Class II, Type C1 Biosafety Cabinet: Versatility, Safety & Savings Comparison

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Abstract

Comparisons of conventional Class II, Type A and Type B biosafety cabinets discern gaps in laboratory cost, safety, energy conservation and versatility. These four facets have become parameters by which all laboratory equipment is weighed and measured. The following gap analysis highlights the strengths and limitations of today's Class II Type A and B biosafety cabinets (BSCs) and introduces the new Class II, Type C1 BSC. The Type C1 bridges the gap between the recirculating Type As and the vented Type Bs.

Introduction

Just when you thought you knew all aspects of the various types of Class II biosafety cabinets, along comes something truly innovative. Biosafety cabinets have experienced some general upgrades over recent years. Controls have become more interactive and energy-saving blowers have given us a reason to replace older cabinets. Since the dawn of the modern era, biosafety cabinet (1990's), the airflows have remained essentially the same.

In 2014, a new type of biosafety cabinet, introduced by Labconco, drove leading industry experts to conclude that there are still new and enhanced ways to move air. Many industry experts agreed that this new cabinet fit neither the definition of a Type A, nor the definition of a Type B. Its unique airflow and design required it to have an entirely new classification – welcome the Class II, Type C1 biosafety cabinet (BSC).

This new Class II subtype meets or exceeds all criteria for Class II product and personnel protection, supported by 3rd party testing. Its unique airflow configuration, installation, and exclusive ability to maintain safety even during emergency situations, compelled NSF® (National Sanitation Foundation) to adopt, define and designate the new type of BSC in NSF/ANSI Standard 49.

The inventors at Labconco Corporation describe the benefits of the Type C1 as, "unparalleled with conventional cabinets when summing up **versatility, safety and savings**. If you took the best features from A2s, B1s, B2s and put them all in a bowl with some new ideas and mixed them up you have the Type C1."

New Concept in BSC Airflow

New technologies or re-adaptations of existing technologies break paradigms. Our commonly held practices and assumptions sometimes undergo shifts to create the new standard in the industry. Among us are those that openly accept and take advantage of the new concepts. Embracing the concept of the Type C1 BSC requires a paradigm shift.

From a distance, the Purifier® Axiom® Class II, Type C1 takes on the appearance of other contemporary Labconco BSCs. Draw near and one notices a very unique work surface inside. What sets this cabinet apart is a patent-pending "zoned" work area. The center two-thirds of the work surface is clearly bordered by a pattern of intake slots. Called the Chem-Zone™, the center section is the dedicated exhaust portion of the cabinet (Figure 1). Particulates and vapors produced in or near the Chem-Zone are ensured a direct path to the exhaust filter and out of the cabinet. Within this zone, there is no recirculation of air. Air outside this zone – downflow air at the ends of the work surface and air taken in at the front grille – is recirculated to save energy in ducted applications.

"If you took the best features from A2s, B1s, B2s and put them all in a bowl with some new ideas and mixed them up, you have the Type C1."

Under this fresh approach, since air is recirculated within the cabinet, the ends of the work surface functions as a Type A2 cabinet, providing a staging area for procedures and a place to keep supplies and equipment. One simply performs tasks that generate volatiles near the center two-thirds of the cabinet. In installations where the Type C1 is ducted to the outside, the Chem-Zone has the identical performance one would expect from a Type B2 cabinet, but without the high air flow demands.

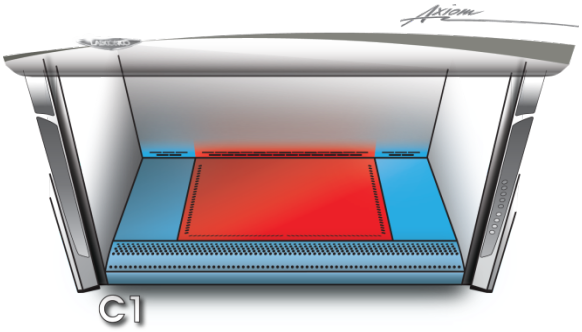

Figure 1 – The Chem-Zone™ (red) is a dedicated exhaust area of the work zone where vapor-forming chemicals are to be handled. The wings and grille (blue) provide supply air for the cabinet's sterile down flow supply air.

The Type C1 challenges that applications typically suitable for a Type B must have a "hard ducted," dedicated blower exhaust. Common Type B biosafety cabinets require a hard duct (no canopy) because of the high vacuums necessary for their operation. On Type B BSCs, a dedicated roof-mounted blower, above the BSC, pulls the air through the BSC's exhaust HEPA filter. As the HEPA filter loads, the required vacuum increases. A large remote blower is required because, over time, the pressure caused by a loading HEPA filter may increase to 4.0 inches H_2O or greater. In contrast, the Type C1 does not require a large dedicated remote blower, yet allows for the safe removal of chemicals in a single pass. How? Because the total exhaust area of the BSC is limited to the center portion of the work surface, exhaust air volume is reduced to approximately 40% of a comparable Type B2 BSC. Furthermore, a second blower, positioned downstream of the exhaust HEPA filter, pulls air through the BSCs exhaust HEPA filter, and delivers the air to the ductwork, where house exhaust can take over.

The Type C1 will cause many institutions to rethink their requirements for exhausted biosafety cabinets. It should make facility and lab managers reconsider which cabinet type they will want to own, whether it vents to the outside or not (Table 1).

Table 1 – Class II Gap Analysis. This analysis looks at the impact each Class II biosafety cabinet subtype has on both safety and ventilation of the laboratory. Historically, a series of tradeoffs would have to be considered between safety, efficiency and expense. The new Type C1 dispels that notion, allowing a simple choice that offers safety, efficiency and cost savings, while adding flexibility.

Class II Type*	A2	A2 with Canopy	B1	B2	C1	
Exhausts to	Room	Outside	Outside	Outside	Room	Outside
Approximate exhausted volume (CFM)	N/A	270-400 CFM	270-400 CFM	660-800 CFM	N/A	300-400 CFM
Approximate vacuum req'd (static pressure - in. w.g.)	N/A	0.15-0.25	0.7	1.6-4.0	N/A	0.2-0.4
Requires dedicated remote blower exhaust system	N/A	No	Yes	Yes	N/A	No
Volatile chemicals and radionuclides	No	Yes	Yes	Yes	No	Yes
Safe dedicated exhaust for chemicals	N/A	No	Yes**	Yes	N/A	Yes

*Data based on average of several 4' models for various subtypes.
** Type B1 BSCs do not have a clearly delineated or labeled dedicated exhaust area.

Versatility

Before the Type C1, deciding between a Type A and Type B required considerable forethought. Does one select the more economical Type A BSC or opt for the more costly Type B that offers a broader application potential? Making the right decision required answering questions such as: Will my researchers be using toxic volatile chemicals? Will I need to exhaust air out of the building for the life of this Type B BSC? If I commit to exhausting chemicals, will I require the installation of an additional exhaust duct and blower system? What will be the needs when this researcher moves out or changes applications? Since the Type C1 can operate as either a recirculating or exhausted cabinet, the buying decision is simplified and the risk of choosing the wrong cabinet eliminated. Here's why:

- The Type C1 BSC can easily convert from Type A mode (exhausting back into the laboratory) to Type B mode (venting exhaust to the outside), and vice versa.
- The Type C1 can be connected to general laboratory exhaust systems, including those with fume hoods. Type B1 and B2 installations require dedicated remote exhaust systems for each cabinet.
- When connected to laboratory exhaust systems, the Type C1 is quite tolerant.
- Not sure if you want a cabinet that operates at the 8- or 10-inch sash opening? Sash height is another facet of the BSC design that can be changed in the lab.

The Purifier Axiom conversion from Type A mode to Type B mode is as "easy" as connecting or disconnecting the exhaust

duct, selecting the exhaust preference in the software and having a certified technician verify inflow. The Type C1 BSC has the flexibility to change as the work in the lab changes.

The reason for dedicated remote exhaust systems on Type B BSCs are their inherently large negative static pressures (>1.5" W.C. or 0.37 kPa) along with airflow variations caused by other fume hoods in the system. In contrast, the new Type C1 claims extremely low exhaust static pressures in the range of 0.2 - 0.4" W.C. (or < 0.1 kPa).

Unlike Type B1 and B2 cabinets, where personnel protective inflow velocities are directly influenced by fluctuations in the building exhaust, the Type C1 delivers a constant inflow regardless of drifts in the building's system. Additionally, it accomplishes this difficult task without the need for airflow or pressure sensors. Such devices require periodic calibration and replacement in order to keep the BSC operating as designed. (Hunter, et al., 2010).

In review, these benefits allow the NSF-listed Type C1 to be capable of functioning in Type B mode for maximum safety with volatiles or fumes and do so at a 10-inch sash height. Due to the exhaust requirements stated above, Type B cabinets only exist in 8-inch operational sash heights.

The Purifier Axiom, Class II, Type C1 has a software program selection that allows the transition from 8-inch to 10-inch operation to occur during any certification.

Unconventional Wisdom

First consider modern convention for Type B BSCs: personnel and product protection is entirely dependent upon the roof blower's proper operation. The ability for the Type B to protect the worker is challenged when there is a problem with the building exhaust system. There are a series of events that must happen in the BSC in a very short period of time to hope for a positive outcome. Current standards require ducted Type B cabinets to recognize when there is a loss of vacuum/flow (usually at less than 80% of exhaust capacity) and signal the cabinet to go into exhaust alarm within 15 seconds (NSF International, 2016). The design and calibration of the Type C1 allow that failure to be detected much sooner.

Centers for Disease Control and Prevention write that with Type B cabinets (U.S. Department of Health and Human Services, CDC, 2009):

> *Should the building exhaust system fail, the cabinet will be pressurized, resulting in a flow of air from the work area back into the laboratory.*

Solving "Puff-Back"

Puff-back occurs when a Class II, Type B cabinet's remote exhaust system fails. As the internal blower windmills down, it continues to push air through the cabinet, and with no exhaust to remove that air, can result in a flow of air from the work area back into the laboratory.

Even with the best BSC, the risk of "*puff-back*" can occur. To remedy this, Labconco developed a programmable active protection sequence. This system utilizes the Purifier's Constant Airflow Profile™ (CAP) to maintain safe inflow, downflow and exhaust through the cabinet. The safety officer is able to program how long this active protection is engaged between 0-300 seconds.

- IF THE TYPE C1 IS ALONE and not ganged (or manifolded) with other exhaust systems, then the full 5 minutes can be allotted to allow BSC operators ample time to cease work, perform emergency containment protocols and remove themselves from the cabinet safely.
- IF THE TYPE C1 IS GANGED with other ventilation or exhausted safety enclosures, then the appropriate period of time should be programmed allowing for the greatest protection duration at the face of the BSC while not violating safety protocols for other equipment.

The momentum of the supply blower and the mass of downflow air may create a condition referred to as "puff-back," which has historically been visualized during smoke tests.

The design and calibration of the Type C allow [a remote exhaust] failure to be detected much sooner.

Labconco's solution to "puff-back" opposes conventional thinking of shutting down the cabinet as soon as possible during a building exhaust failure. In addition, the Type C1, equipped with its own exhaust blower, provides the means to maintain air flow; hence maintaining containment. Facility managers and safety officers should understand how the BSC reacts to loss of duct vacuum, and program the alarm conditions accordingly. A risk assessment is recommended to evaluate the possible outcomes in the event of building exhaust blower failure.

This argues against another commonly held rule in lab design and operations: a lab should never operate with positively pressurized fume hood or biosafety cabinet exhaust systems. Positive pressure can lead to chemicals being introduced to the building interior through openings or leaks. Following the loss of flow from a roof blower, Labconco realizes that the Type C1's built-in exhaust blower will, to some extent, positively pressurize the building duct for a short period of time. If the cabinet is connected to a shared duct system with other ventilation equipment, positive pressure can cause back-flows through other connected hoods; however, the pressure of the lab or room itself is more critical to determining the flow of air in these devices (Hunter, et al., 2016).

The recommended risk assessment will highlight the greatest potential for immediate harm. Is the most concentrated and immediate danger to life or health the loss of hazardous materials through the front of the biosafety cabinet? If so, then those users must be provided the necessary time to close containers and wipe surfaces. Operations being carried out in fume hoods during a building exhaust blower failure must be shut down regardless of adjacent biosafety cabinets. The Type C1's delayed shut down affords personnel time to manage the emergency situation systematically. Control the most hazardous chemicals and biohazards first, and then carry out other shutdown protocols wearing the proper PPE.

Safety

The Labconco Purifier Axiom deliberately maintains the cabinet's exhaust blower for 10 seconds after the supply downflow blower has shut down. This patent-pending feature ensures the interior remains negatively pressurized and eliminates any possibility for "puff-back." Additionally, the Type C1 has a programmable shutdown timer. The countdown timer should be set to the shortest possible interval required for lab personnel to secure hazards inside the cabinet upon an emergency.

To be clear, the Type C1 is **not** designed to operate indefinitely with a failed building exhaust blower. The BSC will not start up until it detects adequate exhaust; furthermore, the maximum period of time that the cabinet can be programmed to maintain containment during an exhaust alarm is 5 minutes. When the shutdown timer reaches zero, the cabinet will sequentially turn off the supply blower followed by the cabinet's exhaust blower 10 seconds later. The cabinet will not

automatically return to operation until it is restarted by the operator and the building exhaust system problem has been remedied.

All biosafety cabinets that have met the standards of NSF/ANSI 49 or EN 12469 and have been properly certified by a qualified technician should safely protect the operator and the work samples. The question is where can new biosafety cabinet technology exceed the accepted norm? Labconco's Type C1 advances BSC safety in two ways. First, by enhancing the handling of emergency situations and secondly by ensuring consistent airflow performance between periodic validations by certifiers.

- The Labconco Purifier Axiom BSC is able to maintain complete containment and product protection upon exhaust system failure. Instead of attempting to shut down the cabinet quickly as all other Type B cabinets do, it does the opposite.
- More advanced controls available in the new Purifier Axiom essentially eliminates adjustments once required of certifiers.

The Axiom makes necessary adjustments to inflow and downflow to maintain normal operating airflows. The lab personnel are instantly made aware of the building exhaust failure audibly and visually through the color display. A highly visible countdown timer affords the researcher a preset 10 to 310 seconds to secure hazardous or valuable materials and surface decontaminate before the cabinet shuts down.

Furthermore, the Purifier Axiom carries on the proven reliability of earlier Labconco Purifiers with high quality ECM (electronically commutated motors) driven blowers. The same Constant Airflow Profile™ (or CAP) first utilized in 2007 on the Purifier Logic® (Hunter, et al., 2010) ensures the blowers deliver the same volume of air despite blockages in the grille or HEPA/ULPA filter loading. The inflow and downflow volumes remain constant between periodic certification inspections.

Savings

How would the Type C1 compare in total cost of ownership with conventional biosafety cabinet types? Since it has the ability to exhaust back into the laboratory like an A2, or the adaptability to be ducted for single-pass exhaust from the center of the work surface like a B2, let's view it both ways.

Certainly in terms of electrical power usage and the loss of conditioned air, the most energy efficient way to operate a BSC is to return the exhaust air back into the laboratory. Returning the air to the room is **not** acceptable when the application involves volatile toxic chemicals, odors or radionuclides.

When the cabinet is exhausting back into the room, the Type C1 consumes the same energy as any of the energy-efficient A2 cabinets that utilize ECM blower motors.

- Energy savings is readily apparent in the Type C1 when used in an application that requires ducting the exhaust to the outside. In terms of removing heated or cooled air from the building, the Type C1 exhausts similar air volumes as do Type B1s and A2s. These cabinets remove 50% less air than does a Type B2. Employing any one of them will reduce operating cost by half.
- The "green" design intent for the Type C1 is to permit the facility manager along with the research managers to optimize energy

savings and allow the Type C1 to run in 'Type A mode'. This is done by disconnecting Type C1 cabinets from exhaust ducts where possible. Applications change; why not employ a biosafety cabinet that can adapt?

- A further comparison with Type B1 or Type B2 cabinets reveals the potential for greatly reduced expenses in design and construction. The Type C1 is capable of being connected to typical ganged laboratory exhaust systems thereby eliminating the need for additional dedicated duct and blower systems. The savings comprised of consulting services, utility space, heavy ducting, exhaust blower, installation, wiring and roof penetrations are substantial.

Occasionally products emerge that have the potential to provide an option not previously available in our industry. We believe the Labconco Purifier Axiom, Class II, Type C1 is the new generation of BSC in a world that is ready to evolve. Uncommon versatility allows the BSC to replicate the strengths of the Type As and Type Bs while addressing each of their limitations. It also provides lifelong flexibility to convert at any time necessary.

Cost of ownership is far less than conventional Type B BSCs. Low exhaust volume, the lowest required vacuums and the ability to connect to ganged exhaust systems add up to big savings.

Finally, the purpose for biosafety cabinets is safety. Original thinking and new technology provide consistent containment and product protection even in emergency situations. The Type C1 is a genuine advancement in bio-containment that deserves attention.

Conclusion

Table 2 – Life Cycle Cost Analysis. With purchase price and cost an ever mounting concern for capital laboratory equipment, it is important to know what the different Class II subtypes will cost through the life of the product (based on the 15 year life of a 4' BSC, 20' of epoxy-coated duct for exhausting out of a single story). Costs are approximate only.

Class II Type	A2	A2 with Canopy	B1	B2	C1	
					A-mode	B-mode
Upfront cost of installation*	$300	$400	$5,150	$5,150	$300	$400
Lifetime maintenance Cost (Service & HEPA/ULPA filters)	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500
Lifetime operating cost (based on $8 / CFM / year)	N/A	$40,500	$40,500	$87,000	N/A	$42,000
ESTIMATED TOTAL COST (INSTALLATION & OPERATION)	**$4,800**	**$45,400**	**$50,150**	**$96,650**	**$4,800**	**$46,900**

*Cost of installation includes materials for ductwork, exhaust stack, and labor on a single cabinet.

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