Innovative Technologies Result in a More Sustainable and Energy-Efficient Total Exhaust Biological Safety Cabinet

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Abstract

Biological safety cabinets (BSCs) provide the primary source of containment for microbiological research. Laboratories that need containment and removal of vapors, mists and particulates will often choose a Class II, Type B2 total exhaust BSC (Type B2). Because this type of BSC must be totally exhausted to the outside through a facility's HVAC system, it requires a great deal of energy to operate and can add significantly to a laboratory or facility's operating costs.

According to an analysis published by the U.S. Environmental Protection Agency, laboratories consume 5 to 10 times more energy per square foot than typical office buildings.[1] Access to more energy-efficient equipment, without any sacrifice in safety and performance, will allow labs to decrease not only energy consumption and operating costs, but also their environmental impact. The BioChemGARD® e3 total exhaust BSC from The Baker Company (Baker) is engineered to help achieve this.

With the BioChemGARD e3, a reduction in exhaust airflow and resistance cuts the electrical power, noise and static pressure requirements for the facility and reduces the volume of conditioned air exhausted from the laboratory. The nominal size 4-foot model operates at only 664 CFM and uses new, three-phase Variable Frequency Drive (VFD) motor technology to help deliver a reduction of up to 86% in electrical power when compared to traditional Type B2 total exhaust cabinets. This combination contributes to an overall reduction in the energy/power consumption requirements for most facility exhaust systems of up to 23%, providing a potential for annual operational cost savings of up to 49% over traditional Type B2 total exhaust cabinets listed with NSF International. Performance and productivity remain high, while protection for both the product and personnel exceed NSF International Standards #49.

Introduction

As one of the most frequently used devices in the laboratory, BSCs are critical in 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 vertical laminar airflow. Type B2 total exhaust BSCs are designed to exhaust all HEPA-filtered air through the building exhaust system. This exhausted air must be replaced by the laboratory's air supply system and is typically heated or cooled.

A significant amount of energy is required to maintain the necessary airflow, so total exhaust cabinets can incur major operating costs for a facility. Because BSCs are often operated continuously, hot or cold conditioned air adds considerable costs for a laboratory, typically ranging anywhere from $4 -$8 per cubic feet per minute (CFM) per year.[2]

The BioChemGARD e3, a revolutionary Type B2 total exhaust BSC from The Baker Company, couples a change in airflow throughout the cabinet with many unique energy-saving features, including a patent-pending sealed-access filter-exchange system, a motor/blower system with variable frequency drive technology and a low-flow operating mode.

The result is a major reduction in power consumption and exhaust airflow, as well as the exhaust static pressure and the energy required by a facility to remove conditioned air from the laboratory; all without compromising the performance of the cabinet or safety of laboratory personnel.

The following paper discusses these unique features and compares the efficiency of the nominal size 4-foot model BioChemGARD e3 to an average efficiency of traditional Type B2 total exhaust cabinets available today.[3-4]

Airflow Design Enhances Sustainability, Performance and Safety

Innovative Filter Placement

Most Type B2 total exhaust cabinets bring room air into the cabinet through both an opening in the top of the cabinet and through an inlet grille. Air from the top of the cabinet flows through an initial HEPA filter and then downward through the work area. All of the contaminated air, including the air coming through the inlet grill, is then drawn into a negative-pressure plenum and exhausted through a second HEPA filter at the top of the cabinet. A dedicated exhaust system and remote blower draw all of the filtered exhaust air out of the laboratory (Figure 1).

The BioChemGARD e3 takes a different approach. The HEPA/ULPA filters for the exhausted air are located underneath the work surface in the drain pan area allowing the exhausted air to travel directly to the building exhaust system through a duct on the back of the cabinet (Figure 2).

Like other B2 cabinets, room air enters the front access opening of the BioChemGARD e3 at a minimum of 100 FPM calculated face velocity then enters the front work surface perforation. The cabinet supply blower draws room air in at the top rear of the cabinet and pushes it into the supply plenum and through the HEPA/ULPA supply filter. The filtered down flow air in the work area splits at the work surface. Some of the air enters the rear work area perforation while most of the air enters the front work surface perforation.

What makes this design unique is that the air is pulled into the drain pan area where the exhaust HEPA/ULPA filters are located; then travels up the rear exhaust plenums, and exits the cabinet to the facility exhaust system through a 12" exhaust collar at the top of the cabinet. The lower volume of air and improved plenum design lower the static pressure required to exhaust through an external building exhaust system directly connected to the top of the cabinet, reducing energy requirements.

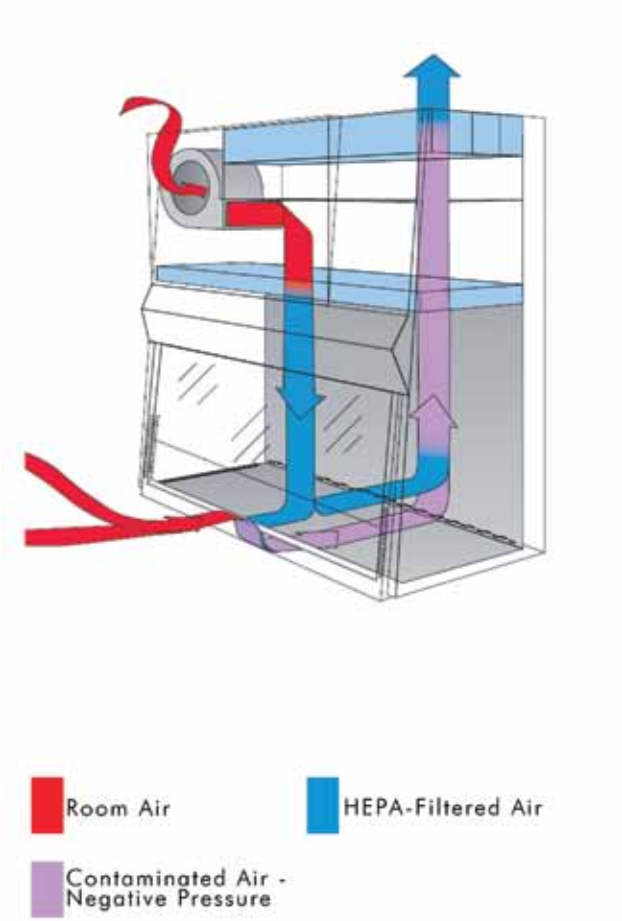

Figure 1: Traditional Type B2 Cabinet and Air Flow Design

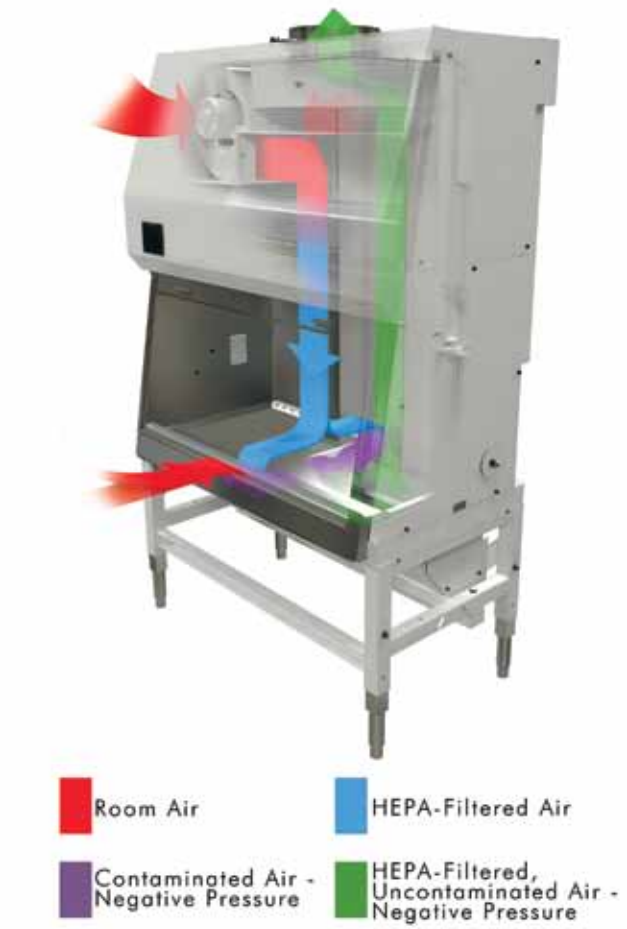

Figure 2: BioChemGARD e3 Cabinet and Air Flow Design

Baker pioneered a similar design in 2005, placing the filters below the work surface in the NCB-D Type B1 cabinet. After proving performance in the field, this was adapted and incorporated within the design for this new Type B2 cabinet, the BioChemGARD e3 (Figure 3).

Figure 3: The HEPA / ULPA filters are located below the work surface on the BioChemGARD e3.

Safe, Simple Filter Exchange

The filter placement also allows for the exclusive, patent pending, ExchangeSAFE™ Sealed Access Filter Exchange System (patent pending). Many traditional bag-in/bag-out (BIBO) filter systems, which are typically located in the upper cabinet plenums above the work area, require complex and time-consuming procedures for changing filters that can result in a higher risk of exposure to contaminants. Baker's new ExchangeSAFE system permits filter bagging and exchanges within the work area, providing improved access, a simpler process and an overall reduction in maintenance time while still minimizing exposure to contaminants by running the exhaust during the filter change.

Most total exhaust BSCs locate the exhaust filters in the top of the cabinet. The Baker design locates the exhaust filters at the source of the contamination. By locating the exhaust filters below the work surface, contaminants are collected immediately after they are generated, keeping the remainder of the cabinet uncontaminated.

Enhanced Performance and Reduced Downflow Air

An exclusive momentum air curtain is utilized in many Baker cabinets. Located directly behind the view screen, it creates a strong air barrier at the front of the cabinet, increasing protective capabilities for both products and personnel (Figure 4).

Research performed by Baker shows that by increasing the speed of this air curtain, one may in turn decrease the speed of the downflow air in the work space and actually achieve better results for product and personnel protection. Microbiological testing yielded better results for product and personnel protection at lower levels of downflow air velocity.[5] The momentum air curtain of the BioChemGARD e3 was modified to take advantage of this.

Reducing the rate of downflow air reduces the energy consumption of the cabinet and significantly reduces the overall energy required by a laboratory or facility to condition a room and exhaust the air from the cabinet.

Innovative Technology Provides Energy Savings While Increasing Productivity and Performance

StediFLOW™ VFD Motor Technology

The BioChemGARD e3 design incorporates the airflow management system used and proven in Baker's core line of Type A2 biological safety cabinets (the SterilGARD® e3). It utilizes the three-phase VFD motor controller (StediFLOW) to provide constant air volume and automatically compensate for normal power line variations, air disruptions and filter loading.

During testing, the BioChemGARD e3 4-foot nominal model was able to automatically handle an increase in pressure drop of up to 420% across the filter without reducing total air delivery by more than 10%. The motor itself draws only 0.6 amps – a 90% reduction from the power consumption required by the previous Baker B2 cabinet, the SterilChemGARD.

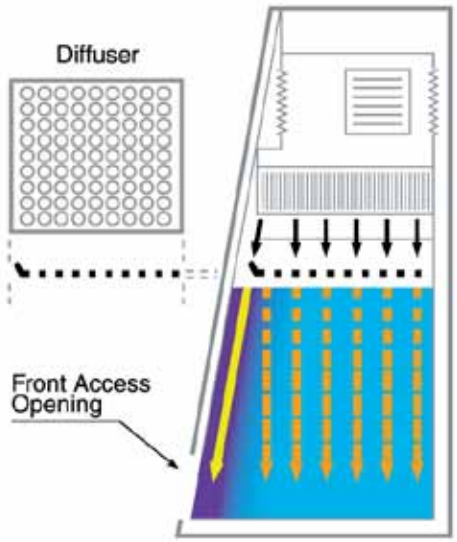

Figure 4: Momentum air curtain offers an added measure of containment and protection.

The StediFLOW VFD motor uses less energy, reduces heat output and operates more quietly. With state-of-the-art three-phase motor technology, the VFD has a low failure rate, uses less conductor material to transmit electric power than equivalent single-phase or two-phase systems at the same voltage and is less expensive to repair when compared to more common DC-ECM motors used by other BSC suppliers. The BioChemGARD e3 motor controller is located in a clean zone away from contaminants, which makes maintenance safer.

ReadySAFE™ Operating Mode

The SteadiFLOW VFD also controls the ReadySAFE operating mode that preserves containment conditions when the BioChemGARD e3 is not in use. This further reduces cabinet downtime, the heat emitted to the lab and the energy consumption of the cabinet itself (Table 1).

Since BSCs utilize motor/blower technology to manage the flow of HEPA-filtered air, airflow must be reduced in order to reduce the energy consumption. While significant energy savings may be achieved by shutting down the BSC completely, this is not recommended. Complete cabinet shut-down often necessitates additional procedures for time-consuming decontamination and disinfection, resulting in long periods of cabinet down time and significantly impacting the productivity of the lab.

	Traditional B2 BSC [A]	BCG e3 [B]	BCG e3, ReadySAFE [C]	BCG e3, Optimal [D]
Operating Amperage (A)	2.4	1.0	0.3	0.5
Power Consumption (W)	280.0	115.0	35.0	61.7
Power Consumption (kWh/24 hr)	6.7	2.8	0.8	1.5
Heat Generation (BTU / hr)	955	392	119	212

[A] Average of Type B2 Total Exhaust Cabinets listed on the NSF website, cited July 2011.
[B] In a normal operating mode for 24 hours, the BioChemGARD e3 reduces the electrical power consumption up to 60% when compared to traditional Type B2 BSCs.
[C] In ReadySAFE mode only, the BioChemGARD e3 reduces the electrical power consumption by up to 90%, when compared to traditional Type B2 BSCs.
[D] Operating in normal mode during the work day (8 hours) and ReadySAFE mode at night (16 hours), the BioChemGARD e3 reduces the power consumption by up to 80%, when compared to traditional Type B2 BSCs.

Table 1: Power Consumption, the BioChemGARD e3 versus other 4-foot Type B2 BSCs

The Baker ReadySAFE mode provides a reduced flow operating mode for the BioChemGARD e3. The speed of the motor can be reduced when the cabinet sash is closed and operate continuously at a reduced flow rate. In this mode it draws less energy, but still provides personnel, product and environmental protection. The cabinet can automatically switch between the ReadySAFE low airflow mode when the sash is closed and the normal airflow mode when the sash is opened.

The BioChemGARD e3 meets and exceeds NSF / ANSI Standard 49 Class II BSC requirements for product protection, personnel protection and cross contamination, as well as ISO Class 4 air cleanliness criteria (for 0.3 µm and 0.5 µm particles) in ReadySAFE mode, based on microbiological and cleanliness-class / particle-count tests performed by Baker.[6]

Reducing Facility Power Requirements

Based on the unique features of the BioChemGARD e3, a facility can significantly decrease the amount of power required to provide conditioned air to the room and exhaust air through the facility's exhaust system.

Reduced Volume of Air Exhausted from Building

A reduction in downflow air, from 55 to 40 feet per minute (FPM), has resulted in a reduction in the exhaust airflow by 196 cubic feet per minute (CFM) over Baker's previous Type B2 total exhaust cabinet (SterilChemGARD) and 142 CFM over traditional NSF listed Type B2 cabinets.

Since less conditioned air is exhausted from the laboratory, less energy will be required by the facility to heat or cool this air. At $4 per CFM per year, each BioChemGARD e3 unit can provide total annual conditioned air savings of up to $1,523 when compared to other Type B2 cabinets (Table 2).

	Traditional B2 BSC	BCG e3	BCG e3, Optimal
Heat Generation (BTU / Hr)	955	392	212
Exhaust Flow Rate (Total CFM)	802	664	421
Annual Operating Costs	$3,208	$2,656	$1,685

Table 2: Heat, Exhaust Flow Rate, Annual Operational Costs

Decreased Static Pressure of Building Exhaust System

The building exhaust system needs to provide sufficient exhaust airflow and static pressure to meet the Concurrent Balance Values (CBVs) of a total exhaust BSC. CBVs help ensure that sufficient airflow and static pressure is designed into the building exhaust system; these values are factored into the performance requirements of the building exhaust system.

When tested in the Baker Laboratory, the BioChemGARD e3 showed a 20% reduction in the resistance or static pressure requirements for a facility to exhaust the air when compared to the SterilChemGARD cabinet. The measured static pressure values and CBVs are shown below (Table 3).

	Traditional B2 BSC	BCG e3
Exhaust Flow Rate (Total CFM)	802	664
Exhaust Negative Static Pressure (W.G.) – Measured	1.0	0.8
Exhaust Negative Static Pressure (W.G.) – Concurrent Balance Values	1.7	1.5

Table 3: Exhaust Negative Static Pressure and CBVs of 4-foot nominal model with 12-inch collar.

These values can be used to calculate the amount of energy needed to meet the CBV and static pressure requirements for any given facility. The Fan Affinity Laws in The Industrial Ventilation Manual show how to calculate the power required for a facility to exhaust a BSC.[7] This formula was applied to our BioChemGARD e3 and other Type B2 cabinets to compare static pressure requirements (Table 4). Please note, typical fan efficiency is 65% to 85%, so an average of 75% was used in the below calculations.

	Traditional B2 BSC	BCG e3	BCG e3, ReadySAFE	BCG e3, Optimal
Heat Generation (BTU / Hr)	955	392	119	212
Exhaust Flow Rate (Total CFM)	802	664	300	421
Exhaust Negative Static Pressure (W.G.)	1.7	1.5	1.5	1.5
Horsepower	0.29	0.208	0.09	0.13
kWh	0.21	0.16	0.07	0.10
kWh / 24	5.12	3.74	1.69	2.37

Table 4: Static Pressure Power Requirements

Based on the performance data listed above, when the cabinet is running in optimal conditions for 24 hours, a facility may realize a reduction up to 55% in the horsepower required to exhaust the BSC when compared to other B2 cabinets.

Results for a specific facility are largely dependent upon the size of the fan and the configuration and construction details of its exhaust system. In the Baker laboratory, a SterilChemGARD and a BioChemGARD e3 were attached to an exhaust system measuring 25 feet to more closely simulate a real-life application of this analysis (Table 5).

Fan efficiency was measured at 75%, further validating the calculations performed above and shown in table 5. These tests corroborate the impact that reductions in volume (CFM) and static pressure (inches, W.C.) have on the exhaust power requirements for a laboratory.

The BioChemGARD e3 can help facilities and laboratories achieve significant energy savings, not only from normal cabinet operation but also from the reduction in the conditioned air and static pressure requirements for the laboratory and the facility.

	SterilChem-GARD	BCG e3
Exhaust Flow Rate (Total CFM)	860	664
Exhaust Negative Static Pressure (W.G.)	1.7	1.5
Horsepower	.45	.208
kWh / 24 hr	8.08	3.74

Table 5: Static Pressure Study

Sustainable Design Reduces Total Cost of Ownership

As a result of the efficiencies gained from the sustainable design concepts and reduced airflow described above, the BioChemGARD e3 total exhaust cabinet will reduce the total amount of energy consumed within a laboratory, thereby creating significant operational cost savings for the facility (Table 6).

Operating at only 664 CFM, electrical power requirements for a nominal 4-foot cabinet are 70% less

when compared to other traditional Type B2 cabinets. In fact, the combined savings in electricity, conditioned air removal, and a reduction in static pressure can potentially reduce the overall annual operational costs by up to 49% (Figure 5).

Sustainable Design Results in Reduced Noise Levels

In addition to the significant energy savings, the unique design of the BioChemGARD e3 provides safe and quiet cabinet operation. A recent article found in one of our industry's common trade publications asserts that, "Excess noise is not a good thing... background noise from HVAC systems or other laboratory activities can become insidious. It can make conversation difficult, affect concentration, distract workers and increase fatigue not to mention the potential adverse effects on other support personnel who enter the area."[8]

The BioChemGARD e3 is the quietest Type B2 total exhaust BSC currently on the market, providing an optimal work environment for laboratory personnel. NSF International tested the cabinet at 59 dBa, which includes readings for both an exhaust system and the cabinet itself. The cabinet itself yields a level of <50 dBA under normal operation and 42 dBA when operating in ReadySAFE mode.

Moreover, the National Institute of Health (NIH) Office of Research Facilities guidelines for Noise and Vibration stipulates that the maximum noise level for research laboratories to be no more than 45 Noise Criterion (NC).[9] NC was established in the United States for rating indoor noise. While there is not an exact correlation

	Traditional B2 BSC	BCG e3	BCG e3, Optimal
Operating Amperage (Amps)	2.4	1.0	0.5
Power Consumption (W)	280.0	115.0	61.7
Power Consumption (kWh/24 hr)	6.7	2.8	1.5
Annual Operating Costs[A]	$165	$68	$36
Exhaust Flow Rate (Total CFM)	802	664	421
Annual Operating Costs[2]	$3,208	$2,656	$1,685
Exhaust Negative Static Pressure (W.G.)	1.7	1.5	1.5
Horsepower	0.29	0.21	0.13
kWh	0.21	0.16	0.10
kWh / 24	5.12	3.74	2.37
Annual Operating Costs[A]	$126	$92	$58
Total Annual Operating Costs[B]	$3,499	$2,816	$1,780
Savings vs. Other B2 Cabinet		$683 (20%)	$1,719 (49%)

[A] Assumes an average daily US industrial electrical operating cost of $.0673 / kWh
[B] Assumes $4.00 / CFM / Year, lowest customer sampled

Table 6: Operational Cost Analysis

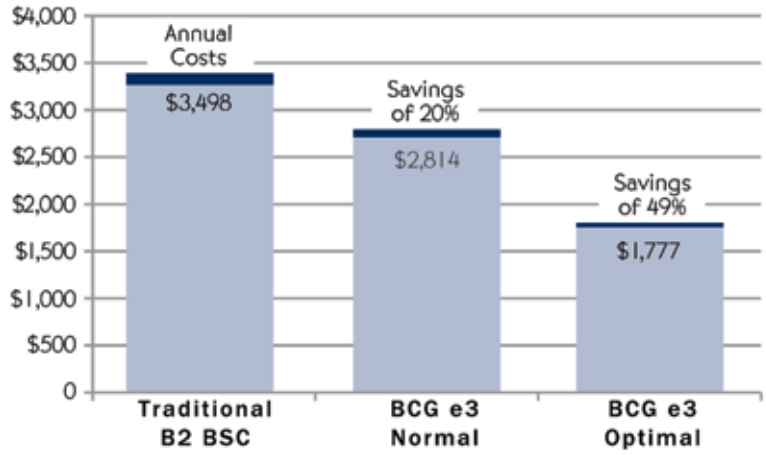

Figure 5: Annual savings using the BioChemGARD e3.

between the NC scale of noise and the dBa scale, according to a noise rating curve utilized by industry professionals, the NC 45 equates approximately to 53 dBa.[10] The BioChemGARD e3 is the only total exhaust cabinet capable of meeting that recommendation.

Conclusion

Based on six decades of research and innovation, the BioChemGARD e3 has been optimally designed to provide superior energy efficiency without compromising performance. Designed for sustainability, the BioChemGARD e3 combines innovative technology with reduced airflow characteristics that allow laboratories and facilities to achieve a major reduction in energy consumption, while increasing the performance, safety and protection of its users. With a performance profile that is unparalleled in the industry, the BioChemGARD e3 utilizes significantly less energy than any other Type B2 total exhaust cabinet registered with NSF International, potentially providing a laboratory or facility with annual operation cost savings of up to 49%.

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