CETA Application Guide for the Exhaust System Requirements of Class II, Type B Biosafety Cabinets
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1. Background

Class II Type B Biosafety Cabinets (BSCs) are unique laboratory ventilation products, in that they protect the operator and their laboratory environment from biohazardous aerosols *and* volatile toxic chemicals. Type B BSCs also have special exhaust system requirements that set them apart from laboratory chemical fume hoods and other laboratory exhausted devices.

2. Class II BSC use with volatile toxic chemicals

Class II BSC's integral HEPA or ULPA filters remove particulates, but they do not remove gases. If volatile toxic chemicals are used in a Class II BSC, the cabinet's exhaust airflow must be removed from the room and subsequently from the facility. The selection and use of volatile toxic chemicals used in any class II BSC should be in small or minute quantities per NSF/ANSI 49. Class II BSC's in general should never be used as a laboratory chemical fume hood because of material incompatibility and fire protection requirements of NFPA 45.

3. Theory of Operation

3.1. Laboratory Chemical Fume hoods

Laboratory chemical fume hoods are an enclosure that requires a remote exhaust blower to draw a volume of air through the work area, exhausting at the top of the hood, through ductwork, to be exhausted remotely from the laboratory. When typically operating at an average inflow velocity of 80-120 FPM, most modern fume hoods require a constant airflow at a negative static pressure of 0.25 to 0.75 inches of H_2O. The volume and negative static pressure requirements will not change over the operational life of the hood. Because fume hoods are intended to be used with a wide variety of reactive chemicals, the hood sash, liner and exhaust system are constructed out of chemically-resistant materials.

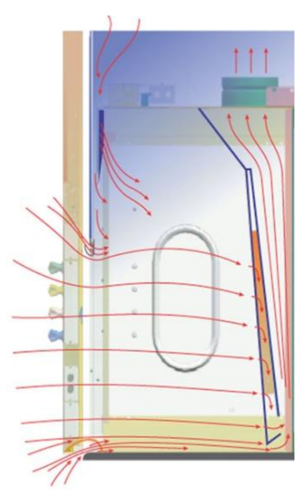

Figure 1.

3.2. Class II Type A BSCs

In Type A1 and A2 BSCs, room air is drawn into the front opening. This air, and contaminated air flowing down through the work area, is drawn into the cabinet's internal blower(s). The blower(s) then pressurize the air sending the majority of it through the supply HEPA filter (recirculated), and the balance through the exhaust filter (exhausted).

When the Type A BSCs are only used for biological containment and no work is done with volatile toxic chemicals or radionuclides, the cabinet exhaust can be safely returned to the room.

When work is done with minute quantities of volatile toxic chemicals or radionuclides, the BSC exhaust airflow must be captured and exhausted out of the building. For Type A BSCs connected to an external exhaust system with a canopy connection, the exhaust system need only to convey that volume of air expelled by the BSC and an additional volume, typically 10-30% required by the canopy connection. This type of connection requires a lower negative static pressure than a Type B2 cabinet; typically less than 0.25 inches of water column. The volume and negative static pressure requirements will not change over the operational life of the Type A2. Canopy connections are required in the current NSF/ANSI 49 as the proper exhaust connection for Type A2 BSCs, for their ability to handle variations in external exhaust while maintaining proper airflows within the cabinet. Class II, Type A1 BSCs are not recommended for use with volatile toxic chemicals and radionuclides, even if they are connected to a canopy, because their average inflow velocity is too low.

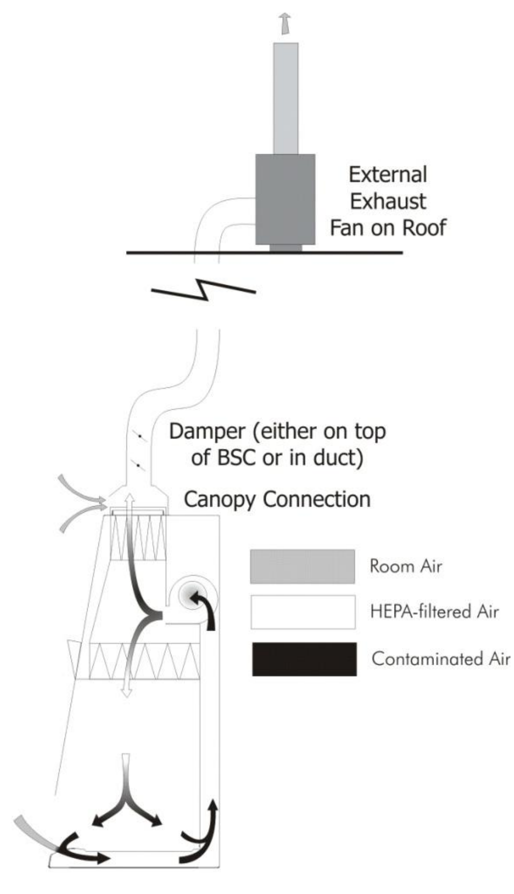

Figure 2 - Typical Type A exhaust system

3.3. Class II Type B BSCs

Type B1 and B2 BSCs are defined by NSF/ANSI 49 as exhausting some or all of their contaminated air without recirculation, through an exhaust HEPA filter before being exhausted to the atmosphere. Type B BSCs are connected to their exhaust systems via a direct (sealed) connection. Unlike the more prevalent Type A models, in Type B cabinets, the cabinet blower(s) do not force any air through the exhaust HEPA filter(s). A remote blower is needed to pull the air through the Exhaust HEPA and then through the exhaust system. This will require the exhaust system to pull the volume of air required at a typical negative static pressure of 1.5 inches of H_2O or higher at the BSC's connection to the exhaust system. The volume will remain constant, but the negative static pressure requirements will increase as the exhaust HEPA filter loads with particulates.

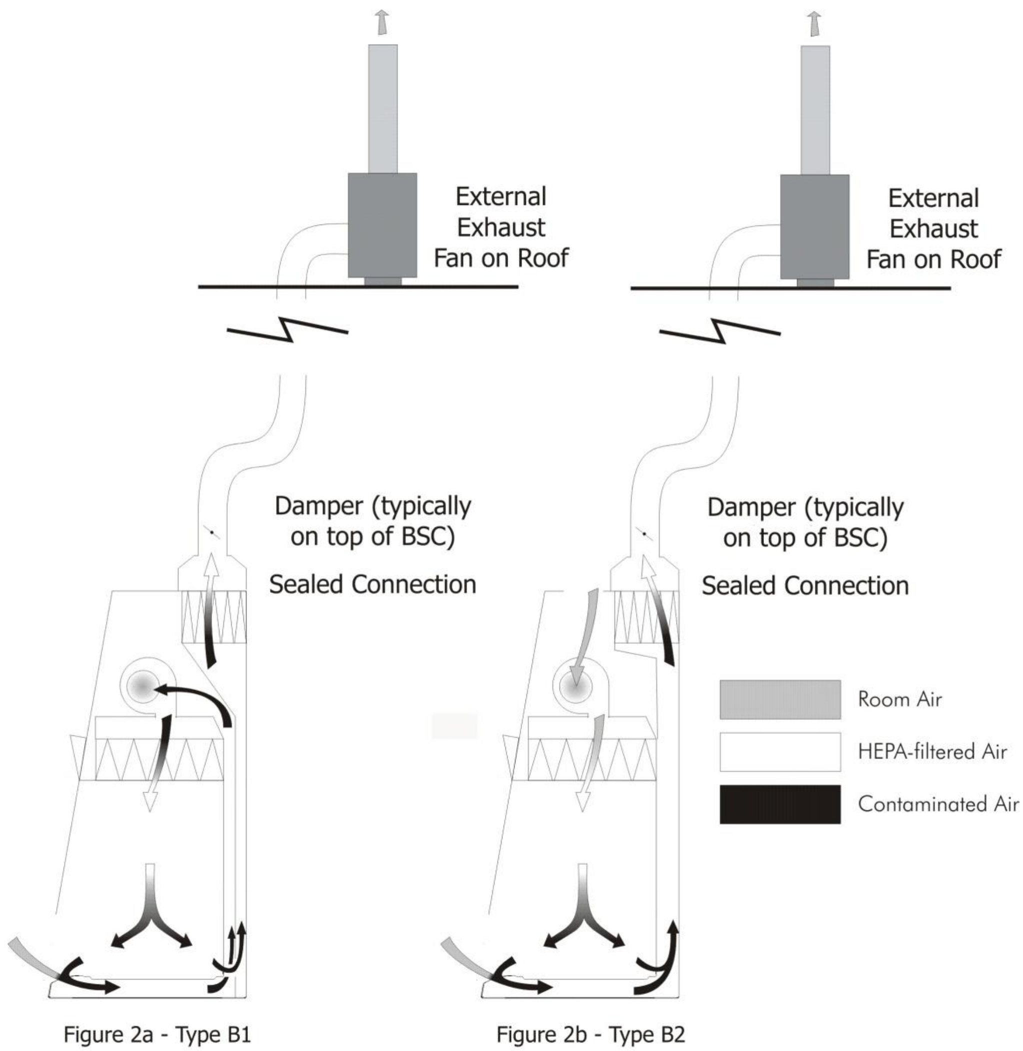

Figure 3 - Typical Type B exhaust systems

4. Characteristics of Class II Type A and Type B BSCs

Table 4.1 Characteristics of Type A1 and A2 BSCs

	Type A1	Type A2
Intended Purpose	Routine microbiological work. Not appropriate for work with volatile toxic chemicals and/or radionuclides. If working with malodorous products, the unit may be canopy-connected to external exhaust for odor control.	Routine microbiological work. Routine work with minute quantities of volatile toxic chemicals and/or radionuclides required as an adjunct to microbiological research, if canopy-connected to external exhaust.
Airflow Pattern	Room air is drawn in through the sash opening, protecting the operator. HEPA- filtered air flows down through the work area, protecting the product. Both bodies of air are mixed and drawn into cabinet blower(s). A portion flows out of the cabinet via an Exhaust HEPA filter, and the remainder recirculates through a Supply HEPA filter before flowing down through the work area.	Room air is drawn in through the sash opening, protecting the operator. HEPA- filtered air flows down through the work area, protecting the product. Both bodies of air are mixed and drawn into cabinet blower(s). A portion flows out of the cabinet via an Exhaust HEPA filter, and the remainder recirculates through a Supply HEPA filter before flowing down through the work area.
% Recirculation	Varies by model; typically 70%	Varies by model; typically 70%
Inflow	Minimum 75 FPM Average	Minimum 100 FPM Average
Downflow	Varies by model, typically 50-80 FPM average	Varies by model, typically 50-80 FPM average
Biological Containment	All NSF-Listed BSCs must pass the same Biological Containment Tests.	All NSF-Listed BSCs must pass the same Biological Containment Tests.
Exhaust System	Canopy connection as needed.	Canopy connection as needed.
Exhaust System Type	Due to the superior ability to handle external exhaust variation, canopy connected Type A BSCs may be ganged into a multiple-cabinet exhaust system, if all BSCs are balanced properly.	Due to the superior ability to handle external exhaust variation, canopy connected Type A BSCs may be ganged into a multiple-cabinet exhaust system, if all BSCs are balanced properly.
Exhaust System Function	To convey the BSC exhaust air, plus an additional volume required by the canopy through the ductwork.	To convey the BSC exhaust air, plus an additional volume required by the canopy through the ductwork.
Exhaust System Volume	About 10 to 20% more than Type B1. Less than Type B2.	About 10 to 20% more than Type B1. Less than Type B2.
Exhaust System Negative Static Pressure at BSC	Typically 0.1 – 0.5 inches H_2O.	Typically 0.1 – 0.5 inches H_2O.
Exhaust System Reserve Capacity	Vacuum requirements will not change as the cabinet filters load.	Vacuum requirements will not change as the cabinet filters load.
Cabinet Flexibility	Can be connected or disconnected from exhaust system as needs change.	Can be connected or disconnected from exhaust system as needs change.
Cabinet Cost	Less than Type B	Less than Type B
Installation Cost	Less than Type B if recirculating; similar to Type B1 if canopy-connected.	Less than Type B if recirculating; similar to Type B1 if canopy-connected.
Operation Cost		
Electrical Cost (BSC Only)	Equal to Type B	Equal to Type B
Tempered air loss	If recirculating in lab; none. If canopy-connected, typically 100 CFM/foot of BSC width or less.	If recirculating in lab; none. If canopy-connected, typically 100 CFM/foot of BSC width or less.

Table 4.2. Characteristics of Type B1 and Type B2 BSCs

	Type B1	Type B2
Intended Purpose	Routine work with minute quantities of volatile toxic chemicals and/or radionuclides required as an adjunct to microbiological research, if canopy-connected to external exhaust.	Routine work using volatile toxic chemicals or radionuclides required as an adjunct to microbiological research.
Airflow Pattern	Room air is drawn in through the sash opening, protecting the operator. HEPAno- filtered air flows down through the work area, protecting the product. The room air, and a portion of downflow air in the front of the work area is recirculated through a supply HEPA filter before flowing down through the work area. The air in the rear of the work area flows out of the cabinet via an Exhaust HEPA filter.	Room air is drawn in through the sash opening, protecting the operator. HEPA-filtered room air flows down through the work area, protecting the product. Both bodies of air are drawn out of the cabinet via an Exhaust HEPA filter.
% Recirculation	Varies by model; typically 30%	0%
Inflow	Minimum 100 FPM Average	Minimum 100 FPM Average
Downflow	Varies by model, typically 50-80 FPM average	Varies by model, typically 50-80 FPM average
Biological Containment	All NSF-Listed BSCs must pass the same Biological Containment Tests.	All NSF-Listed BSCs must pass the same Biological Containment Tests.
Exhaust System	Required.	Required.
Exhaust System Type	Should have dedicated ductwork and exhaust blower for each BSC.	Should have dedicated ductwork and exhaust blower for each BSC.
Exhaust System Function	Must pull exhaust air through the Cabinet's Exhaust HEPA filter and then through ductwork.	Must pull exhaust air through the Cabinet's Exhaust HEPA filter and then through ductwork.
Exhaust System Volume	B1 is approximately 20% less than a Type A.	B2 exhausts 100% or more than a Type B1.
Exhaust System Negative Static Pressure at BSC	Typically 1.5 inches H_2O minimum; Maximum may exceed 4.0 inches H_2O.	Typically 1.5 inches H_2O minimum; Maximum may exceed 4.0 inches H_2O.
Exhaust System Reserve Capacity	Vacuum requirements may increase up to 2.0 inches H_2O as exhaust HEPA filter loads.	Vacuum requirements may increase up to 2.0 inches H_2O as exhaust HEPA filter loads.
Cabinet Flexibility	Must be permanently connected to an exhaust system to function properly.	Must be permanently connected to an exhaust system to function properly.
Cabinet Cost	More expensive than Type A	More expensive than Type A
Installation Cost	Similar to a canopy connected Type A.	More expensive than Type A or B1; higher volumes may require larger ductwork.
Operation Cost		
Electrical Cost (BSC Only)	Equal to Type A	Equal to Type A
Tempered air loss	May be less than a canopy connected Type A. Typically 50-100 CFM/foot of BSC width.	Typically 175 CFM/foot of BSC width.

5. BSC Selection Process

Given the constraints of the Type B design and the additional, demanding requirements of the exhaust system, the user's requirements and the installation site should be carefully reviewed before choosing a Type B BSC. If there are no volatile toxic chemicals or radionuclides to be used in the BSC, then the non-canopy connected (recirculating) Type A BSC would be the preferred choice.

There are two issues concerning the use of volatile toxic chemicals within a Class II BSC; recirculation and exhaust. Type A2 BSCs recirculate typically 70% of the filtered air within the work area. There is rapid dilution of any gaseous materials within the work space. The rapid dilution occurs due to the volumetric exchange of the air being exhausted with the fresh air being taken in from the laboratory through the work access opening. A uniform concentration of a gas through the entire cabinet would typically be diluted 100 times within a minute and over four million times within two minutes after ceasing generation of the gas. Applications where even rapid dilution is insufficient would require using a Type B cabinet in a manner so as to eliminate any recirculation within the work area.

Containment of the volatile toxic chemicals within the cabinet work area should never be a deciding factor; all NSF-listed BSCs pass the same containment tests. The direct exhausting of HEPA-filtered air in the Type B BSCs does not infer superior containment.

6. Site Requirements

6.1.1. Cabinet Location

All Class II Biosafety Cabinets must be located away from interfering drafts or air handling or moving products that could interfere with its proper operation. The Type B cabinet's exhaust system requirements must also be considered, preferably at the time of the laboratory design. The exhaust duct, typically 10- or 12-inch in diameter, or greater, should run directly from the cabinet to the remote blower. Excessive elbows, particularly when placed less than 10 duct diameters from each other, may prevent sufficient or stable air flow through the exhaust system. These conditions may prevent the cabinet from running, or result in erratic operation, with the cabinet frequently going into an exhaust alarm condition.

6.2 Type B Exhaust System Parameters

6.2.1 Volume and Negative static pressure Requirements

As stated in Section 4, A Type B2 cabinet will typically exhaust a total of at least 175 CFM/foot of cabinet width. A Type B1 may only require 75 CFM/foot of cabinet width, as some air is recirculated in the cabinet. Because the remote blower must pull the exhaust air through part of the BSC ductwork and its exhaust HEPA filter, the initial negative static pressure required by the cabinet at its connection to the system may be 1.5 inches H_2O or higher. As the Exhaust HEPA filter loads, the negative static pressure will need to increase in order to maintain constant airflows. Depending on the design of the cabinet, and its filter, the exhaust system may need to have a reserve of an additional 2 inches H_2O to obtain the maximum Exhaust HEPA filter life.

6.2.2 Exhaust Volume Fluctuation and its Impact

The supply blower(s) in a Type B BSC deliver a constant volume of filtered air downward through the work area during normal operation. Fluctuations in the exhaust volume will directly impact the inflow volume and thus the average inflow velocity.

This impact can be calculated by dividing the change in exhaust volume by the area of the work access opening (the height of the sash multiplied by the width of the opening). Using this formula, for a 4-foot Type B2 BSC, with an exhaust volume of 600CFM, a change in exhaust volume of 30CFM will translate into a change in the average inflow velocity of approximately 10FPM. Thus, in normal operation, the exhaust volume should not fluctuate more than +/- 5% in order to maintain consistent cabinet containment. If the exhaust volume were to decrease 10%, the calculation yields a drop in the BSCs face velocity of 20FPM, with a potential loss of containment.

Note: This demanding requirement for consistent exhaust volume must be carefully considered when selecting a Type B2 BSC. Limiting exhaust variation to 5% or less exceeds the stated tolerance of most constant volume airflow controls.

6.2.3 Class II, Type B System Design & Construction

6.2.3.1 Balancing Damper

A balancing damper is typically positioned in the exhaust duct above the air-Tight damper to adjust the volume of air flowing through the system. In some systems, the function of Balancing and Air-Tight damper may be combined into a single damper.

6.2.3.2 Air-Tight Damper

An Air-Tight damper is recommended for class II, type B BSC's installed directly above the exhaust HEPA filter. It's normal position would be open, but would be closed to allow for the space decontamination of the BSC before exhaust HEPA filter replacement.

6.2.3.3 General Description

As previously discussed, the class II, type A2's filtered exhaust air can be recirculated back into the room. If desired, a canopy connection can be attached to the exhaust opening of the BSC, as shown in Figure 2. The canopy connection is connected to exhaust ducting, typically

some type of damper or flow control is located in the duct, downstream of the canopy.

6.2.3.4 Concurrent Balance Value

There are two different test methods used to establish the volume of air being exhausted out of a Class II, type B BSC when it is operating nominally. The first method is the certification method used by NSF International and the second method in the concurrent balance value method used by ASHRAE. Each test method frequently yields different results, however both method results are required for a successful BSC installation and certification. The certification method per NSF/ANSI 49 was designed to offer a repeatable method of measurement for the BSC field certifier directly on the BSC. The certification method used by NSF international and the BSC manufacturers is the capture hood or DIM (Direct Inflow Measurement) device. A tent-like funnel, equipped with a flow meter, is sealed to the front opening of the cabinet. When attached to a Type B1 BSC, or to a Type B2 that has its air intake blocked, the meter establishes the total exhaust volume in the duct.

The concurrent balance value method per ASHRAE 111-2008 is used for all building duct ventilation measurements and calculations from the mechanical design process to the final air balancing process. The concurrent balance value method will use the Pitot Tube Traverse to calculate the airflow volume through the exhaust duct per ASHRAE standard 111-2008. Class II, type B BSC manufacturers are required to provide both values so the mechanical designer can appropriately size the exhaust system as well as the air balancer using the concurrent balance value to balance the laboratory. Then the certifier can use the certification value to certify the BSC to NSF/ANSI 49, Annex F.

6.2.3.5 Dedicated System

A single dedicated external exhaust blower and duct system is required for each Type B cabinet, in order to maintain a constant inflow velocity. The use of manifold connections (ganging) with other devices is not recommended. Ganging Type B BSCs to other devices may result in unstable operation of the cabinet due to fluctuations in exhaust system pressure caused by these other devices.

6.2.3.6 Materials of Construction

The ductwork used must comply with all local building codes and be designed to operate at the maximum negative static pressure without distortion or collapse.

6.2.3.7 At the Cabinet Connection

The facility exhaust system ductwork should connect directly to the cabinet connection on the top of the unit or to the Air-Tight damper as previously mentioned. The cabinet’s exhaust connection should never be modified; such modifications may adversely affect the airflow through the exhaust filter or airflow sensors, preventing proper operation of the cabinet. It is also recommended that the final duct connection use an elastomeric seal between the facility ductwork and the cabinet connection. This will isolate the cabinet from duct vibrations and allow for a method of disconnect for future maintenance. Exhaust static pressure measurements should be taken no more than 2 duct diameters from the cabinet connection, not at the remote fan location.

Most biosafety cabinets will require biological decontamination at various times over the life of the cabinet to facilitate filter changes and other maintenance requirements. The cabinet will be completely sealed and isolated from the external exhaust system and filled with an appropriate decontaminant. Isolation from the external exhaust system is most easily accomplished by disconnecting the canopy or exhaust transition at the cabinet from the external exhaust ducting. Alternatively, air tight dampers in the exhaust duct just downstream of the canopy connection can be used and additional decontaminant provided include the space between the cabinet and the damper. The exhaust ducting between the cabinet and the air tight damper and the canopy must also be sealed to prevent leakage of the decontaminant into the surrounding area.

6.2.3.8 Throughout the system

The Exhaust System must traverse from the BSC to the roof with a minimum of elbows around the building's structural elements or other piping or ducting. Multiple 90^{o} elbows, placed less than 10 duct diameters apart, should be avoided, as this arrangement may seriously impact system performance and will prevent accurately establishing the exhaust volume via duct traverse methodologies.

6.2.3.9 Traverse Velocity Sampling Holes

Two 0.25 inch (6 mm) holes that are 90° separated need be drilled at the distance meeting the requirements of ASHRAE 111-2008. The holes should be positioned as close to the BSC as practicable, for better accuracy. These holes are to be used by the HVAC engineer to do duct traverse velocity readings, to establish the exhaust flow rate.

6.2.3.10 HEPA Filter Leak Test Sampling Holes

Two 0.25 inch (6 mm) holes that are 90° separated need be drilled as far away from the BSC as possible (to allow for thorough mixing of the air being sampled). This will allow the certifier to perform the total penetration exhaust filter scanning using PAO / DOP aerosol challenge. of the exhaust air.

6.2.3.11 Minor adjustment in exhaust flow

Most BSCs undergo annual or semi-annual certification where the cabinet performance is tested and adjusted as necessary to meet manufacturer and other requirements. It is not uncommon for Type B cabinets to require adjustment of as little as 2% of the total exhaust flow. Efficient exhaust installation should provide for easy adjustment of the BSC exhaust flow.

6.2.3.12 Ganging with other Type B Cabinets

If unavoidable, multiple Type B BSCs of the same type have been manifolded to a common system with varying degrees of success. It must be noted that even in the presence of Constant Air Volume (CAV) exhaust control systems, many factors can compromise the safety of the user(s), such as increasing the number of cabinets ganged, the distance between the cabinets, or the accuracy and repeatability of the control system itself.

6.2.3.13 Ganging with other devices

Manifolding Type B BSC(s) with other devices (Type A BSCs or chemical fume hoods) should never be done. The different flow rates and the negative static pressures required will make stable operation impossible or highly unlikely, particularly when manifolded fume hoods sashes are fully open or closed. The readjustment of the Type B's exhaust damper to compensate for exhaust filter loading will also affect every other component connected to the system.

6.3 Conversion/Reconfiguring of Existing Exhaust Systems

Care must be taken when attempting to convert a preexisting fume hood or general exhaust system for use with a Type B cabinet. The exhaust blower must be properly sized to handle the higher negative static pressure required by the BSC at its connection point, and the ductwork itself must be capable of handling the additional negative static pressure without distortion or collapse.

6.4 Room Exhaust

The air exhausted out of the Type B cabinet should never be relied on to be the sole room ventilation exhaust. This practice may create a pressure differential between the room and its environment, adversely affecting BSC performance, and make the BSC difficult to test and decontaminate.

6.5 Control Valves

If a modulated flow exhaust system is used, it is recommended that the operation of the cabinet exhaust be verified under a variety of conditions over time. Furthermore, the type of exhaust alarm must be assessed in light of the type of sensors and controls used in the modulated flow system.

6.6 Night Setback

There is interest in utilizing increasingly sophisticated modulated flow exhaust ventilation systems where the exhaust volume is reduced during periods of inactivity to maximize energy savings. As the BSC is designed by the manufacturer (and often tested by NSF International) to properly operate at a nominal exhaust flow, the BSC should never be allowed to operate in night setback, or at a reduced exhaust volume during periods of BSC activity. The BSC should be equipped to directly signal the exhaust system controller that its blower has been turned on, so that nominal exhaust flow can be resumed, or the BSC must have a manufacturer-supplied interlock to prevent its operation during periods of reduced exhaust flow. Control valve accuracy and repeatability in switching from night setback to nominal operation must be established, and should meet the requirements discussed in Section 6.2.2.

6.7 Remote Blower Switching

In some applications, users have requested that the remote blower be controlled by the Type B cabinet, operating only when the user activates the BSC blower(s). The following concerns must be addressed before modifying a BSC to switch the remote blower:

- The BSC must never turn the remote blower on or off directly; the cabinet should only activate a (preferably) low voltage relay or contact that energizes the remote blower.
- The BSC must be capable of either actuating the low voltage relay or signaling a control system without major modification of the cabinet’s wiring system or its components.
- If the cabinet’s wiring is altered, its wiring diagram should accurately reflect the changes to the cabinet’s electrical system for future reference.

6.8 Altering the Cabinet Exhaust Alarm

The Type B cabinet exhaust alarm serves a crucial function; the protection of the operator from a potentially hazardous loss of containment. As such, it should never be deactivated or inappropriately adjusted to maintain cabinet operation when connected to unstable or inadequate exhaust systems.

6.9 Altering the Cabinet Sash Height

Unlike most general purpose chemical fume hoods, the Type B cabinet does not maintain a constant inflow velocity as the sash height is changed; Cabinet performance is validated at the manufacturer's designated sash height. Closing the sash below, or raising it above this point will increase or decrease the average inflow velocity that could affect the product or personnel protection, respectively.

6.10 Altering the Type B Cabinet

The Type B cabinet is designed for a specific purpose; to be connected to a proper exhaust system and to protect the operator from biohazardous aerosols and/or volatile toxic chemicals used in biological research. The cabinet should never be modified or altered to serve in a different capacity, or to operate without connection to a properly functioning exhaust system.