exhaust system fluctuations.

Three sizes (4-foot, 5-foot and 6-foot) of the SterilGARD e3 cabinet (4-foot model SG403, 5-foot model SG503 and 6-foot model SG603) were positioned and balanced with window sash openings at 8" and then 10" (Figure 6). The cabinets were ducted to a building exhaust system attached to an incline manometer to measure airflow. Each cabinet was set up to operate at the nominal operating airflow set point for intake and downflow air velocities. Before each test the exhaust system was adjusted to a high air flow initially to ensure containment.

The exhaust system was increased and intake airflow was recorded to determine at what exhaust airflow (CFM) the intake airflow velocity was greater than allowed by NSF. Then the exhaust system was turned completely off and intake airflow of the cabinet was recorded.

Figure 6: SterilGARD e3 cabinet ducted to building exhaust system in the Baker laboratory.

RESULTS and DISCUSSION

Energy and Cost Savings

Table 1 compares the SterilGARD e3 cabinet in a normal operating mode for 24 hours, seven days a week, using a standard canopy exhaust connection versus the FlexAIR. The 4-foot, 5-foot and 6-foot cabinets provide a 15%, 16% and 12% savings respectively.

Cabinet Model	Exhaust Standard CEC (CFM)	Exhaust FlexAIR (CFM)	CF / Year Standard CEC	CF / Year FlexAIR	CF Savings / Year	Annual Savings %
SG403	345	293	181,332,000	154,000,800	27,331,200	15%
SG503	430	360	226,008,000	189,216,000	36,792,000	16%
SG603	520	458	273,312,000	240,724,800	32,587,200	12%

Table 1. Comparison of exhausted air using a standard CEC and FlexAIR with cabinet sash height at 8" and operating in normal mode for 24 hours per day.

Assuming the annual cost of conditioned air is $4.00 per CFM, the annual savings realized by using FlexAIR were calculated. The results are shown in Table 2.

Cabinet Model	Exhaust Standard CEC (CFM)	Exhaust FlexAIR (CFM)	Cost / Year with Standard CEC	Cost / Year with FlexAIR	$ Savings / Year	Annual Savings %
SG403	345	293	$ 1,380	$ 1,172	$ 208	15%
SG503	430	360	$ 1,720	$ 1,440	$ 280	16%
SG603	520	458	$ 2,080	$ 1,832	$ 248	12%

Table 2. Comparison of cost of exhausted air using a standard CEC and FlexAIR with cabinet sash height at 8" and operating in normal mode for 24 hours per day.

FlexAIR Gas Containment Test Data

Table 3 compares the average volume of air exhausted from the cabinets during normal operating mode to the minimum building exhaust air volume required for the FlexAIR to maintain gas containment. The results show that less than an additional 2.2 % more exhaust is required. Traditional canopy designs require up to 20% of cabinet discharge air to maintain smoke containment. Therefore, the FlexAIR demonstrates better containment capabilities at a significantly reduced air volume compared to traditional canopy designs, ensuring environmental protection in the lab.

	8" Sash Opening			10" Sash Opening		
Cabinet Model	Average Cabinet Exhaust (CFM)	Average Exhaust Required for Gas Containment (CFM)	Additional Exhaust Required for Gas Containment (%)	Average Cabinet Exhaust (CFM)	Average Exhaust Required for Gas Containment (CFM)	Additional Exhaust Required for Gas Containment (%)
SG403	289	293	1.4%	354	362	2.2%
SG503	360	366	1.6%	n/a*	n/a*	n/a*
SG603	455	458	0.7%	560	564	0.7%

* Baker does not manufacture an SG-503 with a 10" sash, so no test data is available.

Table 3: Air discharge volume from the cabinets versus the minimum building exhaust air volume required for the Flex AIR to maintain gas containment.

Cabinet Performance Data

Impact to Product Protection from Increased Building Exhaust (Too Much Suction)

Table 4 shows the maximum amount of air the building exhaust system could pull from the SterilGARD e3 units with FlexAIR before the cabinets' intake airflow exceeded 110 FPM (the maximum prescribed by NSF Standard 49). With the FlexAIR, the SterilGARD e3 could handle between 30% and 50% more air being pulled from the exhaust system before the intake air velocity exceeded 110 FPM; therefore, a significant range of fluctuation is permitted without diminishing product protection.

	8" Sash Opening			10" Sash Opening		
Cabinet Model	Average Cabinet Exhaust (CFM)	Average Maximum Building Exhaust (before cabinets exceeded 110 fpm intake air velocity) (CFM)	Increase in Exhaust (%)	Average Cabinet Exhaust (CFM)	Average Maximum Building Exhaust (before cabinets exceeded 110 fpm intake air velocity) (CFM)	Increase in Exhaust (%)
SG403	289	584	50.5%	354	586	39.6%
SG503	360	619	41.8%	n/a*	n/a*	n/a*
SG603	455	658	30.8%	560	871	35.7%

* Baker does not manufacture an SG-503 with a 10" sash, so no test data is available.

Table 4: Maximum volume of building exhaust before cabinets exceeded 110 FPM intake air velocity.

Impact to Personnel Protection from Decreased Building Exhaust or Failure (Not Enough Suction)

Table 5 shows the average cabinet intake airflow velocity of the SterilGARD e3 with FlexAIR when the exhaust system was turned off. The intake airflow velocity never went below 100 FPM (the minimum prescribed by NSF Standard 49). Therefore, when an exhaust system fails, the intake airflow of a SterilGARD e3 with FlexAIR will maintain personnel protection. (Additionally, when an exhaust system is not pulling enough air or fails, an audible and visual alarm on the SterilGARD e3 will notify the worker.)

	8" Sash Opening	10" Sash Opening
Cabinet Model	Average Intake Airflow Velocity (FPM)	Average Intake Airflow Velocity (FPM)
SG403	100	102
SG503	102	n/a*
SG603	104	101

* Baker does not manufacture an SG-503 with a 10" sash, so no test data is available.

Table 5: Cabinet intake airflow velocity during building exhaust system failure.

CONCLUSION

The FlexAIR canopy exhaust connection from Baker improves on the safety of a traditional canopy (thimble) exhaust connection while lowering energy requirements.

With FlexAIR, only the minimum amount of air necessary to achieve cabinet exhaust containment is used. Therefore, adding a FlexAIR canopy exhaust connection to a SterilGARD e3 can reduce energy requirements (and costs) about 15%, depending on unit size. This adds up to significant annual savings for a facility, especially when multiple cabinets are in use.

Additionally, the FlexAIR provides added safety to the product and user during building exhaust system fluctuations. When a building exhaust system fails, traditional canopies cause cabinet intake air to drop to around 80 FPM which is well below the minimum NSF requirement of 100 FPM. With the FlexAIR, when a building exhaust system fails, cabinet intake airflow velocity is not reduced below 100 FPM. If a building exhaust system fluctuates above the required air flow setting, or if the HVAC design requires the exhausting of additional room air, the FlexAIR can handle almost double a cabinet's maximum exhaust air flow setting without causing the cabinet to exceed the maximum NSF-allowed intake air flow setting of 110 FPM.

FlexAIR is a unique canopy alternative that will meet NSF 49 requirements while offering operating cost savings and improved performance.

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