

Personnel &  
Product  
Protection:  
A Guide To  
Biosafety  
Enclosures



## Foreword

*This booklet was developed as a guide to selecting a biosafety enclosure that provides personnel and/or product protection. The information presented is unbiased and generic in nature compiled with help from experienced microbiologists, engineers and safety enclosure users. While this booklet should raise the questions necessary to identify your specific enclosure requirements, it may not answer those questions. Only you and your safety officer or industrial hygienist can identify your laboratory's unique requirements.*

## Types of Laboratory Enclosures

Different types of enclosures provide protection and containment in the laboratory. Before selecting an enclosure for your particular application, a thorough review of the work and a risk assessment should be performed. Briefly, the major types of enclosures include:



Labconco Protector®  
Premier® Laboratory  
Hood

**Laboratory Fume Hoods.** Laboratory fume hoods are ventilated enclosures that capture, contain, and remove chemical fumes and vapors from the laboratory. The fume hood provides protection by an inward flow of room air through the work area of the hood and out of the laboratory through an exhaust system. Fume hoods are designed to control chemical fumes and vapors that are hazardous in high concentrations, and should not be used with materials that are hazardous in lower concentrations. Laboratory fume hoods should never be used to contain biohazardous materials, as the contaminated exhaust is released directly to the outside environment. Finally, because room air is drawn through the work area, fume hoods do not protect the materials inside from contaminants in the air. If your application requires a chemical fume hood, Labconco's industry service publication, *How To Select The Right Laboratory Hood System*, may provide helpful reading. To request your free copy, call Labconco at **800-821-5525** or **816-333-8811**.

**Clean Benches.** Clean benches use a blower to force air through a High Efficiency Particulate Air (HEPA) filter, and over a work surface. The filtered air may be directed vertically or horizontally across the work area, as shown in Figure 1. This laminar flow of clean air protects materials in the work area from particulate and cross contamination. Clean benches were developed as part of “clean room” technology, and are widely used in the electronics and pharmaceutical industries. They have been successfully used in research laboratories for tissue culture and media preparation. The major limitation of the clean bench is it only provides product protection; the operator is constantly exposed to any aerosols generated in the work area. Thus, work with toxic, allergenic or bio-hazardous materials should not be performed in a clean bench.



Labconco Purifier® Horizontal Clean Bench



Labconco Purifier® Vertical Clean Bench

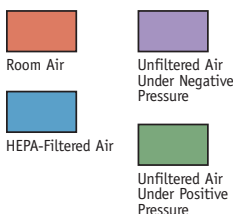
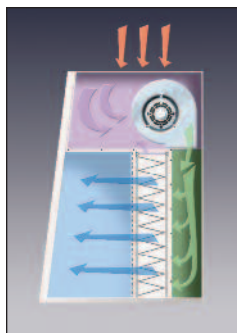


Figure 1. Horizontal Clean Bench (left) and Vertical Clean Bench (below)

**Controlled Atmosphere Glove Boxes.** Controlled atmosphere glove boxes, sometimes called dry boxes, are enclosures that maintain a leak-free environment so that experiments may be carried out under controlled conditions, as in the absence of oxygen or moisture, in an atmosphere of inert gas or under controlled pressure. Controlled atmosphere glove boxes are widely used for oxygen-sensitive, inorganic, organic, organometallic, and non-hazardous biochemical materials. The controlled atmosphere glove box should not be used with biohazardous materials because it has no means to capture aerosols generated within the work area.



Labconco Protector® HEPA-Filtered Glove Box is a type of ventilated glove box.

**Ventilated Glove Boxes** fitted with appropriate filters are enclosures that protect the product inside the work area from particulate contamination, and protect personnel from potentially hazardous materials by filtration and a physical barrier. Applications for ventilated glove boxes include weighing reactive solids, loading capillary tubes for x-ray diffusion, and transfer of low level radioactive, carcinogenic and toxic materials. The Class III Biosafety Cabinet is a type of ventilated glove box, specially designed to sterilize or disinfect materials before they enter or exit the work area of the enclosure. Other ventilated glove boxes should not be used with biohazardous materials, as there is no way to disinfect materials before they are removed from the work area.

**Balance and Bulk Powder Enclosures** provide an enclosed work area where potent compounds may be safely weighed and/or handled. Used frequently in the pharmaceutical research industry, these enclosures have features that address the unique challenges of handling potent powders. While the dimensions of the interior are deep enough to accommodate analytical or micro balances, the overall dimensions of balance enclosures are typically smaller than a traditional fume hood. Balance enclosure widths start as small as at two feet wide. Bulk powder enclosures are wider, starting at five feet, and provide a means to transfer powders from large drum containers. Unlike balance enclosures they are usually floor mounted and have an opening in the work surface to access tall bins. Many balance and bulk powder enclosures utilize exhaust HEPA, carbon or combination of filters to trap particulates and/or vapors.

Filtered enclosures may be ducted back into the room. Many large facilities duct their enclosures to the outside. Finally, to reduce the influence of airflow on sensitive balances, manufacturers suggest that balance enclosures be operated at 60-80 fpm.



*Labconco XPert® Nano Enclosure*

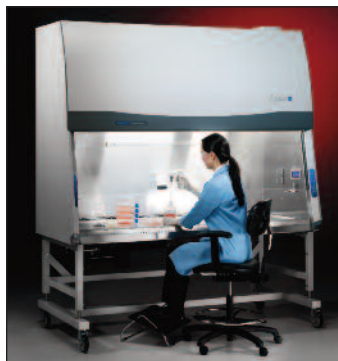
**Nanotechnology Enclosures** were developed in 2008 in response to concerns about the safety of exposure to nanoparticles, which are engineered structures sized between 1 to 100 nanometer. In a 2007 pilot study at the University of Edinburgh, carbon nanotubes introduced into the abdominal cavity of mice showed asbestos-like pathogenicity. Since nanoparticles often exhibit unique physical and chemical qualities, health risks are largely unknown. Due to the limited evidence available about their potential hazards, the National Institute of Occupational Safety and Health (NIOSH) suggests caution when exposed to them. In a 2011 bulletin, the first of its kind, NIOSH recommended time weighted average exposure limits of 2.4 mg/m<sup>3</sup> for fine Titanium Dioxide (TiO<sub>2</sub>) and 0.3 mg/m<sup>3</sup> for ultrafine TiO<sub>2</sub>. Using a combination of airflow and filtration, nanotechnology enclosures provide user protection by keeping nanoparticles contained. Room air is pulled into the enclosure through the front, flows to the baffle and then passes through a 99.999% efficient Ultra Low Penetration Air (ULPA) filter before returning to the laboratory or cleanroom. Few regulatory safety standards currently exist on nanoparticle manipulation. However, organizations, such as NANOSAFE INC., offer independent third-party testing of nanotechnology products verify their ability to contain nanoparticles.



*Labconco XPert® Filtered Balance System*



*Labconco XPert® Bulk Powder Filtered System*



*Labconco Purifier® Logic® Class II Biological Safety Cabinet*

## Biological Safety Cabinets

The terms biological safety cabinet and biosafety cabinet have been widely used to describe a variety of containment devices equipped with HEPA filter(s), designed to provide personnel or both personnel and product protection from biohazardous materials. The terms should only be applied to those devices that meet the requirements of Class I, II, or III specifications, based on their construction, airflow velocities and patterns, and their exhaust systems.

## Biohazards and Biosafety Levels

The word biohazard is a contraction of the words biological and hazard, and defined as: “an infectious agent, or part thereof, presenting a real or potential risk to the well-being of man, animals and/or plants,

directly through infection or indirectly through disruption of the environment.”\*

Biosafety Levels 1 through 4 were established by the Centers for Disease Control (CDC) and the National Institutes of Health (NIH) and are combinations of laboratory practices and techniques, safety equipment and facilities. All of these levels are appropriate for the biohazard posed by the agents used and for the laboratory activity.

The complete definitions and summary of Biosafety Levels 1 through 4 are described in Tables 1 and 2. For further information regarding Biosafety Levels, refer to *Biosafety in Microbiology and Biomedical Laboratories*, U.S. Department of Health and Human Services, HHS publication (CDC) 99-8395, 5th edition, September 2009.

### Biosafety Level 1

Biosafety Level 1 is suitable for work involving well-characterized agents not known to consistently cause disease in immunocompetent adult humans, and present minimal potential hazard to laboratory personnel and the environment. BSL-1 laboratories are not necessarily separated from the general traffic patterns in the building. Work is typically conducted on open bench tops using standard microbiological practices. Special containment equipment or facility design is not required, but may be used as determined by appropriate risk assessment. Laboratory personnel must have specific training in the procedures conducted in the laboratory and must be supervised by a scientist with training in microbiology or a related science.

Special containment devices or equipment, such as BSCs, are not generally required.

### Biosafety Level 2

Biosafety Level 2 builds upon BSL-1. BSL-2 is suitable for work involving agents that pose moderate hazards to personnel and the environment. It differs from BSL-1 in that: 1) laboratory personnel have specific training in handling pathogenic agents and are supervised by scientists competent in handling infectious agents and the associated procedures; 2) access to the laboratory is restricted when work is being conducted; and 3) all procedures in which infectious aerosols or splashes may be created are conducted in BSCs or other physical containment equipment.

All procedures involving the manipulation of infectious materials that may generate an aerosol should be conducted within a BSC or other physical containment devices.

### Biosafety Level 3

Biosafety Level 3 is applicable to clinical, diagnostic, teaching, research, or production facilities where work is performed with indigenous or exotic agents that may cause serious or potentially lethal disease through the inhalation route or exposure. Laboratory personnel must receive specific training in handling pathogenic and potentially lethal agents, and must be supervised by scientists competent in handling infectious agents and associated procedures.

All procedures involving the manipulation of infectious materials must be conducted within a BSC (preferably Class II or Class III), or other physical containment devices.

HEPA filtered exhaust air from a Class II BSC can be safely re-circulated into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations. BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or directly exhausted to the outside through a hard connection. Provisions to assure proper safety cabinet performance and air system operation must be verified. BSCs should be certified at least annually to assure correct performance. Class III BSCs must be directly (hard) connected up through the second exhaust HEPA filter of the cabinet. Supply air must be provided in such a manner that prevents positive pressurization of the cabinet.

### Biosafety Level 4

Biosafety Level 4 is required for work with dangerous and exotic agents that pose a high individual risk of aerosol-transmitted laboratory infections and life-threatening disease that is frequently fatal, for which there are no vaccines or treatments, or a related agent with unknown risk of transmission. Agents with a close or identical antigenic relationship to agents requiring BSL-4 containment must be handled at this level until sufficient data are obtained either to confirm continued work at this level, or re-designate the level. Laboratory staff must have specific and thorough training in handling extremely hazardous infectious agents. Laboratory staff must understand the primary and secondary containment functions of standard and special practices, containment equipment, and laboratory design characteristics. All laboratory staff and supervisors must be competent in handling agents and procedures requiring BSL-4 containment. The laboratory supervisor in accordance with institutional policies controls access to the laboratory.

There are two models for BSL-4 laboratories:

1. A Cabinet Laboratory—Manipulation of agents must be performed in a Class III BSC; and
2. A Suit Laboratory—Personnel must wear a positive pressure supplied air protective suit.

From *Biosafety in Microbiology and Biomedical Laboratories*, U.S. Department of Health and Human Services, HHS publication (CDC) 99-8395, 5th ed. December 2009. Available for downloading from CDC's website at [www.cdc.gov](http://www.cdc.gov).

Table 1. Biosafety Levels

\*NSF International Standard/American National Standard for Biosafety Cabinetry—Class II (Laminar Flow) Biosafety Cabinetry, Ann Arbor, Michigan

Biosafety Level	1	2	3	4
<b>Agents</b>	Not known to consistently cause disease in healthy adults.	<ul style="list-style-type: none"> <li>• Agents associated with human disease</li> <li>• Routes of transmission include percutaneous injury, ingestion, mucous membrane exposure</li> </ul>	Indigenous or exotic agents that may cause serious or potentially lethal disease through the inhalation route of exposure	<ul style="list-style-type: none"> <li>• Dangerous/exotic agents which pose high individual risk of aerosol-transmitted laboratory infections that are frequently fatal, for which there are no vaccines or treatments</li> <li>• Agents with a close or identical antigenic relationship to an agent requiring BSL-4 until data are available to redesignate the level</li> <li>• Related agents with unknown risk of transmission</li> </ul>
<b>Practices</b>	Standard microbiological practices	BSL-1 practice plus: <ul style="list-style-type: none"> <li>• Limited access</li> <li>• Biohazard warning signs</li> <li>• “Sharps” precautions</li> <li>• Biosafety manual defining any needed waste decontamination or medical surveillance policies</li> </ul>	BSL-2 practice plus: <ul style="list-style-type: none"> <li>• Controlled access</li> <li>• Decontamination of all waste</li> <li>• Decontamination of laboratory clothing before laundering</li> </ul>	BSL-3 practices plus: <ul style="list-style-type: none"> <li>• Clothing change before entering</li> <li>• Shower on exit</li> <li>• All material decontaminated on exit from facility</li> </ul>
<b>Primary Barriers and Safety Equipment</b>	<ul style="list-style-type: none"> <li>• No primary barriers required.</li> <li>• PPE; laboratory coats and gloves; eye, face protection as needed.</li> </ul>	Primary barriers: <ul style="list-style-type: none"> <li>• BSCs or other physical containment devices used for all manipulations of agents that cause splashes or aerosols of infectious materials</li> <li>• PPE: Laboratory coats, gloves, face and eye protection, as needed</li> </ul>	Primary barriers: <ul style="list-style-type: none"> <li>• BSCs or other physical containment devices used for all open manipulations of agents</li> <li>• PPE: Protective laboratory clothing, gloves, face, eye and respiratory protection, as needed</li> </ul>	Primary barriers: <ul style="list-style-type: none"> <li>• All procedures conducted in Class III BSCs or Class I or II BSCs in combination with full-body, air-supplied, positive pressure suit</li> </ul>
<b>Facilities (Secondary Barriers)</b>	Laboratory bench and sink required	BSL-1 plus: <ul style="list-style-type: none"> <li>• Autoclave available</li> </ul>	BSL-2 plus: <ul style="list-style-type: none"> <li>• Physical separation from access corridors</li> <li>• Self-closing, double-door access</li> <li>• Exhausted air not recirculated</li> <li>• Negative airflow into laboratory</li> <li>• Entry through airlock or anteroom</li> <li>• Hand washing sink near laboratory exit</li> </ul>	BSL-3 plus: <ul style="list-style-type: none"> <li>• Separate building or isolated zone</li> <li>• Dedicated supply and exhaust, vacuum, and decontamination systems</li> <li>• Other requirements outlined in the text</li> </ul>

Table 2. Summary of Biosafety Levels and Infectious Agents

## History of the Biological Safety Cabinet

The biosafety cabinet began as a microbiological isolation box developed in 1909. Prefiltered air was drawn through the cabinet, maintained under nega-

tive pressure, and exhausted through a flask containing disinfectant. Van den Ende developed the first “modern” biological safety cabinet in 1943 at the National Institute for Medical Research in London, England. A gas burner in the exhaust stack created

an inward movement of air into the enclosure and incinerated the exhaust. The design was refined, and by 1953, recognizable predecessors of the modern Class I cabinet were in use, albeit with spun glass exhaust filters.

Glass wool or cotton filters are, at best, only 95% efficient, so exhaust air frequently had to be incinerated as well, and recirculation of the exhaust air was unthinkable. In 1962 the HEPA filter was developed, which was 99.5 to 99.99% efficient. This allowed for filtered air to be exhausted directly outside the laboratory, or to be recirculated in the cabinet, leading to the establishment of the current Class I, Class II, and Class III cabinets available today.

### HEPA Filters

The HEPA filter is the heart of the biosafety cabinet. The HEPA filter is a disposable dry-type filter, constructed of boron silicate microfibers cast into a thin sheet, much like a piece of paper. Although the media is a flat sheet, the glass microfibers form a complex three dimensional matrix that traps particulate matter. The filter media is folded to increase its surface area and lines of glue are placed between the layers to allow the air to penetrate to the deepest part of the pleat (Figure 2).

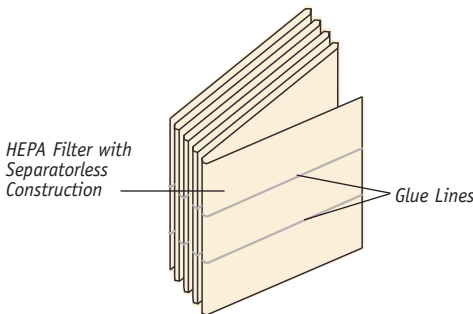


Figure 2. HEPA Filter Details

The HEPA filter is a particulate filter, retaining airborne particles and microorganisms, however, gases pass freely through the filter. HEPA filters retain particulate matter by five distinct mechanisms: sedimentation, electrostatic attraction, interception, inertial impaction, and diffusion.

Sedimentation occurs when a particle settles onto a filter fiber due to gravitational force. Electrostatic attraction is the attraction of a particle to the filter fiber due to its opposite electrical charge. These are the least effective mechanisms of particulate removal by HEPA filtration.

Interception is dependent on particle size and occurs when a particle follows the air stream onto a filter

fiber, and is retained. Inertial impaction occurs when a large particle leaves the air stream to be impacted directly on the filter fiber. Diffusion occurs with very small particles, and is aided by the Brownian (random) motion of the particle (Figures 3 and 4).

HEPA filters are rated on their ability to retain particles 0.3 micron ( $\mu\text{m}$ ) in diameter. The filters are most commonly tested by injecting mineral oil, which has a large number of 0.3  $\mu\text{m}$  droplets, into the upstream side of the filter during operation. Readings are taken on the opposite side of the filter to quantify the number of droplets that penetrate. Thus, if a filter allows one or less droplet to penetrate the filter with an initial concentration of 10,000, the filter is rated at 99.99% efficiency.

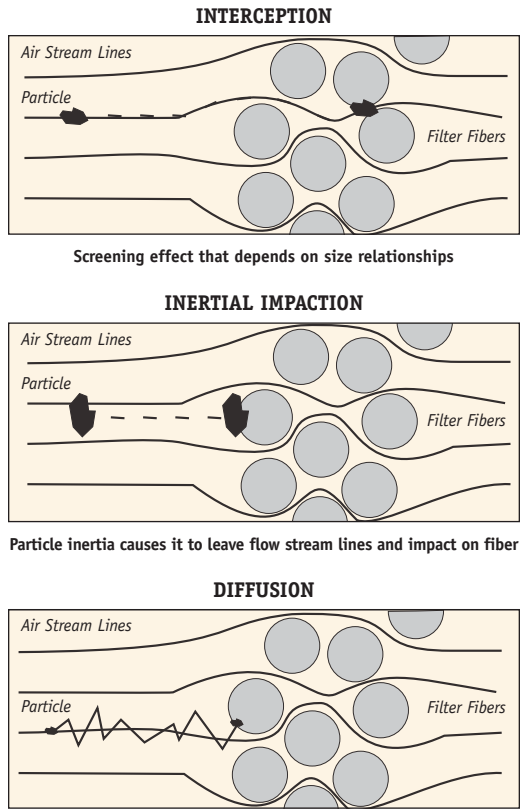


Figure 3. Air Filtration Theory Particle Collection Mechanisms

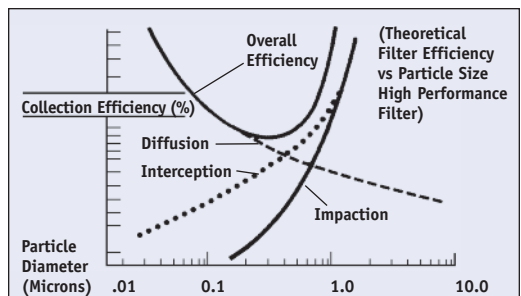


Figure 4. Relative Effect of Particle Collection Mechanism

As most aerosol droplets are larger than 0.3  $\mu\text{m}$ , the collection efficiency of HEPA filters for these droplets is actually higher than its rating. Variations in filter efficiency, for example from 99.95% to 99.99%, are usually due to the filter media used or manufacturing techniques.

ULPA stands for Ultra Low Penetration Air. ULPA filters remove 99.999% of particles 0.12 micron in size. Use of these filters in a biosafety cabinet is not commonly seen but possible. Consult your safety officer for recommendations based on your specific application.

The filter life varies depending on factors such as hours of operation, cleanliness of the laboratory, and nature of the work being done. All other factors being equal, variances in filter life from one biosafety cabinet to the other would be the result of the power or torque of the motor. The greater the horsepower and/or power of the motor, the longer the filters will last. As the filters load, resistance increases. To overcome this resistance, the torque of some motors may be adjusted to extend the life of the filter. With typical usage, HEPA filters commonly last five years or more before needing replacement. Extraordinary claims about filter life should be backed by the manufacturer's warranty.

## Class I Cabinet

The Class I cabinet is defined as a ventilated cabinet for personnel and environmental protection, with unrecirculated airflow away from the operator. Class I cabinets have a similar airflow pattern to a fume hood, except that the Class I cabinet has a HEPA filter at the exhaust outlet, and it may or may not be connected to an exhaust duct system (Figure 5). The Class I cabinet operates with an inflow or face velocity of 75 to 100 feet per minute (fpm).

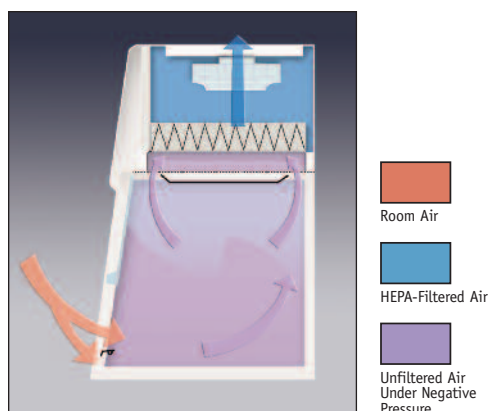


Figure 5. The Class I Cabinet

Class I cabinets are suitable for work with agents that require **Biosafety Level 1, 2 or 3 containment**. The major disadvantage of the Class I Cabinet is that it offers no product protection from contamination and therefore is very limited in its application.

## Class III Cabinets

The Class III cabinet is defined as a totally enclosed, ventilated cabinet of leak-tight construction. Operations in the cabinet are conducted through attached rubber gloves. The cabinet is maintained under negative air pressure of at least 0.5 inch (12.7 mm) water gauge (w.g.). Supply air is drawn into the cabinet through HEPA filters. The exhaust air is treated by double HEPA filtration, or by HEPA filtration and incineration (Figure 6). The cabinet also has a transfer chamber capable of sterilizing work materials before exiting the glove box containment system. Class III cabinets are suitable for work with agents that require **Biosafety Level 1, 2, 3 or 4 containment**.

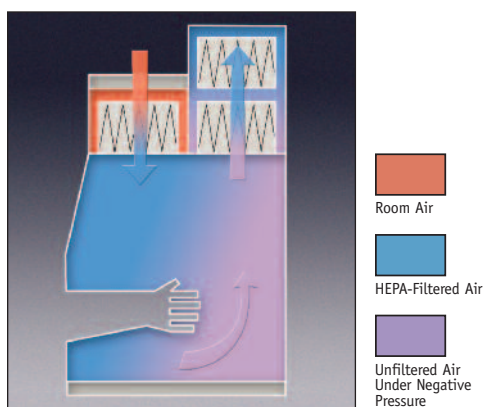


Figure 6. The Class III Cabinet

## Class II Cabinets

The Class II cabinet is defined as a ventilated cabinet for personnel, product and environmental protection, having an open front with inward airflow for personnel protection, downward HEPA-filtered laminar airflow for product protection, and HEPA-filtered exhaust air for environmental protection. Class II cabinets are suitable for use with agents that require Biosafety Level 1, 2 or 3 containment. The cabinets are differentiated into various types based on their construction, airflow velocities and patterns, and by their exhaust system (Table 3).

## Types of Class II Cabinets

The primary design differences between Type A and Type B Class II cabinets are briefly summarized. The minimum average face velocity for Type A1 is 75 fpm; Type A2 and B is 100 fpm. Type A cabinets intermix and recirculate some (approximately 70%) of their air



Type	A1		A2		B1	B2
Minimum average inflow velocity (fpm)	75		100		100	100
Percentage air recirculated in cabinet (approximate)	70		70		30-50	0
Exhausts to	Room	Outside	Room	Outside	Outside	Outside
Exhaust duct connection	None	Canopy	None	Canopy	Hard Duct	Hard Duct
Requires dedicated exhaust connection	No	No	No	No	Yes	Yes
Requires face velocity alarm	No	No	No	No	Yes	Yes
Suitable for work with odorous materials	No	Yes	No	Yes	Yes	Yes
Suitable for work with volatile chemicals and radionuclides	No	No	No	*	**	***
Capital cost	Low	Moderate	Low	Moderate	High	High
Installation cost	Low	Moderate	Low	Moderate	High	High
Energy loss	Low	Moderate	Low	Moderate	High	High

Table 3. Class II Cabinet Characteristics

\* Type A2 cabinets used for work with minute quantities of volatile chemicals and tracer amounts of volatile radionuclides required as an adjunct to microbiological studies must be exhausted through properly functioning exhaust canopies.

\*\* Type B1 cabinets may be used for work with volatile chemicals and tracer amounts of volatile radionuclides required as an adjunct to microbiological studies if work is done in the direct exhausted portion of the cabinet, or if the chemicals or radionuclides will not interfere with the work when recirculated in the downflow air.

\*\*\* Type B2 cabinets may be used for work with volatile chemicals and radionuclides required as adjuncts to microbiological studies.

after HEPA filtration; Type B cabinets directly exhaust (30-50% for Type B1) or all (Type B2) of their air out of the laboratory after HEPA filtration. Type A cabinets are exhausted into the lab or outside via a canopy connection; Type B must have a dedicated, sealed exhaust system with remote blower and appropriate alarm system.

### Type A1

Type A1 cabinets (1) maintain minimum average inflow velocity of 75 fpm through the work area access opening; (2) have HEPA-filtered downflow air that is a portion of the mixed downflow and inflow air from a common plenum (i.e. plenum from which a portion of the air is exhausted from the cabinet and

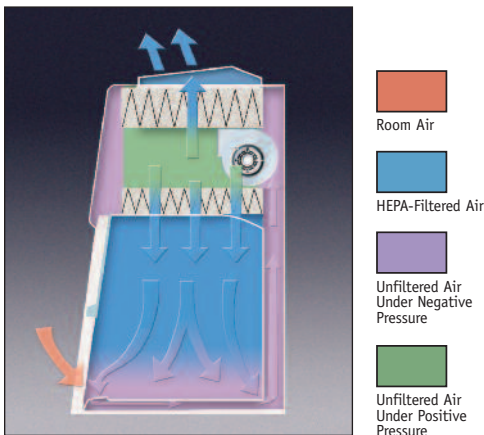


Figure 7. The Class II, Type A1 or A2 Cabinet

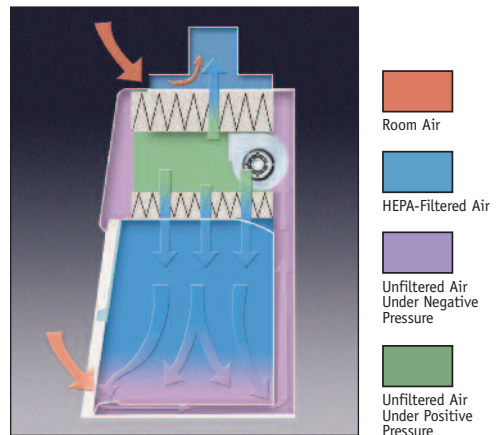


Figure 8. The Class II, Type A1 or A2 Cabinet with Canopy-Type Connection

the remainder supplied to the work area); (3) may exhaust HEPA-filtered air back into the laboratory or to the environment through an exhaust canopy; and (4) have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums. Type A1 cabinets are suitable for work with biological agents in the absence of volatile toxic chemicals and volatile radionuclides.

The Class II, Type A1 cabinet may exhaust HEPA-filtered air back into the laboratory (Figure 7). A Type A1 cabinet may also be exhausted to the outside via a canopy-type connection to remove non-toxic odors (Figure 8). In this installation, the cabinet exhausts its HEPA-filtered air and a portion of the laboratory's air to the outside.

### Type A2 Cabinet

Type A2 cabinets (1) maintain a minimum average inflow velocity of 100 fpm through the work access opening; (2) have HEPA-filtered downflow air that is a portion of the mixed downflow and inflow air from a common exhaust plenum; (3) may exhaust HEPA-filtered air back into the laboratory (Figure 7) or to the environment through an exhaust canopy (Figure 8); and (4) have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums. Type A2 cabinets with a canopy are suitable for work with biological agents treated with minute quantities of toxic chemicals and tracer quantities of radionuclides that will not interfere with the work if recirculated in the downflow air.

### Type B1 Cabinet

Type B1 cabinets (1) maintain a minimum average inflow velocity of 100 fpm through the work access

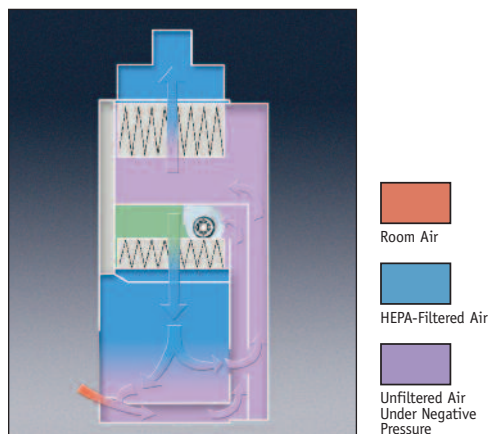


Figure 9. The Class II, Type B1 Cabinet

opening; (2) have HEPA-filtered downflow air composed largely of uncontaminated recirculated inflow air; (3) exhaust most of the contaminated downflow air through a dedicated duct exhausted to the atmosphere after passing through a HEPA filter; and (4) have all biologically-contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums (Figure 9).

Type B1 cabinets are suitable for work with agents treated with minute quantities of toxic chemicals and tracer amounts of radionuclides required as an adjunct to microbiological studies if work is done in the directly exhausted portion of the cabinet, or if the chemicals or radionuclides will not interfere with the work when recirculated in the downflow air.

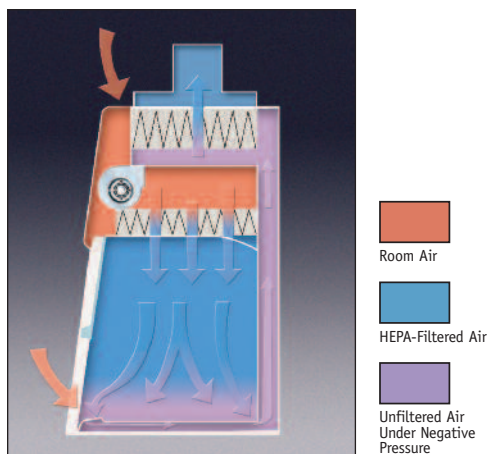


Figure 10. The Class II, Type B2 Cabinet

### Type B2 Cabinet

Type B2 cabinets, which are sometimes referred to as "total exhaust," (1) maintain minimum average inflow velocity of 100 fpm through the work area access opening; (2) have HEPA-filtered downflow air drawn from the laboratory or the outside air (i.e. downflow air is not recirculated from the cabinet exhaust air); (3) exhaust all inflow and downflow air to the atmosphere after filtration through a HEPA filter without recirculation in the cabinet or return to the laboratory; and (4) have all contaminated ducts and plenums under negative pressure or surrounded by directly exhausted (nonrecirculated through the work area) negative pressure ducts and plenums (Figure 10). Type B2 cabinets may be used with biological agents treated with toxic chemicals and radionuclides required as an adjunct to microbiological studies.

## NSF/ANSI Standard Number 49

In the late 1960's to mid 1970's, researchers often submitted their own Class II cabinet specifications and options to manufacturers. In order to standardize cabinet design and performance used by governmental researchers, the National Institutes of Health developed a specification for Type A cabinets in 1973. The National Cancer Institute also developed its own specifications for a Type B1 cabinet the same year. The government specifications were demanding



*The NSF International mark appears on Class II Cabinets that are listed by NSF International*

ones, and often an impediment to improvements by the manufacturers. In an attempt to develop impartial specifications, NIH contacted the National Sanitation Foundation (NSF International) in the early 1970's. NSF International is an independent organization that acts as a neutral agency serving the consumer, government and industry in developing solutions for problems pertaining to public health and the environment. After numerous meetings with government officials, scientists, and manufacturers, NSF International published NSF Standard 49 in 1976.

The NSF/ANSI Standard 49, *Biosafety Cabinetry: Design, Construction, Performance, and Field Certification*, establishes minimum materials, design, construction and performance requirements for Class II biosafety cabinets, the quality control tests that the manufacturer must perform on every unit, and the tests that should be performed in the field. The Standard also provides the Type designations, which were described above, that further delineate the various cabinets based on airflow characteristics. NSF International periodically reviews and changes the Standard as needed with direction and guidance from the Standard 49 Joint Committee, which is a group of individuals representing the industry, users of biosafety cabinets and public health/regulatory officials.

Its policy establishes requirements for testing and periodic retesting of cabinets by the NSF International Laboratory in Ann Arbor, Michigan, and annual unannounced audits of the manufacturer's facility. The Standard requires three separate biological challenge tests to be passed in order for the cabinet to be listed. The Personnel Protection Test measures the number of bacterial spores escaping from the cabinet's work area into the environment. The Product Protection Test establishes the number of

bacterial spores entering the work area from the outside environment. Finally, the Cross Contamination Protection Test measures how far bacterial spores can drift across the cabinet work area.

Performance Zone Tests are additional biological challenges performed at various inflow and downflow velocity settings. These tests ensure that the cabinet still functions properly, even when it is not operating at the manufacturer's recommended downflow and inflow velocity settings.

These tests are performed by NSF International before a cabinet is listed, and periodically thereafter. Typically, most manufacturers perform biological challenge tests while their cabinets are in the prototype stage of development, and periodically during production, to ensure that the cabinets protect personnel, environment and product.

## Selecting the proper Biosafety Cabinet

### Primary Consideration—Safety

Selecting the proper type of biosafety cabinet depends on the following: (1) the type of protection required—a) product protection only b) personnel and environmental protection only c) product, personnel, and environmental protection, (2) the different types of work that will be done in the cabinet, (3) the types and quantities of toxic materials that will be used in the course of the work, (4) the type of exhaust system that will be needed. Items 1, 2 and 3 are all determined by the user of the cabinet, based on his/her individual needs. Item 4 will be determined by the first three. Biological containment is not an issue—ALL Class II cabinets are designed for Biosafety Levels 1, 2 and 3 containment. No one type offers superior aerosol containment over the others.

### Secondary Consideration—Cost, Energy Savings and Environmental Responsibility

Understanding the costs involved in owning and operating a biosafety cabinet is important. Capital expenditures include the cabinet, the remote blower, the ductwork and other hardware such as alarms and dampers. Initial outlays include installation of the cabinet, the exhaust systems and its blower, and certification. Maintenance costs including recertification and HEPA filter replacement are considerations that should not be overlooked.

Ongoing energy cost is another important factor to consider. Under normal operation, biosafety cabinets with energy-efficient electronically commutated (ECM/or DC) consume up to 60% less energy than cabinets with conventional motors. If these biosafety cabinets have a night setback mode that idles the

blower at a lower speed when the sash is fully closed, then even greater energy savings can be realized. Any upcharges associated with an ECM are quickly paid back by the energy savings achieved during operation.

Related to energy savings is the LEED\* 2009 Rating System developed by the United States Green Building Council. When used in new construction projects, biosafety cabinets that use less energy, contribute toward less heat load of a building and/or contain recycled materials of construction can contribute toward a building's overall LEED points.

### **Tertiary Considerations—Ergonomics, ADA-Compliance and Options**

Ergonomic features of a biological safety cabinet are important considerations because they can affect the safety and comfort of the user. When monitors and controls are in close proximity to the user's field of vision or reach, the user experiences less fatigue and reduced risk of personal injury. Low-mounted features comply with the Americans with Disabilities Act, essential for wheelchair-bound users. An angled front sash allows closer viewing without glare. A contoured air foil permits the user's forearms to rest comfortably. Accessories that contribute to the user's comfort such as an adjustable, ergonomic chair and footrest should be considered. Supporting base stands that may be adjusted with a hydraulic lift may be beneficial if several users of differing body types will be using the cabinet. Ensure that adjustable height base stands meet NSF standards for tip resistance and construction stability.

Many options and accessories are available that customize a biosafety cabinet to the user's needs. Cabinets come in various widths. The most common outside widths of biosafety cabinets are 3-, 4-, and 6- feet. The three foot wide cabinet offers the greatest savings of money and bench space, however, many researchers find the limited work space too confining. The four foot wide cabinet is by far the most popular, offering a larger work area, at a slightly higher cost. The six foot wide cabinet offers room for two researchers to work side-by-side, however, its size and weight may make some installations difficult.

If the user is confused about which size is needed, it is useful to mark a section of laboratory benchtop space equal to the dimensions of the cabinet's work area. The researcher should then perform several "dry runs" of his/her work within the marked area, to see if it is large enough.

Service valves are accessories that many researchers prefer to have on their cabinets. The valves, which

should be easily accessible to the operator, may provide water, vacuum, air or a variety of other gases. The use of flammable gases or solvents in biosafety cabinets should be avoided. Open flames and gases under high pressure should not be used because they disrupt the airflow patterns in the cabinet. Open flames may also burn the HEPA filter and/or damage the filter's adhesive.

Many researchers prefer the convenience of electrical outlets on the biosafety cabinet. The outlets should be factory installed with a dedicated circuit breaker, so that a short circuit would not prevent the cabinet from operating. The outlets and their breakers should be rated for the requirements of the user and should be easily accessible. Ground fault circuit interrupters (GFCI) may be considered.

Ultraviolet (UV) lamps are often installed in a biosafety cabinet as an aid in decontamination of the work area. The lamps are similar in construction to fluorescent lights, except they emit ultraviolet light with a wavelength of 254 nanometers (nm). This wavelength of light is disruptive to DNA molecules, resulting in a broad spectrum disinfection. While UV light is effective when it strikes a microbial cell directly, it is ineffective when the cell is protected by dust, dirt, or organic matter. UV irradiation of the work area should only be used as a supplemental method of maintaining the disinfected status of the cabinet; it should never be relied on alone to disinfect a contaminated work area. Ultraviolet irradiation is irritating to the eyes and skin, and the UV lamp should never be on when using the cabinet.

An intravenous (IV) bar is simply a rod suspended across the top of the work area, from which the technician can hang IV bags or bottles during their preparation. Placing an IV bar in the work area disrupts the airflow patterns in the cabinet, so the user must be sure that the cabinet has passed all NSF/ANSI Standard 49 tests with the bar in place.

Microscope-compatible biosafety cabinets are becoming increasingly more popular. Look for cabinets that have been designed and manufactured to have sashes with cutouts and vibration-resistant work surfaces that can accommodate inverted or stereo microscopes. Use caution in attempting to modify existing biosafety cabinets as these changes may interfere with the cabinet's airflow and would nullify the manufacturer's warranty.

A temperature-controlled work surface is an available option on some biosafety cabinets. Applications that involve warm or chilled samples benefit from an area inside the cabinet that can maintain the desired sample temperature. These work surface areas have circu-

lated fluid beneath the surface to achieve the desired temperature.

A sink in a biosafety cabinet is one feature that should never be considered since potentially biohazardous effluents would drain into municipal wastewater.

For benchtop-style biosafety cabinets, a base stand is a necessary accessory. The base stand must pass NSF/ANSI Standard 49 stability tests with the cabinet attached in order to be used with the cabinet.

## Installation

The cabinet should be located away from fans, heating and air conditioning registers, laboratory hoods, high traffic areas and doors that could interfere with its airflow patterns (Figure 12). All windows in the room should remain closed. The floor should be level, and of solid construction. A dedicated electrical outlet should also be available.

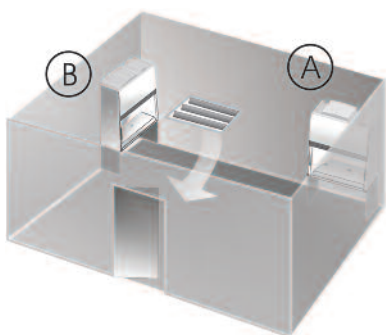


Figure 12. Suggested Locations for Class II Biosafety Cabinets. Location “A” shows the preferred location. Location “B” is an alternate location. The air supply register(s) above or near the cabinet’s location should be directed away from the cabinet face.

There should be a minimum clearance of 6" between the exhaust outlet on the top of the cabinet and any overhead obstructions. Whenever possible, a minimum 12" clearance should be provided at the back and both sides of the cabinet.

## Type B Cabinet Exhaust System Requirements

Controlled Environment Testing Association (CETA) has established guidelines for the installation of Type B biosafety cabinets. CETA’s guidelines require a single dedicated external exhaust blower and duct system for each cabinet. CETA strongly discourages ganging (manifolding) cabinets to a common system. A single Type B cabinet exhaust system requires 1000 CFM air volume or more and has a static pressure loss of 4.5" w.g. or more. Pulling the required amount of air volume and overcoming static resistance for multiple HEPA filters that increase in static pressure as they load would require an extremely large exhaust

blower. In addition, NSF 49 requires that Type B cabinets have integrated shutdown functions when the exhaust falls below 80% of nominal. Integrating electronic valves to control a ganged system of Type B biosafety cabinets is extremely difficult. According to CETA, ganging a Type B cabinets with another device, such as a chemical fume hood, should never be done. The different flow rates and the negative static pressures required would make stable operation highly unlikely. The readjustment of the Type B’s exhaust damper to compensate for exhaust filter loading would also affect every other component of the system.

## Certification

Certification of biosafety cabinets plays a critical role in their performance. Certification should be performed at least annually and whenever the cabinet is moved, serviced or when the HEPA filters are replaced. The recommended tests in Table 4 and their procedures are outlined in NSF/ANSI Standard 49.

Selecting the right certifier is critical to ensure that the biosafety cabinet performs as it was designed. The efforts of the manufacturer’s research and development, and NSF’s testing and validation can easily be nullified by an improper or inaccurate certification.

NSF International and other agencies offer accreditation programs for biosafety cabinet certifiers. Upon successful completion of written and practical examinations by NSF, the certifier is accredited to certify biosafety cabinets using test methods described in NSF/ANSI Standard 49.

PRIMARY TESTS	
<b>Downflow Velocity Profile</b>	Establishes the average downflow velocity of the cabinet.
<b>Inflow Velocity</b>	Establishes the average inflow velocity of the cabinet.
<b>Airflow Smoke Pattern Test</b>	Establishes the airflow patterns around the work access opening and within the work area.
<b>HEPA Filter Leak Test</b>	Tests the HEPA filters for leaks.
SECONDARY TESTS	
<b>Vibration Test</b>	Measures the vibration of the cabinet during operation.
<b>Noise Level Test</b>	Measures the sound pressure of the cabinet during operation.
<b>Lighting Intensity Test</b>	Establishes the light intensity in the work area.

Table 4. Recommended Certification Tests

If the certifier is not accredited by NSF, then the following should be considered: The user should ask the certifier about his experience certifying biosafety cabinets in general, and the user's model specifically. The user should ask the certifier about his attendance at technical courses or the manufacturer's training sessions. The certifier should describe all the tests he will perform and his procedures. Any deviations from NSF/ANSI Standard 49 should be explained and understood before the certification begins. The certifier's test equipment should be annually calibrated to a National Institute of Standards & Testing (NIST) traceable standard.

## Special Applications for Biosafety Cabinets

### Working with clinical material

The Centers for Disease Control and the National Institutes of Health have recommended Universal Blood and Body Fluid Precautions or Universal Precautions. Under these precautions, blood and certain body fluids of all patients are considered potentially infectious for Human Immunodeficiency Virus (HIV), hepatitis B virus (HBV), and other bloodborne pathogens.

Recommended biosafety levels, facility requirements, and the classification of many agents are included in the CDC-NIH publication *Biosafety in Microbiology and Biomedical Laboratories*, U.S. Department of Health and Human Services, HHS publication (CDC) 99-8395, 5th edition, December 2009. The publication is available for downloading from CDC's website at [www.cdc.gov](http://www.cdc.gov). CDC/NIH recommended precautions for laboratory work with HIV follow: (Table 5).

Activities Involving:	Practices & Procedures	Facility
clinical specimens/ body fluids	Biosafety Level 2	Biosafety Level 2
human/animal tissues infected with HIV, growing HIV at research lab scale, growing HIV-producing cell lines, working with concentrated HIV preparation, droplet/aerosol production	Biosafety Level 3	Biosafety Level 2
HIV at industrial-scale levels, large volume, or high concentration production and manipulation	Biosafety Level 3	Biosafety Level 3

Table 5. CDC/NIH Recommended Precautions for Laboratory Work with HIV

### Cell Research/In Vitro Fertilization

Manipulation of human cells involved in culture analysis, microdissection, recombinant DNA technology and in vitro fertilization require that the cells be maintained at optimum temperature to prevent cell death. Most of these procedures also require a microscope. For recombinant DNA technology applications, compliance to NIH Guidelines is mandatory for research funded by the NIH. NIH Guidelines apply containment requirements based on Risk Group. Agents are classified into four Risk Groups (RGs) based on their relative pathogenicity for healthy adult humans. RG1 agents are not associated with disease. RG2 are associated with disease which is rarely serious and for which preventive or therapeutic interventions are often available. RG3 agents are associated with serious or lethal disease for which preventive or therapeutic interventions may be available. RG4 agents are likely to cause serious or lethal disease for which preventive or therapeutic interventions are not usually available. Research involving RG2 agents require handling in a Class I or II biological safety cabinet, RG3 agents in a Class II biological safety cabinet, and RG4 agents in a Class III biological safety cabinets or positive-pressure personnel suits. Other institutions not funded by NIH have also adopted these guidelines. Currently, no specific govern-



Labconco Purifier Cell Logic Biosafety Cabinet includes a temperature-controlled work area heated/cooled by an auxiliary circulator and a modified sash to accommodate a microscope.

ment standards exist for in vitro fertilization laboratories. However, since handling human cells pose a potential hazard of transmitting diseases to personnel or to other patients' gametes, zygotes or embryos; the same Universal Precautions recommended for clinical material apply. Some manufacturers offer biosafety cabinets with temperature-controlled areas in the work surface to keep cell cultures at optimum temperature. Additionally, some manufacturers offer biosafety cabinets modified to accommodate stereo and/or inverted microscopes. These biosafety cabinets may conform to NSF standards for airflow, but may not have NSF listing due to these modifications.

### Handling hazardous drugs

Hazardous drugs include antineoplastic agents, antiviral agents, biological modifiers and hormones. Workers in pharmacies, pharmaceutical research or pharmaceutical manufacturing may generate aerosols or chemical dusts during routine handling and preparation of hazardous drugs. Potential health risks of these drug procedures include cancer, gene mutations and adverse reproductive outcomes. The National Institute for Occupational Safety and Health (NIOSH), American Society of Health-System Pharmacists (ASHP), and the United States Pharmacopeia (USP) have issued guidelines for the safe handling of hazardous drugs. USP mandates compliance to its Chapter <797>, "Pharmaceutical Compounding—Sterile Preparations." All three organizations recommend a Class II, Type B2 biosafety cabinet for workers handling hazardous drugs. USP Chapter <797> further stipulates that sterile compounding of hazardous drugs must be done in an ISO Class 5 device (either a Class II, Type B2 biosafety cabinet or a isolator/laminar flow glove box) located in an ISO Class 7 Buffer Room connected to an ante room, both under negative pressure.

### Laboratory Animal Research

Research with small mammals, such as mice and rats, pose occupational health risks. Animal hair and dander may cause allergic reactions. Animals are often inoculated with microorganisms that cause illness in humans or are of unknown risks to humans. According to World Health Organization's (WHO) Laboratory Biosafety Manual, vivariums, like laboratories, must designate practices and safety equipment according to the Risk Group of the microorganisms being investigated. These Risk Groups correlate to the Biosafety Levels identified by the CDC (Table 1). Table 6 indicates when Class I, II or III biosafety cabinets are suitable for vivarium use.

Risk Group	Containment Level	Laboratory Practices and Safety Equipment
1	ABSL*-1	Limited access, protective clothing and gloves.
2	ABSL-2	ABSL-1 practices plus: hazard warning signs. Class I or II BSCs** for activities that produce aerosols. Decontamination of waste and cages before washing.
3	ABSL-3	ABSL-2 practices plus: controlled access. BSCs and special protective clothing for all activities.
4	ABSL-4	ABSL-3 plus: strictly limited access. Clothing change before entering. Class II BSCs or positive pressure suits. Shower on exit. Decontamination of all wastes before removal from facility.

\* Animal Facility Biosafety Level \*\* Biological safety cabinets

Table 6. Animal facility containment levels: summary of practice and safety equipment. From WHO Laboratory Biosafety Manual.

Biosafety cabinets for animal handling use may feature taller work access openings than standard BSCs. Work opening heights of 10" or 12" are common to allow the worker freedom of movement while conducting procedures such as cage changing, weighing, anesthesia delivery or surgery.

### Handling Suspicious Mail

Bioterrorism involving mail potentially contaminated with biohazards such as anthrax and smallpox has created demand for enclosures where suspicious mail can be safely sorted and opened. The Centers for Disease Control and Prevention (CDC) recommends handling anthrax and smallpox using Biosafety Level 2 practices, containment equipment and facilities. The Biosafety Level 2 recommendation is required for work on a laboratory scale, which would be similar to the small amounts of infected agents found in dangerous mail. Class I enclosures are Biosafety Level 2 equipment that provide the necessary personnel protection without providing unneeded product protection. Class I enclosures, like any laboratory device, have the potential for misuse by persons unfamiliar with biological safety cabinets or common laboratory practices such as aseptic technique. Training of personnel is essential and the risk of misuse must be weighed against the potential for exposure to biohazards. Consult your safety officer for recommendations based on your specific application.

## Use of the Cabinet

### Planning

Thoroughly understand procedures and equipment required before beginning work.

Arrange for minimal disruptions, such as room traffic or entry into the room, while the cabinet is in use.

### Start-Up

Turn off UV light if in use. Ensure that the sash is set in the correct operating position.

Turn on fluorescent light and cabinet blower.

Check the return air grilles for obstructions, and note cabinet status.

Allow the cabinet to operate unobstructed for at least four minutes.

Wash hands and arms thoroughly with germicidal soap.

Wear appropriate protective equipment.

### Wipe-Down

Wipe down the interior surfaces of the cabinet with 70% ethanol, or a suitable disinfectant, and allow to dry.

### Loading Materials and Equipment

Only load the materials required for the procedure. Do not overload the cabinet.

Do not obstruct the front, side, or rear return air grilles. Large objects should not be placed close together.

### Work Techniques

Keep all materials at least four inches inside the sash, and perform all contaminated operations as far to the rear of the work area as possible.

Segregate all clean and contaminated materials in the work area.

Arrange materials to minimize the movement of contaminated materials into clean areas.

Keep all discarded contaminated material to the rear of the cabinet.

Avoid moving materials or excessive motion of the operator's hands and arms through the front access opening during use.

Avoid the use of an open flame.

Use proper aseptic technique.

Avoid using techniques or procedures that disrupt the airflow patterns of the cabinet.

If there is a spill or splatter during use, all objects in the cabinet should be surface decontaminated before removal. Thoroughly disinfect the working area of the

cabinet WHILE IT IS STILL IN OPERATION. This will prevent the release of contaminants from the cabinet.

### Final Purging

Upon completion of work, the cabinet should be allowed to operate for two to three minutes undisturbed, to purge airborne contaminants from the work area.

### Unloading Materials and Equipment

Objects in contact with contaminated material should be surface decontaminated before removal from the cabinet.

All open trays or containers should be covered before being removed from the cabinet.

### Wipe-Down

Wipe down the interior surfaces of the cabinet with 70% ethanol, or a suitable disinfectant, and allow to dry.

Periodically remove the work surface and wipe down the area beneath it.

Dispose of rubber gloves appropriately, and have the lab coat laundered properly.

### Shutdown (Optional)

Turn off the fluorescent light and cabinet blower, if desired, and turn on the UV light if appropriate.

## Routine Maintenance Schedule

Under normal operation, biosafety cabinets require little routine maintenance. The following schedule is recommended:

### Weekly

Using 70% ethanol, or a suitable disinfectant, surface disinfect the inside of the cabinet and the work surface.

Using an appropriate glass cleaner, clean the sash and the surface of the UV lamp, if so equipped.

Operate the cabinet blower, noting the filter gauge reading in the operational log.

### Monthly (or more often as required)

Using a damp cloth, clean the exterior surfaces of the cabinet, particularly the front and the top of the cabinet, to remove any accumulated dust.

Disinfect and remove the work surface. Surface disinfect the lower plenum with a solution of 70% ethanol, or a suitable disinfectant.

Check all service valves, if so equipped, for proper operation.



**Annually**

Have the cabinet recertified by a qualified certification technician.

Replace the UV lamp, if so equipped.

**Biannually**

Replace the fluorescent lamp(s).

## Glossary

**absolute filter:** Obsolete term for HEPA filter.

**aerosol:** A colloid of liquid or solid particles suspended in a gas, usually air.

**agent:** Any biological, chemical or physical power, principle or substance capable of acting upon a subject organism, usually to its detriment.

**air barrier (“air curtain”):** The unidirectional movement of air past and parallel to the plane of an opening and at a velocity greater than that on either side, thereby creating an impedance to transverse movement of airborne particulates through the opening.

**air stream:** A current of air; airflow.

**antiseptic:** A compound that prevents the multiplication of microorganisms. Bacteriostatic in action, not bactericidal. Its use applies to tissues rather than inanimate surfaces.

**aseptic technique:** The performance of a procedure or operation in a manner that prevents the introduction of microorganisms, which are capable of causing infection or contamination.

**assessment of risk:** The process of defining biological hazard associated with a microbial or antigenic entity.

**biohazard:** A contraction of the words biological and hazard; infectious agent(s) presenting a real or potential risk to the well-being of man, other animals, or plants, either directly through infection or indirectly through disruption of the environment.

**biosafety cabinet:** See biological safety cabinet.

**biological challenge:** A series of tests performed to assure that aerosols are contained within the cabinet, that outside contaminants do not enter the cabinet, and contaminants in the cabinet remain localized. Suspensions of *Bacillus subtilis subsp. niger* spores are used as an indicator in the tests.

**biological safety cabinet:** Cabinet intended to protect the user and environment from the hazards of handling infectious material and other biohazardous material. Some types may also protect the materials being handled in them from contamination.

**BSC:** Three-letter abbreviation for biological safety cabinet.

**Brownian motion:** A random movement of microscopic particles suspended in liquids or gases resulting from impact of the molecules of the suspending agent on the particles.

**canopy connection:** A biosafety cabinet exhaust system with a physical gap or space between the cabinet’s exhaust and the exhaust system intake. During operation, the exhaust system draws all of the cabinet’s exhaust air through the duct, plus a small volume of room air through the gap.

**certification:** When pertaining to safety cabinets, measurement and/or correction of a safety cabinet’s air velocities, balance and filtration system integrity by a qualified technician.

**chemical carcinogen:** Those chemicals designated as posing a potential occupational carcinogenic risk to workers by OSHA or the Department of Health and Human Services Committee for Coordinating Toxicology and Related Programs.

**clean room or cleanroom:** An environment, typically found in manufacturing or scientific research, that has low levels of environmental pollutants such as dust, airborne microbes, aerosol particles and chemical vapors.

**collection efficiency:** Usually expressed as the percentage of material collected compared with the total amount present, it may be calculated on a particle number basis or a total weight basis.

**contamination:** Any foreign substance that makes an unwanted incursion. In the present context, usually viable airborne particulates.

**decontamination:** The destruction or removal of living organisms (this does not imply either total destruction or total removal), or the removal or neutralization of toxic agents or chemical carcinogens; to make an object safe for unprotected individuals.

**di- (2 ethyl hexyl) phthalate:** See DOP.

**di-sec-octyl phthalate:** See DOP.

**diffuser:** A device, often a screen, used to distribute airflow evenly.

**diffusion:** A phenomenon of HEPA filtration by which Brownian motion causes particles to diffuse across air stream lines impacting them on a filter fiber.

**dioctyl phthalate:** See DOP.

**disinfectant:** A chemical agent that kills or inactivates vegetative bacteria, fungi, and viruses, but not necessarily spores. This term applies to inanimate surfaces as opposed to tissues.

**DOP:** Dioctylphthalate, an oil that can be aerosolized to an extremely uniform size; i.e. 0.3  $\mu\text{m}$  for a major portion of any sample; the aerosol is used to challenge HEPA filters.

**hot DOP:** Produced by controlled vaporization and condensation of liquid DOP to give a cloud of monodisperse droplets with diameters of approximately 0.3  $\mu\text{m}$ .

**cold DOP:** Produced by compressed air atomization of room temperature liquid DOP, aerosol size 0.3 to 3.0  $\mu\text{m}$  with a mean diameter of 0.7  $\mu\text{m}$ .

**downstream:** In the direction of the flow.

**droplet:** An airborne particle consisting primarily of liquid. While some settle out quickly, many dry to become droplet nuclei and can add significant numbers of microorganisms to the air.

**exhaust:** The withdrawing and expelling of air from the cabinet by means of a blower or fan; that portion of the cabinet air that is discharged after filtration, either to the room or into a ventilation system.

**filter:** A device used for removal of particulates, including microorganisms, from air or other gases. (Also see HEPA filter.)

**filter efficiency:** The efficiency of various filters can be established on the basis of entrapped particles, i.e., collection efficiency; or on the basis of particles passed through the filter, i.e., penetration efficiency.

**germicidal:** Able to destroy bacteria, fungi, viruses and other similar organisms.

**hard-ducting:** Permanently installed airtight ductwork not intended to be disassembled for normal cabinet servicing or testing.

**HEPA filter:** High-efficiency particulate air filter. A disposable extended-pleated dry-type filter with (1) a rigid casing enclosing the full depth of the pleats; (2) a minimum particle removal efficiency of 99.9% for thermally generated monodisperse DOP smoke particles with a diameter of 0.3  $\mu\text{m}$ ; and (3) a maximum pressure drop of 1 inch water gauge when clean and operated at its rated airflow capacity.

**high efficiency particulate air filter:** See HEPA filter.

**horizontal laminar flow bench:** A ventilated cubicle with solid sides having a table-height work surface and unidirectional, minimum turbulence air entering from a vertically mounted high efficiency filter at one side and leaving the cubicle at the opposite (open) side.

**inches of water gauge (in w.g.):** A unit of pressure equal to the weight of a column of liquid water one inch high at 20°C (1 in. w.g.= 0.036 psi).

**infectious agent:** As used in this text, agents capable of producing a disease or abnormal response in man, laboratory animals, or a tissue culture system.

**inflow velocity:** Air velocity at the cabinet’s work opening; velocity of the air entering the cabinet at the work opening.

**laminar airflow:** Airflow in which the entire body of air within a designated space moves with uniform velocity along parallel flow lines.

**monodisperse aerosol:** An aerosol containing particles of nearly the same size.

**negative pressure:** Pressure in a space that causes an inflow of air.

**partial containment enclosure:** An enclosure that is constructed so that contamination between its interior and the surroundings is minimized by the controlled movement of air. Class I and Class II safety cabinets are examples.

**plenum:** An enclosure for flowing gases in which the static pressure at all points is relatively uniform.

**POA:** See poly-alpha-olefin.

**poly-alpha-olefin:** POA, a synthetic oil used as a substitute for DOP in HEPA filter challenge testing.

**positive pressure:** Pressure in a space that causes an outflow of air.

**protection:** In Class II cabinets:

**environmental protection:** Any aerosol generated within the cabinet is removed from the air or deactivated (such as by incineration) before the air from the cabinet is discharged either inside or outside the facility.

**personnel protection:** Any aerosol generated within the cabinet is kept away from the technician doing the work.

**product protection:** The air at the work surface of the cabinet has been filtered so that it is free of airborne particles and organisms that could contaminate the work.

**static pressure:** The pressure of a fluid exerted in all directions equal and opposite to the pressure tending to compress the fluid. In ventilation applications, static pressure is usually the difference between the absolute pressure in an exhaust system and atmospheric pressure.

**sterile:** The absence of all life on or in an object. This is an absolute term; there can be no such description as nearly sterile, partially sterile, etc.

**sterilize:** Any process, physical or chemical, which results in the absence of all life in an object, applied especially to microorganisms, including bacteria, fungi, and their spores and the inactivation of viruses.

**supply air:** Air entering the cabinet through the work opening to make up for the volume of air exhausted.

**thimble connection:** See canopy connection.

**ULPA filter:** Ultra low penetration air filter. A filter that can remove airborne particulates, 0.12 micron in size or larger, at 99.999% efficiency or greater.

**ultra low penetration air filter:** See ULPA filter.

**ultraviolet (UV) light:** Radiation in the electromagnetic spectrum having wavelengths from approximately 200 to 390 nanometers.

**velocity:** The time rate of linear motion in a given direction.

**capture and/or containment velocity:** The velocity necessary to capture or contain a generated contaminant, in a cabinet this usually ranges from 50 to 200 fpm.

**viable:** Literally, capable of life. Generally refers to the ability of microbial cells to grow and multiply as evidenced by formation of colonies on an agar culture medium; or, as with viruses, to divert the host cell's metabolism to replication of the parasite.

**virus:** A parasitic microorganism, smaller than a bacterium. Viruses have no independent metabolic activity, and may replicate only within a cell of a living plant or animal host.

Portions of glossary taken from First, Melvin et al., *Student Manual: Testing of Class II Biological Safety Cabinets*, 1986. Dept. of Environmental Health Science, Harvard School of Public Health, Boston, MA

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American Society of Health-System Pharmacists  
<http://www.ashp.org/bestpractices>

American Society for Microbiology  
<http://www.asm.org>

CDC Office of Health and Safety Information System  
<http://www.cdc.gov/od/ohs>

Controlled Environment Test Association  
<http://www.cetainternational.org>

European Biosafety Association  
<http://www.ebsa.be>

European Society of Human Reproduction and Embryology  
<http://www.eshre.com>

National Institutes of Health  
<http://www.nih.gov>

NSF International  
<http://www.nsf.org>

Occupational Health & Safety Administration  
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