Laboratory Ventilation Codes and Standards

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Notice

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Introduction

This guide covers the codes and standards requirements for ventilation systems serving laboratory facilities. Pertinent factors affecting laboratory ventilation systems are listed in tabular format in the left hand column while applicable regulatory and standard document quotations are identified and listed in the adjoining (middle) column. The right hand column provides commentary that includes explanatory information and, in some instances, suggests a preferred means of fulfilling the requirements.

Laboratory facility planners, ventilation system designers, laboratory users and those responsible for laboratory facility safety should find this information helpful in attaining and ensuring a safe working environment. Every effort has been made by Siemens Industry, Technologies, Inc. to make this guide complete and up-to-date. However, since regulatory agency requirements and safety standards are subject to change, those responsible for ensuring regulatory compliance and workplace safety for a specific facility are advised to determine whether the requirements referenced are current. In addition, state, provincial and local codes may impose additional or different requirements. The reader should, therefore, also determine what additional or specific local requirements apply to their facility[1].

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[1] Local codes as well as state, provincial and federal regulatory agencies may pose additional requirements on the quantities, usage, storage and handling of specific chemicals, biological agents, substances and associated equipment. In addition, local codes often address the disposal and discharge of certain chemicals, waste material, residues and substances into the atmosphere, groundwater and wastewater systems. Those responsible for ensuring compliance with regulatory requirements must determine the regulations that apply to their facility.

Applicable Definitions (Alphabetical Listing)

Term	Definition	Commentary
Air Changes per Hour (ACH)	A unit of measurement that expresses the ventilation rate for a space (room). Each ACH represents a quantity of airflow per hour relative to the overall room volume. For instance, if a room's dimensions are 12 feet wide by 20 feet long by 10 feet in height, its volume would be 2,400 cubic feet. One ACH for that room would then equal a ventilation airflow rate of 2,400 cubic feet per hour. However, since airflow is mostly expressed in terms of cubic feet per minute (cfm), it's necessary to divide cubic feet per hour by 60 (minutes per hour) to find the cfm rate. In this example, 2,400 cubic feet per hour divided by 60 yields an airflow rate of 40 cfm. Therefore to ventilate a room of 2400 cubic feet at the rate of 8 ACH would require an airflow rate of 40 cfm × 8 cfm which equals 320 cfm.	Note that an ACH rate is always based on a room's gross (totally empty) volume. As contents are added to the room (furniture, fume hoods, people, etc.) actual net room air volume becomes less and thus a given ACH rate provides more effective ventilation since it needs to dilute less room air.
Airlock	A room entry/exit arrangement using two doors separated by a small vestibule that is applied when it is necessary to prevent air transfer into or out of a space. The airlock doors are set up with mechanisms that only allow one door to be open at a time. Without these interlocking mechanisms, the area does not have an airlock. It can only be categorized as an ante-room or vestibule or a double entry/exit door. Airlocks are most often applied to clean rooms to prevent the entry of (non-clean) air whenever personnel enter or leave the cleanroom. In addition, the airlock vestibule is typically provided with a high amount of exhaust or clean supply air to prevent unwanted contamination of the cleanroom space. Airlocks are also applied to biological and high toxicity laboratories when it is necessary to ensure against having any air migrate to the area outside the laboratory room.	Airlock arrangements are also utilized in the design of other types of safety equipment such as a glovebox where materials are moved into or out by means of special drawer arrangements that only allow access from one end at a time. This prevents any toxic air from inside of the glovebox from escaping during a transfer of materials.
Anemometer	An instrument to measure airflow velocity, usually at a single point. For ventilation applications the measurement is usually in feet per minute (fpm) or meters per second (m/sec). However, since airflow velocity typically has a wide variation across any given area, it is necessary to take many measurements at different points to obtain an 'average velocity'. The practice of measuring airflow velocities in a carefully defined pattern across an area to obtain the average velocity is referred to as a 'traverse'.	For test purposes, fume hood or biosafety cabinet average face velocity is often measured by performing an airflow measurement traverse in the Face Opening with a "hot wire" or "thermo" anemometer. This type of anemometer can measure very low airflow velocities with excellent accuracy.

Term	Definition	Commentary
ASHRAE 110 Test Standard	This is a very comprehensive series of test procedures that was very painstakingly developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. over many years for the purpose of determining the performance of bench type fume hoods. These tests can be used to quantify a fume hood's performance under three conditions: As Manufactured (AM), As Installed (AI) and As Used (AU). • AM tests are intended to be conducted in a 'test room' at the fume hood manufacturer's facility and will reveal a specific fume hood's performance under tightly controlled room conditions. An AM test would be expected to provide the most favorable results since it is conducted under nearly ideal conditions that would probably not exist in an actual laboratory. AM tests can provide a performance comparison for different models of fume hoods provided they are all tested in the same facility or under exactly the same identical test conditions. • AI tests are intended to be conducted in a newly constructed or renovated laboratory room. The laboratory room must be fully 'setup' and have all furniture, fixtures, fume hoods and permanent test equipment in place. The laboratory should be ready for occupancy and usage (but not yet be occupied or in use.) The laboratory ventilation system must be in full operation with all required testing, balancing and adjustments properly completed. The laboratory room's ventilation control system must also be fully checked out and properly functioning. The fume hoods should have their baffles properly adjusted and not have any contents. An AI test thus includes all influences of the actual laboratory room and the test results will likely reflect the most favorable functionality for a given fume hood in the room. • AU tests are conducted in a laboratory room that is currently in actual use and will thus reflect the influences of all laboratory room conditions and situations. For instance, the laboratory ventilation system performance may have degraded from when an AI test was performed. Fume hood baffles may no longer be in proper adjustment and the chemicals and apparatus in the fume hoods may not be positioned in accord with best safe usage practices. These and other factors that exist in the room can adversely impact fume hood containment. The AU test results may indicate a substantial degradation in fume hood performance and can thus be indicative of the need to correct ventilation system functional deficiencies and improper fume hood usage practices.	The full compliment of ASHRAE 110 tests requires a substantial investment in test apparatus and extensive 'know how' to properly conduct the tests and interpret the results. ASHRAE 110 tests are normally conducted by experienced specialists in fume hood testing and not by the laboratory occupants or fume hood users themselves. The ASHRAE 110 Tests do not have a 'pass or fail' or set of acceptance criteria for the individual test results. Rather they provide specific procedures to obtain functional data that can be used to compare one fume hood to another (as do the AM Tests). Most importantly, they enable periodic examination (as do the AU Tests) to ascertain whether or not acceptable overall performance still exists or if performance has substantially deteriorated to the point where remedial action must be taken. Individual ASHRAE 110 Tests include: • (6.1) Face Velocity Measurements • (6.2) VAV Face Velocity Control Test • (6.3) VAV Response Tests • (7.1) Flow Visualization • (7.2) Airflow Patterns • (7.3) Local Visualization Challenge • (7.4) Large Visualization Challenge • (7.5) Smoke Evaluation • (8.0) Tracer Gas Tests • (8.2) Peripheral Scan • (8.3) Sash Movement Containment Test (See *ASHRAE 110 Tests* for a description of each of these tests.)

Term	Definition	Commentary
ASHRAE 110 Tests • (6.1(6.1) Face Velocity Measurements	An anemometer mounted on a stand is used to measure the air velocity at the mid point of an imaginary grid across the plane of the fume hood's design sash opening, The grid spaces must consist of less than 1.0 square feet (0.9 square meters). The anemometer must read and record 20 measurements at one per second at the mid point of each grid space. An average air velocity is then calculated for each grid mid point. The average face velocity for the fume hood will be the average of all grid point average face velocities The highest and lowest grid space average face velocities are also to be recorded.	Since the air velocity readings are required to be taken and then recorded at a rate of one per second at each grid space an automatic measurement and data logging system is necessary.
• (6.2) VAV Face Velocity Control Test	This test is for VAV fume hoods. *(VAV fume hoods are equipped with a VAV fume hood controller to always maintain a constant face velocity regardless of the size of the Face Opening).* The test consists of measuring the average face velocity at the sash design openings of 25%, 50% and also at the maximum sash design opening.	The average face velocity at each sash opening is to be obtained following the face velocity measurement procedure described in 6.1.
• (6.3) VAV Response Tests	This test is for VAV fume hoods and consists of two parts. *(VAV fume hoods are equipped with a VAV fume hood controller to always maintain a constant face velocity regardless of the size of the Face Opening)*. 1. VAV Speed of Response determines the time in seconds required to first restore the average face velocity to within 90% of its required value from the time a fully closed sash is repositioned (opened) to the sash design opening. The sash is to be moved at a rate of 1.5 feet per second. 2. VAV time to Steady State determines the time in seconds required until the hood maintains the average face velocity within 90% and 110 % of its required value from the time a fully closed sash is repositioned (opened) to the sash design opening. The sash is to be moved at a rate of 1.5 feet per second.	The average face velocity measurements for the VAV Response Tests can be made by directly measuring the air velocity through the fume hood slot (see *Fume Hood Airfoil*) or by measuring the fume hood exhaust air velocity. *(This latter method requires first determining the exhaust air velocity that corresponds to the required average face velocity.)*
• (7.1) Flow Visualization	This test provides a visualization of a fume hood's ability to contain vapors. Smoke is released just outside of the plane of the sash and its flow pattern is observed. Under ideal conditions the smoke will flow into the fume hood and flow toward and through the fume hood's baffle openings at the rear.	The person releasing the smoke at the front of the fume hood must be careful not to make any 'abnormal' movements that would influence the smoke flow pattern.
• (7.2) Airflow Patterns	This is a description of the Flow Visualization smoke flow patterns that might be observed. 'Reverse Flow' is when the smoke reverses direction and flows toward the front of the fume hood. 'Lazy' is used to describe a smoke flow that remains on the work surface without smoothly flowing to the rear baffle openings.	Some minimal amount of reverse flow can normally be expected at the places where there is a pronounced change in the fume hood interior surfaces such as at the work surface recesses.

Term	Definition	Commentary
• (7.3) Local Visualization Challenge	This consists of releasing a modest amount of smoke at several locations with the sash in the 'test' position. • Under the fume hood airfoil • Along both side walls of the fume hood • Along the fume hood's work surface • For an 'As Used' test, smoke is released around the equipment inside of the hood • Above the bottom of the open sash inside the fume hood • At the vertical openings of horizontal and combination sashes • Inside the fume hood cavity above the sash	A small or modest source of smoke (that is, chemical smoke tubes or titanium tetrachloride) can be used for these tests. The 'test 'position would usually be the maximum fume hood sash opening or the sash design opening.
• (7.4) Large Visualization Challenge	This consists of releasing a relatively large volume of smoke at several locations with the sash in the 'test' position. • Under the fume hood airfoil • Along both side walls of the fume hood • Along the fume hood's work surface • For an 'As Used' test, smoke is released around the equipment inside of the hood with all equipment in operation • Above the bottom of the open sash inside the fume hood • At the vertical openings of horizontal and combination sashes • Inside the fume hood cavity above the sash • Outside of the fume hood to determine the effect of room air currents	Generally a theatrical smoke generator is best for generating the large volume of smoke required for these tests.
• (7.5) Smoke Evaluation	This consists of making a notation for the observation for all of the individual procedures above (7.4). If any visible smoke flows out of the fume hood, the hood fails the entire Large Visualization Challenge.	

Term	Definition	Commentary
• (8.1) Tracer Gas Tests (Continued)	This is the most intricate part of the ASHRAE 110 test and uses a precise release of sulfur hexafluoride gas (or a gas of similar molecular weight and stability) inside of the fume hood. The gas is released through a very specifically fabricated ejector unit and the presence of gas molecules in parts per million (ppm) in the breathing zone of a mannequin positioned in front of the fume hood are detected by very sensitive instrumentation. The entire test arrangement including the required instrumentation and apparatus (including instrumentation accuracy and calibration requirements) and the actual test procedures are very intricately detailed in the ASHRAE 110 Standard.	As stated previously, the requirements to perform the full compliment of ASHRAE 110 tests requires a substantial investment in test apparatus and extensive 'know how' to properly conduct the tests. For this reason ASHRAE 110 tests are normally conducted by outside (third party) experienced specialists in fume hood testing and not by the laboratory occupants or fume hood users themselves.
• (8.2) Peripheral Scan	This is a part of the tracer gas test but is performed without the mannequin. The gas detector probe is manually traversed at precise locations around the periphery of the fume hood openings.	This test is intended to detect fume leakage from the fume hood at locations that are not in a user's normal breathing zone.
• (8.3) Sash movement Containment Test	This part of the tracer gas test is intended to determine the potential for fume escape immediately following a sash movement. A very specific procedure is described and the results are referred to as the sash movement effect (sme) and are given in ppm.	Note again that the ASHRAE 110 Test Standard does not provide any pass/fail or acceptance criteria for the tracer gas tests. The ASHRAE 110 tests are not only intended to establish the adequacy of a fume hood at a given point in time, but also to establish a baseline of quantifying a fume hood's performance so that subsequent repeat testing can be done to track continued performance. Actual test pass/fail criteria are intended to be established by the laboratory facility or the designated Chemical Hygiene Officer. However, other outside authorities having jurisdiction (that is, local government agencies or insurance companies, etc.) may institute a set of required criteria based upon certain ASHRAE 110 Tests.

Term	Definition	Commentary
Autoclave	A laboratory facility appliance used to destroy biohazardous waste and sterilize certain apparatus by means of high temperatures. Autoclaves come in various sizes and arrangements and commonly use pressurized steam as the sterilizing agent.	
Barriers – Primary & Secondary	A barrier is a means of protection against contact with potentially harmful chemical or biological agents. Primary barriers commonly include fume hoods, biosafety cabinets and gloveboxes which provide protection by limiting the size of opening(s) to the interior and also maintain a constant inward airflow through the opening(s) to prevent hazardous agents from escaping. (Gloveboxes provide maximum protection by not having any opening to the interior.) Secondary barriers commonly consist of the laboratory room itself. The room ventilation system design which normally must provide a constant inward airflow through any openings (doorways) to prevent potentially contaminated air from flowing out of the room, along with air filtering, room airlocks and even redundant ventilation equipment can be considered part of the secondary barrier.	
Biohazard **Biohazardous**	Biohazard or biohazardous refers to a situation where there is the potential for exposure to or direct contact with a disease causing agent. Such agents include anything that is capable of causing diseases in humans and/or animals and includes viruses, microbes and sub viral agents. Aside from the biohazard agent itself, biohazards include the products of such agents as well as materials that may harbor biohazardous agents. Often these consist of human blood, body fluids, body wastes or tissues that may be or may have been contaminated with biohazardous agents.	The presence of a biohazard cannot always be known beforehand. For instance, it cannot always be known if a tissue sample or other item is or is not infectious. Therefore it must be assumed when working with such items that a biohazard does exist and following appropriate safety measures and proper work procedures must be followed.
Biological Safety Cabinet **Biosafety Cabinet**	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. *(*Also see ***Biological Laboratories,*** *Biological Safety Cabinets and Classifications* in this document.)	

Term	Definition	Commentary
Chemical Hygiene Plan	***U.S. OSHA:*** *"A written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment and work practices that are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace and meets the requirements of paragraph (e) of this section."* **General:** A documented comprehensive plan that establishes policies and detailed procedures for the safe handling of chemicals. All laboratory facilities are required by law to have and to enforce compliance with the plan. All workers must be made aware of the plan and routinely follow it's procedures for their own safety as well as the safety of fellow workers. The plan must not only address the 'normal' handling of chemicals but also the procedures for handling emergency situations including chemical spills and accidental worker exposure. Typically a person referred to as the 'Chemical Hygiene Officer' is responsible for implementation and enforcement of the Chemical Hygiene Plan. Also *see Chemical Hygiene Officer*.	A chemical hygiene plan must address all phases of handling chemicals (receiving, storage, internal transport, safe laboratory usage, and disposal). Laboratory workers (and all facility workers involved in handling chemicals) must be properly trained and made aware of the procedures stipulated by the chemical hygiene plan. The chemical hygiene plan must be readily available for examination by governmental enforcement agencies. In addition to the Chemical Hygiene Plan, laboratories may also need a Radiation Safety Plan and Biological Safety Protocols to address the associated hazards.
Chemical Hygiene Officer	***U.S. OSHA:*** *"An employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan."* **General:** A well qualified person who understands the hazards associated with chemicals and is highly knowledgeable on safe laboratory practices. This person is given responsibility and authority to set safe work practices, policies and chemical handling procedures. This person is normally responsible for administering (and often composing) the Chemical Hygiene Plan. Although the Chemical Hygiene Officer has the responsibility and authority to enforce chemical safety, all of this person's superiors (including the CEO) still have the same responsibility of ensuring worker safety–thus the responsibility for safety cannot delegated away.	U.S. OSHA's 'non-mandatory' Laboratory safety recommendations were largely extracted form *"Prudent Practices" for Handling Hazardous Chemicals in Laboratories"*, which was published in 1981 by the National Research Council and is available from the National Academy Press, 2101 Constitution Ave., NW,. Washington DC 20418.
Cleanroom	A specially constructed tightly enclosed room (space) that is positively pressurized and supplied with a high rate of ventilation air that is purified by high efficiency particulate air (HEPA) filters to ensure a specific level of airborne cleanliness is always maintained. Cleanrooms are classified according to the permissible airborne particulate in a specific volume. The lowest number classification is the most pure or "cleanest" ambient condition.	Clean rooms are most often utilized to ensure purity in the production of pharmaceuticals and in the fabrication of micro-electronic devices.

Term	Definition	Commentary
Flow Tracking (Airflow Tracking)	A method of maintaining a room under either a 'negative' or 'positive' pressure. Laboratory rooms are normally required to be under negative pressure which means that the room is deliberately kept a slight vacuum with respect to the corridor and/or surrounding area. (Also see the definition for *'Pressurization'.)* In this condition, air and contaminants generally migrate into the laboratory from the surrounding spaces, rather than outward. Flow tracking (to maintain negative pressure) consists of carefully controlling the ventilation system so that the fresh air being supplied to the room will always be a certain amount less than the total amount of air exhausted from the room.	Experience has demonstrated that Flow Tracking is the preferred method of maintaining control over room pressure. Other control methods such as those based upon actual sensing of room pressure are normally less stable and require appreciably more time to react to changing conditions.
Fume	Small solid particles formed by the condensation of vapors of solid materials.	
Gas	A formless fluid which tends to occupy the entire space in which it is released.	
Fume Hood	A ventilated enclosure designed to contain and remove fumes, gases, vapors, mists, and particulate matter generated within the hood interior. A fume hood must be integrated with a properly designed laboratory ventilation system that includes a provision for exhausting the fume hood interior and supplying fresh air to the laboratory room to replace the air exhausted from the fume hood. When properly used and safe laboratory work practices are followed, a fume hood enables the user to manipulate chemicals and associated apparatus without being exposed to harmful fumes. There are several different fume hood designs which are intended to meet specific needs. This document describes their inherent characteristics and the requirements which various safety standards impose for safe utilization.	A "fume hood" is intended to provide an <u>enclosure</u> for the safe manipulation of chemicals and gases. This differentiates it from other various types of hoods such as canopy hoods or slot hoods which are primarily intended to remove heat, water vapor, offensive odors, dusts and in general non-hazardous 'fumes'. These exhaust provisions do not provide the same level of protection and are not a substitute for and should not be used in place of a fume hood.
Fume Hood: Airfoil	A horizontal slightly angled, shelf-like protrusion on the front exterior of a fume hood that extends outward a few inches from the fume hood face and is typically just above the level of the fume hood's interior work surface. Its purpose is to create a 'streamlined' airflow over the work surface within the fume hood. It also serves to keep the fume hood user several inches back from the fume hood face opening for added safety. Airfoils usually have a narrow slot along the full width of their underside to ensure that some air always sweeps across the fume hood's work surface even when the sash is fully closed.	Note that the various safety standards quoted in this document often utilize slightly different terminology (such as: chemical hood, chemical fume hood, laboratory chemical hood, laboratory fume hood, fume cupboard, etc.) for what is most commonly referred to as a "fume hood". For consistency the generic term <u>fume hood</u> is always used in this 'Commentary' column.

Term	Definition	Commentary
Fume Hood: Baffle	Interior panel(s) on the rear wall of a fume hood that can be adjusted to direct the air flowing through the fume hood interior for maximum effectiveness.	
Fume Hood: California Hood	A fume hood with multiple or all sides being transparent and often with access to the interior from two or more sides. It is often utilized when large distillation equipment is required and in teaching labs when greater visibility is desired.	The nomenclature "California" is a carryover from the initial versions of this specialized type of fume hood design that were first utilized in California.
Fume Hood: Containment	Keeping hazardous or unhealthy airborne substances such as fumes, gasses, smoke, particulate, etc. from leaving the fume hood interior through the sash opening. Providing containment of harmful airborne chemical substances so they can be removed by the exhaust system is a fume hood's primary function.	
Fume Hood: Face Opening	The fume hood opening at any given time (usually in the front) through which a user can reach in and manipulate the chemicals and associated experimental apparatus.	
Fume Hood: Face Velocity	The velocity or speed of the airflow moving into the fume hood, perpendicular to the face opening, expressed in feet per minute (fpm) or meters per second (m/sec). This airflow serves to prevent the user from being exposed to fumes emanating within the fume hood interior. Since the actual velocity of the air is different throughout the overall face opening, fume hood face velocity is always the average velocity in the plane of the fume hood face opening. The average face velocity must be within certain minimum and maximum limits to provide proper user protection. (Also see the section on *Fume Hoods: Face Velocity.)*	The preferred way of determining fume hood average face velocity is by first calculating the fume hood's face opening area in square feet (or square meters). Next, the total fume hood exhaust airflow in cubic feet per minute (or liters per second) is measured. Lastly, the total fume hood exhaust airflow is divided by the face opening area to determine the average face velocity in feet per minute (or meters per second). For example, if a fume hood had a face opening area of 8 square feet and a total exhaust airflow of 800 cubic feet per minute, the average face velocity would be 800 cubic feet per minute ÷ 8 square feet which equals 100 feet per minute. Note that fume hoods with multiple sashes can have multiple face openings depending upon the individual sash positions. The total face open area then consists of a summation of the individual sash face opening areas.
Fume Hood: Interior	The internal volume within the fume hood's sides, back, top, work surface, sash and the internal exhaust plenum. The interior surfaces are normally lined with material that is both chemically resistant and has a high resistance to combustion (that is, a flame spread rating 25 or less in accordance with ASTM-E84).	
Fume Hood: Low Flow	A fume hood design that provides a means to reduce overall air consumption primarily by utilizing a sash arrangement (See *Fume Hood Sash)* that reduces the maximum attainable face opening. For instance, the same width of fume hood with horizontal sliding sashes will require less total airflow (cfm) to maintain the same face velocity at the maximum attainable face opening than the same width fume hood that has a single vertical rising sash.	

Term	Definition	Commentary
Fume Hood: Low Velocity	A fume hood designed to provide containment at a lower face velocity (typically 60 fpm or less). Low flow fume hoods achieve their performance through various means that include specific airflow/airfoil designs, unique baffle configurations and may also incorporate internal apparatus (that is, fans, etc.) to achieve their stated performance.	
Fume Hood: Response Time	This pertains to fume hoods equipped with variable air volume systems that control the fume hood's exhaust to always maintain the desired face velocity at a constant rate. Response time is generally defined as the time that it takes to restore the face velocity to within 10% of the desired rate after the completion of sash movement. The major standards that cover laboratory ventilation system performance (ASHRAE 110, ANSI/AIHA Z9.5 and NFPA 45, 2011) do not state a required minimum response time. Recognized research on fume hood response *time (An Approach to Determining the Required Response Time for a VAV Fume Hood Control System, ASHRAE Transactions 1990)* states: "The result of this research indicates that tracer gas did not escape the fume hood when control action was taken within 2 to 3 seconds….."	
Fume Hood: Sash	The movable transparent panel(s), that enable access to the fume hood interior. When access to the interior is not required, good safety practice requires the user to keep the sash(es) closed to provide a protective barrier between the interior and fume hood user and the other laboratory room occupants. Fume hood designs may incorporate single or multiple sashes and the sashes may be arranged to move vertically (up and down) or horizontal (sideways). Some fume hood designs (termed combination sash) consist of one or more vertical sashes which also contain horizontal sliding sashes. Sashes are typically comprised of safety glass or other types of highly durable transparent material.	
Fume Hood: Sash Design Opening or Sash Design Position	The maximum allowable sash opening that will ensure that the required face velocity can be maintained. In most instances the sash design opening or sash design position will be the same as the fume hood's maximum possible sash opening. However, if the laboratory ventilation system was not designed (or cannot be relied upon) to maintain the required face velocity at a fume hood's maximum possible sash opening, then a maximum allowable sash opening needs to be imposed for safe usage.	If the fume hood design sash opening or design sash position is less than the maximum possible sash opening, a mechanical stop to limit sash travel should be utilized.
Fume Hood: VAV	A fume hood equipped with a VAV fume hood controller that controls the airflow through the fume hood to maintain a constant average face velocity regardless of the size of the fume hood's Face Opening.	VAV fume hoods normally require that the laboratory room ventilation (that is, room supply air, etc.) is also provided by a VAV system.

Term	Definition	Commentary
Glovebox	A fully enclosed protective enclosure in which a user gains access to the inside by inserting their hands into impervious gloves which are permanently attached to one or more sides of the glovebox. A glovebox is used when chemical or biological substances are too hazardous to be manipulated in a regular fume hood or biological safety cabinet or in certain instances where the substance itself requires an extremely high degree of protection (that is, a highly sterile ambient). Also known as a Class III BSC.	Various models of gloveboxes are available including some for high containment and medium containment applications. Those used mainly for user protection have a dedicated filtered exhaust system to ensure the interior is always under a negative pressure (slight vacuum) to prevent interior air from leaking into the room. Dangerous substances are put into or removed from the interior by special airlock type drawer arrangements and the use of tightly sealed containers that are only open when inside the glovebox. Gloveboxes are also available with air purging systems to facilitate internal purification and a provision to maintain specific internal ambient conditions.
Hazardous Chemical	***U.S. OSHA:*** *"A chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems and agents which damage the lungs, skin, eyes, or mucous membranes."*	
HEPA & ULPA Filters	High Efficiency Particulate Air filter and Ultra Low Penetrating Air filter. Very highly efficient paper air filters. HEPA filters trap at least 99.97% of particles as small as 0.3 microns (0.00001 inches) in diameter at a rated airflow velocity. ULPA filters trap at least 99.999% of particles as small as 0.1 to 0.2 microns (0.000004 to 0.000008 inches) in diameter at a rated airflow velocity. They both have a rigid casing that encloses the full depth of the pleats. When new, HEPA & ULPA filters should have a maximum pressure drop of 1.0 inch w. g. (250 Pa). HEPA filters should conform to all requirements of a Type C filter, while ULPA filters should conform to all requirements of a Type F filter per the Institute of Environmental Sciences and Technology's Filter Standard: IEST-RP-CC001.	HEPA filters provide the cleanest practical airflow for most ventilation system applications and are typically applied to cleanroom supply and exhaust systems. Biosafety cabinets use HEPA filters to provide clean air to protect the contents and to filter the exhaust before it is released into the atmosphere. Although HEPA and ULPA filters will trap virtually all airborne particulate, including bacteria, they will not trap chemical fumes or gasses.
Hood: **Canopy Hood**	A containment unit with an open bottom that is suspended above a process or some equipment that requires (or will benefit from) an overhead exhaust provision. Canopy hoods are the standard type of exhaust hood used for cooking applications to remove heat, steam and grease vapors. In laboratories they are normally utilized to remove excess heat, water vapor and other non-toxic fumes that rise above certain equipment.	
Hood: **Clean Bench or Laminar Flow Hood**	A ventilated enclosure intended to also provide clean filtered air to protect the contents of the hood and exhaust fumes generated internally. Such hoods are used for acid digestion research and for applications where the contents (micro-electronic circuits, etc.) need to be kept free from contamination by unfiltered room air.	
Hood: **Slot Hood**	A narrow vertical hood that is typically set up for horizontal applications such as on the side of a workbench (rather than above) to exhaust non-toxic elements such as particulate, dust and other airborne fumes close to room temperature.	

Term	Definition	Commentary
Hood: **Snorkel or 'Elephant Trunk'**	A small exhaust provision, usually for bench-top work, that can be positioned very close to the source of the fumes for optimum effect. It usually consists of a length of 3 inch to 6 inch diameter flexible metallic duct and provides essentially the same functionality as a slot hood.	
Laboratory	**National Fire Protection Association, Standard NFPA 45, 2011, 3.3.32:** "A facility where the containers used for reactions, transfers, and other handling of chemicals are designed to be easily and safely manipulated by one person. A laboratory is a workplace where chemicals are used or synthesized on a nonproduction basis." **U.S. OSHA:** "A facility where the "laboratory use of hazardous chemicals" occurs. It is a workplace where relatively small quantities of hazardous chemicals are used on a non-production basis."	A "true" laboratory conducts research and testing associated with product development or other analytical functions, is not a routine part of an ongoing manufacturing process. The most common laboratory work is associated with chemical or biological agents. However, many other kinds of laboratories are involved with physics, electronics, lasers, radiology, etc.
Laboratory Module	A laboratory module is a basic unit of space that is initially optimized to accommodate the smallest anticipated size of laboratory room. It is generally used for architectural planning (window and door arrangement, column placement, stairway and elevator location, etc.) as well as the mechanical and utility system arrangements (plumbing risers, electrical distribution, ventilation components, etc.) to facilitate later reconfiguration of the research facility into larger (or smaller) laboratory rooms by combining or dividing laboratory modules. Utilizing this modular design concept when planning a new research facility makes it much easier to make changes to meet future needs.	A typical two person laboratory module usually approximates 200 to 360 square feet in size (that is, 10 or 12 feet wide and 20 to 30 feet deep). If desired, the wall between two single sized lab modules may be removed to make the resulting room two (or more) times larger than a single module size room. Alterations to modules should not require significant changes to the facility mechanical system layout.
Laboratory Scale	***U.S. OSHA:*** *"Work with substances in which the containers used for reactions, transfers, and other handling of substances are designed to be easily and safety manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials."*	
Laboratory Unit	**National Fire Protection Association, Standard NFPA 45, 2011, 3.3.36:** "An enclosed space used for experiments or tests. A laboratory unit can include offices, lavatories, and other incidental contiguous rooms maintained for or used by laboratory personnel, and corridors within the unit. It can contain one or more separate laboratory work areas. It can be an entire building."	The terms 'Laboratory Unit' and 'Laboratory Work Area' are utilized by the NFPA to establish hazard classifications for these areas based upon the quantities of flammable liquids present. The hazard classifications then stipulate the fire protection systems, fire resistive construction and exit arrangements required. These terms do not directly impact laboratory ventilation systems. For specific details, see *NFPA 45, 2011, Chapters 4 through 7*.
Laboratory Work Area	**National Fire Protection Association, Standard NFPA 45, 2011 3.3.38:** "A room or space for testing, analysis, research, instruction, or similar activities that involve the use of chemicals."	

Term	Definition	Commentary
Microenvironment **Macroenvironment**	These terms are mainly associated with animal housing facilities. A microenvironment usually refers to small ventilated cages (shoe box size) for small animals – mostly mice. The macroenvironment typically refers to the overall room which contains the individual ventilated cages. The microenvironment (temperature, humidity, ventilation rate, etc.) can be quite different from the room macroenvironment.	
Space Pressurization:	A ventilation technology that controls movement of air between spaces by adjustment of the mechanically driven air flows to and from the spaces. Pressurization is used to oppose migration of air contaminants between spaces and for air conditioning purposes related to the differing temperature and humidity in the various spaces. In laboratory design, controlling contaminants is the main purpose.	*Note: For additional information on space pressurization and detailed explanations of pressurization concepts, controls and related parameters refer to the Room Pressurization Control Application Guide* (125-2191).
Stack Velocity	The speed of the exhaust air while still inside of an exhaust stack. The term 'stack velocity' should not be used interchangeably with 'stack exit velocity' (see definition below). Stack velocity should normally be limited to no more than 2400 fpm (12.2 m/sec) which enables droplets of condensing exhaust vapors to trickle down the inside of the stack and be channeled to a drain near the base of the stack. This will prevent condensation droplets (which may be highly corrosive) from being entrained in the exhaust air that is discharged from the stack.	Do not confuse Stack Velocity with Stack Exit Velocity. Stack Velocity is the exhaust air speed while it is still inside of the exhaust stack. Stack Exit Velocity is the exhaust air speed at the point where the exhaust air has just left the stack. A significantly higher Stack Exit Velocity is desirable in order to propel the exhaust air as high as possible into the outside air for better dispersion.
Stack Exit Velocity	The speed at which the exhaust air leaves the stack. Stack exit velocity should be at least 3000 fpm (15.3 m/sec) to ensure the exhaust air is dispersed sufficiently high into the outdoor air to prevent re-entrainment into fresh air intakes nor pose a hazard to nearby buildings. A higher stack exit velocity (than the 'stack velocity' inside the stack) is normally attained by adding a conical shaped top onto the stack.	
Threshold Limit Value (TLV®)	The values for airborne toxic materials which are to be use as guides in the control of health hazards and represent time-weighted concentrations to which nearly all workers may be exposed 8 hours per day over extended periods of time without adverse effects. Threshold Limit Values for toxic substances that have been established by the American Conference of Governmental Industrial Hygienists (ACGIH). TLV-TWA (Time Weighted Average) values are the maximum allowable average exposure values for an 8 hour workday and a 40 hour work week. TLV-STEL (Short Term Exposure Limit) values are typically higher but are for a total of 15 minutes per day and no further worker exposure to the substance at any level for the remainder of the day. TLV-C (Ceiling) is the absolute concentration level that should never be exceeded.	American Conference of Governmental Industrial Hygienists (ACGIH) defined this term and registered it.

Term	Definition	Commentary
Time Weighted Average (TWA)	The concentration value of an airborne toxic substance obtained by averaging the concentration level over a specified period of time.	
Ventilation System: CAV and VAV	These are common abbreviations for a Constant Air Volume (CAV) and a Variable Air Volume (VAV) ventilation system respectively. A CAV system is a fan driven ventilation system that essentially keeps its airflow at a constant rate and has no provision to enable varying the airflow rate. It is the most common type of ventilation system and the least complex to control. A VAV system is a fan driven ventilation system that can vary the overall airflow rate (normally by automatic controls) to meet the actual airflow needs of the rooms or spaces served. It is a less common type of ventilation system and somewhat more complex to control. Both types of systems generally consist of a supply side that provides conditioned (heated, cooled, humidified or de-humidified) air and an exhaust side to remove contaminated air. Both types of systems can be designed for utilization as a laboratory ventilation system.	CAV ventilation systems are usually less complex than VAV systems. However, CAV systems normally consume more energy because a CAV system has no provision for reducing airflow to meet reduced ventilation requirements that typically occur during milder weather. VAV systems can significantly reduce energy consumption since they can provide only the amount of conditioned airflow needed to meet ventilation requirements during periods of decreased demand.
Ventilation System: Two State Control or Two State CAV	A two state ventilation system is a CAV system designed to provide two separate levels of ventilation airflow rather than the one level of an ordinary CAV system. The two levels typically consist of a higher level of ventilation airflow that is normally used during regular occupancy periods when research activities in laboratory rooms and the active use of fume hoods would normally benefit from a higher level of ventilation airflow (Air Changes per Hour – ACH). The lower level is normally applied when a laboratory room is unoccupied and therefore a lesser amount of ventilation air is usually sufficient. Two state CAV systems are utilized for energy efficiency since less ventilation airflow also requires less heating or cooling. (Also see ***Ventilation Systems:*** *Ventilation Rates for Chemical Laboratories and* ***Fume Hoods:*** *Minimum Exhaust.*)	To use Two-state CAV systems, all CAV fume hoods in a laboratory room must have their sashes closed when the room is unoccupied so both the room supply airflow and the fume hood exhaust airflow can be reduced. The CAV system controller must receive confirmation that all fume hood sashes are closed (usually by sash position switches) before the unoccupied ventilation mode can be initiated. Laboratory personnel must be sure to close all sashes at the end of the occupied period. Laboratory rooms that have long unoccupancy periods (such as academic teaching labs) will receive the greatest benefit from a Two-state CAV System.

Laboratory Safety

Term	Definition	Commentary
Hazard Assessment	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances, 1910.1450, A:** 1. It is prudent to minimize all chemical exposures. Because few laboratory chemicals are without hazards, general precautions for handling all laboratory chemicals should be adopted, rather than specific guidelines for particular chemicals. Skin contact with chemicals should always be avoided as the cardinal rule. 2. Avoid underestimation of risk. Even for substances of no known significant hazard, exposure should be minimized; for work with substances which present special hazards, special precautions should be taken. One should assume that any mixture will be more toxic than its most toxic component and that all substances of unknown toxicity are toxic. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.2** **Hazard Assessment:** Before the laboratory is designed, the owner's designated safety officers should perform a comprehensive hazard assessment which must be completed before the laboratory can be designed. These safety officers include, but are not limited to, the chemical hygiene officer, radiation safety officer, biological safety officer, and fire and loss prevention official. The hazard assessment should be incorporated into the chemical hygiene plan, radiation safety plan, and biological safety protocols.	
Chemical Hygiene Plan	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances, Standard 1910.1450 (e)** When hazardous chemicals as defined by this standard are used in the workplace, the employer shall develop and carry out the provisions of a written Chemical Hygiene Plan which is: • Capable of protecting employees from health hazards associated with hazardous chemicals in that laboratory and • Capable of keeping exposures below the limits specified. The employer shall review and evaluate the effectiveness of the Chemical Hygiene Plan at least annually and update it as necessary. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **AIHA 2.1.** Management shall establish a Laboratory Ventilation Management Plan to ensure proper selection, operation, use, and maintenance of laboratory ventilation equipment. (Continued on Next Page)	By law, employers are required to actively manage safety in the laboratories. Not only do they need to write a plan, they must carry it out and verify that it's working. This is a continuing responsibility. The organization's responsibility does not end with design or procurement. It extends throughout day-to-day usage and maintenance.

Term	Definition	Commentary
Chemical Hygiene Plan (Continued)	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003 AIHA 2.2.** The laboratory shall develop a Chemical Hygiene Plan according to the OSHA Laboratory Standard. **American National Standard for Occupational Health and Safety Management Systems , ANSI/AIHA Z10–2005** 6.1 Monitoring, Measurement, and Assessment. The organization shall establish and implement processes to monitor and evaluate hazards, risks, and their controls to assess OHSMS performance. **U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450, Appendix A - A4:** Institute a chemical hygiene program. A mandatory chemical hygiene program designed to minimize exposures is needed; it should be a regular, continuing effort, not merely a standby or short-term activity. Its recommendations should be followed in academic teaching laboratories as well as by full-time laboratory workers.	AIHA says a Chemical Hygiene Plan is necessary even where OSHA regulations don't apply. After developing, and implementing an Occupational Health and Safety Management System, it is necessary to verify that the system is effective and stays effective. Appendix A in the U.S. OSHA regulation contains a suggested example.
Chemical Hygiene Responsibilities	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Title: Toxic and Hazardous Substances,1910.1450, Appendix A - B:** Responsibility for chemical hygiene rests at all levels including the: 1. Chief executive officer, who has ultimate responsibility for chemical hygiene within the institution and must, with other administrators, provide continuing support for institutional chemical hygiene. 2. Supervisor of the department or other administrative unit, who is responsible for chemical hygiene in that unit. 3. Chemical hygiene officer(s), whose appointment is essential and who must: (a) Work with administrators and other employees to develop and implement appropriate chemical hygiene policies and practices; (b) Monitor procurement, use, and disposal of chemicals used in the lab; (c) See that appropriate audits are maintained; (d) Help project directors develop precautions and adequate facilities; (e) Know the current legal requirements concerning regulated substances and; (f) Seek ways to improve the chemical hygiene program. (Continued on Next Page)	Note that aside from the Chemical Hygiene Officer, OSHA mandates that all persons in the laboratory facility have a responsibility to ensure worker safety. This includes the CEO, as well as other administrators, supervisors and even the individual workers themselves.

Term	Definition	Commentary
Chemical Hygiene Responsibilities (Continued)	4. Laboratory supervisor, who has overall responsibility for chemical hygiene in the laboratory including responsibility to: (a) Ensure that workers know and follow the chemical hygiene rules, that protective equipment is available and in working order, and that appropriate training has been provided; (b) Provide regular, formal chemical hygiene and housekeeping inspections including routine inspections of emergency equipment ; (c) Know the current legal requirements concerning regulated substances; c) Know the current legal requirements concerning regulated substances; (d) Determine the required levels of protective apparel and equipment; and (e) Ensure that facilities and training for use of any material being ordered are adequate. 5. Project director or director of other specific operation, who has primary responsibility for chemical hygiene procedures for that operation. 6. Laboratory worker, who is responsible for: (a) Planning and conducting each operation in accordance with the institutional chemical hygiene procedures (7, 21, 22, 230); and (b) Developing good personal chemical hygiene habits (22). Records (a) Accident records should be written and retained (b) Chemical Hygiene Plan records should document that the facilities and precautions were compatible with current knowledge and regulations. (c) Inventory and usage records for high-risk substances should be kept. (d) Medical records should be retained by the institution in accordance with the requirements of state and federal regulations.	To ensure that workers follow the rules, the supervisor needs to actively monitor the operation.
	American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003 American Industrial Hygiene Association, AIHA 2.3 In each operation using laboratory ventilation systems, the user shall designate a “responsible person.”	Someone must be assigned to make sure that the laboratory operates according to the plan.

Fume Hoods

Topic	Requirement(s)	Commentary
When Required & Safe Usage	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,A3,C4(b),E1(n)(q),E3(f):** Provide adequate ventilation. The best way to prevent exposure to airborne substances is to prevent their escape into the working atmosphere by use of hoods and other ventilation devices. A laboratory hood with 2.5 linear feet of hood space per person should be provided for every 2 workers if they spend most of their time working with chemicals. Use the hood for operations which might result in release of toxic chemical vapors or dust. (n) As a rule of thumb, use a hood or other local ventilation device when working with any appreciably volatile substance with a TLV of less than 50 ppm. Confirm adequate hood performance before use; keep hood closed at all times except when adjustments within the hood are being made; keep materials stored in hoods to a minimum and do not allow them to block vents or air flow. Leave the hood "on" when it is not in active use if toxic substances are stored in it or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is "off". **American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **2.1.1** Adequate laboratory chemical hoods, special purpose hoods, or other engineering controls shall be used when there is a possibility of employee overexposure to air contaminants generated by a laboratory activity. **3.1.1** Sash-limiting devices (stop s) shall not be removed if the design opening is less than full opening. **3.1.1.1** Vertical sashes shall be designed and operated so as not to be opened more than the design opening when hazardous materials are being used within the hood. When the design sash opening is less than the maximum sash opening area the hood shall be equipped with a mechanical sash stop and alarm to indicate openings in excess of the design sash opening area. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
When Required & Safe Usage (Continued)	**Scientific Equipment & Furniture Association** **SEFA 1-2006 Recommended Practices for Laboratory Fume Hoods** **6.1** The employer is responsible for ensuring that the hood meets satisfactory safety standards. A hood operator is responsible for ensuring that the hood is used in a safe manner and according to your organization's safety guidelines. A hood operator is also responsible for helping their organization maintain proper operation of the hood systems. The following guidelines are provided to help reduce your potential for exposure when working with hazardous materials. • Plan for conducting experiments. • Wear appropriate personal protection. • Verify proper system operation. • Utilize proper work practices. **6.5.2 Desired Operator Position and Movements** The hood user should always be aware of locations within the hood where concentrations of contaminants can accumulate. The user should never allow his head to break the plane of the sash because this will cause contaminated air to pass through the breathing zone. When materials are being generated in the hood, ensure that you slowly approach and withdraw from the hood. The wake zone created by movement near the hood opening can withdraw materials from within the hood. Rapid arm and body movements near the hood opening should be avoided. **6.5.3 Proper Configuration of Vertical and Horizontal Sliding Sashes** The vertical rising sash should always be lowered as much as possible to protect the user and to minimize visual obstruction from sash handle. Raise the sash to full open position for set-up purposes only. Reducing the sash to below the user's breathing zone provides a protective barrier between the researcher and the experiment. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
When Required & Safe Usage (Continued)	**American Conference of Governmental Industrial Hygienists (ACGIH) INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition VS-35-04 (WORK PRACTICES FOR LABORATORY HOODS)** 1. Conduct all operations that may generate air contaminants at or above the appropriate TLV® inside a hood.[2] 2. Keep all apparatus at least 6 inches back from the face of the hood. A stripe on the bench surface is a good reminder. 3. Do not put your head in the hood when contaminants are being generated. 4. Do not use the hood as a waste disposal mechanism except for very small quantities of volatile material. 5. Do not store chemicals or apparatus in the hood. Store hazardous chemicals in an approved safety cabinet. 6. Keep the hood sash closed as much as possible. 7. Keep the slots in the hood baffle free of obstruction by apparatus or containers. 8. Minimize foot traffic past the face of the hood 9. Keep laboratory doors closed. 10. Do not remove hood sash or panels except when necessary for apparatus set-up; replace sash or panels before operating. 11. Do not place electrical receptacles or other spark sources inside the hood when flammable liquids or gasses are present. No permanent electrical receptacles are permitted in the hood. 12. Use an appropriate barricade if there is a chance of an explosion or eruption. 13. Provide adequate maintenance for the hood exhaust system and the building supply system. Use static pressure gauge on the hood throat, across any filters in the exhaust system, or other appropriate indicators to ensure flow is appropriate. 14. If hood sash is supposed to be partially closed for the operation, the hood should so be labeled and the appropriate closure point clearly indicated.	
Gloveboxes:	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,E1,E4(k),B4(b):** Inspect gloves and test glove boxes before use. For a negative pressure glove box, ventilation rate must be at least 2 volume changes/hour and pressure at least 0.5 inches of water. For a positive pressure glove box, thoroughly check for leaks before each use. In either case, trap the exit gases or filter them through a HEPA filter and then release them into the hood. Exhaust air from glove boxes and isolation rooms should be passed through scrubbers or other treatment before release into the regular exhaust system.	

[2] Threshold Limit Value. TLVs have been established by the ACGIH. They are intended as a guide to the allowable time-weighted concentration level of airborne toxic materials that will not cause adverse health effects for the majority of workers who are exposed for 8 hour per day over extended periods. (See APPENDIX A of the American Conference of Governmental Industrial Hygienists (ACGIH) INDUSTRIAL VENTILATION, A Manual of Recommended Practice, 27th Edition) for more information on TLVs and TLV values.

Topic	Requirement(s)	Commentary
Face Velocity	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(g):** General air flow should not be turbulent and should be relatively uniform throughout the laboratory, with no high velocity or static areas; airflow into and within the hood should not be excessively turbulent; hood face velocity should be adequate (typically 60-100 lfm). *["lfm" stands for linear feet per minute or simply 'feet per minute'.]* **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** (c) Ventilation Rates. Laboratory-type hood face velocities shall be sufficient to maintain an inward flow of air at all openings into the hood under operating conditions. The hood shall provide confinement of the possible hazards and protection of the employees for the work which is performed. The exhaust system shall provide an average face velocity of at least 100 linear feet per minute with a minimum of 70 lfm at any point, except where more stringent special requirements are prescribed in other sections of the General Industry Safety Orders, such as Section 5209. The minimum velocity requirement excludes those measurements made within 1 inch of the perimeter of the work opening The face velocity required by subsection (c) should be obtainable with the movable sashes fully opened. Where the required velocity can only be obtained by partly closing the sash, the sash and/or jamb shall be marked to show the maximum opening at which the hood face velocity will meet the requirements of subsection (c). Any hood failing to meet requirements of subsection (c) and this paragraph shall be considered deficient in airflow and shall be posted with placards, plainly visible, which prohibit use of hazardous substances within the hood **National Fire Protection Association, Standard NFPA 45, 2011** **8.4.6** Chemical fume hood face velocities and exhaust volumes shall be sufficient to contain contaminants generated within the hood and exhaust them outside of the laboratory building. **8.4.7** The hood shall provide containment of the possible hazards and protection for personnel at all times when chemicals are present in the hood. **A.8.4.7** Laboratory fume hood containment can be evaluated using the procedures contained in ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*. Face velocities of 0.4 m/sec to 0.6 m/sec (80 ft/min to 120 ft/ min) generally provide containment if the hood location requirements and laboratory ventilation criteria of this standard are met. (Continued on Next Page)	Face velocity is defined as the average velocity of the air entering a hood perpendicular to the face opening in the plane of the sash opening. A measurement of the average face velocity requires that either an airflow measurement traverse be made in the Fume Hood Face Opening or the total exhaust airflow must be measured and then divided by the face opening area. These face velocity requirements apply to all types of fume hoods regardless of physical arrangement (that is, bench top, walk-in, etc.) or application of the hood (general chemistry, perchloric acid, radioisotope, etc.). In addition to face velocity, room design, room air cross currents (cross drafts), personnel movement, and safe user practice all have a major impact on a hood's ability to provide effective fume containment. Even though a fume hood may have a face velocity at or slightly above the recommended level, it may not provide adequate containment due to the impact of one or more of the foregoing factors. (Also these the next section, *Room Air Cross Currents*.)

Topic	Requirement(s)	Commentary
Face Velocity (Continued)	In addition to maintaining proper fume hood face velocity, fume hoods that reduce the exhaust volume as the sash opening is reduced should maintain a minimum exhaust volume to ensure that contaminants are diluted and exhausted from a hood. The chemical fume hood exhaust airflow should not be reduced to less than the flow rate recommended in ANSI/AIHA Z9.5. **A.8.9.1** A person walking past the hood can create sufficient turbulence to disrupt a face velocity of 0.5 m/sec (100 ft/min). In addition, open windows or air impingement from an air diffuser can completely negate or dramatically reduce the face velocity and can also affect negative differential air pressure. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.4.1** Face velocity shall be adequate to provide containment. Face velocity is not a measure of safety. The most widely accepted range of average face velocities is 60 FPM to 100 FPM. The measured deviation across the face may vary + 20 FPM. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **3.7.1** If the enclosure is not complete and an operator must be located at an opening, such as in front of a laboratory hood, the maximum control velocity should not exceed 125 fpm. Air velocities higher than this value will create eddies in front of the operator which may pull contaminants from the hood into the operator's breathing zone. **3.7.2** For low activity radioactive laboratory work, a laboratory fume hood may be acceptable. For such hoods, an average face velocity of 80 t0 100 fpm is recommended. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **3.3.1** The average face velocity of the hood shall provide sufficient capture and containment of hazardous chemicals generated under as-used conditions.	Fume hood face velocity is often cited by safety professionals as not (of itself) indicative of safe fume hood containment. However, once the average face velocity needed for proper containment for a particular fume hood has been determined and verified by recognized test methods (notably the ASHRAE 110 containment test), that fume hood's average face velocity can be used as a 'benchmark' for safe performance as long as other room factors (that is, air cross currents, etc.) remain essentially unchanged. Therefore continued measurement and monitoring of a fume hood's average face velocity is a key factor in assuring continued safe performance. An average face velocity above 100 fpm can create 'eddies' and air turbulence around the person in front of the fume hood causing contaminants to be pulled out of the fume hood interior. Thus, trying to attain an average face velocity appreciably more than 100 fpm may not improve a fume hood's containment, and may also worsen the situation. *Fume hoods were previously classified by ANSI/AIHA Z9.5 in 1992 as Class A and B according to face velocity, but are no longer so classified by the AIHA.* *Fume hoods were also previously classified by SEFA in 1992 as Class A, B, and C according to face velocity. The SEFA organization no longer classifies fume hoods in this way.*

Topic	Requirement(s)	Commentary
Face Velocity Setback	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** (2) When a laboratory-type hood is in use to contain airborne hazardous substances and no employee is in the immediate area of the hood opening, the ventilation rate may be reduced from the minimum average face velocity of at least 100 feet per minute to a minimum average face velocity of 60 feet per minute if the following conditions are met: (A) The reduction in face velocity is controlled by an automatic system which does not require manual intervention. The automatic system shall increase the airflow to the flow required by (c)(1) when the hood is accessed (B) The laboratory-type hood has been tested at the reduced flow rate according to the tracer gas method specified in Section 7, Tracer Gas Test Procedure, of ANSI/ASHRAE 110-1995, Method of Testing Performance of Laboratory Fume Hoods, which is hereby incorporated by reference, and has a hood performance rating of 4.0 AU 0.1 or less. The test may be performed with or without the mannequin described in the ANSI/ASHRAE 110-1995 tracer gas method. The tracer gas test need only be performed once per hood. However, if employers have chosen to perform the tracer gas test on subsequent occasions, it is the most recent record of test results and test configuration that shall be maintained pursuant to subsection (c)(2)(C). (C) The record of the most recent tracer gas test results and the "as used" test configuration shall be maintained as long as the automatic system is operable and thereafter for five years. (d) Operation. Mechanical ventilation shall remain in operation at all times when hoods are in use and for a sufficient time thereafter to clear hoods of airborne hazardous substances. When mechanical ventilation is not in operation, hazardous substances in the hood shall be covered or capped off.	A face velocity setback (automatically reducing the exhaust flow of an unattended fume hood (when the sash is left open) is sometimes promoted as a means to reduce fume hood air consumption and thus reduce energy usage. Be certain that local code requirements do not prevent reducing the face velocity under these conditions. • This attempt to save energy only pays off if lab workers neglect to close the sashes. Selecting such a system constitutes sanctioning unsafe practices. • A fume hood must provide containment whether or not a user is present. If the face velocity is reduced, the fume hood becomes more susceptible to room cross currents and other factors that adversely affect a fume hood's ability to maintain safe containment. (See ***Fume Hoods:*** *Room Cross Currents*.) • The face velocity setback provision may be perceived by fume hood users that they can leave sashes open and that this unsafe practice is okay. This undermines the chemical hygiene plan. • A sash left open presents is an unnecessary hazard to all persons in the room since it does not provide a physical barrier from potentially dangerous conditions that might develop in the unattended fume hood. For example, high volumes of toxic fumes can be suddenly given off from unexpected chemical reactions or an explosion within the hood can propel objects such as glass fragments out from the hood interior. *Safer alternatives to face velocity setback include sounds that alert room occupants of a sash left open (chirps, beeps or tones) and automatic sash closure devices.*

Topic	Requirement(s)	Commentary
Size & ADA Compliance	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(b):** A laboratory hood with 2.5 linear feet of hood space per person should be provided for every 2 workers if they spend most of their time working with chemicals. **U.S. ADA, 28 CFR Part 36** New facilities constructed and occupied after January 26, 1993 must be constructed to make them "readily accessible" to and usable by persons with disabilities. Any existing facility that undergoes major alterations or renovations after January 26, 1992 must be "readily accessible"...unless the cost of compliance is disproportionate to the overall cost of the alterations.	Fume hoods must accommodate laboratory workers with physical impairments. This includes allowing variations in workbench height, wheel chair accessibility, and easier access to hood controls (electrical switches, valves, sash, safety devices, etc.).
CAV (Constant Air Volume) Bypass	**American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **3.2.1** Bypass hoods are laboratory hoods with either vertical or horizontal moving sashes that shall meet the requirements of 3.3. *(3.3 requires adequate face velocity, periodic face velocity measurement and an airflow measuring device on the hood.)* The face velocity of the hood opening should not exceed three times the nominal face velocity with the sash fully open.	Specifically, a 'bypass' type fume hood is designed to limit the variation in fume hood face velocity that would occur as the sash opening varies. This is done by incorporating a 'bypass' or air diversion opening that is fully uncovered when the sash is fully closed but is progressively covered as the sash is moved from closed to fully open. The bypass opening is normally located in the upper portion of the hood and covered with a grille or louvers. Bypass type fume hoods are typically utilized when there is no other provision to automatically control fume hood face velocity. Also refer to *Fume Hoods: VAV (Variable Air Volume).*
CAV (Constant Air Volume) Conventional	**American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **3.2.2** Conventional hoods shall meet the requirements in Section 3.3. *(3.3 requires adequate face velocity, periodic face velocity measurement and an airflow measuring device on the hood.)* The hood exhaust volume shall remain unchanged with the sash in full open or in the design open position. As the sash is lowered, the face velocity will increase. In the fully closed position, airflow would be through the airfoil only. **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** When flammable gases or liquids are used, or when combustible liquids are heated above their flashpoints, hoods shall be designed, constructed, and installed so that hood openings at all sash positions provide sufficient airflow to prevent ignitable concentrations.	A 'conventional' fume hood is the most basic design and has no provision to maintain a constant face velocity or even to limit the variation in face velocity that occurs as the sash opening changes. Conventional fume hoods have limited application since the face velocity variations do not conform to current safety requirements. See *Fume Hood: Face Velocity* on the pages that follow.

Topic	Requirement(s)	Commentary
VAV (Variable Air Volume)	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **3.2.6** A variable air volume hood is a laboratory hood that shall meet the requirements in 3.2.1 and 3.3 and is designed so the exhaust volume is varied in proportion to the opening of the hood face. *(3.2.1 requires hood construction be adequate and 3.3 requires adequate face velocity, periodic face velocity measurement and an airflow measuring device on the hood.)* The *(laboratory)* supply and exhaust systems shall be balanced. If the laboratory uses variable air volume, the supply and exhaust shall modulate together to maintain this balance In addition, modification of the hood exhaust shall not compromise the total laboratory exhaust. Any modification of the hood exhaust shall not compromise other fundamental concerns. **6.5.3.3** The VAV hood controls shall provide stable control of flow in the exhaust and supply ducts and variation of flow must not exceed 10% from design at each sash configuration or operating mode.	VAV fume hoods are termed 'restricted bypass' hoods by certain manufacturers since the bypass area is only required to allow the required minimum airflow through the fume hood when the sash is completely closed. VAV fume hoods require automatic exhaust air controls that adjust the hood exhaust in conjunction with the VAV fume hood's sash position and the exhaust system's static pressure. These controls must also be integrated with the overall laboratory room ventilation control system to maintain the 'balance' referred to in the AIHA/Z9.5 **3.2.6** text. VAV type fume hoods offer the following advantages over non-VAV fume hoods: • Positive face velocity control. • Less laboratory room supply makeup air is required when VAV hood sashes are not fully open thus yielding an energy savings. • Less fume hood exhaust and a correspondingly less room supply makeup airflow often reduce the room sound level. • Less overall ventilation air requirements in the building can reduce the size of HVAC system components including the boilers, chillers, fans, ducts, etc. which yields a lower installed system cost. (Also see *Diversity* on the pages that follow.)

Topic	Requirement(s)	Commentary
VAV Diversity	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.1.2** The following issues shall be evaluated in order to design for diversity: • Use patterns of hoods • Type, size and operating times of the facility • Quantity of hoods and researchers • Sash management (sash habits of users) • Requirements to maintain a minimum exhaust volume for each hood on the system. • Type of ventilation system • Type of laboratory chemical hood controls • Minimum and maximum ventilation rates for each laboratory • Capacity of any existing equipment • Expansion considerations • Thermal loads • Maintenance department's ability to perform periodic maintenance The following conditions shall be met in order to design a system diversity: • Acceptance of hood-use restrictions by the user groups. Designers must take into account the common work practices of the site users. • A training plan must be in place for all laboratory users to make them aware of any limitations imposed on their freedom to use the hoods at any time • An airflow alarm system must be installed to warn users when the system is operating beyond capabilities allowed by diversity. • Restrictions on future expansions of flexibility must be identified. **6.5.3.4** System diversity shall be verified prior to use of laboratory chemical hoods. The tests shall be designed to verify that users will be alerted when system capacity is exceeded and unsafe conditions may exist.	If a VAV ventilation system is designed to satisfy the likely maximum ventilation needs rather than the theoretical absolute maximum, the size of the HVAC system (that is, boilers, chillers, fans, ducts, etc.) can be reduced to yield a lower installed cost and less energy consumption. This 'downsizing' of the mechanical systems is based on the fact that actual ventilation needs of the facility will be less than the theoretical absolute maximum (100%) during the vast majority of the time. The 'theoretical absolute maximum' of 100% would only occur only if every fume hood sash was fully open on the hottest or coldest day and the HVAC systems had to meet this high demand condition. This might never occur or only very rarely. A laboratory VAV system could thus be fully satisfactory even though its capacity is less than the 100% value. Using an HVAC design capacity less than the 100% but still likely to meet the actual requirement is termed applying a 'diversity factor'. Experienced design professionals generally feel that a diversity factor of 60% to 70% is acceptable for this purpose. Note however that it cannot be guaranteed that a VAV system design based on diversity will not at some time be unable to meet actual demand. Therefore an acknowledgement and agreement of this possibility by the laboratory staff is necessary before a designer incorporates a diversity factor in the VAV system design.

Topic	Requirement(s)	Commentary
Automatic Sash Closure	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **3.1.1.4** The following conditions shall be met before using automatic sash closing devices: users must be made aware of any limitations imposed on their ability to use the hood; • Automatic sash positioning systems shall have obstruction sensing capable of stopping travel during sash closing operations without breaking glassware, etc. • Automatic sash positioning shall allow manual override of positioning with forces of no more than 10 lbs (45 N) mechanical both when powered and during fault modes during power failures.	Implementing sash closure devices should be done with consideration of the following: • Energy savings will not occur if automatic sash closures are applied to non-VAV fume hoods. Except for VAV fume hoods, hood air consumption is not reduced when sashes are closed on CAV fume hoods since CAV hoods cannot vary overall airflow based on sash position. • Safe user practice and discipline requires call for closing the sashes whenever possible. Automatic sash closures tend to negate this aspect of safety consciousness and the time delay before automatic sash closures operate may be reduce the overall time that the sashes are actually closed. • Alternate means to encourage and attain sash closure by the users include having 'warning beeps or chirps' when unattended hoods sashes remain open.

Topic	Requirement(s)	Commentary
Safe Operation of Sashes	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450, Appendix A** Confirm adequate hood performance before use; keep hood closed at all times except when adjustments within the hood are being made; **American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **7 Work Practices** The sash or panels shall be closed to the maximum position possible while still allowing comfortable working conditions. Hood users shall be trained to close the sash or panels when the hood is not in use. **National Fire Protection Association, Standard NFPA 45, 2011** **8.8.3.1** Chemical fume hood sashes shall be kept closed whenever possible. **8.8.3.2** When a fume hood is unattended, its sash shall remain fully closed. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **6.5.3 Proper Configuration of Vertical and Horizontal Sliding Sashes** The vertically sliding sash should always be located lowered as much as possible to protect the user and to minimize visual obstruction from sash handle. Raise the sash to full open position for set- up purposes only. Reducing the sash to below the user's breathing zone provides a protective barrier between the researcher and the experiment. Always close the sash when not working in the hood. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **VS-35-04** Keep the hood sash closed as much as possible.	The standards are clear and unanimous with regard to closing sashes. For safety, lab workers must close sashes whenever possible. Laboratories are advised to address sash closure in the Chemical Hygiene Plan in terms of: • Establishing the practice • Training the workers • Monitoring the results Engineering options (like face velocity setback) that accommodate work practices of leaving sashes open directly contradict safety standards and regulations. Safe user practice and discipline requires call for closing the sashes whenever possible. Automatic sash closures tend to negate this aspect of safety consciousness and the time delay before automatic sash closures operate may be reduce the overall time that the sashes are actually closed.

Topic	Requirement(s)	Commentary
Accessories, Services and Explosion Protection	**National Fire Protection Association, Standard NFPA 45, 2011** **8.2.3** Chemical fume hoods shall not be relied upon to provide explosion (blast) protection unless specifically designed to do so. **A.8.2.3** Hoods having explosionproof electrical devices are sometimes referred to as *explosionproof hoods*. This term does not imply that they will contain an explosion, only that the electrical equipment will not provide a source of ignition. **American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **1.1** This standard does not apply to the following types of laboratories or hoods except as it may relate to general laboratory ventilation: • Explosives laboratories; • Radioisotope laboratories; • Laminar flow hoods (e.g., a clean bench for product protection, not employee protection); • Biological safety cabinets. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.1.9** Many hood manufacturers can equip hoods with a variety of amenities or services. The more popular services include electrical outlets, sinks, fixtures and plumbing for gas vacuum, and air. For increased safety, controls for these services should always be accessible from outside the hood opening. **Service Fixtures** All service fixtures shall be installed so that service supply lines can be connected or disconnected, either by design of the piping assembly or through an access panel in the hood interior or exterior. All service valves shall be accessible for maintenance. All service fixture controls (e.g., gas, air, water, vacuum) should be external to the hood interior, clearly identified and within easy reach. All internal corrosion fixture outlets shall be corrosion resistant to the application. **Electrical Receptacles** All electrical receptacles should be readily accessible. Provision shall be made so that all electrical wiring will be isolated and physically separated from vapors handled within the hood interior after the fume hood is installed. The receptacle shall be installed with the ground outlet above the power slots.	Although a conventional laboratory fume hood with a closed sash may provide protection from an active chemical reaction or even a 'small' detonation, they are not typically designed to provide explosion protection and should not be used in applications where an explosion hazard exists. In order to not have a source of ignition present at the fume hood, all of the hood's internal and external electrical fixtures (lights, switches, outlets, etc.) have to be explosion-proof and any equipment placed within the fume hood interior (heaters, analyzers, stirrers, etc.) must also be explosion-proof.

Topic	Requirement(s)	Commentary
Ductless	**American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **4.2** Ductless hoods shall meet the general requirements of Section 3.1 and 3.3 as applicable. *(3.1 requires hood construction be adequate and 3.3 requires adequate face velocity, periodic face velocity measurement and an airflow measuring device on the hood.)* Ductless fume hoods shall have signage prominently posted on the ductless hood to inform operators and maintenance personnel on the allowable chemical used in the hood, type and limitation of filters in place, filter changeout schedule and that the hood recirculates air to the room.	Ductless fume hoods should only be used with quantities and types of chemicals that do not pose a health hazard and where the exhaust filter media can remove any particulate released within the hood. In general ductless fume hoods are only suitable used when the chemicals pose an annoying odor rather than a health hazard and/or where airborne dust is generated.
Auxiliary Air	**National Fire Protection Association, Standard NFPA 45, 2011** **8.8.6** For auxiliary air fume hoods, auxiliary air shall be introduced exterior to the hood face in such a manner that the airflow does not compromise the protection provided by the hood and so that an imbalance of auxiliary air to exhaust air will not pressurize the hood interior. A.8.13.1 The operating characteristics of some chemical fume hood designs, particularly auxiliary air chemical fume hoods, change at intermediate positions of sash height. It is, therefore, important to verify inward airflow over the face of the hood according to 8.13.1(5) at several sash heights from full open to closed. **American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **3.2.3** Auxiliary air hoods are laboratory hoods that meet the requirements in Section 3.3 *(3.3 requires adequate face velocity, periodic face velocity measurement and an airflow measuring device on the hood.)* In addition: • The supply plenum shall be located externally and above the top of the hood face; moreover, the auxiliary air shall be released outside the hood. • The supply jet shall be distributed so as not to affect containment. • The auxiliary air shall not disrupt hood containment or increase potential for escape. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.2.6 Auxiliary Air Fume Hood** The auxiliary air system, when added to a standard laboratory fume hood, shall function to reduce the consumption of conditioned room air. The auxiliary air is typically introduced exterior to the fume hood and enters the fume hood through the face with the sashes open. With the sash(es) closed auxiliary air shall be drawn into the fume hood interior in such a manner as to aid in the dilution of heat and fumes generated in the work area. (Continued on Next Page)	Auxiliary air fume hoods are generally CAV type fume hoods that have a supply air outlet added to the upper portion of the front of the fume hood to enable using unconditioned outside air for part of the fume hood's ventilation air. This reduces the amount of conditioned room air necessary to offset the fume hood exhaust. Use of this auxiliary air is intended to attain a reduction in the energy needed to condition the room air. Many safety professionals do not recommend using auxiliary air fume hoods because of the complications and potential problems that usually arise. Also, many lab designers do not consider auxiliary air fume hoods as a worthwhile option. Auxiliary air fume hoods have specific drawbacks such as requiring additional fans and ducts to bring the outside air directly to the front of the fume hoods and can complicate attempts to create optimum fume hood airflow patterns. In addition, it is usually necessary to temper the incoming outside air, especially during extreme weather, since the user is typically exposed to this airflow.

Topic	Requirement(s)	Commentary
Auxiliary Air (Continued)	NOTE: Consideration should be given to preconditioning and filtering auxiliary air. Auxiliary air fume hoods shall also conform to the following requirements: • Provide safe capture and efficient removal of fumes from the hood when operated at air ratios specified by the manufacturer. • Capture the percentage of auxiliary air specified by the manufacturer when operated with the sash(es) open or closed. • Capture, contain and carry away fumes generated in the work area when operated at a condition of imbalance between the auxiliary air and room air as specified by the manufacturers. • Function in accordance with the performance characteristics listed above when tested by appropriate evaluation procedures. • Never pressurize the hood chamber with auxiliary air. The manufacturers shall include auxiliary air static pressure data for all standard catalog models.	

Topic	Requirement(s)	Commentary
(Special Purpose) Perchloric Acid	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** When perchloric acid is evaporated in laboratory-type hoods…. the materials of construction shall be inert, smooth, and nonabsorbent. Organic polymers shall not be used except for inert fluoropolymers, such as polytetrafluoroethylene [PTFE] and tetrafluoroethylene-hexafluoropropylene copolymer [Teflon FEP], or similar nonreactive material. The hood and exhaust system shall be washed down with water for decontamination and prior to opening for maintenance. Exception: Portable laboratory scrubbing apparatus for perchloric acid digestions may be used in lieu of the special requirements of this paragraph **National Fire Protection Association, Standard NFPA 45, 2011** **8.5.7** Flexible connectors containing pockets in which conveyed material can collect shall not be used in any concealed space or where strong oxidizing chemicals (e.g., perchloric acid) are used. **8-11.1** Perchloric acid heated above ambient temperatures shall only be used in a chemical fume hood specifically designed for its use and identified as follows: FOR PERCHLORIC ACID OPERATIONS *Exception: Hoods not specifically designed for use with perchloric acid shall be permitted to be used where the vapors are trapped and scrubbed before they are released into the hood. (See also 12.1.2.5)* **8.11.2** Perchloric acid hoods and exhaust ductwork shall be constructed of materials that are acid resistant, nonreactive and impervious to perchloric acid. **8.11.3** The exhaust fan shall be acid resistant and spark resistant. **8.11.4** The exhaust fan motor shall not be located within the ductwork **8.11.5** Drive belts shall be conductive and shall not be located within the ductwork. **8.11.6** Ductwork for perchloric acid hoods and exhaust systems shall take the shortest and straightest path to the outside of the building and shall not be manifolded with other exhaust systems. **8.11.6.1** Horizontal runs shall be as short as possible, with no sharp turns or bends. **8.11.6.2** The ductwork shall provide a positive drainage slope back into the hood. **8.11.6.3** Ductwork shall consist of sealed sections. **8.11.6.4** Flexible connectors shall not be used. **8.11.7** Sealants, gaskets and lubricants used with perchloric acid hoods, ductwork and exhaust systems shall be acid resistant and nonreactive with perchloric acid. **8.11.8** A water spray system shall be provided for washing down the hood interior behind the baffle and the entire exhaust system. (Continued on Next Page)	When perchloric acid is heated above ambient temperature it gives off vapors which can condense and form potentially explosive perchlorates. In addition, other chemicals that are known to have similar properties should also only be used in a perchloric acid hood. Perchloric acid hoods should be washed down after each use. Perchloric acid fume hoods and related exhaust systems should always be separate from other fume hoods and exhaust systems. Due to the need to keep the exhaust system short and direct, it is advantageous to locate the laboratories that have perchloric acid hoods just below roof level. Along with type 316 stainless steel, type 1 PVC and ceramic coated materials may be used for the exhaust system.

Topic	Requirement(s)	Commentary
(Special Purpose) Perchloric Acid (Continued)	**A8.11.8** Perchloric acid hoods should be washed down after each use. **8.11.8.1** The hood work surface shall be watertight with a minimum depression of 13 mm (1/2 in.) at the front and sides. **8.11.8.2** An integral trough shall be provided at the rear of the hood to collect wash-down water. **8.11.9** The hood baffle shall be removable for inspection & cleaning. **8.11.10** If a chemical fume hood or exhaust system was used for perchloric acid heated above ambient temperature, tests shall be conducted for explosive perchlorates before any inspection, cleaning, maintenance, or any other work is done on any part of the exhaust system or hood interior. **8.11.11** Prior to using a perchloric acid hood for any purpose, the hood shall be water-washed and shall be tested according to 8.11.9 to ensure residual perchlorates are not present. **12.1.2.5** Strong oxidizing materials, such as perchloric acid, shall not be heated by gas flames or oil baths. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **VS-35-03 (PERCHLORIC ACID HOOD DATA)** 1. Do not use perchloric acid in a hood designed for other purposes. Identify perchloric acid hoods with large warning signs. 2. Provide exhaust ventilation and room supply air with minimal challenge to hood. 3. Utilize local exhaust ventilation within the hood to minimize condensation of vapors inside the hood. 4. Locate all utility controls outside the hood. 5. Materials of construction for this type of hood and duct must be nonreactive, and acid resistant, and relatively impervious. AVOID ORGANIC MATERIALS unless known to be safe. Stainless steel type 316 with welded joints is preferred. Unplasticized polyvinyl chloride or an inorganic ceramic coating, such as porcelain, is acceptable. 6. Ease of cleanliness is paramount. Use stainless steel with accessible rounded corners and all welded construction. 7. The work surface should be watertight with a minimum of 0.5 inch dished front and sides and an integral trough at the rear to collect the washdown water. 8. Design washdown facilities into the hood and duct. Use daily or more often to thoroughly clean perchloric acid from the exhaust system surfaces. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
(Special Purpose) Perchloric Acid (Continued)	9. Each perchloric acid hood should have an individual exhaust system. Slope horizontal runs to drain. Avoid sharp turns. 10. Construct the hood and duct to allow easy visual inspection. 11. Where required, use a high efficiency (greater than 80%) wet collector constructed for perchloric acid service. Locate as close to the hood as possible to minimize accumulation of perchloric acid in the exhaust duct. 12. Use only an acid-resistant metallic fan protected by an inorganic coating or an air injector. 13. Lubricate the fan with fluorocarbon grease. 14. Locate the fan outside the building. 15. The exhaust discharge must terminate out-of-doors, preferably using a vertical discharge stack that extends well above the roof eddy zone.	

Topic	Requirement(s)	Commentary
(Special Purpose) Radioisotope	**National Fire Protection Association, Standard NFPA 45, 2011** **A-8-12.1** Laboratory hoods in which radioactive materials are handled should be identified with the radiation hazard symbol. For information, see NFPA 801, *Standard for Fire Protection for Facilities Handling Radioactive Materials.* **American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **1.1** This standard does not apply to the following types of laboratories or hoods except as it may relate to general laboratory ventilation: • Explosives laboratories; • Radioisotope laboratories • Laminar flow hoods (e.g., a clean bench for product protection, not employee protection); • Biological safety cabinets **5.3.2.2** Where there is a potential contamination from hood operations as determined by the Hazard Evaluation and Analysis of Section 2.4, radioisotope hoods shall not be manifolded with nonradioisotope hoods unless in-line HEPA filtration and/or another necessary air-cleaning system is provided between the hood and the manifold. **5.3.2.3** Exhaust streams comprised of radioactive materials shall be adequately filtered to ensure removal of radioactive material before being connected to a centralize exhaust system. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.2.2 Radio Isotope Fume Hood** A fume hood used for Beta and Gamma radiation shall be referred to as a radioisotope hood. A radioisotope hood has the general characteristics of a bench-top fume hood except the work surface and interior lining must be type 304 stainless steel with coved seamless welded seams for easy cleaning and decontamination. The hood design is identical to other hood types in nearly all other respects. Horizontal sash panels are not appropriate for this fume hood type. The work surface shall be dished t o contain spills and cleaning liquids and shall be properly reinforced to support lead shielding and shielded containers. The load-bearing capacity shall be 200 pounds per square foot (978.5 Kg/m 2) minimum up to a total weight of 1,000 pounds (453.6 Kg) per fume hood or base cabinet section. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **3.7.2** For low activity radioactive laboratory work, a laboratory fume hood may be acceptable. For such hoods, an average face velocity of 80 to 100 fpm is recommended.	Few definitive requirements exist for radioisotope fume hoods. However, experience indicates that they should be constructed of a continuous (no seams) cleanable non-porous material such as 304 stainless steel (18 GA. minimum) without any sharp corners or recesses. Isotope fume hood exhaust should not be combined with other fume hood exhaust due to the potential for contamination of exhaust system fans and other components which could then pose a danger to maintenance personnel. VAV controls should also be avoided due to possible component contamination. Isotope fume hood exhaust systems should have provisions for a HEPA or carbon filter.

Topic	Requirement(s)	Commentary
Room Air Cross Currents	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(g):** General air flow should not be turbulent and should be relatively uniform throughout the laboratory, with no high velocity or static areas; airflow into and within the hood should not be excessively turbulent. **National Fire Protection Association, Standard NFPA 45, 2011** **8.8.6** For auxiliary air fume hoods, auxiliary air shall be introduced exterior to the hood face in such a manner that the airflow does not compromise the protection provided by the hood and so that an imbalance of auxiliary air to exhaust air will not pressurize the hood interior. **8.9.1** Chemical fume hoods shall be located in areas of minimum air turbulence. **A.8.9.1** A person walking past the hood can create sufficient turbulence to disrupt a face velocity of 0.5 m/sec (100 ft/min). In addition, open windows or air impingement from an air diffuser can completely negate or dramatically reduce the face velocity and can also affect negative differential air pressure. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.2.2** Supply air distribution shall be designed to keep air jet velocities less than half, preferably less than one-third of the capture velocity or the face velocity of the laboratory chemical hoods at their face opening. For most laboratory chemical hoods, this requirement will mean 50 fpm (0.25 m/s) or less terminal throw velocity at 6 ft. (1.8 m) above the floor. **6.3.5** Excessive cross draft velocities (>50% of the average face velocity) have been demonstrated to significantly affect hood containment and should be identified and alleviated. Ideally, cross draft velocities should be less than 30%. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **5.1 Location in Laboratory** Laboratory fume hoods should be so located within the laboratory to avoid crosscurrents at the fume hood face due to heating, cooling, or ventilating inlets. **5.2 Safety Considerations** Laboratory fume hoods should be located away from high traffic lanes within the laboratory because personnel walking past the sash opening may disrupt the flow of air into the unit and cause turbulence, drawing hazardous fumes into the laboratory. (Continued on Next Page)	Virtually all standards point out that room air currents at a fume hood's open face area (that is, cross drafts) can adversely affect fume hood containment when the air currents are above specific levels. Excessive cross drafts typically result from: • Improper room supply air diffusers (conventional high velocity, mixing diffusers rather than the perforated type). • Having too few supply air diffusers resulting in high supply air velocity from each unit. • Improper diffuser location (such as directly above the fume hoods or on room side walls). • Room occupants using portable cooling fans or having operable windows in the open position. • Too rapid movement of persons working at or passing by fume hoods. Also, having room doors open. Both NFPA 45 and ANSI/Z9.5 recommend that cross draft velocities should (ideally) not exceed 30% of the average face velocity. For a nominal 100 FPM face velocity the cross drafts should therefore not exceed 30 FPM. This is slightly less than 3 miles per hour which is a person's nominal walking speed. For low velocity hoods, the allowable cross draft is even lower. Better fume hood containment can be attained with good room air distribution than with higher face velocities and poor air distribution (higher cross current velocities).

Topic	Requirement(s)	Commentary
Room Air Cross Currents (Continued)	**American Conference of Governmental Industrial Hygienists (ACGIH) INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **3.7.1**. Replacement air should be introduced at a low velocity and in a direction which does not cause disruptive cross-drafts at the hood opening. **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** (1) The outside air supply shall enter the workroom in a manner which will not reduce the effectiveness of any local exhaust systems. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.5, Air Currents:** Air currents external to the fume hood can jeopardize the hood's effectiveness and expose the researcher to materials used in the hood. Detrimental air currents can be produced by: • Air supply distribution patterns in the laboratory • Movements of the researcher • People walking past the hood • Thermal convection • Opening of doors and windows Disturbance velocities at the face of the hood should be no more than one-half and preferably one-fifth the face velocity of the hood. This is an especially critical factor in designs that use low face velocities. For example, a fume hood with a face velocity of 100 fpm could tolerate a maximum disturbance velocity of 50 fpm. If the design face velocity were 60 fpm, the maximum disturbance velocity would be 30 fpm.	

Topic	Requirement(s)	Commentary
Minimum Exhaust	**National Fire Protection Association, Standard NFPA 45, 2011** **A-8.4.7** In addition to maintaining proper fume hood face velocity, fume hoods that reduce the exhaust In addition to maintaining proper fume hood face velocity, fume hoods that reduce the exhaust volume as the sash opening is reduced should maintain a minimum exhaust volume to ensure that contaminants are diluted and exhausted from a hood. The chemical fume hood exhaust airflow should not be reduced to less than the flow rate recommended in ANSI/AIHA Z9.5, *Laboratory Ventilation*. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **3.3.1** The mechanism that controls the exhaust fan speed or damper position to regulate the hood exhaust volume shall be designed to ensure a minimum exhaust volume in constant volume systems equal to the larger of 50 cfm/ft of hood width, or 25 cfm/ft^2 of hood work surface area, except where a written hazard characterization indicates otherwise, or if the hood is not in use.	The NFPA 45 stated minimum exhaust of 25 cfm per square foot of internal hood work surface typically equates to 20% to 25% of the required exhaust rate for a fully open sash and 100 fpm face velocity. Frequently this limits the “turndown” on a VAV hood to about 5:1. An example of where a written hazard classification would indicate that a minimum exhaust is not required could be where the fume hood is used only for odor control and where hazardous fumes are never present. Note that in ANSIAIHA Z9.5-2003, there is a likely typo in that the term “constant volume systems” should probably be “variable air volume” since VAV fume hoods and not CAV fume hoods have a mechanism to regulate the exhaust.

Topic	Requirement(s)	Commentary
Fire Protection/ Emergency Control Provisions	**National Fire Protection Association, Standard NFPA 45, 2011** **8.10.1** Automatic fire protection systems shall not be required in chemical fume hoods or exhaust systems except in the following cases: (1) Existing hoods having interiors with a flame spread index greater than 25 in which flammable liquids are handled. (2) If a hazard assessment shows that an automatic extinguishing system is required for the chemical fume hood, then the applicable automatic fire suppression system standard shall be followed. **8.10.2** Automatic fire protection systems, where provided, shall comply with the following standards, as applicable: (1) NFPA 11, *Standard for Low, Medium, and High-Expansion Foam* (2) NFPA 12, *Standard for Carbon Dioxide Extinguishing Systems* (3) NFPA 12A, *Standard for Halon 1301 Fire Extinguishing Systems* (4) NFPA 13, *Standard for the installation of Sprinkler Systems* (5) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection* (6) NFPA 17, *Standard for Dry Chemical Extinguishing Systems* (7) NFPA 17A, *Standard for Wet Chemical Extinguishing Systems* (8) NFPA 69, *Standard on Explosion Prevention Systems* (9) NFPA 750, *Standard on Water Mist Fire Protection Systems* (10) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems* **8.10.3.1** Automatic fire dampers shall not be used in chemical fume hood exhaust systems. **8.10.4** Fire detection and alarm systems shall not be interlocked to automatically shut down chemical fume hood exhaust fans. **8.10.6** Chemical fume hoods equipped with control systems that vary the hood exhaust airflow as the sash opening varies and/or in conjunction with whether the laboratory room is in use (occupied/unoccupied) shall be equipped with a user accessible means to attain maximum hood exhaust airflow regardless of sash position when necessary or desirable to ensure containment and removal of a potential hazard within the hood. (Continued on Next Page)	The requirement that a user be able to apply maximum exhaust to a fume hood regardless of sash position primarily pertains to fume hoods with VAV control systems that decrease fume hood exhaust to maintain a constant face velocity as the sash opening decreases. It is conceivable that even with a sash fully closed (and the exhaust thus minimized) a fire or highly active chemical reaction may warrant maximizing the fume hood exhaust without having to open the sash. This capability is normally implemented by including an appropriate emergency exhaust activation pushbutton on the fume hood's monitoring device.

Topic	Requirement(s)	Commentary
Fire Protection/ Emergency Control Provisions (Continued)	**Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.1.9 Hood Services** • Any fire protection system used in a chemical fume hood should be compliant with local codes and regulations, and NFPA 17. • Any fire suppression system used in a chemical fume hood should be rated for fire classes A, B, or C with manual and thermal activation triggers. Other water or liquid based systems may be acceptable if appropriate testing and certification are available. • No fire dampers of any kind should ever be installed in a chemical fume hood exhaust system. • Flammable materials should never be stored directly below a chemical fume hood in anything but an NFPA specified, UL listed or FM approved solvent storage cabinet. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.13 Fire Safety/Fire Protection** **d.** Fire dampers shall not be provided on any fume hood system.	Although the safety standards specifically prohibit fire dampers in fume hood exhaust systems, individual local codes may still require their inclusion. The laboratory ventilation system designer is advised to seek a variance from such a requirement with the *authority having jurisdiction* (AHJ). If a variance is not attainable, the designer will have to comply with the local code requirement but it is recommended that they confirm by letter to the AHJ that although the exhaust system will have the required fire dampers, it is contrary to NFPA 45, AIHA Z9.5 and other laboratory safety references. If a fire situation should later occur and the integrity of the system design becomes subject to investigation or litigation, the recommended documentation will help substantiate the designer's desire to follow noted safety standards.

Topic	Requirement(s)	Commentary
Monitoring	**National Fire Protection Association, Standard NFPA 45, 2011** **8.8.7 Measuring Device for Hood Airflow.** A measuring device for hood airflow shall be provided on each chemical fume hood. **8.8.7.1** The measuring device for hood airflow shall be a permanently installed device. **8.8.7.2** The measuring device for hood airflow shall provide constant indication to the hood user of adequate or inadequate hood airflow. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **3.3.3** All hoods shall be equipped with a flow-indicator, flow alarm, or face velocity alarm indicator to alert users to improper exhaust airflow. The flow-measuring device shall be capable of indicating airflows at the design flow and ±20% of the design flow. The device shall be calibrated at least annually and whenever damaged. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.1.10 Hood Monitor** All hoods shall have some type of monitor for indicating face velocity or exhaust flow verification. The monitor can be a simple pressure gage connected to a Pitot tube in the exhaust duct, one of many electronic monitors, or a vane anemometer. Regardless of the monitor installed, it should provide clear indication to the hood user whether exhaust flow or face velocity is within design parameters. A ribbon taped to the bottom of the sash is not acceptable. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.18, Operation and Maintenance:** Centralized monitoring of laboratory variables (e.g., pressure differentials, face velocity of fume hoods, supply flows, and exhaust flows) is useful for predictive maintenance of equipment and for ensuring safe conditions **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** By January 1, 2008, hoods shall be equipped with a quantitative airflow monitor that continuously indicates whether air is flowing into the exhaust system during operation. The quantitative airflow monitor shall measure either the exact rate of inward airflow or the relative amount of inward airflow. Examples of acceptable devices that measure the relative amount of inward airflow include: diaphragm pressure gauges, inclined manometers, and vane gauges. The requirement for a quantitative airflow monitor may also be met by an airflow alarm system if the system provides an audible or visual alarm when the airflow decreases to less than 80% of the airflow required. (Continued on Next Page)	Fume hood users must be immediately notified if the fume hood is not operating properly. This mainly occurs due to a face velocity that is too low or too high, or if there is insufficient minimum exhaust airflow when the sash is closed. Maximum user protection is achieved by providing both a visual and an audible annunciation of improper fume hood airflow conditions. In addition, fume hood airflow alarms that also report at a designated location (such as on the facility's ventilation control and monitoring system) provide added assurance that unsafe conditions will be reported and those responsible for maintaining safe laboratory conditions will take appropriate action.

Topic	Requirement(s)	Commentary
Monitoring (Continued)	(B) Qualitative airflow measurements that indicate the ability of the hood to maintain an inward airflow at all openings of the hood as required shall be demonstrated using smoke tubes or other suitable qualitative methods. This demonstration shall be performed: 1. Upon initial installation 2. On an annual basis *Exception to (B) 2*: The frequency of the tests may be reduced to every two years if a calibration and maintenance program is in place for the quantitative airflow monitor or alarm system. 3. After repairs or renovations of the hood or the ventilation system in that part of the facility where the hood is located; or 4. After the addition of large equipment into the hood **U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Title: Toxic and Hazardous Substances,1910.1450,C4(b):** …each hood should have a continuous monitoring device to allow convenient confirmation of adequate hood performance before use. If this is not possible, work with substances of unknown toxicity should be avoided or other types of local ventilation devices should be provided.	

Topic	Requirement(s)	Commentary
Selection Criteria and Performance Specifications	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **6.3** Specifications and procurement of laboratory chemical hoods shall be based on tests conducted on the hood (or prototype hood) that demonstrate adequate hood containment. The containment tests shall include: • Exhaust Flow Measurements • Hood Static Pressure Measurement • Face Velocity Tests • Auxiliary Air Velocity Tests (if applicable) • Cross Draft Velocity Tests • Airflow Visualization Tests • Tracer gas Containment Tests The tests shall be conducted under constant volume conditions where exhaust and air supply flow are stable and exhibit no more than 5% variation from set-point. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **10.35.1** The ANSI/ASHRAE Hood Performance Test may be used as a specification. The specified performance should be required of both the hood manufacturer and the designer of the room air supply system. The specification takes the form of: AUyyy, AIyyy, or AMyyy where: AU identifies an “as used” test. AI identifies an “as installed” test. AM identifies an “as manufactured” test. yyy = control level, ppm, at the breathing zone of the worker. Any well-designed airfoil hood, properly balanced, can achieve <0.10 ppm control level when the supply air distribution is good. Therefore it would seem appropriate that the “AM” requirements would be <0.10 ppm. The “AU” requirement involves the design of the room supply system and the toxicity of the materials handled in the hood. The “AU” specification would be tailored to suit the needs of the laboratory room location. **VS-35-02 (GENERAL USE LABORATORY HOODS)** **C.** Use corrosion resistant materials suitable for expected use. **E.** Avoid sharp corners at jambs and sill. Tapered or round hood inlets are desirable; an airfoil shroud at sill is important. **G.** Bypass opening in hood is desirable to avoid excessive indraft under partially closed sash condition. Opening to be baffled to prevent splash eruption in hood. **J.** For air conservation, use horizontal sliding sash with airfoil sill. **K.** All bench hoods should have a recessed work surface and airfoil sill.	The requirement of ANSI/AIHA Z9.5-2003 6.3 refers to “As Manufactured” tests which are intended to be conducted by the various fume hood manufacturers in accordance with the procedure specified in ANSI/ASHRAE 110. The test data is intended to provide potential fume hood specifiers or buyers with a way to compare the performance of various types, models, sizes, etc. of fume hoods offered by different manufacturers. In addition, the “As Manufactured” tests are intended to provide the necessary performance criteria so a determination can be made as to whether a given fume hood can meet the required level of performance. VAV Response Time: The major providers of VAV fume hood control systems generally attain a response time of approximately one second, which is within the time necessary to maintain safe containment as determined by widely recognized research[3] on this topic. However, a specific fume hood’s response time when installed (that is, 1.0 seconds, 1.1 seconds, 1.2 seconds, etc.) is dependent upon the overall dynamics of the room ventilation system. So it is advisable to specify response time as a ‘not to exceed’ value such as 2 seconds.

[3] *An Approach to Determining the Required Response Time for a VAV Fume Hood Control System, ASHRAE Transactions 1990* states “The result of this research indicates that tracer gas did not escape the fume hood when control action was taken within 2 to 3 seconds…”

Topic	Requirement(s)	Commentary
Laboratory Design & Fume Hood Implementation	**Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **6.6** The following list provides a summary of responsibilities for each group involved with ensuring proper operation of laboratory fume hood systems. **6.6.1 Management** • Provide Commitment to Health and Safety • Provide leadership • Direct and coordinate activities. • Allocate sufficient resources. **6.6.2 Principal Research Investigators** • Identify personnel risks and characterize scientific procedures. • Evaluate hazard potential. • Work with Health and Safety to develop safety protocols, training programs, and select appropriate tools. • Submit all requests for new hoods to Health and Safety. • Inform Health and Safety of significant changes in research activities. • Support (embrace) Health and Safety's Standard Operating Procedures. **6.6.3 Health and Safety** • Develop and manage the Chemical Hygiene Plan (Standard Operating Procedures). • Administer Laboratory Fume Hood Safety Program. • Determine exposure control requirements. Provide hood operators with MSDS information on materials being used in the fume hood. • Ensure proper selection and use of hoods. • Determine protocol for proper operation. • Ensure users are informed of hood capabilities and limitations (Training). • Develop and review safety standards periodically. • Review all requests for new hoods. • Conduct and /or review periodic hood performance tests. • Confirm that hood performs as required. **6.6.4 Laboratory Design Team and Engineering** • Identify needs. • Design appropriate building systems (architectural, mechanical, electrical, plumbing, structural, etc.) • Design and specify appropriate fume hood system • Assist with pre-qualification of construction team. • Review all proposed changes. • Prepare as-built documents. • Ensure design intent is achieved and commissioned. (Continued on Next Page)	A properly functioning VAV laboratory ventilation system with VAV fume hoods requires that all parties involved understand their responsibilities and conscientiously fulfill their obligations.

Topic	Requirement(s)	Commentary
Laboratory Design and Fume Hood Implementation (Continued)	**6.6.5 Construction Team** • Construct in accordance with contract documents, and regional, local, and national codes. • Provide coordinated effort to meet design and performance requirements. • Coordinate field changes with other appropriate team members. **6.6.6 Controls Manufacturer** • Supports design and specification of appropriate fume hood control system. • Provide product in accordance with specifications and contracts. • Provide start-up of fume hood control system. • Provide training in proper operations and maintenance for product. **6.6.7 Building System Commissioning** • Verify fume hood flow rate. • Verify function of controls. • Verify ability to meet design set points for temperature, airflow, and room pressurization. **6.6.8 Operations and Maintenance** • Ensure regular maintenance on all system components. • Ensure proper operation within specified tolerances. • Ensure no unauthorized changes to hood systems. • Ensure maintenance personnel are familiar with hazards and safe work procedures. • Ensure maintenance personnel are fully trained. **6.6.9 Laboratory Personnel and Hood Users** • Understand the capabilities and limitations of hoods. • Verify proper operation prior to use. • Use proper work practices in compliance with SOP. • Report suspected operational problems. **6.6.10 Hood Manufacturer** • Hood is built to specifications • Hood performs as expected “as manufactured.” • Provide technical information associated with hood design. • Hood shall be manufactured in conformance with SEFA-1 • Provide product training and verification as requested. • Provide basic safety precautions posted clearly on the fume hood. • Provide troubleshooting assistance when hood fails to meet expectation “as Installed.” **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **VS-35-02 (GENERAL USE LABORATORY HOODS)** **B.** Locate hood away from heavy traffic aisles and doorways. Hoods near doors are acceptable if: 1) there is a second safe means of egress from room, 2) traffic past hood is low, and 3) door is normally closed.	

Topic	Requirement(s)	Commentary
Maintenance	**Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **5.5** Fume hood maintenance procedures primarily consist of clean up, adjustments, lubrication and replacement of worn, damaged or nonfunctioning parts. Use good housekeeping in laboratory fume hoods at all times Periodically clean sash(es) exterior and interior surfaces, including light panel. Replace lamps periodically to maintain adequate illumination. Clean up should be accomplished by, or under supervision of a knowledgeable laboratory safety officer and should include removal of the baffle for clean up of all interior surfaces. Lubrication of sash guides, cables, pulley wheels and other working parts should be accomplished as required or in accordance with manufacturer's recommendations. Flush all spills immediately using neutralizing compounds as required and clean thoroughly. **6.6.8 Operations and Maintenance** • Ensure regular maintenance on all system components. • Ensure proper operation within specified tolerances. • Ensure no unauthorized changes to hood systems. • Ensure maintenance personnel are familiar with hazards and safe work procedures. • Ensure maintenance personnel are fully trained. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **VS-35-03 (PERCHLORIC ACID HOOD DATA)** 8. Design washdown facilities into the hood and duct. Use daily or more often to thoroughly clean perchloric acid from the exhaust system surfaces. 13. Lubricate the fan with fluorocarbon grease. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 18, Operation and Maintenance:** Centralized monitoring of laboratory variables (e.g., pressure differentials, face velocity of fume hoods, supply flows, and exhaust flows) is useful for predictive maintenance of equipment and for ensuring safe conditions	

Topic	Requirement(s)	Commentary
Periodic Testing	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Title: Toxic and Hazardous Substances,1910.1450,C4(h):** (h) Evaluation. Quality and quantity of ventilation should be evaluated on installation, regularly monitored (at least every 3 months), and reevaluated whenever a change in local ventilation devices is made. **Canada - Public Works, Standards and Guidelines** **MD 15128 Laboratory Fume Hoods** **A.2.1.4** Performance tests The following performance test shall be performed at least once per year: 1. Test for face velocity 2. Test for exhaust air flow rate 3. Test for exhaust fan performance 4. Test of controls 5. Tests for entrainment of auxiliary air supply (auxiliary air supply fume hoods only). **National Fire Protection Association, Standard NFPA 45, 2011** **8.13.1** When installed or modified and at least annually thereafter, chemical fume hoods, chemical fume hood exhaust systems, and laboratory special exhaust systems shall be inspected and tested as applicable, as follows: (1) Visual inspection of the physical condition of the hood interior, sash, and ductwork *(see 7.5.3)* (2) Measuring device for hood airflow (3) Low airflow and loss-of-airflow alarms at each alarm location (4) Face velocity (5) Verification of inward airflow over the entire hood face (6) Changes in work area conditions that might affect hood performance **8.13.3** Chemical fume hood face velocity profile or hood exhaust air quantity shall be checked after any adjustment to the ventilation system balance. **8.13.4.1** Air system flow detectors, if installed, shall be inspected and tested annually.	Periodic fume hood testing is necessary to ensure against degradation of the fume hood and associated ventilation system. Generally, all laboratory safety standards recommend or mandate that, as a minimum, both the fume hoods and the associated ventilation system be tested annually. Aside from regular periodic testing, re-testing should be performed anytime changes are made to the laboratory room or the associated ventilation system serving the laboratory rooms.

Topic	Requirement(s)	Commentary
Periodic Testing (Continued)	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **6.4** Routine performances tests shall be conducted at least annually or whenever a significant change has been made to the operational characteristics of the hood system. A hood that is found to be operating with an average face velocity more than 10% below the designated average face velocity shall be labeled as out of service or restricted use and corrective actions shall be taken to increase flow. Each hood shall be posted with a notice giving the date of the routine performance test, and the measured average face velocity. If it is taken out of service it shall be posted with A restricted use or out-of-service notice. The restricted use notice shall state the requisite precautions concerning the type of materials permitted or prohibited for use in the hood. **8.0** Inspection and maintenance shall follow an Inspection and Maintenance (I&M) Program developed by the user. **8.1** Operations served by equipment being shutdown for inspection shall be safely discontinued and secured during such maintenance. Lock-out/tag-out procedures shall be implemented. Laboratory workers shall be notified in advance of inspection and maintenance operations. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **5.3.5** SEFA recommends the ASHRAE 110 -1995 (or most current edition) TESTS. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.18, OPERATION AND MAINTENANCE:** Users should request periodic testing of the devices to ensure that they and the connected ventilation systems are operating properly.	Also see *Appendix 4 - Audit Form in ANSI/AIHA Z9.5-2003*, which provides a comprehensive checklist for the Laboratory Ventilation Management Program including Inspection and Maintenance.

Topic	Requirement(s)	Commentary
Test Procedures	**National Fire Protection Association, Standard NFPA 45, 2011** **8.13.1** When installed or modified and at least annually thereafter, chemical fume hoods, chemical fume hood exhaust systems, and laboratory special exhaust systems shall be inspected and tested as applicable, as follows: (1) Visual inspection of the physical conditions of the hood interior, sash and ductwork. (2) Measuring device for hood airflow. (3) Low airflow and loss-of-airflow alarms at each alarm location. (4) Face velocity. (5) Verification of inward airflow over the entire hood face (6) Changes in work area conditions that might affect hood performance **8.13.3** Chemical fume hood face velocity profile or hood exhaust air quantity shall be checked after any adjustment to the ventilation system balance. **8.13.4.1** Air system flow detectors, if installed, shall be inspected and tested annually. **A.8.13.1** The operating characteristics of some chemical fume hood designs, particularly auxiliary air chemical fume hoods, change at intermediate positions of sash height. It is, therefore, important to verify inward airflow over the face of the hood according to 8.13.1 (5) at several sash heights from full open to closed. A number of test procedures for verifying performance of chemical fume hoods that have been installed in the field have been published. A test procedure is given in *Standard on Laboratory Fume Hoods*, by the Scientific Equipment and Furniture Association (SEFA) that uses a velometer and visible fume for checking hood performance. A very detailed standard has been issued by the American Society of Heating, Refrigerating and Air Conditioning Engineers titled ASHRAE 110, *Method of Testing Performance of Laboratory Fume Hoods*. The Environmental Protection Agency's *Procedure for Certifying Laboratory Fume Hoods to Meet EPA Standards* contains a test procedure utilizing sulfur hexafluoride as a test gas. **A.8.13.5.1** The annual inspection of air supply and exhaust fans, motors, and components should ensure that equipment is clean, dry, tight, and friction-free. Bearings should be properly lubricated on a regular basis, according to manufacturers' recommendations. Protective devices should be checked to ensure that settings are correct and that ratings have been tested under simulated overload conditions. Inspections should be made by personnel familiar with the manufacturers' instructions and equipped with proper instruments, gauges, and tools. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Test Procedures *(Continued)*	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **6.6** If practical, the exhaust flow rate from hoods shall be tested by measuring the flow in the duct by the hood throat suction method or by flow meter. If flow measurement in the duct is not practical, velocity at the hood face or opening shall be measured at a sufficient number of points to obtain a realistic average velocity and multiplied by the open area in the plane of the velocity measurements to obtain the flow rate. If the flow rate is more than 10% different from design, corrective action shall be taken. **8.6.2.1** Allowable variations from design conditions, or conditions determined other wise satisfactory, shall be: • For air velocity, 10% • For ventilation air pressure or differential pressure, +20%; For pneumatic control system air pressure , <5%; and • For electronic control system, +/- 2% of full scale values. **ASHRAE Standard: Method of Testing Performance of Laboratory Fume Hoods, ANSI/ASHRAE 110-2006** Individual ASHRAE 110 Fume Hood Tests include: • (6.1) Face Velocity Measurements • (6.2) VAV Face Velocity Control Test • (6.3) VAV Response Tests • (7.1) Flow Visualization • (7.2) Airflow Patterns • (7.3) Local Visualization Challenge • (7.4) Large Visualization Challenge • (7.5) Smoke Evaluation • (8.0) Tracer Gas Tests • (8.2) Peripheral Scan • (8.3) Sash Movement Containment Test *(Refer to ASHRAE 110 Test Standard in the Applicable Definitions section for a description of each of these tests.)*	Also see *Appendix 4 - Audit Form in ANSI/AIHA Z9.5-2003*, which provides a comprehensive checklist for the Laboratory Ventilation Management Program including Fume Hood inspection and testing. The ASHRAE 110 tests are the most comprehensive and widely recognized method to test and quantify fume hood performance. These tests are extremely thorough and include: • Determining fume hood average face velocity. • Testing the airflow into the fume hood at the edges and corners of the sash opening. • Smoke visualization of the internal airflow pattern. • Tracer gas containment. • Sash movement effect. The ASHRAE 110 tests can establish a baseline to quantify a fume hood's performance so that subsequent repeat testing can be done to track continued performance to determine if significant performance deterioration has occurred.

Topic	Requirement(s)	Commentary
Signage and Recordkeeping	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** The record of the most recent tracer gas test results and the "as used" test configuration shall be maintained as long as the automatic system is operable and thereafter for five years. The face velocity required should be obtainable with the movable sashes fully opened. Where the required velocity can only be obtained by partly closing the sash, the sash and/or jamb shall be marked to show the maximum opening at which the hood face velocity will meet the requirements of subsection. Any hood failing to meet requirements of this paragraph shall be considered deficient in airflow and shall be posted with placards, plainly visible, which prohibit use of hazardous substances within the hood. **5154.2. Ventilation Requirements for Laboratory-Type Hood Operations:** (2) Inspections and maintenance of the HVAC system shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years. (3) The employer shall make all records required by this section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division, to any employee of the employer affected by this section, and to any designated representative of said employee of the employer affected by this section. **Canada - Public Works, Standards and Guidelines - MD 15128** **Laboratory Fume Hoods, 5.0 TESTING LABORATORY FUME HOODS** **5.2** Test results: a permanent sticker shall be affixed to the laboratory fume hood. **National Fire Protection Association, Standard NFPA 45, 2011** **8.12.2** A sign containing the following information from the last inspection shall be affixed to each hood, or a properly maintained log of all hoods providing the following information shall be maintained: (1) Inspection interval (2) Last inspection date (3) Average face velocity (4) Location of fan that serves hood (5) Inspector's name (Continued on Next Page)	Individuals performing fume hood testing should affix a label on the fume hood or record in appropriate documentation the person(s) performing the test, their affiliation and the information listed.

Topic	**Requirement(s)**	**Commentary**
Signage and Recordkeeping *(Continued)*	**American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **7.5** Each hood shall be posted with a notice giving the date of the last periodic field test. If the hood failed the performance test, it shall be taken out of service until repaired, or posted with a use restriction. The notice shall state the partially closed sash position necessary for safe/normal operation and any other precaution concerning the type of work and materials permitted or prohibited. **4.2** Ductless fume hoods shall have signage prominently posted on the ductless hood to inform operators and maintenance personnel on the allowable chemical used in the hood, type and limitation of filters in place, filter changeout schedule and that the hood recirculates air to the room. **4.2** Records shall be maintained for all inspections and maintenance. If testing involves Quantitative values (such as throat suction) the observed values shall be recorded. Inspection forms designed for several categories of testing shall be provided and shall include the normal values for the parameter tested. Each hood shall be posted with a notice giving the date of the routine performance test, and the measured average face velocity. If it is taken out of service it shall be posted with a restricted use or out of service notice. The restricted use notice shall state the requisite precautions concerning the type of materials permitted or prohibited for use in the hood. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **VS-35-03 (PERCHLORIC ACID HOOD DATA)** 1. Identify perchloric acid hoods with large warning signs.	

Topic	Requirement(s)	Commentary
Shutdown Procedures	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,E1(n):** Leave the hood "on" when it is not in active use if toxic substances are stored in it or if it is uncertain whether adequate general laboratory ventilation will be maintained when it is "off". **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** (d) Operation. Mechanical ventilation shall remain in operation at all times when hoods are in use and for a sufficient time thereafter to clear hoods of airborne hazardous substances. When mechanical ventilation is not in operation, hazardous substances in the hood shall be covered or capped off. **American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **7.6** Hoods shall be in operation whenever hazardous volatile materials are being used or stored inside. **5.3.2.4** If the hood is completely turned off, the hood shall be emptied and decontaminated and provisions shall be implemented to prevent the hood from back drafting. **8.1** Operations served by equipment being shutdown for inspection shall be safely discontinued and secured during such maintenance. Lock-out/tag-out procedures shall be implemented. Laboratory workers shall be notified in advance of inspection and maintenance operations.	"Turing off" or shutting down a fume hood generally means stopping the fume hood's exhaust and is permissible only if the following requirements are fulfilled: • No chemicals remain in the hood – either in use or in storage. • The hood interior is cleaned to remove all chemical residues. • The hood sash is kept fully closed. • The cessation of the hood's exhaust airflow does not reduce the laboratory room's ventilation rate to less than the allowable minimum. *(*Unless all chemicals are also removed from the room, the room still remains a 'laboratory' even though no one is present an/or no hoods are in use.) • The laboratory room's negative static pressurization can be maintained. • Adequate and prominent signs on the fume hood warn that it cannot be used until the fume hood is returned to safe operational status. (Safe operational status requires ensuring that proper fume hood exhaust and the required face velocity is again present and any associated fume hood controls and monitoring provisions are in proper operation.) It may be beneficial from an energy savings standpoint to 'shut down' a fume hood if the above conditions can be met. In general, educational facilities normally can derive the greatest benefit from this practice if a lab class will not be in session for a semester or for an extended holiday period.

Fume Hood Ventilation Systems

Topic	Requirement(s)	Commentary
Evaluating CAV (Constant Air Volume) Systems	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **6.5.1 Single Hood CAV Systems** Commissioning tests on single hood, constant air volume (CAV) systems shall consist of: • Fan Performance Tests; • Exhaust Duct Measurements; • Hood Performance Tests; and • Hood Monitor Calibration Fan Performance Tests shall include measurement of fan speed, fan static pressure, motor speed, and amp draw. Exhaust duct measurement shall consist of exhaust flow measurement and hood static pressure measurement. **6.5.1 Multiple Hood CAV Systems** Commissioning of multiple hood, constant air volume systems shall include: • Fan Performance Tests; • Verification of proper test, adjustment, and balance of branch exhaust flow and static pressures (exhaust flow and static pressure for each branch duct shall be recorded after final balancing is complete); • Hood Performance Tests as described above in Sections 6.3.1 through 6.3.6; *(See Fume Hoods: Periodic Testing)* and • Hood and System Monitor Calibration. **6.5.4.1 CAV Laboratory Room Tests** These tests shall ensure that the ventilation system design airflow is being maintained within the allowable tolerance in: • All hood exhausts; • All other bench-top and equipment exhaust provisions that may be present; • The room general exhaust if present; • The room supply; and • Room air cross currents at the hood face opening. If a specific room differential pressure (dP) has been specified, the dP shall be measured to ensure that it is within its allowable range. If a room differential airflow is specified, actual room differential airflow shall be determined to ensure that it is within allowable maximum and minimum limits and in the proper direction. If the room has more than one ventilation control mode (that is occupied/unoccupied, etc.), each individual mode shall be enabled and applicable parameters (that is, room supply, room total exhaust, etc.) shall be performed for each separate mode. Room ambient conditions (temperature, humidity, air currents, etc.) shall also be measured to ensure they are being maintained under the conditions specified.	Also see *Appendix 4 - Audit Form in ANSI/AIHA Z9.5-2003,* which provides a comprehensive checklist for the Laboratory Ventilation Management Program including Commissioning Tests.

Topic	Requirement(s)	Commentary
Evaluating VAV (Variable Air Volume) Systems	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **6.5.3** VAV hood systems shall be commissioned prior to use by laboratory personnel to ensure that all system components function properly and the system operates as designed under all anticipated operating modes. The commissioning procedure for VAV systems shall include: • Verification of VAV sensor calibration; • VAV Hood performance Tests; • VAV Laboratory and Ventilation System Tests; and • Verification of System Diversity *(See VAV Diversity on the next page.)* **6.5.3.1** VAV sensors shall be capable of accurate measurements and control within 10% of actual at the design maximum and minimum flow conditions. **6.5.3.2** In addition to hood performance tests described for evaluation of CAV hood systems, commissioning tests on VAV hood systems shall include measurement of flow or face velocities at different sash configurations and VAV Response and Stability tests. Flow or face velocity tests shall be conducted at a minimum of two separate sash configurations. VAV Response and Stability tests shall include continuous measurements and recording of flow while opening and closing the sashes for each hood (calibrated flow sensors or measurements of slot velocity within the hood can be used as an indicator of flow. VAV Response shall be sufficient to increase or decrease flow within 90% of the target flow or face velocity in a manner that does not increase potential for escape. VAV stability shall be sufficient to prevent flow variations in excess of 10% from design at each sash configuration or operating mode. **6.5.3.3** The VAV hood controls shall provide stable control of flow in the exhaust and supply ducts and variation of flow must not exceed 10% from design at each sash configuration or operating mode.	VAV ventilation systems need to be properly tested, adjusted and balanced initially and thereafter closely monitored to ensure proper functionality and attainment of the potential energy savings. Also see *Appendix 4 - Audit Form in ANSI/AIHA Z9.5-2003,* which provides a comprehensive checklist for the Laboratory Ventilation Management Program including Commissioning Tests.

Biological Laboratories

Topic	Requirement(s)	Commentary
Biosafety Level 1	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.17, Containment Laboratories:** **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. The laboratory is 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 is neither required nor generally used. The laboratory may be cleaned easily and contains a sink for washing hands. Federal guidelines for these laboratories contain no specific HVAC requirements. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009** ***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. **National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **3 Definitions** **3.3.2 Biosafety Level 1** Practices, safety equipment, and facility design and construction are appropriate for undergraduate and secondary educational training and teaching laboratories and for other laboratories in which work is done with defined and characterized strains of viable microorganisms not known to consistently cause disease in healthy adult humans.	The National Sanitation Foundation (NSF) is a not-for-profit organization best known for its health standards. NSF conducts research, tests and evaluates equipment, products, and services for compliance with NSF standards and criteria. It grants and controls the use of its "NSF" mark NSF essentially repeats the BSL 1 definition from the BMBL.

Topic	Requirement(s)	Commentary
Biosafety Level 2	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.17, Containment Laboratories:** **Biosafety Level 2** is suitable for work involving agents of moderate potential hazard to personnel and the environment. Laboratory access is limited when certain work is in progress. The laboratory may be cleaned easily and contains a sink for washing hands. Biological safety cabinets (Class 1 or II A2) are used whenever • Procedures with a high potential for creating infectious aerosols are conducted • High concentrations or large volumes of infectious agents are used. Most biomedical research laboratories are designed for Bio-safety Level 2. However, the laboratory director must evaluate the risks and determine the correct containment level before design begins. **Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** ***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 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. **National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **3 Definitions** **3.3.2 Biosafety Level 2** Practices, equipment, and facilities are applicable to clinical, diagnostic, teaching, and other facilities in which work is done with the broad spectrum of indigenous moderate-risk agents present in the community and associated with human disease of varying severity. With good microbiological techniques, these agents can be used safely in activities conducted on the open bench, if the potential for producing aerosols is low. Hepatitis B virus, human immunodeficiency virus, the *salmonellae*, and *Toxoplasma spp*. are representative of microorganisms assigned to this containment level. Biosafety Level 2 is appropriate when work is done with any human-derived blood, body fluids, tissues, or primary human cell lines where the presence of an infectious agent may be unknown. (Laboratory personnel working with human-derived materials should refer to the OSHA *Bloodborne Pathogen Standard* for specific required precautions.)	The vast majority of biological laboratories operate at BSL-2. NSF essentially repeats the BSL 2 definition from the BMBL.

Topic	Requirement(s)	Commentary
Biosafety Level 3	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.17, Containment Laboratories:** **Biosafety Level 3** applies to facilities in which work is done with indigenous or exotic agents that may cause serious or potentially lethal disease as a result of exposure by inhalation. The Biosafety Level 3 laboratory uses a physical barrier of two sets of self-closing doors to separate the laboratory work area from areas with unrestricted personnel access. This barrier enhances biological containment to within the laboratory work area. All procedures involving the manipulation of infectious materials are conducted inside biological safety cabinets. The engineer must ensure that the connection of the cabinets to the exhaust system does not adversely affect the performance of the biological safety cabinets or the exhaust system. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** ***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 of 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. A BSL-3 laboratory has special engineering and design features All procedures involving the manipulation of infectious materials must be conducted within BSCs or other physical containment devices. Laboratory doors must be self-closing and have locks in accordance with the institutional policies. The laboratory must be separated from areas that are open to unrestricted traffic flow within the building. Laboratory access is restricted. Access to the laboratory is through two self-closing doors. A clothing change room (anteroom) may be included in the passageway between the two self-closing doors. All windows in the laboratory must be sealed. A ducted air ventilation system is required. This system must provide sustained directional airflow by drawing air into the laboratory from “clean” areas toward “potentially contaminated” areas. The laboratory shall be designed such that under failure conditions the airflow will not be reversed. a. Laboratory personnel must be able to verify directional airflow. A visual monitoring device, which confirms directional airflow, must be provided at the laboratory entry. Audible alarms should be considered to notify personnel of air flow disruption. (Continued on Next Page)	BSL-3 laboratories are not very common, but it is not unusual to find a few of them on the campus of a major university. Note that the authors of the 2009 edition of BMBL may not have realized that their statement *“under failure conditions the airflow will not be reversed”* can be (and apparently has been) interpreted by the industry to mean that no reverse airflow can take place even for a second regardless of the situation. Such an interpretation would require extremely expensive power backup systems and perhaps redundant HVAC to handle a seemingly very short transient period. This may not be the consensus opinion of the BMBL committee. Also refer to the requirements of NFPA 45 (page 115) for insight into this situation.

Topic	Requirement(s)	Commentary
Biosafety Level 3 (Continued)	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **3 Definitions** **3.3. 3 Biosafety Level 3** Practices, safety equipment, and facility design and construction are applicable to clinical, diagnostic, teaching, research, or production facilities in which work is done with indigenous or exotic agents with a potential for respiratory transmission and that may cause serious and potentially lethal infection. *Mycobacterium tuberculosis*, St. Louis encephalitis virus, and *Coxiella burnetii* are representative of the microorganisms assigned to this level. Primary hazards to personnel working with these agents relate to autoinoculation, ingestion, and exposure to infectious aerosols. At Biosafety Level 3, more emphasis is placed on primary and secondary barriers to protect personnel in contiguous areas, the community, and the environment from exposure to potentially infectious aerosols. For example, all laboratory manipulations should be performed in a BSC or other enclosed equipment, such as a gas-tight aerosol generation chamber. Secondary barriers for this level include controlled access to the laboratory and ventilation requirements that minimize the release of infectious aerosols from the laboratory.	

Topic	Requirement(s)	Commentary
Biosafety Level 4	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.17, Containment Laboratories:** **Biosafety Level 4** is required for work with dangerous and exotic agents that pose a high risk of aerosol transmitted laboratory infections and life-threatening disease. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** ***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 There are two models for BSL-4 laboratories: BSL-4 cabinet and suit laboratories have special engineering and design features to prevent microorganisms from being disseminated into the environment. 1. *Cabinet Laboratory*- The BSL-4 cabinet laboratory consists of either a separate building or a clearly demarcated and isolated zone within a building. Laboratory doors must have locks in accordance with the institutional policies. Manipulation of agents must be performed in a Class III BSC. Rooms in the facility must be arranged to ensure sequential passage through an inner (dirty) changing area, a personal shower and an outer (clean) change room upon exiting the room(s) containing the Class III BSC(s). If Class II BSCs are needed in the cabinet laboratory, they must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. Class II cabinets should be located away from doors, heavily traveled laboratory areas, and other possible airflow disruptions. All penetrations in the internal shell of the laboratory and inner change room must be sealed and doors equipped with gaskets. An automatically activated emergency power source must be provided at a minimum for the laboratory exhaust system, life support systems, alarms, lighting, entry and exit controls, BSCs, and door gaskets. Monitoring and control systems for air supply, exhaust, life support, alarms, entry and exit controls, and security systems should be on an uninterrupted power supply (UPS). 2. *Suit Laboratory* The BSL-4 suit laboratory consists of either a separate building or a clearly demarcated and isolated zone within a building. Laboratory doors must have locks in accordance with the institutional policies. Rooms in the facility must be arranged to ensure exit by sequential passage through the chemical shower, inner (dirty) change room, personal shower, and outer (clean) changing area.-Personnel must wear a positive pressure supplied air protective suit. All manipulations of infectious agents must be performed within a BSC or other primary barrier system. An automatically activated emergency power source must be provided, at a minimum, for the laboratory exhaust system, life support systems, alarms, lighting, entry and exit controls, BSCs, and door gaskets (Continued on Next Page)	BSL 4 laboratories are extremely rare. **These are very special facilities.** Level 4 laboratories are extremely sophisticated facilities in terms of the physical layout, the types systems required, assurance of performance, and failure modes.

Topic	Requirement(s)	Commentary
Biosafety Level 4 (Continued)	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **3 Definitions** **3.3. 4 Biosafety Level** 4 Practices, safety equipment, and facility design and construction are applicable for work with dangerous and exotic agents that have a high individual risk of life-threatening disease, which may be transmitted via the aerosol route and for which there is no available vaccine or therapy. Agents with a close or identical antigenic relationship to Biosafety Level 4 agents also should be handled at this level. When sufficient data are obtained, work with these agents may continue at this level or at a lower level. Viruses such as Marburg or Congo-Crimean hemorrhagic fever are manipulated at Biosafety Level 4. The primary hazards to personnel working with Biosafety Level 4 agents are respiratory exposure to infectious aerosols, mucous membrane or broken skin exposure to infectious droplets, and autoinoculation. All manipulations of potentially infectious diagnostic materials, isolates, and naturally or experimentally infected animals pose a high risk of exposure and infection to laboratory personnel, the community, and the environment. The laboratory worker's complete isolation from aerosolized infectious materials is accomplished primarily by working in a Class III BSC or in a full-body, air-supplied, positive-pressure personnel suit. The Biosafety Level 4 facility itself is generally a separate building or completely isolated zone with complex, specialized ventilation requirements and waste management systems to prevent release of viable agents to the environment. A dedicated non-recirculating ventilation system is provided. Only laboratories with the same HVAC requirements (i.e., other BSL-4 labs, ABSL-4, BSL-3-Ag labs) may share ventilation systems if gas-tight dampers and HEPA filters isolate each individual laboratory system. The supply and exhaust components of the ventilation system must be designed to maintain the laboratory at negative pressure to surrounding areas and provide differential pressure or directional airflow, as appropriate, between adjacent areas within the laboratory. Redundant supply fans are recommended. Redundant exhaust fans are required. Supply and exhaust fans must be interlocked to prevent positive pressurization of the laboratory. The ventilation system must be monitored and alarmed to indicate malfunction or deviation from design parameters. A visual monitoring device must be installed near the clean change room so proper differential pressures within the laboratory may be verified prior to entry.	NSF essentially repeats the BSL definitions from the BMBL.

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 1	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 14.16, Containment Laboratories:** Federal guidelines for these laboratories contain no specific HVAC requirements. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** Special containment equipment or facility design is not required, but may be used as determined by appropriate risk assessment.	

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 2	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 14.16, Containment Laboratories:** **Biosafety Level 2** Federal guidelines for these laboratories contain minimum facility guidelines….however typical HVAC design criteria can include the following: • 100% outdoor air systems • 6 to 15 air changes per hour • Directional airflow into the laboratory rooms • Site-specified hood face velocity at fume hoods (many institutions specify 80 to 100 fpm) • An assessment of research equipment heat load in a room. • Inclusion of biological safety cabinets **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** There are no specific requirements for ventilation systems. However, planning of new facilities should consider mechanical ventilation systems that provide an inward flow of air without recirculation to spaces outside of the laboratory. BSCs must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. BSCs should be located away from doors, windows that can be opened, heavily traveled laboratory areas, and other possible airflow disruptions 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. HEPA filtered exhaust air from a Class II BSC can be safely recirculation back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.11.3 BL-2 b. Directional Airflow:** All laboratories shall have single-pass air. The airflow shall be directed from clean areas to potentially contaminated areas and from low-hazard to high-hazard area. Air supply diffusers must be supplied with diffusers to direct air away from fume hoods and BSCs in order to minimize potential disruptive air currents.	Ventilation systems serving laboratories with a BL2 or higher classification should be designed to allow easy access for regular inspection, testing and adjustment without the necessity to disturb or upset the laboratory function. Locating ventilation components (terminal units, filters, distribution ducts, etc.) in an interstitial space is recommended. The AIA requires directional air flow. However, the CDC only suggests it.

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 3	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 14.16, Containment Laboratories:** The ventilation system must be single pass, nonrecirculating and configures to maintain the laboratory at negative pressure relative to surrounding areas. Audible alarms and visual monitoring devices are recommended to notify personnel if the laboratory pressure relationship changes from a negative to a positive condition. The user may wish to have alarms reported to a remote constantly monitored location. Gastight dampers are required in the supply and exhaust ductwork to allow decontamination of the laboratory. The ductwork between these dampers and the laboratory must also be gastight. All penetrations of the Biosafety Level 3 laboratory envelope must be sealable for containment and to facilitate gaseous decontamination of the work area. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** A BSL-3 laboratory has special engineering and design features All procedures involving the manipulation of infectious materials must be conducted within BSC's or other physical containment devices. BSC's must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. BSCs should be located away from doors, heavily traveled laboratory areas, and other possible airflow disruptions. A ducted air ventilation system is required. This system must provide sustained directional airflow by drawing air into the laboratory from "clean" areas toward "potentially contaminated" areas. The laboratory shall be designed such that under failure conditions the airflow will not be reversed. The laboratory exhaust air must not re-circulate to any other area of the building. The laboratory building exhaust air should be dispersed away from occupied areas and from building air intake locations or the exhaust air must be HEPA filtered. 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. 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 Laboratory personnel must be able to verify directional airflow. A visual monitoring device, which confirms directional airflow, must be provided at the laboratory entry. Audible alarms should be considered to notify personnel of air flow disruption. (Continued on Next Page)	The need to seal the laboratory for decontamination sometimes adds components such as filters and shut-off dampers to the ventilation system. In some cases, it also leads to a very tight room envelope, which affects design of the pressurization system. As a practical matter, it is helpful if the facility operators using the Building Automation System, get the same pressurization information that the laboratory workers see at the entry.

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 3 *(Continued)*	**American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.11.4 BL-3 b. Containment Requirements:** Laboratories require all of the design considerations for BL-2 laboratories plus specific requirements for additional containment of those bio-hazardous materials used in the laboratory. Ventilation must be single-pass air, and all BL-3 space must be kept negative with respect to outside corridors and laboratories. Exhaust ducts must be under negative pressure until the air is discharged outside the building. Supply and exhaust ducts for BL-3 laboratories must be supplied with gas-tight dampers to maintain the capability of gas decontamination of the laboratory without compromising the rest of the building. Ductwork between the laboratory and the damper must be gas tight. **n. Alarms:** BL-3 facilities must be designed to ensure notification of inappropriate directional airflows. Both visual (gauges) and audible local alarms are acceptable. In addition, alarms indicating the potential failure of BL-3 containment shall be tied to a central system at the Building Engineer's office, where possible. Notification devices shall indicate the failure to maintain a negative pressure differential between a non-contaminated area and potentially contaminated areas. All alarm systems shall be validated prior to occupancy of the containment space by research personnel. **o. Filtration of Laboratory Exhaust:** The need for HEPA filtration shall be determined on a case by case basis in consultation with the facility safety personnel and shall be based on a hazard assessment of the materials in use and the procedures to be performed. **p. Autoclave Exhaust Filtration:** The exhaust from an autoclave contains a significant amount of moisture, and exhaust ductwork shall be designed accordingly. Filtration of this exhaust, when necessary, (as determined above in Filtration of Laboratory Exhaust) must be through a moisture-resistant (hydrophobic) filter such as a 0.2 micron filter or equivalent. Filtration of moist exhaust through a cold filter housing containing a paper HEPA filter will result in the destruction of the HEPA filter and a break in integrity. **q. HEPA Filter Housings:** When installed, HEPA filter exhaust housings must be constructed in such a manner as allow for appropriate particulate testing (that is, DOP or equivalent) and must be capable of being isolated from the ventilation system for gas decontamination and testing (that is, gas-tight dampers and housings). Facility safety personnel must be consulted with regard to the suitability of the decontamination mechanism design and approve the system prior to finalization of the design.	While BMBL requires sealable penetrations" AIA specifies gas-tight dampers and ducts.

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 4, Cabinet Laboratory	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 14.16, Containment Laboratories:** Ventilation systems for these areas will have stringent design requirements that must be determined by the biological safety officer. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** A dedicated non-recirculating ventilation system must be provided. Only laboratories with the same HVAC requirements (i.e., other BSL-4 labs, ABSL-4, BSL-3-Ag labs) may share ventilation systems if gas-tight dampers and HEPA filters isolate each individual laboratory system. The supply and exhaust components of the ventilation system must be designed to maintain the laboratory at negative pressure to surrounding areas and provide differential pressure or directional airflow, as appropriate, between adjacent areas within the laboratory. Redundant supply fans are recommended. Redundant exhaust fans are required. Supply and exhaust fans must be interlocked to prevent positive pressurization of the laboratory. The ventilation system must be monitored and alarmed to indicate malfunction or deviation from design parameters. A visual monitoring device must be installed near the clean change room so proper differential pressures within the laboratory may be verified prior to entry. Supply air to and exhaust air from the cabinet room, inner change room, and fumigation/decontamination chambers must pass through HEPA filter(s). The air exhaust discharge must be located away from occupied spaces and building air intakes. Class III BSCs must be directly and independently exhausted through two HEPA filters in series. Supply air must be provided in such a manner that prevents positive pressurization of the cabinet. If Class II BSCs are needed in the cabinet laboratory, they must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. 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 the manufacturer's recommendations. If BSC exhaust is to be recirculated to the outside, BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or a hard ducted, direct connection ensuring that cabinet exhaust air passes through two (2) HEPA filters—including the HEPA in the BSC—prior to release outside. Provisions to assure proper safety cabinet performance and air system operation must be verified.	As a practical matter, it is helpful if the facility operators using the Building Automation System, get the same pressurization information that the laboratory workers see at the entry.

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 4, Suit Laboratory	**U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** An automatically activated emergency power source must be provided, at a minimum, for the laboratory exhaust system, life support systems, alarms, lighting, entry and exit controls, BSCs, and door gaskets. Monitoring and control systems for air supply, exhaust, life support, alarms, entry and exit controls, and security systems should be on a UPS. BSCs and other primary containment barrier systems must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations. BSCs should be located away from doors, heavily traveled laboratory areas, and other possible airflow disruptions. A dedicated, non-recirculating ventilation system is provided. Only laboratories with the same HVAC requirements (i.e., other BSL-4 labs, ABSL-4, BSL-3 Ag labs) may share ventilation systems if gas-tight dampers and HEPA filters isolate each individual laboratory system. The supply and exhaust components of the ventilation system must be designed to maintain the laboratory at negative pressure to surrounding areas and provide differential pressure or directional airflow as appropriate between adjacent areas within the laboratory. Redundant supply fans are recommended. Redundant exhaust fans are required. Supply and exhaust fans must be interlocked to prevent positive pressurization of the laboratory. The ventilation system must be monitored and alarmed to indicate malfunction or deviation from design parameters. A visual monitoring device must be installed near the clean change room so proper differential pressures within the laboratory may be verified prior to entry. Supply air to the laboratory, including the decontamination shower, must pass through a HEPA filter. All exhaust air from the suit laboratory, decontamination shower and fumigation or decontamination chambers must pass through two HEPA filters, in series, before discharge to the outside. The exhaust air discharge must be located away from occupied spaces and air intakes. All HEPA filters must be located as near as practicable to the laboratory in order to minimize the length of potentially contaminated ductwork. All HEPA filters must be tested and certified annually. The HEPA filter housings must be designed to allow for *in situ* decontamination and validation of the filter prior to removal. The design of the HEPA filter housing must have gas-tight isolation dampers, decontamination ports, and ability to scan each filter assembly for leaks. (Continued on Next Page)	As a practical matter, it is helpful if the facility operators using the Building Automation System, get the same pressurization information that the laboratory workers see at the entry.

Topic	Requirement(s)	Commentary
Ventilation for Biosafety Level 4, Suit Laboratory *(Continued)*	HEPA filtered exhaust air from a Class II BSC can be safely re-circulated back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to the manufacturer's recommendations. Biological safety cabinets can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or a direct (hard) connection. Provisions to assure proper safety cabinet performance and air system operation must be verified.	

Topic	Requirement(s)	Commentary
Containment Levels - Canada	**Public Health Agency of Canada, Office of Laboratory Security, Biosafety Division, Laboratory Biosafety Guidelines, 3rd Edition 2011:** **Containment level 1 (CL1)** CL1 requires no special design features beyond those suitable for a well-designed and functional laboratory. Biological safety cabinets (BSC's) are not required. Work may be done on an open bench top, and containment is achieved through the use of practices normally employed in a basic microbiology laboratory. **Containment level 2 (CL2)** The primary exposure hazards associated with organisms requiring CL2 are through the ingestion, inoculation and mucous membrane route. Agents requiring CL2 facilities are not generally transmitted by airborne routes, but care must be taken to avoid the generation of aerosols (aerosols can settle on bench tops and become an ingestion hazard through contamination of the hands) or splashes. Primary containment devices such as BSC's and centrifuges with sealed rotors or safety cups are to be used as well as appropriate personal protective equipment (that is, gloves, laboratory coats, protective eyewear). As well, environmental contamination must be minimized by the use of handwashing sinks and decontamination facilities (autoclaves). **Containment Level 3 (CL3)** These agents may be transmitted by the airborne route, often have a low infectious dose to produce effects and can cause serious or life-threatening disease. CL3 emphasizes additional primary and secondary barriers to minimize the release of infectious organisms into the immediate laboratory and the environment. Additional features to prevent transmission of CL3 organisms are appropriate respiratory protection, HEPA filtration of exhausted laboratory air and strictly controlled laboratory access. **Containment Level 4 (CL4)** These agents have the potential for aerosol transmission, often have a low infectious dose and produce very serious and often fatal disease; there is generally no treatment or vaccine available. This level of containment represents an isolated unit, functionally and, when necessary, structurally independent of other areas. CL4 emphasizes maximum containment of the infectious agent by complete sealing of the facility perimeter with confirmation by pressure decay testing; isolation of the researcher from the pathogen by his or her containment in a positive pressure suit or containment of the pathogen in a Class III BSC line; and decontamination of air and other effluents produced in the facility. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Containment Levels and Ventilation Requirements: Canada	**Public Health Agency of Canada, Office of Laboratory Security, Biosafety Division, Laboratory Biosafety Guidelines, 3rd Edition 2011:** **Containment level 1 (CL1)** No special ventilation features are required. **Containment level 2 (CL2)** 1. 100% Outside air is recommended for room ventilation **Containment Level 3 (CL3)** 1. 100% Outside air for room ventilation 2. Directional inward airflow provided such that air will always flow towards areas of higher containment (e.g., ± 25 Pa differential). 3. Visual pressure differential monitoring devices to be provided at entry to containment laboratory. 5. Alarm (visual or audible) to be provided in the laboratory and outside laboratory area (that is, to warn others and maintenance personnel) to signal air handling systems failure. 6. Where determined necessary by a local risk assessment, supply air duct to be provided with backdraft protection (that is, HEPA filter; bubble tight backdraft damper). 8. Supply air system to be independent of other laboratory areas. CL3 supply can be combined with areas of lower containment when provided with backdraft protection (that is, HEPA filter, bubble tight backdraft damper) downstream from the connection. (For CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation this criterion is only recommended.) 9. Supply air system to be interlocked (that is, fans, dampers, electrical) with exhaust air system, to prevent sustained laboratory positive pressurization. 10. Exhaust air to be HEPA filtered. (CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation are not required to fulfill this criterion.) 12. HEPA filters installed in the supply and exhaust system to conform to the requirements of*: HEPA and ULPA filters. IEST-RP-CC001.3. Rolling Meadows, IL: The Institute of Environmental Science and Technology, 1993.* 14. Where HEPA filters are used for backdraft protection in accordance with local risk assessment, supply HEPA filter housings to be designed to withstand structural change at applied pressure of 2500 Pa [10 in. w.g.]. 15. Exhaust HEPA filter housings to be designed to withstand structural change at applied pressure of 2500 Pa [10 in. w.g.] and to be provided with a method of isolation and decontamination. For CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation this criterion is only recommended. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Containment Levels and Ventilation Requirements: Canada *(Continued)*	**Containment Level 3 (CL3) (Continued)** 16. Exhaust air system to be independent of other laboratory areas. CL3 exhaust can be combined with areas of lower containment when provided with a HEPA filter upstream from the connection. (For CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation this criterion is only recommended.) 17. It is recommended that supply and exhaust systems be located outside of containment to be accessible for repairs, maintenance, cleaning and inspection. 19. Where backdraft protection is required in accordance with local risk assessment, supply air ductwork that is outside the containment perimeter (e.g., between containment perimeter and HEPA filter or bubble tight backdraft damper) to be sealed airtight in accordance with: *Seal Class A, HVAC Air Duct Leakage Test Manual, 1985. Sheet Metal and Air Conditioning Contractors National Association Inc., (SMACNA), Chantilly, Virginia.* 20. Exhaust air ductwork that is outside the containment perimeter (e.g., between containment perimeter and HEPA filter or bubble tight backdraft damper) to be sealed airtight in accordance with: *Seal Class A, HVAC Air Duct Leakage Test Manual, 1985. Sheet Metal and Air Conditioning Contractors National Association Inc., (SMACNA), Chantilly, Virginia.* (CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation are not required to fulfill this criterion.) 21. Airflow control devices and duct sensors located downstream of the exhaust HEPA filter and upstream of the supply bubble tight backdraft damper or HEPA filter, or if located upstream, duct penetrations to be sealed in accordance with: *Seal Class A, HVAC Air Duct Leakage Test Manual, 1985. Sheet Metal and Air Conditioning Contractors National Association Inc., (SMACNA), Chantilly, Virginia.* (CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation are not required to fulfill this criterion.) 22. Bubble tight backdraft dampers and HEPA filters to be located in close proximity to the containment perimeter. (CL3 laboratories manipulating organisms, such as HIV, that are not infectious via inhalation are not required to fulfill this criterion.) *(*Continued on Next Page)	Although the phraseology regarding the location of duct penetrations that need to be sealed is rather ambiguous, it would be good practice to seal all control device duct penetrations as well as duct penetrations made for any other purpose.

Topic	Requirement(s)	Commentary
Containment Levels and Ventilation Requirements: Canada *(Continued)*	**Containment Level 4 (CL4)** 1. 100% Outside air for room ventilation 2. Directional inward airflow provided such that air will always flow towards areas of higher containment (e.g., ± 25 Pa differential). 3. Visual pressure differential monitoring devices to be provided at entry to containment laboratory. 4. Room pressure differential monitoring lines penetrating the containment barrier to be provided with filters of efficiency equal to that of HEPA filtration. 5. Alarm (visual or audible) to be provided in the laboratory and outside laboratory area (that is, to warn others and maintenance personnel) to signal air handling systems failure. 7. Supply air to be HEPA filtered. 8. Supply air system to be independent of other laboratory areas. 9. Supply air system to be interlocked (that is, fans, dampers, electrical) with exhaust air system, to prevent sustained laboratory positive pressurization. 10. Exhaust air to be HEPA Filtered 11. Exhaust air to pass through two stages of HEPA filtration. 12. HEPA filters installed in the supply and exhaust system to conform to the requirements of*: HEPA and ULPA filters. IEST-RP-CC001.3. Rolling Meadows, IL: The Institute of Environmental Science and Technology, 1993.* 13. Supply HEPA filter housings to be designed to withstand structural change at applied pressure of 2500 Pa [10 in. w.g.]. 15. Exhaust HEPA filter housings to be designed to withstand structural change at applied pressure of 2500 Pa [10 in. w.g.] and to be provided with a method of isolation and decontamination. 16. Exhaust air system to be independent of other laboratory areas. 17. Supply and exhaust systems to be located outside of containment to be accessible for repairs, maintenance, cleaning and inspection. 18. Supply air ductwork that is outside the containment perimeter (e.g., between containment perimeter and HEPA filter or bubble tight backdraft damper) to be sealed airtight in accordance with: *Seal Class A, HVAC Air Duct Leakage Test Manual, 1985. Sheet Metal and Air Conditioning Contractors National Association Inc., (SMACNA), Chantilly, Virginia*. 20. Exhaust air ductwork that is outside the containment perimeter (e.g., between containment perimeter and HEPA filter or bubble tight backdraft damper) to be sealed airtight in accordance with: SMACNA Seal Class A *(as listed above).* (Continued on Next Page)	

Term	Definition	Commentary
Containment Levels and Ventilation Requirements: Canada *(Continued)*	21. Airflow control devices and duct sensors located downstream of the exhaust HEPA filter and upstream of the supply bubble tight backdraft damper or HEPA filter, or if located upstream, duct penetrations to be sealed in accordance with: 22. Bubble tight backdraft dampers and HEPA filters to be located in close proximity to the containment perimeter.	Although the phraseology regarding the location of duct penetrations that need to be sealed is rather ambiguous, it would seem to be good practice to seal all control device duct penetrations as well as duct penetrations made for any other purpose.

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications	**U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** ***CLASS I*** The Class I BSC provides personnel and environmental protection, but no product protection. It is similar in terms of air movement to a chemical fume hood, but has a HEPA filter in the exhaust system to protect the environment. In the Class I BSC, unfiltered room air is drawn in through the work opening and across the work surface. Personnel protection is provided by this inward airflow as long as a minimum velocity of 75 linear feet per minute (lfm) is maintained[6] through the front opening. Because product protection is provided by the Class II BSCs, general usage of the Class I BSC has declined. However, in many cases, Class I BSCs are used specifically to enclose equipment (e.g., centrifuges, harvesting equipment or small fermenters), or procedures with potential to generate aerosols (e.g., cage dumping, culture aeration or tissue homogenation). The classical Class I BSC is hard-ducted (i.e., direct connection) to the building exhaust system and the building exhaust fan provides the negative pressure necessary to draw room air into the cabinet. Cabinet air is drawn through a HEPA filter as it enters the cabinet exhaust plenum. A second HEPA filter may be installed at the terminal end of the building exhaust system prior to the exhaust fan. Some Class I BSCs are equipped with an integral exhaust fan. The cabinet exhaust fan must be interlocked with the building exhaust fan. In the event that the building exhaust fan fails, the cabinet exhaust fan must turn off so that the building exhaust ducts are not pressurized. If the ducts are pressurized and the HEPA filter has developed a leak, contaminated air could be discharged into other parts of the building or the environment. The use of two filters in the cabinet increases the static pressure on the fan. A panel with openings to allow access for the hands and arms to the work surface can be added to the Class I cabinet. The restricted opening results in increased inward air velocity, increasing worker protection. For added safety, arm-length gloves can be attached to the panel. Makeup air is then drawn through an auxiliary air supply opening (which may contain a filter) and/or around a loose-fitting front panel. (Continued on Next Page.)	Note that Class I BSCs are currently being manufactured on a limited basis; many have been replaced by Class II BSCs.

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	Some Class I models used for animal cage changing are designed to allow recirculation of air into the room after HEPA filtration and may require more frequent filter replacement due to filter loading and odor from organic materials captured on the filter. This type of Class I BSC should be certified annually for sufficient airflow and filter integrity. ***CLASS II*** As biomedical researchers began to use sterile animal tissue and cell culture systems, particularly for the propagation of viruses, cabinets were needed that also provided product protection. In the early 1960s, the "laminar flow" principle evolved. Unidirectional air moving at a fixed velocity along parallel lines was demonstrated to reduce turbulence resulting in predictable particle behavior. Biocontainment technology also incorporated this laminar flow principle with the use of the HEPA filter to aid in the capture and removal of airborne contaminants from the air stream.[7] This combination of technologies serves to help protect the laboratory worker from potentially infectious aerosols[4] generated within the cabinet and provides necessary product protection, as well. Class II BSCs are partial barrier systems that rely on the directional movement of air to provide containment. As the air curtain is disrupted (e.g., movement of materials in and out of a cabinet, rapid or sweeping movement of the arms) the potential for contaminant release into the laboratory work environment is increased, as is the risk of product contamination. The Class II (Types A1, A2, B1 and B2)[8] BSCs provide personnel, environmental and product protection. Airflow is drawn into the front grille of the cabinet, providing personnel protection. In addition, the downward flow of HEPA-filtered air provides product protection by minimizing the chance of cross-contamination across the work surface of the cabinet. Because cabinet exhaust air is passed through a certified HEPA filter, it is particulate-free (environmental protection), and may be recirculated to the laboratory (Type A1 and A2 BSCs) or discharged from the building via a canopy or "thimble" connected to the building exhaust. Exhaust air from Types B1 and B2 BSCs must be discharged directly to the outdoors via a hard connection. HEPA filters are effective at trapping particulates and thus infectious agents but do not capture volatile chemicals or gases. Only Type A2-exhausted or Types B1and B2 BSCs exhausting to the outside should be used when working with volatile, toxic chemicals, but amounts must be limited. All Class II cabinets are designed for work involving microorganisms assigned to biosafety levels 1, 2, 3 and 4.[1] Class II BSCs provide the microbe-free work environment necessary for cell culture propagation and also may be used for the formulation of nonvolatile antineoplastic or chemotherapeutic drugs.[9] Class II BSCs may be used with organisms requiring BSL-4 containment in a BSL-4 suit laboratory by a worker wearing a positive pressure protective suit. (Continued on Next Page.)	

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications: (Continued)	***The Class II, Type A1 BSC****:* An internal fan draws sufficient room air through the front grille to maintain a minimum calculated or measured average inflow velocity of at least 75 lfm at the face opening of the cabinet. The supply air flows through a HEPA filter and provides particulate-free air to the work surface. Airflow provided in this manner reduces turbulence in the work zone and minimizes the potential for cross-contamination. The downward moving air "splits" as it approaches the work surface; the fan[6] draws part of the air to the front grille and the remainder to the rear grille. Although there are variations among different cabinets, this split generally occurs about halfway between the front and rear grilles and two to six inches above the work surface. The air is drawn through the front and rear grilles by a fan pushed into the space between the supply and exhaust filters. Due to the relative size of these two filters, approximately 30% of the air passes through the exhaust HEPA filter and 70% recirculates through the supply HEPA filter back into the work zone of the cabinet. Most Class II, Type A1 and A2 cabinets have dampers to modulate this division of airflow. A Class II Type A1 BSC is not to be used for work involving volatile toxic chemicals. The buildup of chemical vapors in the cabinet (by recirculated air) and in the laboratory (from exhaust air) could create health and safety hazards. The proper method of connecting a Type A1 or A2 cabinet to the building exhaust system is through use of a canopy hood,[8,10] which provides a small opening or air gap (usually 1 inch) around the cabinet exhaust filter housing (Figure 4). The airflow of the building exhaust must be sufficient to maintain the flow of room air into the gap between the canopy unit and the filter housing. The canopy must be removable or be designed to allow for operational testing of the cabinet. Class II Type A1 or A2 cabinets should never be hard-ducted to the building exhaust system.[8] Fluctuations in air volume and pressure that are common to all building exhaust systems sometimes make it difficult to match the airflow requirements of the cabinet. ***The Class II, Type B1 BSC****:* Some biomedical research requires the use of small quantities of hazardous chemicals, such as organic solvents or carcinogens. Carcinogens used in cell culture or microbial systems require both biological and chemical containment. The Class II, Type B cabinet was designed for manipulations of minute quantities of hazardous chemicals with *in vitro* biological systems. The cabinet supply blowers draw room air (plus a portion of the cabinet's recirculated air) through the front grille and through the supply HEPA filters located immediately below the work surface. This particulate-free air flows upward through a plenum at each side of the cabinet and then downward to the work area through a backpressure plate. In some cabinets, there is an additional supply HEPA filter to remove particulates that may be generated by the blower-motor system. (Continued on Next Page	

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	Room air is drawn through the face opening of the cabinet at a minimum measured inflow velocity of 100 fpm. As with the Type A1 and A2 cabinets, there is a split in the down-flowing air stream just above the work surface. In the Type B1 cabinet, approximately 70 percent of the down flow air exits through the rear grille, passes through the exhaust HEPA filter, and is discharged from the building. The remaining 30 percent of the down flow air is drawn through the front grille. (Continued on Next Page.) Since the air that flows to the rear grille is discharged into the exhaust system, activities that may generate hazardous chemical vapors or particulates should be conducted toward the rear of the cabinetwork area. Type B1 cabinets must be hard-ducted, preferably to a dedicated, independent exhaust system. As indicated earlier, fans for laboratory exhaust systems should be located at the terminal end of the ductwork to avoid pressuring the exhaust ducts. A failure in the building exhaust system may not be apparent to the user, as the supply blowers in the cabinet will continue to operate. A pressure-independent monitor and alarm should be installed to provide warning and shut off the BSC supply fan, should failure in exhaust airflow occur. Since this feature is not supplied by all cabinet manufacturers, it is prudent to install a sensor such as a flow monitor and alarm in the exhaust system as necessary. To maintain critical operations, laboratories using Type B1 BSCs should connect the exhaust blower to the emergency power supply. ***The Class II, Type B2 BSC:*** This BSC is a total-exhaust cabinet; no air is recirculated within it. This cabinet provides simultaneous primary biological and chemical (small quantity) containment. Consideration must be given to the chemicals used in BSCs as some chemicals can destroy the filter medium, housings and/or gaskets causing loss of containment. The supply blower draws either room or outside air in at the top of the cabinet, passes it through a HEPA filter and down into the work area of the cabinet. The building exhaust system draws air through both the rear and front grills, capturing the supply air plus the additional amount of room air needed to produce a minimum calculated or measured inflow face velocity of 100 fpm. All air entering this cabinet is exhausted, and passes through a HEPA filter prior to discharge to the outside. This cabinet exhausts as much as 1200 cubic feet per minute of conditioned room air making this cabinet expensive to operate. The higher static air pressure required to operate this cabinet also results in additional costs associated with heavier gauge ductwork and higher capacity exhaust fan. The need for the Class II, Type B2 should be justified by the research to be conducted. Should the building exhaust system fail, the cabinet will be pressurized, resulting in a flow of air from the work area back into the laboratory. Cabinets built since the early 1980's usually have an interlock system, installed by the manufacturer, to prevent the supply blower from operating whenever the exhaust flow is insufficient; systems can be retrofitted if necessary. Exhaust air movement should be monitored by a pressure-independent device, such as a flow monitor.	

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	***The Class II, Type A2 BS.C*** *(Formerly called A/B3):* Only when this BSC is ducted to the outdoors does it meet the requirements of the former Class II Type B3.[8] The Type A2 cabinet has a minimum calculated or measured inflow velocity of 100 fpm. All positive pressure contaminated plenums within the cabinet are surrounded by a negative air pressure plenum thus ensuring that any leakage from a contaminated plenum will be drawn into the cabinet and not released to the environment. Minute quantities of volatile toxic chemicals or radionuclide can be used in a Type A2 cabinet only if it exhausts to the outside via a properly functioning canopy connection. ***Class III*** The Class III BSC was designed for work with highly infectious microbiological agents and for the conduct of hazardous operations and provides maximum protection for the environment and the worker. It is a gas-tight (no leak greater than 1x10-7 cc/sec with 1% test gas at 3 inches water gauge enclosure with a non-opening view window. Access for passage of materials into the cabinet is through a dunk tank, that is accessible through the cabinet floor, or double-door pass-through box (e.g., an autoclave) that can be decontaminated between uses. Reversing that process allows materials to be removed from the Class III BSC safely. Both supply and exhaust air are HEPA filtered on a Class III cabinet. Exhaust air must pass through two HEPA filters, or a HEPA filter and an air incinerator, before discharge directly to the outdoors. Class III cabinets are not exhausted through the general laboratory exhaust system. Airflow is maintained by an exhaust system exterior to the cabinet, which keeps the cabinet under negative pressure (minimum of 0.5 inches of water gauge.) Long, heavy-duty rubber gloves are attached in a gas-tight manner to ports in the cabinet to allow direct manipulation of the materials isolated inside. Although these gloves restrict movement, they prevent the user's direct contact with the hazardous materials. The trade-off is clearly on the side of maximizing personal safety. Depending on the design of the cabinet, the supply HEPA filter provides particulate-free, albeit somewhat turbulent, airflow within the work environment. Laminar airflow is not a characteristic of a Class III cabinet. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **3 Definitions** **3.4.1 Class I:** A ventilated cabinet for personnel and environmental protection, having an unrecirculated inward airflow away from the operator that exhausts all air to the atmosphere after filtration through a HEPA filter. Class I cabinets are suitable for work where no product protection is required. NOTE – Although the traditional Class I BSC is exhausted to the atmosphere without recirculation into the lab, it is recognized that some of the benefits of the Class I BSC can be obtained even when the unit's HEPA filtered exhaust is vented back into the laboratory. **3.4.2 Class II**: 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 exhausted air for environmental protection. *NOTE – When toxic chemicals or radionuclides are used as adjuncts to biological studies or pharmaceutical work, Class II cabinets designed and constructed for this purpose should be used.* **3.4.2.1 Class II Type A1 cabinets (formerly designated Type A):** cabinets that: – maintain minimum average inflow velocity of 75 ft/min (0.38 m/s) through the work access opening; – have HEPA filtered downflow air that is a portion of the mixed downflow and inflow air from a common plenum (i. e., a plenum from which a portion of the air is exhausted from the cabinet and the remainder supplied to the work area); – may exhaust HEPA filtered air back into the laboratory or to the environment through an exhaust canopy; and – have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums. *Type A1 cabinets are not suitable for work with volatile toxic chemicals and volatile radionuclides.* (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	**3.4.2.2 Class II, Type A2 cabinets (when exhausted to the environment were formerly designated Type B3):** cabinets that: – maintain a minimum average inflow velocity of 100 ft/min (0.51 m/s) through the work access opening; – have HEPA filtered downflow air that is a portion of the mixed downflow and inflow air from a common exhaust plenum; – may exhaust HEPA filtered air back into the laboratory or to the environment through an exhaust canopy; and – have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums. *Type A2 cabinets used for work with minute quantities of volatile toxic chemicals and tracer amounts of radionuclides required as an adjunct to microbiological studies must be exhausted through properly functioning exhaust canopies.* **3.4.2.3 Class II Type B1 cabinets:** cabinets that: – maintain a minimum average inflow velocity of 100 ft/min (0.51 m/s) through the work access opening; – have HEPA filtered downflow air composed largely of uncontaminated recirculated inflow air – exhaust most of the contaminated downflow air through a dedicated duct exhausted to the atmosphere after passing through a HEPA filter; and – have all biologically contaminated ducts and plenums under negative pressure or surrounded by negative pressure ducts and plenums. *Type B1 cabinets may be used for work treated with minute quantities of volatile toxic chemicals and tracer amounts of 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.* **3.4.2.4 Class II, Type B2 cabinets:** Cabinets that: – maintain a minimum average inflow velocity of 100 ft/min (0.51 m/s) through the work access opening; – 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); – 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 – have all contaminated ducts and plenums under negative pressure or surrounded by directly exhausted (nonrecirculated through the work area) negative pressure ducts and plenums. *Type B2 cabinets may be used for work with volatile toxic chemicals and radionuclides required as adjuncts to microbiological studies.* (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	**3.4.3 Class III:** 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 0.50 in w.g. (120 Pa). Downflow air is drawn into the cabinet through HEPA filters. The exhaust air is treated by double HEPA filtration or by HEPA filtration and incineration. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **8.4.1 Class I Cabinets** • **Description** A ventilated *cabinet* that provides personnel and environmental[4] protection. It is characterized by an unrecirculated inward flow of air away from the operator through a limited fixed access opening. Exhaust air must be HEPA filtered if recirculated back into the laboratory. It may or may not be vented via a remote ventilation system. This cabinet does not offer product protection. **8.4.2 Class II Cabinets** • **Description** A ventilated cabinet that provides personnel, product and environmental[3] protection. It is characterized by a limited fixed inward airflow access opening that provides personnel protection, a vertical downward HEPA filtered work zone that provides product protection and HEPA filtered exhaust providing environmental protection. They are divided into types by the NSF and Identified in Standard 49. **Class II Type A1 cabinets (Formally designated Type A)** • Minimum of 75 FPM (.36m/s) inflow. • HEPA filtered downflow mixed with recycled air. • May exhaust some or all HEPA filtered air back into the laboratory. • May have positive pressure duct system. **Class II Type A2 cabinets (Formally designated Type B3)** • Minimum of 100 FPM (0.5m/s) inflow. • HEPA filtered downflow mixed with recycled air. • May exhaust some or all HEPA filtered air back into the laboratory. • Has negative pressure duct system. (Continued on Next Page)	

[4] Environmental protection requires a HEPA filter in the exhaust air stream prior to release outdoors.

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	**Class II Type B1 cabinets** • Minimum of 100 FPM (0.5m/s) inflow. • HEPA filtered largely uncontaminated recirculated air. • Exhausts most contaminated air to atmosphere through a dedicated duct system. • Has negative pressure duct system or surrounded by a negative pressure duct system. **Class II Type B2 cabinets** • Minimum of 100 FPM (0.5m/s) inflow. • HEPA filtered non-recirculated, downward airflow. • HEPA filtered exhaust air to atmosphere. • Has negative pressure duct system or surrounded by a negative pressure duct system. **8.4.3 Class III Cabinets** • **Description** Provides absolute personnel protection, environmental[5] protection and may provide product protection. It is characterized by a totally enclosed, gas tight. negative pressure, HEPA filtered, ventilated workspace accessed through attached rubber gloves and purged interchange chambers. Exhaust air is treated by double HEPA filtration and/or incineration. **American Conference of Governmental Industrial Hygienists (ACGIH) INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **10.35.2 Biological Safety cabinets** A laboratory hood…could be considered a Class I BSC if the exhausted air is passed through HEPA filters prior to release to the atmosphere. Type A cabinets that discharge into the work area are not recommended for use with gasses or vapors. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 14.6, - 14.8 BIOLOGICAL SAFETY CABINETS** • Class I Similar to chemical fume hood, no research material protection, 100% exhaust through a HEPA filter • Class II Type A1 70% recirculation within the cabinet; 30% exhaust through a HEPA filter; common plenum configuration; can be recirculated into the laboratory • Type A2 70% recirculation within the cabinet; 30% exhaust through a HEPA filter; common plenum configuration; can be recirculated to the room or exhausted to the outside (Continued on Next Page)	

[5] Environmental protection requires a HEPA filtering in the exhaust duct prior to discharging outdoors.

Topic	Requirement(s)	Commentary
Biological Safety Cabinets and Classifications (Continued)	• Type B1 40% recirculation within the cabinet; 60% exhaust through a HEPA filter; separate plenum configuration, must be exhausted to the outside • Type B2 100% exhaust through a HEPA filter to the outside • Class III Special applications; 100% exhaust through a HEPA filter to the outside; researcher manipulates material within cabinet through physical barriers (gloves) A general rule of thumb should be that, if the cross draft or other disruptive room airflow exceeds the velocity of the air curtain at the unit's face, then problems do exist. Drafts from open windows and doors are the most hazardous sources because they can be far in excess of 200 fpm and accompanied by substantial turbulence. Heating and air-conditioning vents perhaps pose the greatest threat to the safety cabinet because they are much less obvious and therefore seldom considered….. It is imperative then that all room airflow sources and patterns be considered before laboratory installation of a safety cabinet. Biological safety cabinets may require periodic decontamination before service and filter replacement. During the decontamination procedure, the cabinet must be isolated or sealed from the laboratory and the exhaust system. The responsible safety officer should be consulted to determine the need for and placement of isolation dampers to facilitate decontamination operations. If provisions for decontamination are necessary, the ventilation system design should maintain laboratory airflow and pressure during the decontamination procedure. **Class I Cabinets** The Class I cabinet is a partial containment device designed for research operations with low and moderate risk etiologic agents. It does not provide protection for materials used in the cabinet. Room airflows through a fixed opening and prevents aerosols that may be generated in the cabinet enclosure from escaping into the room. Depending on cabinet usage, air exhausted through the cabinet may be HEPA filtered prior to being discharged into the exhaust system. The fixed opening through which the researcher works is usually 8 in. high. To provide adequate personnel protection, the air velocity through the fixed opening is usually at least 75 fpm. If approved by the appropriate safety officer, it is possible to modify the Class I cabinet to contain chemical carcinogens by adding appropriate exhaust air treatment and increasing the velocity through the opening to 100 fpm. Large pieces of research equipment can be placed in the cabinet if adequate shielding is provided. The Class I cabinet is not appropriate for containing systems that are vulnerable to airborne contamination because the air flowing into the cabinet is untreated. Also, the Class I cabinet is not recommended for use with highly infectious agents because an interruption of the inward airflow may allow aerosolized particles to escape. (Continued on Next Page)	

Term	Definition	Commentary
Biological Safety Cabinets and Classifications (Continued)	**Class II Cabinets** The Class II cabinets provide protection to personnel, product and the environment. The cabinets feature an open front with inward airflow and HEPA-filtered recirculated exhaust air. The Class II Type A1 cabinet has a fixed opening with a minimum inward airflow velocity of 75 fpm. The average downward velocity is established by the manufacturer and is typically 50 to 80 fpm. The Class II Type A1 cabinet is suitable for use with agents meeting Biosafety Level 2 criteria (DHHS 1999), and, if properly certified, can meet Biosafety Level 3. However, because approximately 70% of the airflow is recirculated, the cabinet is not suitable for use with flammable, toxic, or radioactive agents. The Class II Type A2 cabinet maintains an inward airflow velocity of 100 fpm and is similar in performance to the Class II Type A1. The Class II Type B1 cabinet has a vertical sliding sash and maintains an inward airflow of 100 fpm at a sash opening of 8 inches. The average downward velocity of the internal airflow is typically 50 to 80 fpm. The Class II Type B1 cabinet is suitable for use with agents meeting Biosafety Level 3. Approximately 70% of the internal airflow is exhausted through HEPA filters; this allows the use of biological agents treated with limited quantities of toxic chemicals and trace amounts of radionuclides, provided the work is performed in the direct exhaust area of the cabinet. The Class II Type B2 cabinet maintains an inward airflow velocity of 100 fpm through the work opening. The cabinet is 100% exhausted through HEPA filters to the outdoors. All downward airflow is drawn from the laboratory or other supply source and is HEPA filtered before being introduced into the workspace. The Class II Type B2 cabinet may be used for the same level of work as the Class II Type B1 and is used when the primary consideration is protection of the material inside the hood. In addition, the design permits use of small quantities of toxic chemicals and radionuclides in microbiological studies. In Class II Type A2 cabinets, exhaust air delivered to the outlet of the cabinet by internal blowers must be handled by the laboratory exhaust system. This arrangement requires a delicate balance between the cabinet and the laboratory's exhaust system, and it may incorporate a thimble connection between the cabinet and the laboratory exhaust ductwork. Thimble (or canopy) connections incorporate an air gap between the biological safety cabinet and the exhaust duct. The purpose of the air gap is to buffer the effect of any exhaust system fluctuations on the biological safety cabinet airflow. The exhaust system must pull more air than is exhausted by the biological safety cabinet to make air flow in through the gap. The designer should confirm the amount of air to be drawn through the air gap. A minimum flow is required to provide the specified level of containment, and a maximum flow cannot be exceeded without causing an imbalance through aspiration. In the event of an exhaust system failure, the air gap allows the cabinet to maintain safe intake velocity by exhausting HEPA-filtered air through the air gap. (continued on Next Page)	

Term	Definition	Commentary
Biological Safety Cabinets and Classifications (Continued)	Class II Type B1 and Type B2 cabinets rely on the building exhaust system to pull the air from the cabinet's workspace and through the exhaust HEPA filters. Because containment in this type of cabinet depends on the building's exhaust system, the exhaust fan(s) should have redundant backups. **Class III Cabinets** The Class III cabinet is a gastight, negative pressure containment system that physically separates the agent from the worker. These cabinets provide the highest degree of personnel protection. Work is performed through arm-length rubber gloves attached to a sealed front panel. Room air is drawn into the cabinet through HEPA filters. The American glovebox Society (AGS 2007) indicates that Class III cabinets should be maintained at 0.5 in. of water below ambient pressure. Exhaust flow rate should provide a minimum of 100 fpm inward containment velocity through a glove port opening in the event of a glove being inadvertently removed. HEPA filtration or incineration before discharge to the atmosphere removes or destroys particulate material entrained in the exhaust air. Class III systems can contain highly infectious materials and radioactive contaminants. Although there are operational inconveniences with these cabinets, they are the equipment of choice when a high degree of personnel protection is required. Note that explosions have occurred in Class III cabinets used for research involving volatile substances	
Biosafety Cabinet Applications	(See *Types of Biological Laboratories & Required Type of Biosafety Cabinet – A Summation of Applicable Code & Standards Requirements* on the following page)	The following table provides a comprehensive listing of biological laboratory levels, anticipated hazard, and suitable biological safety cabinets along with the appropriate biosafety cabinet exhaust arrangements. This table is a summation of the descriptions and requirements of all standards that cover biological laboratories and biosafety containment devices.

Types of Biological Laboratories & Required Type of Biosafety Cabinet – A Summation of Applicable Code & Standards Requirements

Laboratory Classification	Biosafety Level 1 (BSL-1)	Biosafety Level 2 (BSL-2)		Biosafety Level 3 (BSL-3)		Biosafety Level 4 (BSL-4)
Potential Hazard & Risk To Workers and Room Occupants:	None to Minimal	Moderate *Appropriate For Use With Human Body Fluids*		Moderate to High *(that is, TB, HIV, Encephalitis)*		Very High *Extremely Lethal Substances - No Known Antidote or Cure*
Class & Type of Biosafety Cabinet Normally Required:	None Required Class I biosafety cabinets are often utilized in BSL-1 labs.	Class II* Type A1	Class II* Type A2	Class II* Type B1	Class II* Type B2	Class III *Use of lower class cabinets requires full body pressure suits.*
Minimum Required Average Face Velocity of Air Entering the Cabinet:	75 fpm (0.38 m/s) *(If Biosafety Cabinets are used)*	75 fpm (0.38 m/s)	100 fpm (0.51 m/s)	100 fpm (0.51 m/s)		100 fpm (0.51 m/s)***
Minimum Amount of Room Makeup Air Required:	100% of face opening input airflow *(if biosafety cabinets are used)*	30% of face opening input airflow		100% of face opening input airflow		100% of face opening input airflow *if class II cabinets are used.*
Type of Cabinet Exhaust Air Arrangement:	HEPA Filtered *(If Class II A1 or A2 biosafety cabinets are used they should not be 'hard ducted" to the outdoors.)*	HEPA Filtered (May use a canopy (thimble) connection to the exhaust duct at the room.)		HEPA Filtered Requires 'hard duct' to the outdoors.		HEPA Filtered Requires 'hard duct' to the outdoors.
Allowable Exhaust Air that may be Recirculated Back into the Laboratory Room:	No Biosafety Cabinet Exhaust may be Recirculated.	70%Maximum Allowed *(HEPA filtering is required for air returned to the room)*		None Allowed		None Allowed
Degree of Protection Normally Provided for the Biological Substances or Agents Present:	*No Protection	Good Protection		Good Protection	Very Good Protection	Total Protection
Method of Protection for the Biological Substances or Agents Present:	None	Recirculated HEPA Filtered Exhaust Air		Recirculated HEPA Filtered Exhaust Air	Non - Recirculated HEPA Filtered Air	Non - Recirculated HEPA Filtered Air and an Environmentally Conditioned Interior
Amount Of Toxic Chemicals and/or Radionuclides that may be Present or Used:	None	**Minute Quantities Only		**Minute Quantities Only	As Needed	As Needed *(Except for Class II B1Cabinets**)*
Environmental Protection: (Applies to the air exhausted from the laboratory and the biosafety cabinets.)	If a biosafety cabinet is utilized a HEPA filter is recommended for the exhaust air.	HEPA Filtered Exhaust		HEPA Filtered Exhaust		HEPA Filtered Exhaust

* Class I Biosafety cabinets may also be used in Laboratories of Biosafety levels 2 & 3 if no contamination protection is required for the biological substance. However a Class I Biosafety Cabinet is not recommended for use with highly infectious agents because an interruption of the inward airflow may allow aerosolized particles to escape.

** Because approximately 70% of the airflow is recirculated, the cabinet is not ideally suitable for use with flammable, toxic, or radioactive agents.

*** The cabinet exhaust and room ventilation system should be able to maintain a minimum of 100 fpm (0.51 m/s) through any opening in a Class III cabinet that may occur such as the inadvertent removal of a glove.

Topic	Requirement(s)	Commentary
Biosafety Cabinets – Installation and Safe Usage Recommendations	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **E.1 Location** **E.1.1** The Class II (laminar flow) biosafety cabinet should be located out of the traffic pattern and away from room air currents that could disrupt the containment provided by the work access opening air barrier. **E.1.2** If there is a window in the laboratory, it should remain closed at all times. Cabinets should not be located where room ventilation air inlets blow across the front opening or onto the exhaust filter. **E.1.3** Where space permits, a 12 in (30 cm) clearance should be provided behind and on each side of the cabinet. If not feasible, a minimum 3 in (8 cm) clearance on each side and 1.5 in (3.8 cm) clearance in back are recommended. The electrical outlet for the cabinet should be accessible for the cabinet service and electrical safety testing without moving the cabinet. **E.2 Recommendations for installation** **E.2.1 Type A1 and A2 cabinets** Type A1 and A2 cabinets are designed to return air to the laboratory and do not generally require external venting. It is critical that a minimum of 3 in (8 cm) clearance be provided between the exhaust opening on top of the cabinet and the ceiling. Less than 3 in (8 cm) clearance constricts the exhaust and reduces the flow into the cabinet at the front access opening. At least 12 in (30 cm) clearance is required between the exhaust opening on top of the cabinet and the ceiling to allow the use of a thermal anemometer to measure the exhaust velocity when calculating the cabinet inflow velocity. When it is desirable to exhaust air to the atmosphere, exhaust should be via a 100% exhaust system (i.e., a system that does not recirculate its exhaust air into other parts of the building). The recommended exhaust system connection for types A1 and A2 cabinets is an exhaust canopy connection. Every canopy design must be tested to determine the airflow rate exhausted by the canopy that will ensure performance. Whenever the cabinet is field certified, the minimum exhaust flow by the canopy should be verified by measurements using the approved instruments and techniques. No type A cabinet should ever be hard connected to an exhaust system. It is preferable that cabinets be installed using an exhaust connection that allows for scan testing of the exhaust HEPA filter. A properly designed and installed exhaust canopy will allow a Type A1 or A2 cabinet to maintain acceptable inflow velocity at the front access opening even when the flow through the exhaust canopy is completely stopped. The performance of the exhaust canopy should be assessed by either the manufacturer of the exhaust canopy or the user to ensure awareness of the performance characteristics of the exhaust canopy with the particular model of cabinet being exhausted. When the exhaust canopy is used to capture hazardous nonparticulate material being exhausted from the cabinet, the exhaust and associated alarm system should meet the same criteria as indicated for the Types B1 and B2 cabinets.	

Topic	Requirement(s)	Commentary
Biosafety Cabinets – Installation and Safe Usage Recommendations (Continued)	When Type A1 and A2 cabinets are found to be directly attached to the exhaust system and vented to the outside without the use of an exhaust canopy, it is recommended that the exhaust connection be modified to an exhaust canopy. **E.2.2 Types B1 and B2 cabinets** Type B1 and B2 cabinets are to be vented outside the building without recirculation. The venting system should include a leak-tight duct, a damper in the duct near the cabinet to permit flow adjustment closure and decontamination, and an external exhaust fan as the final system component. The exhaust fan should be sized to deliver the required exhaust airflow (as specified by the cabinet manufacturer), considering pressure losses in the duct and allowing at least 2 in w.g. (500 Pa) for a dirty HEPA filter. If a charcoal filter is used downstream of the HEPA filter, an additional pressure capacity equal to the manufacturer's recommended resistance should be provided. An alarm should be provided at the cabinet to indicate loss of exhaust flow. This can be an exhaust volume flow measuring device in the duct downstream of the exhaust filter, a sail switch at the fan discharge, or a flow measuring station in the exhaust duct. It is recommended that each Type B1 or B2 cabinet have its own (dedicated) exhaust system. The cabinet should be interlocked with the blower in the duct or the building system to prevent pressurization of the exhaust system. In addition, cabinets hard connected to an exhaust system It is recognized that there is interest in utilizing the increasingly sophisticated modulated flow exhaust ventilation systems where the exhaust from Type B1 or B2 cabinets, chemical fume hoods, flexible exhaust hoses, and/or room exhausts are modulated based on use to optimize containment, maintain appropriate pressure differentials, and maximize energy savings by reducing overall exhaust volume. These systems are required to maintain a high level of control of many complex factors over a number of years. Although the potential cost savings are great, the severity of the hazards contained by the biological safety cabinets requires the use of simpler and more reliable constant flow systems for the cabinet exhaust. 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. (Continued on Next page)	

Topic	Requirement(s)	Commentary
Biosafety Cabinets – Certification and Safe Usage - Canada	**E.2.3 Roof exhaust systems** Roof exhaust systems serving biosafety cabinets should have a stack that extends straight upward at least 10 ft (3 m) above the roof surface to avoid re-entrainment by the building, and should be increased in elevation when necessary to avoid the influence of surrounding structures. Raincaps or any other structure that deflects the straight upward flow of the discharged air should be avoided. No precipitation can enter the stack when air is being exhausted at normal stack velocities. To take care of precipitation during periods when system is shut off, a 1 in (2.5 cm) hole can be drilled in the lowest point of the fan casing and the water allowed to drain onto the roof. It is recommended that roof exhaust fans be energized by direct-connected electric motors to avoid failures caused by slipping and breaking of belts. Another advantage of direct-connected fans is the ability to use the motor non-function to activate an alarm in the laboratory, whereas when a malfunctioning belted fan is employed, the motor can be operating when the fan is idle. **Public Health Agency of Canada, Office of Laboratory Security, Biosafety Division, Laboratory Biosafety Guidelines, 3rd Edition 2011:** **9.3 Installation and Certification** The air curtain at the front of the cabinet is fragile and can easily be disrupted by people walking parallel to it, by open windows, air supply registers or laboratory equipment that creates air movement (e.g., vacuum pumps, centrifuges). BSCs should be installed in accordance with the requirements outlined in the Canadian Standards Association (CSA) *Biological Containment Cabinets (Class I and II): Installation and Field Testing*(8). They should be located away from high traffic areas, doors and air supply/exhaust grilles that may interrupt airflow patterns. A minimum unobstructed distance of 40 cm should be provided between the exhaust outlet on top of the cabinet and any overhead obstructions. Whenever possible, a 30 cm clearance should be provided on each side of the cabinet to allow for maintenance access. For ducted cabinets, blowers on the exhaust system should be located at the terminal end of the ductwork; failure of exhaust flow should signal an alarm to the user. To prevent pressurization of the cabinet, an interlock system should be installed to prevent the cabinet blower from operating whenever the exhaust flow is insufficient; an anti-backflow device to prevent reverse airflow through the HEPA filter may be required. Continuous operation of BSCs helps to control dust levels and other airborne particulates in the laboratory. If BSCs are operated only when needed in order to conserve energy, the balancing of laboratory room air must be considered. In some cases, room exhaust is balanced to include the air exhausted through ducted BSCs, and these cabinets must not be turned off. The provision of natural gas to BSCs is not recommended. Open flames in the BSC create turbulence, disrupt airflow patterns and can damage the HEPA filter(1). When suitable alternatives (e.g., disposable sterile loops, micro-incinerators) are not possible, touch-plate micro burners that have a pilot light to provide a flame on demand may be used.	

Topic	Requirement(s)	Commentary
Biosafety Cabinets – Certification and Safe Usage - Canada (Continued)	The correct operation of BSCs must be verified before they are used and then annually, and after any repairs or relocation, in accordance with the field tests outlined in CSA Z316.3-95 or annex F of NSF 49. Moving a cabinet can cause damage to the HEPA filter and its seals. These tests include the downward velocity profile, the work access face velocity, the HEPA filter leak test and the airflow smoke patterns. Measuring and testing equipment must be calibrated and maintained in accordance with the CSA standard. A copy of the certification report must be provided to the user and kept on file. A label indicating the date of certification, the date of the next certification, to what standard the tests were performed and the name of the certifier should be affixed to the exterior of the cabinet. On-site field testing must be performed by experienced qualified individuals. The NSF accreditation program for BSC certifiers provides a list of individuals who have demonstrated their competence by means of written and practical examinations administered by the NSF[(9)]. Whenever possible, it is recommended that NSF-accredited field certifiers be used. Footnote References: 1. Centers for Disease Control and Prevention. *Primary containment for biohazards: selection, installation and use of biological safety cabinets*. Washington, DC: U.S. Government Printing Office, 2000. 2. Kruse, R.H., Puckett, W.H., and Richardson, J.H. *Biological safety cabinetry*. Clin Microbial Rev 1991;4:207-41. 3. Stuart, D.G. *Primary barriers: biological safety cabinets, fume hoods, and glove boxes*. In: Fleming, D.O., and Hunt, D.L. *Biological safety principles and practices*. Washington, DC: ASM Press, 2000; 313-30. 4. NSF International. *Class II (laminar flow) biohazard cabinetry. Standard 49*. Ann Arbor, Michigan: NSF International, 2002. 5. Stuart, D.G., Hilliard, J., Kenkel, R., Kelley, J., and Richmond, J. *Role of the class III cabinet in achieving BSL-4.* In: Richmond, J.Y. *Anthology of biosafety I: perspective on laboratory design.* Mundelein, IL: American Biological Safety Association, 1999; 149-60. 6. National Cancer Institute Office of Research Safety and the Special Committee of Safety and Health Experts. *Laboratory safety monograph, a supplement to NIH guidelines for recombinant DNA research*. Bethesda, MD: NIH, 1979. 7. *Biotechnology – performance criteria for microbiological safety cabinets*. BS EN 12469:2000. European Committee for Standardization (CEN), 2000. 8. *Biological containment cabinets (class I and II): installation and field testing.* Z316.3-95. Canadian Standards Association, Toronto, ON, 1995. 9. NSF International. *NSF listings — field certifier accreditation*. Ann Arbor, Michigan: NSF International, 2000.	The National Sanitation Foundation (NSF) is a not-for-profit organization best known for its health standards. NSF conducts research, tests and evaluates equipment, products, and services for compliance with NSF standards and criteria. It grants and controls the use of its “NSF” mark.

Topic	Requirement(s)	Commentary
Biological Safety Cabinet Design, Construction and Performance Requirements	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **5 Design and construction** **5.1 General** Cabinets shall be designed and constructed to function properly and operate in a safe manner, minimize contamination, provide personnel and product protection, and be capable of being cleaned and decontaminated. Exposed burrs and sharp edges (including, but not limited to, sheet metal screws) shall be eliminated from surfaces of the cabinet that are subject to normal operation, field certification, and maintenance (including those maintained with simple tools). **5.2 Cleanability** Interior work, exposed interior, and the other interior surfaces subject to splash or spillage shall be readily accessible and easily cleanable as assembled or when removed. Interior work, exposed interior, and other interior surfaces, including plenums, shall be capable of being vapor or gas decontaminated. **5.3 Decontamination** Cabinets shall be designed to be decontaminated with an inactivating agent (such as formaldehyde gas) without being moved. Closure to contain decontaminating agents should be limited to gas-tight sealing of air intake and exhaust openings with metal plates, or plastic film and tape, or equivalent. Pressure tight valves, if provided, suitable for decontamination shall be located on the clean side of the HEPA filter. **5.17.4 Sliding Sash Alarm** Sliding sash enclosures shall include an audible alarm activated when the sash is raised above the manufacturer's specified opening height. **Additional design and construction requirements listed in Section 5 cover:** Plenums, Internal Corners, Interior Angles, Joints & Seams, Fastening Methods, Removable Panels Stability, Mounting Provisions, Legs & Feet, Reinforcing & Framing, Fixed Panels, Doors & Covers, Louvers & Openings, Tracks & Guides, Filters, Gaskets, Sealants, Stopcocks & Service Outlets, Alarms, Electrical Components, Lighting, Gauges, Drain Spillage Trough, Diffuser Placement, Work Area Components Placement, Height and Width and Data plates.	

Topic	Requirement(s)	Commentary
Biosafety Cabinet Testing	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **6 Performance Testing**: *Before any performance tests are run, the cabinet shall be properly installed and leveled and airflows adjusted to the nominal set point (± 3.0 ft/min [± 0.015 m/s]). These tests are intended for the qualification of a new cabinet model by the testing organization. The testing organization also requires and performs appropriate tests during periodic requalification. Cabinet models undergoing major redesign shall be requalified.* **Tests Include:** Pressure Decay / Soap Bubble / Tracer Gas Leak Tests, HEPA Filter Leak test, Noise Level, Lighting intensity, Vibration, Personnel, Product, and Cross-Contamination Protection, Stability, Downflow Velocity, Inflow Velocity, Airflow Smoke Patterns, Drain Spillage Trough Leakage, Motor/Blower Performance, Electrical Safety, Performance Data, and Maintenance Records. (Continued on Next Page)	The National Sanitation Foundation (NSF) is a not-for-profit organization best known for its health standards. NSF conducts research, tests and evaluates equipment, products, and services for compliance with NSF standards and criteria. It grants and controls the use of its “NSF” mark. *Refer to NSF/ANSI 49 – 2011 for a description of the tests listed*

Topic	Requirement(s)	Commentary
Biosafety Cabinet Testing (Continued)	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.2. Ventilation Requirements for Biological Safety Cabinets** (f) Airflow measurements and HEPA filter leak testing. Biological safety cabinets shall be tested after installation, alterations, or maintenance, and at least annually. Records of tests performed shall be retained for at least five years. (1) The ventilation test requirements for Class I biological safety cabinets are as follows: (A) Velocity measurements shall be made at the work opening of the cabinet with a calibrated anemometer. (B) A quantitative aerosol challenge test shall be performed on each high-efficiency particulate air filter. The test must be capable of detecting penetrations exceeding 0.005% of particles 0.3 micrometers or larger while the cabinet is in normal operation. Any measurement exceeding 0.03% penetration shall establish a failure of the test. Appendix A contains a recommended high efficiency particulate air filter test protocol. (C) The ability of the hood to maintain an inward flow as required by subsection (e) above shall be demonstrated using smoke tubes or other suitable qualitative methods. (2) The ventilation test requirements for the Class II biological safety cabinets are as follows: (A) For type A and B3 cabinets the average intake face velocity at the normal operating work access opening shall be determined by measuring the exhaust air velocity, calculating the cabinet's exhaust air volume, and dividing this volume by the open area of the work access opening. Average face velocity is calculated by the following equation: (average exhaust velocity X open area of HEPA filter or exhaust port) / (area of normal work access opening) = average face velocity. Exception: Cabinets in which the exhaust filter is not accessible can be measured directly at the work access opening using a calibrated total capture air flow hood to measure the air volume entering the cabinet, and dividing this measurement by the area of the work access opening to determine the average face velocity. (B) For type B1 cabinets the average intake velocity shall be determined by directly measuring the inflow velocity at the normal operating work access opening with the cabinet recirculating blower turned off. A calibrated total captured airflow hood may be used for type B1 cabinets as in (A) above. (C) For type B2 cabinets the average face velocity shall be calculated based on total exhaust air volume (velocity measurement at exhaust port), supply airflow volume, and work access area. Average face velocity is calculated by the following equation: [(average exhaust velocity X area of exhaust port) - (average supply downflow velocity X open area of supply HEPA filter)] / (area of normal work access opening) = average face velocity. (Continued on Next Page)	

Biosafety Cabinet Testing (Continued)	Exception: Average intake velocity can also be measured directly at the work access opening using a calibrated total capture air flow hood to measure the air volume entering the cabinet, and dividing this measurement by the area of the work access opening to determine the average face velocity. (D) A quantitative aerosol challenge test shall be performed on each high-efficiency particulate air filter. The test must be capable of detecting penetrations exceeding 0.005% of particles 0.3 micrometers or larger while the cabinet is in normal operation. Any measurement exceeding 0.03% penetration shall establish a failure of the test. Appendix A contains a recommended high efficiency particulate air filter test protocol. (E) The ability of the hood to maintain an inward flow as required by subsection (e) above shall be demonstrated using smoke tubes or other suitable qualitative methods. (3) The ventilation test requirements for Class III biological safety cabinets are as follows: (A) The airflow through the Class III biological safety cabinet shall be determined by measuring the exhaust velocity at the exhaust port. Total air volume is calculated by the following equation: (exhaust velocity) X (area of exhaust port) = total air volume. The air change rate for a class III biological safety cabinet shall be a minimum of 1 air change in 3 minutes or airflow required to maintain flammable gases/vapors below 20% of the LEL whichever is greater. The measurement of the negative pressure inside the cabinet shall be made with a calibrated gauge. The accuracy of the gauge shall be +5% at the required 0.5 inches of water gauge. (B) A quantitative aerosol challenge test shall be performed on exhaust HEPA filters. The test must be capable of detecting penetrations exceeding 0.005% of particles, 0.3 micrometer or larger while the cabinet is in normal operation. Any measurement exceeding 0.03% penetration shall establish a failure of the test. Appendix A contains a recommended high efficiency particulate air filter test protocol. (g) Special requirements. (1) All test or maintenance activities requiring access to potentially contaminated interior spaces of the cabinet shall be performed after appropriate decontamination. (2) A warning placard shall be placed on the front of the cabinet requiring decontamination prior to opening any service panel or other interior access. (3) Where biological safety cabinets are attached to external duct systems with a blower and the cabinet system also contains a blower, or where the cabinet uses an external blower, an audible and visual alarm system to alert the user indicating the loss of exhaust flow in the external duct shall be used. Biological safety cabinets which are served with a canopy or thimble connected exhaust system shall have a ribbon streamer or like device attached to the edge of the canopy or thimble to indicate the direction of flow and are exempt from the requirement for flow alarms.	

Ventilation Systems

Topic	Requirement(s)	Commentary
Local Ventilation - When Required	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(c):** Ventilated storage cabinets, canopy hoods, snorkels, etc. should be provided as needed. Each canopy hood and snorkel should have a separate exhaust duct. **Local Codes** Some local jurisdictions require bottom venting of flammable liquids storage cabinets. **National Fire Protection Association, Standard NFPA 45, 2011** **8.4.8** Special local exhaust systems, such as snorkels or "elephant trunks", shall have sufficient capture velocities to entrain the chemical being released. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.14.4 Hazardous Waste Storage and Handling** **h.** A separate ventilation system shall be installed for the storage room. Exhaust shall be directed away from the building and the buildings' air intakes. This ventilation system shall be connected to the building's standby power system and contain appropriate filtration and monitoring devices.	Note that snorkels and canopy hoods should not be utilized when hazardous or toxic fumes might be present. These exhaust devices should only be utilized for non hazardous fume applications or to remove water vapor, heat or annoying odors. Manufacturers of flammable liquid storage cabinets typically provide plugged vent connections to accommodate local requirements for venting.

Topic	Requirement(s)	Commentary
Ventilation Rates for Animal Rooms	**Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 45: The primary purpose of ventilation is to provide appropriate air quality and a stable environment. Specifically, ventilation provides an adequate oxygen supply; removes thermal loads caused by the animals, personnel, lights, and equipment; dilutes gaseous and particulate contaminants including allergens and airborne pathogens; adjusts the moisture content and temperature of room air; and, where appropriate, creates air pressure differentials (directional air flow) between adjoining spaces. Importantly, ventilating the room (i.e., the macroenvironment) does not necessarily ensure adequate ventilation of an animal's primary enclosure (i.e., the microenvironment), that is, the air to which the animal is actually exposed. The type of primary enclosure may considerably influence the differences between these two environments - for example, differences may be negligible when animals are housed in open caging or pens, whereas they can be significant when static isolator cages are used. The volume and physical characteristics of the air supplied to a room and its diffusion pattern influence the ventilation of an animal's primary enclosure and are important determinants of the animal's microenvironment. The type and location of supply air diffusers and exhaust registers in relation to the number, arrangement, location, and type of primary and secondary enclosures affect how well the microenvironments are ventilated and should therefore be considered. The use of computer modeling for assessing those factors in relation to heat loading, air diffusion patterns, and particulate movement may be helpful in optimizing ventilation of micro- and macroenvironments. Direct exposure of animals to air moving at high velocity (drafts) should be avoided as the speed of air to which animals are exposed affects the rate at which heat and moisture are removed from an animal. For example, air at 20°C moving at 60 linear feet per minute (18.3 m/min) has a cooling effect of approximately 7°C. Drafts can be particularly problematic for neonatal homeotherms (which may be hairless and have poorly developed mechanisms for thermoregulatory control), for mutants lacking fur, and for semiaquatic amphibians that can desiccate. Provision of 10 to 15 fresh air changes per hour in animal housing rooms is an acceptable guideline to maintain macroenvironmental air quality by constant volume systems and may also ensure microenvironmental air quality. Although this range is effective in many animal housing settings, it does not take into account the range of possible heat loads; the species, size, and number of animals involved; the type of primary enclosure and bedding; the frequency of cage changing; the room dimensions; or the efficiency of air distribution both in the macroenvironment and between the macro- and microenvironments. (Continued on Next Page)	To ensure a proper ventilation rate is in effect, a means of measuring and continuously monitoring room exhaust airflow is necessary. Animal room exhaust airflow sensors should be located after adequate filtering to prevent clogging from airborne matter (that is, dust, hair, bedding material, etc.). A means for automatically monitoring and recording room ambient parameters is recommended to substantiate that the research was conducted in accord with proper practices. Automatic and systematic monitoring and documentation for animal room ambient parameters is recommended to substantiate that research was conducted in accord with proper practices. This is typically necessary for accreditation of research programs. Animal laboratories must generally be accredited by the American Association for Accreditation of Laboratory Animal Care (AAALAC) in accordance with *the "Guide for the Care and Use of Laboratory Animals*". The "*Guide*" is the standard used by AAALAC to accredit more than 650 animal care and use programs worldwide. Compliance with the "*Guide"* is also mandated by the Public Health Service as a prerequisite for receiving support from the NIH. The recommendations of the *"Guide"* carry the force of law based on the Health Research Extension Act passed by Congress in 1985.

Topic	Requirement(s)	Commentary
Ventilation Rates for Animal Rooms (Continued)	In some situations, the use of such a broad guideline might overventilate a macroenvironment containing few animals, thereby wasting energy, or underventilate a microenvironment containing many animals, allowing heat, moisture, and pollutants to accumulate. Modern heating, ventilation, and air conditioning (HVAC) systems (e.g., variable air volume, or VAV, systems) allow ventilation rates to be set in accordance with heat load and other variables. These systems offer considerable advantages with respect to flexibility and energy conservation, but should always provide a minimum amount of air exchange, as recommended for general use laboratories. Individually ventilated cages (IVCs) and other types of specialized primary enclosures, that either directly ventilate the enclosure using filtered room air or are ventilated independently of the room, can effectively address animals' ventilation requirements without the need to increase macroenvironmental ventilation. However, cautions mentioned above regarding high-velocity air should be considered. Nevertheless, the macroenvironment should be ventilated sufficiently to address heat loads, particulates, odors, and waste gases released from primary enclosures. If ventilated primary enclosures have adequate filtration to address contamination risks, air exhausted from the microenvironment may be returned to the room in which animals are housed, although it is generally preferable to exhaust these systems directly into the building's exhaust system to reduce heat load and macroenvironmental contamination. Static isolation caging (without forced ventilation), such as that used in some types of rodent housing, restricts ventilation. To compensate, it may be necessary to adjust husbandry practices, including sanitation and cage change frequency, selection of contact bedding, placement of cages in a secondary enclosure, animal densities in cages, and/or decrease in macroenvironmental relative humidity to improve the microenvironment and heat dissipation. The use of recycled air to ventilate animal rooms may save energy but entails risks. Because many animal pathogens can be airborne or travel on fomites (e.g., dust), exhaust air recycled into HVAC systems that serve multiple rooms presents a risk of cross contamination. Recycling air from nonanimal use areas (e.g., some human occupancy areas and food, bedding, and supply storage areas) may require less intensive filtration or conditioning and pose less risk of infection. The risks in some situations, however, might be too great to consider recycling (e.g., in the case of nonhuman primates and biohazard areas). The exhaust air to be recycled should be filtered, at minimum, with 85-95% ASHRAE efficient filters to remove airborne particles before it is recycled. Depending on the air source, composition, and proportion of recycled air used (e.g., ammonia and other gases emitted from excrement in recirculating air from animal rooms), consideration should also be given to filtering volatile substances. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Ventilation Rates for Animal Rooms (Continued)	In areas that require filtration to ensure personnel and/or animal safety (e.g., hazardous containment holding), filter efficiency, loading, and integrity should be assessed. Page 139: HVAC systems should be designed for reliability (including redundancy where applicable), ease of maintenance, and energy conservation; able to meet requirements for animals as discussed in Chapter 3; and flexible and adaptable to the changing types and numbers of animals and equipment maintained during the life of the facility (ASHRAE). They should be capable of adjustments in and ideally maintain dry-bulb temperatures of ±1°C (±2°F). Relative humidity should generally be maintained within a range of 30-70% throughout the year. The exhaust air to be recycled should be filtered, at minimum, with 85-95% ASHRAE efficient filters to remove airborne particles before it is recycled. Depending on the air source, composition, and proportion of recycled air used (e.g., ammonia and other gases emitted from excrement in recirculating air from animal rooms), consideration should also be given to filtering volatile substances. In areas that require filtration to ensure personnel and/or animal safety (e.g., hazardous containment holding), filter efficiency, loading, and integrity should be assessed. Page 139: HVAC systems should be designed for reliability (including redundancy	
Ventilation Rates for Biological Labs	**Local Codes** Some local jurisdictions may impose other specific ACH requirements for biological laboratories (that is, UBC requires six ACH) **ASHRAE, 2003 Handbook - HVAC Applications, Laboratories, Pg. 7.6, Health Care Facilities:** Radiology 6 ACH with 2 ACH from Outside Air Bacteriology, Biochemistry, Pathology, Serology, etc.: These labs requires a minimum ventilation rate of 6 ACH with the equivalent of 1/3 of the ventilation air (2 ACH) consisting of outside air. **ASHRAE, 2003 Handbook - HVAC Applications, Laboratories, Pg. 14.17, CONTAINMENT LABORATORIES:** • Biosafety Level 1: 3 to 4 ACH • Biosafety Level 2: 6 to 15 ACH • Biosafety Level 3: (No specific ventilation rate is given.) • Biosafety Level 4 (Highly specialized requirements – specific requirements must be determined by the Biological Safety Officer.)	Specific requirements for the ventilation rate of biological laboratories vary somewhat or in many cases are established by the facility's own health and safety standards. Note that in order to ensure that the proper ventilation rate is in effect, a means of measuring and continuously monitoring room exhaust airflow is necessary

Topic	Requirement(s)	Commentary
Ventilation Rates for Chemical Laboratories	**Local Codes** Some local jurisdictions may impose other specific ACH requirements for biological laboratories (that is, UBC requires six ACH) **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 7.6, Health Care Facilities:** Radiology 6 ACH with 2 ACH from Outside Air Bacteriology, Biochemistry, Pathology, Serology, etc.: These labs requires a minimum ventilation rate of 6 ACH with the equivalent of 1/3 of the ventilation air (2 ACH) consisting of outside air. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **2.1.2** The specific room ventilation rate shall be established or agreed upon by the owner or his/her designee. **2.1.3** The general ventilation system shall be designed to replace exhausted air and provide the temperature, humidity, and air quality required for the laboratory procedures without creating drafts at laboratory chemical hoods. **2.1.4** Dilution ventilation shall be provided to control the buildup of fugitive emissions and odors in the laboratory. **U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(f):** 4-12 room air changes/hour is normally adequate general ventilation if local exhaust systems such as hoods are used as the primary method of control. **National Fire Protection Association, Standard NFPA 45, 2011** **A.8.2.2** Laboratory units and laboratory hoods in which chemicals are present shall be continuously ventilated under normal operating conditions. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.8 LABORATORY VENTILATION:** The total airflow rate for a laboratory is dictated by one of the following: • Total amount of exhaust from containment and exhaust devices • Cooling required to offset internal heat gains • Minimum ventilation rate requirements Minimum ventilation rates should be established on a room by room basis considering the hazard levels of materials expected to be used in the room and the operation and procedures to be performed. **Local Codes** Some local jurisdictions may impose other specific ACH requirements for chemical laboratories (that is, UBC requires six ACH).	Specific requirements for the ventilation rate of biological laboratories vary somewhat or in many cases are established by the facility's own health and safety standards. Note that in order to ensure that the proper ventilation rate is in effect, a means of measuring and continuously monitoring room exhaust airflow is necessary The AIHA stresses that the necessary ventilation rate depends on the particular hazards and that one rate does not suit all situations. Although regulatory agency and published standards allow lower ventilation rates, current ventilation system designs for chemical laboratories typically utilize 10 to 12 air changes per hour (ACH) for an occupied laboratory. During unoccupied times the ventilation rate may be reduced to 4 ACH and still comply with national codes and standards, although some local codes may require 6 ACH. Note that a minimum airflow must be maintained through each fume hood even when the fume hood sash is fully closed *(See Fume Hoods: Minimum Exhaust)*. In some labs it is not possible to reduce every laboratory room's ventilation rate down to 4 ACH and still provide sufficient makeup air for the room's fume hoods. In order to ensure that the proper ventilation rate is in effect, a means of measuring and continuously monitoring room exhaust airflow is necessary.
Ventilation rates for Storage areas	**National Fire Protection Association, Standard NFPA 30, Flammable and Combustible Liquids Code, 2000, Liquid Storage Areas:** Mechanical ventilation systems shall provide at least 1 cfm per sq. ft. but not less than 150 cfm for storage rooms.	For a room having over 150 square feet of area and with a 10-foot ceiling, 1 cfm per square foot equals 6 ACH.

Topic	Requirement(s)	Commentary
Room Supply Air	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Title: Toxic and Hazardous Substances,1910.1450,C3,C4:** 3. Usage - The work conducted and its scale must be appropriate to the physical facilities available and, especially, to the quality of ventilation. 4. Ventilation - (a) General laboratory ventilation. This system should: Provide a source of air for breathing and for input to local ventilation devices; it should not be relied on for protection from toxic substances released into the laboratory; ensure that laboratory air is continually replaced, preventing increase of air concentrations of toxic substances during the working day. **National Fire Protection Association, Standard NFPA 45, 2011** **8.3.5** The location of air supply diffusion devices shall be chosen so as to avoid air currents that would adversely affect the performance of chemical fume hoods, exhaust systems and fire detection or extinguishing systems. **A-8-3.5** Room air current velocities in the vicinity of fume hoods should be as low as possible, ideally less than 30 percent of the face velocity of the fume hood. Air supply diffusion devices should be as far away from fume hoods as possible and have low exit velocities. **8.8.6** For auxiliary air fume hoods, auxiliary air shall be introduced exterior to the hood face in such a manner that the airflow does not compromise the protection provided by the hood and so that an imbalance of auxiliary air to exhaust air will not pressurize the hood interior. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.2.2** Supply air distribution shall be designed to keep air jet velocities less than half, preferably less than one-third of the capture velocity or the face velocity of the laboratory chemical hoods at their face opening. For most laboratory chemical hoods, this requirement will mean 50 fpm (0.25 m/s) or less terminal throw velocity at 6 ft (1.8 m) above the floor. For rooms with greater supply air requirements, either perforated ceilings or special large capacity radial diffusers may be necessary. Supply air diffusers where practical should be located as close to the personnel corridor and entry door to the laboratory and as far from the major exhaust devices as is practical. The ideal arrangement is to group the hoods and exhaust devices as far as possible from entry doors and exit corridors and locate supply air diffusers close to entry doors and exit corridors. (Continued on Next Page)	Research on fume hood containment has indicated the importance of ensuring that room air currents (supply air discharge and infiltration air) near the fume hood face opening are kept low, typically no more than 30%to 50% of the fume hood face velocity that is necessary for containment. Excessive cross drafts typically result from: • Improper room supply air diffusers • Too few supply air diffusers resulting in high supply air velocity • Improper diffuser location (such as directly above fume hoods or on room side walls) • Use of portable cooling fans and/or operable windows in the open position. • Rapid movement of persons working at or passing by fume hoods. See *Fume Hoods: Room Air Cross Currents* for requirements. Research has also indicated that better supply air infusion will be attained in a laboratory room by using multiple perforated ceiling air diffusers located as far as practical from the fume hoods or biological cabinets. VAV ventilation systems that are based on maintaining a constant fume hood face velocity and a supply air volume based upon actual room needs can enhance fume hood containment since a reduction in supply air reduces the terminal throw velocity.

Topic	Requirement(s)	Commentary
Room Supply Air (Continued)	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.8** **LABORATORY VENTILATION:** The maximum ventilation rates for the laboratories should be reviewed to ensure that appropriate supply air delivery methods are chosen so supply airflows do not impede the performance of exhaust devices. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.6** Air supplied to a laboratory space must keep temperature gradients and air turbulence to a minimum, especially near the face of the laboratory fume hoods and BSC's. Air outlets must not discharge into the face of fume hoods. Also, cross-flows that impinge on the side of a hood more seriously alter airflow than do cross-flows in front of the hood. **C.11.3.b** All laboratories shall have single pass air. The airflow shall be directed from clean spaces to potentially contaminated areas and from low hazard to high hazard areas. Air supply diffusers must be supplied with diffusers to direct flow away from fume hoods and BSC's in order to minimize potential disruptive air currents.	

Topic	Requirement(s)	Commentary
Supply Air Quality and Filtration	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C1,D3:** The laboratory facility should have (a) An appropriate general ventilation system with air intakes and exhausts located so as to avoid intake of contaminated air. Regular instrumental monitoring of airborne concentrations is not usually justified or practical in laboratories but may be appropriate when testing or redesigning hoods or other ventilation devices or when a highly toxic substance is stored or used regularly (e.g., 3 times/week). **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5143. General Requirements of Mechanical Ventilation Systems.** (d) Make-Up Air. Clean, fresh air, free of contamination from adjacent industrial exhaust systems, chimneys, stacks, or vents, shall be supplied. (1) The outside air supply shall enter the workroom in a manner which will not reduce the effectiveness of any local exhaust systems. (2) All seams and joints shall be sealed if negative pressure exists within inlet ductwork such that there is a possibility of infiltration of harmful quantities of gases, fumes, or mists from areas through which ductwork passes. (3) Where the air supply is filtered, the filters shall be replaced or cleaned regularly to prevent significant reductions in airflow. A pressure gauge shall be installed to show the pressure drop across the filters. This gauge shall be marked to show the pressure drop at which filters require cleaning or replacement. (4) Where make-up air is heated by combustion, except gas, the products of combustion shall not be mixed with the make-up air and shall be vented to a point remote from all points where make-up air enters the building. For gas heating where combustion products are mixed with the make-up air, the following must exist: (A) The gas must be nontoxic and have a distinctive and strong enough odor to warn workmen of its presence if unburned. (B) The maximum rate of gas supply to the make-up air heater shall not yield in excess of 2000 ppm of total combustible gas in the mixture upon flame failure. (C) A fan shall be provided to remove the mixture of heated air and combustion products from gas burner plenum chambers. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.5 c.** Outdoor air intakes shall be located as far as practical (usually on directionally different exposures) but not less than 9,000 mm (30’ 0”) from exhaust outlets of combustion equipment stacks, cooling towers, ventilation exhaust outlets from the building or adjoining buildings vacuum systems, plumbing vent stacks, or areas that may collect vehicular exhaust and other noxious fumes. The bottom of outdoor air intakes serving central systems shall be located as high as practical above the roof or ground level. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Supply Air Quality and Filtration (Continued)	**C.7.5.g.** The use of exposed fiberglass or any fibrous material that allows fibers to break off into the airstream for interior duct lining or insulation is usually not allowed for ductwork and air-handling units. Sound attenuators with suitable linings or other approved means of noise control shall be used where required. Insulation and a vapor barrier shall be installed on the outside of ductwork to prevent condensation. **C.7.5.j.** Supply air for all laboratory systems shall be filtered on the upstream side of fans with prefilters and high-efficiency afterfilters. **C.7.5.i.** HEPA filters shall be provided in special laboratories where research materials are Particularly susceptible to contamination from external sources. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.9** **LABORATORY VENTILATION:** Laboratories in which chemicals and compressed gases are used generally require nonrecirculating or 100% outside air supply systems. The selection of 100% outside air supply systems versus return air systems should be made as part of the hazard assessment process…. Filtration for the air supply depends on the requirements of the laboratory. Conventional chemistry and physics laboratories commonly use 85% dust spot efficient filters. Biological and Biomedical laboratories usually require 85 to 95% dust spot efficient HEPA filtration. HEPA filters should be provided for spaces where research materials or animals are particularly susceptible to contamination from outside sources. HEPA filtration of the supply air is necessary for such applications as environmental studies, studies involving specific pathogen-free research animals or nude mice, dust-sensitive work, and electronic assemblies. In many instances, biological safety cabinets or laminar flow clean benches (which are HEPA filtered) may be used rather than HEPA filtration for the entire laboratory. **Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 141: Air handling system intake locations should avoid entrainment of fumes from vehicles, equipment, and system exhaust. The type and efficiency of supply and exhaust air treatment should be matched to the quantity and types of contaminants and to the risks they pose. Supply air is usually filtered with 85–95% dust spot efficient filters (ASHRAE 2011). In certain instances, higher efficiency filters (e.g., HEPA) may be beneficial for recirculated supply air and air supplied to or exhausted from specialized areas such as surgical and containment facilities.	ASHRAE allows the laboratory supply air to be comprised of a mixture of outside air and recirculated (return) air from non-laboratory areas In lieu of 100% outside air. Chemical laboratories that require HEPA filtered air for only part of the lab activities may realize a cost benefit by utilizing localized containment enclosures (that is, biosafety cabinets, clean benches, etc.) that are available with the required air filtration provisions.

Topic	Requirement(s)	Commentary
Room and Duct Pressurization	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4:** 4. Ventilation - direct air flow into the laboratory from non-laboratory areas and out to the exterior of the building. **National Fire Protection Association, Standard NFPA 45,2011** **8.3.4** The air pressure in the laboratory work areas shall be negative with respect to corridors and non-laboratory areas of the laboratory unit except in the following instances: (1) Where operations such as those requiring clean rooms preclude a negative pressure relative to surrounding areas, alternate means shall be provided to prevent escape of the atmosphere in the laboratory work area or unit to the surrounding area. (2) The desired static pressure level with respect to corridors and non-laboratory areas shall be permitted to undergo momentary variations as the ventilation system components respond to door openings, changes in chemical fume hood sash positions, and other activities that can for a short term affect the static pressure level and its negative relationship. (3) Laboratory work areas within a designated hazardous electrically classified area with a positive air pressure system as described in NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, Chapter 7, Pressurized Control Rooms. **8.4.4** Air exhausted from laboratory units and laboratory work areas in which chemicals are present shall be continuously discharged through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building. (Continued on Next Page)	Note that in most cases, the standards do not set a pressurization level and generally do not specify a method to regulate it. A target in the vicinity of 0.01 inwc to 0.03 inwc (2 Pa to 7 Pa) is often effective in chemical laboratories. Higher levels are used in special cases, but this requires especially tight sealing of the room envelope. Only AIHA Z9.5 discusses the method of pressurization. It explains that controlling a flow offset is usually preferable to controlling the pressure difference. This is largely because of the practicality of measuring the physical quantities. The low room pressure signal is more easily disrupted than the stronger air flow signals measured in the ducts. The flow offset also tends to behave better when the door is opened than a room pressure controller. *Note: For additional information on room pressurization as well as a detailed explanation of static pressure, velocity pressure, total pressure, pressurization control and related parameters refer to Siemens' publication Room Pressurization Control Applications Guide (125-2191).*

Topic	Requirement(s)	Commentary
Room and Duct Pressurization (Continued)	**American National Standard for Laboratory Ventilation, ANSI/AIHA Z9.5-2003** **5.1.1** As a general rule, airflow shall be from areas of low hazard to higher hazard unless the laboratory is used as a Clean Room (such as Class 10,000 or better), or an isolation or sterile laboratory, or other special-type laboratories. When flow from one area to another is critical to emission exposure control, airflow monitoring devices shall be installed to signal or alarm that there is a malfunction. Air shall be allowed to flow from laboratory spaces to adjoining spaces only if • There are no extremely dangerous or life-threatening materials used in the laboratory. • The concentration of air contaminants generated by the maximum credible accident will be lower than the exposure limits required by 2.1.1. *(Note that 2.1.1 references OSHA PELs, NIOSH RELs, ACGIH TLVs, AIHA WEELs and the German MAKs.)* **AIHA Commentary to 5.1.1** In many laboratories, momentary door opening to allow the movement of materials and personnel in and out of the laboratory will not cause a significant safety condition because of the short duration of time for any contaminants to escape from the laboratory to the corridor. **5.1.1.1** Airlocks shall be utilized to prevent undesirable airflow from one area to another in high hazardous applications, or to minimize volume of supply air required by Section 5.1.1 **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **7.2 Room Pressurization** The standards and guidelines stress the importance of room pressurization for laboratory spaces. Laboratories that use laboratory fume hoods should be maintained at a relative negative pressure to corridors and other adjacent spaces in the building (such as the exception of clean room laboratories that may operate under positive pressure). **7.0** In order to maintain the negative pressure requirement, the total exhaust volume for a lab must always exceed the supply air volume by a specific volumetric offset or the flows must be controlled by a pressure differential control system. The volumetric offset method is the most common. If the total of all hood exhaust is less than the maximum possible supply flow, an additional exhaust device, normally referred to as the general exhaust valve, is required. **7.2** Laboratories that use laboratory fume hoods should be maintained at a relative negative pressure to corridors and other adjacent spaces in the building (such as the exception of clean room laboratories that may operate under positive pressure). (Continued on Next Page)	In (2), NFPA 45 recognizes the dynamics involved in maintaining negative room pressurization, particularly with VAV laboratory ventilation systems. For instance, changes in the total room exhaust can occur whenever a VAV fume hood sash is repositioned. This creates a need to make a corresponding change in the room supply makeup airflow which requires a finite amount of time. This time period (albeit perhaps only a few seconds) will nevertheless result in an unavoidable short term room pressure variation. Accepting this fact can greatly simplify acceptance testing AIHA similarly acknowledges the short term pressure changes and downplays their effect on safety. Airlocks are not necessary for the majority of laboratories. They are only applied when very unique and highly toxic chemicals and substances are routinely present (that is; highly poisonous gasses). In such situations consideration should be given to conducting the experiments in gloveboxes in lieu of fume hoods *(Also refer to Airlock definition.)*

Topic	Requirement(s)	Commentary
Room and Duct Pressurization (Continued)	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.12 Room Pressure Control:** Because maintaining an airtight seal is rarely practical, the air pressure in the laboratory must be maintained slightly negative with respect to adjoining areas. Exceptions are sterile facilities or clean spaces that may need to be maintained at a positive pressure with respect to adjoining spaces. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.5.f.** Laboratories containing harmful substances shall be designed and field balanced so that air flows into the laboratory from adjacent (clean) spaces, offices and corridors. Air supplied to the corridor and adjacent clean spaces must be exhausted through the laboratory to attain effective negative pressurization. **C.7.7.a** Laboratories in general should remain at a negative pressure in relation to the corridor and other non-laboratory spaces. Laboratory air shall flow from low-hazard to high-hazard use areas. Administrative areas in laboratory buildings must always be positive with respect to corridors and laboratories. The entire building shall be maintained at an air pressure above atmospheric to reduce or eliminate unwanted, unfiltered air and water infiltration. **C.7.7.b** Corridor supply air distribution shall be sized to offset transfer air to laboratories while maintaining an overall positive building pressure. Loading and receiving docks must be maintained as positive to prevent to prevent the entrance of vehicle fumes. **Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 139: Pressurization assists in controlling airborne contamination and odors by providing directional airflow between spaces. Areas for quarantine, housing and use of animals exposed to hazardous materials, and housing of nonhuman primates should be kept under relative negative pressure, whereas areas for surgery or clean equipment storage should be kept under relative positive pressure with clean air.	The preferred method of preventing cross contamination is by tightly sealed walls and floors and by not allowing recirculation of contaminated exhaust air. However, maintaining proper room pressure differentials adds another level of protection and is necessary to enable persons to pass from one area to another (that is, via doorways, etc.)
Human Occupancy, Room Temperature and Humidity	**ASHRAE, 2011 Handbook - HVAC Applications, Health Care Facilities, Pg. 7.6 DESIGN CONSIDERATIONS:** Ambient design conditions for humans in a laboratory room setting (From Table 3 of the handbook): 74 +/- 2^{o}F and at 30 - 60% RH	Uncomfortable lab conditions may prompt the occupants to use portable fans, heaters, block supply diffusers and use other means that can cause unsafe conditions. Certain biological labs may require specific ambient conditions based on the biological agents present.

Topic	Requirement(s)	Commentary
Animal Rooms Room Temperature and Humidity	**Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 43: The ambient temperature range in which thermoregulation occurs without the need to increase metabolic heat production or activate evaporative heat loss mechanisms is called the *thermoneutral zone (TNZ)* and is bounded by the lower and upper critical temperatures (UCT & LCT). To maintain body temperature under a given environmental temperature animals adjust physiologically (including their metabolism) and behaviorally (including their activity level and resource use). For example, the TNZ of mice ranges between 26°C and 34°C. At lower temperatures, building nests and huddling for resting and sleeping allow them to thermoregulate by behaviorally controlling their microclimate. Although mice choose temperatures below their LCT of 26°C during activity periods, they strongly prefer temperatures above their LCT for maintenance and resting behaviors. Similar LCT values are found in the literature for other rodents, varying between 26-30°C for rats and 28-32°C for gerbils. The LCT's of rabbits and cats and dogs (20-25°C) are slightly lower, while those of nonhuman primates and farm animals vary depending on the species. In general, dry-bulb temperatures in animal rooms should be set below the animals' LCT to avoid heat stress. This, in turn, means that animals should be provided with adequate resources for thermoregulation (nesting material, shelter) to avoid cold stress. Adequate resources for thermoregulation are particularly important for newborn animals whose LCT is normally considerably higher than that of their adult conspecifics. TABLE 3.1: Recommended Dry-Bulb Macroenvironmental Temperatures for Common Laboratory Animals Mouse, rat, hamster, gerbil, guinea pig 20-26^{0}C 68-79ºF Rabbit 16-22^{0}C 61-72ºF Cat, dog, nonhuman primate 18-29^{0}C 64-84ºF Farm animals and poultry 16-27^{0}C 61-81ºF Relative humidity should also be controlled, but not nearly as narrowly as temperature for many mammals; the acceptable range of relative humidity is considered to be 30% to 70% for most mammalian species. Micro environmental relative humidity may be of greater importance for animals housed in a primary enclosure in which the environmental conditions differ greatly from those of the macroenvironment (e.g., in static filter-top [isolator] cages). (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Animal Rooms Room Temperature and Humidity (Continued)	Some species may require conditions with high relative humidity (e.g., selected species of nonhuman primates, tropical reptiles, and amphibians. In mice, both abnormally high and low humidity may increase preweaning mortality. In rats, low relative humidity, especially in combination with temperature extremes, may lead to ringtail, a condition involving ischemic necrosis of the tail and sometimes toes. For some species, elevated relative humidity may affect an animal's ability to cope with thermal extremes. Elevated microenvironmental relative humidity in rodent isolator cages may also lead to high intracage ammonia concentrations, which can be irritating to the nasal passages and alter some biologic responses. In climates where it is difficult to provide a sufficient level of environmental relative humidity, animals should be closely monitored for negative effects such as excessively flaky skin, ecdysis (molting) difficulties in reptiles, and desiccation stress in semiaquatic amphibians. **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Page 16.15** **Laboratory Animal Facilities:** *Source*: ILAR (1996). **(Table 1 Recommended Dry-Bulb Temperatures for Common Laboratory Animals:** Mouse, rat, hamster, gerbil, guinea pig 64 to 79°F Rabbit 61 to 72°F Cat, dog, nonhuman primate 64 to 84°F Farm animals and poultry 61 to 81°F	

Topic	Requirement(s)	Commentary
Load Calculations	**American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.10.a** Complete design load calculations and a moisture control study shall be prepared for each space within a design program and presented in similar format to that outlined in the latest ASHRAE *Handbook of Fundamentals.* Heating and cooling load calculations are required for all projects to facilitate review and to provide a reference for system modifications. Individual room calculations shall be generated and summarized on a system basis and presented with a block load to define the peak system load. Load summary sheets shall indicate individual rooms with area, design air quantity, L/s per m^2, air changes per hour, and corresponding return or exhaust air quantity. Calculations shall include but not be limited to indoor and outdoor design parameters, heat gains and losses, supply and exhaust requirements for central system and each area of the facility, humidification and dehumidification requirements, and heat recovery. As a reference, calculations for assessing heating and cooling loads may include but are not limited to… *Sensible Heat Loads:* External walls, Internal equipment, Computers, Roofs, skylights, Fan (supply, exhaust and return) heat, Floors, Ceilings and Wall adjacent to unconditioned spaces, Infiltration, Uninterruptible power supplies, People, Outside ventilation air, Animals, Lighting, Instrumentation, etc. *Latent Heat Loads:* People, Animals, Outside ventilation air, Moisture generating processes, etc. **C.7.10.b** All heating and cooling load calculations shall include a predetermined safety factor to compensate for load inaccuracies, future flexibility, infiltration, and air leakage. Safety factors shall be clearly defined in a report usually submitted at the end of schematic design. **C.7.11.a** The design engineer shall make a detailed and complete inventory of all laboratory equipment scheduled for installation in each design space, and using estimated utilization factors, determine the project equipment load requirement. Equipment utilization factors shall be indicated in a report usually submitted at the end of schematic design. **C.7.11.b** The designer shall carefully evaluate the following rooms used for laboratory support, which often have higher than normal cooling loads, as well as evaluate the use of supplemental units to remove excessive sensible loads affecting these areas while maintaining minimum ventilation requirements: Common equipment rooms Cage and rack washing rooms Autoclave rooms Glassware washing rooms Darkrooms	

Topic	Requirement(s)	Commentary
Room Sound Level and Vibration	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.1.3** Generation of excessive noise shall be avoided in laboratory ventilation systems. Fan location and noise treatment shall provide for sound pressure level (SPL) in conformance with local ambient criteria. The acoustic character of the ventilation system should help create a pleasant working environment. Sound from the ventilation system should not interfere with laboratory operations. The recommended range for hospital laboratories is 5O-35; higher RC ranges might be acceptable for other types of laboratories. NC curves above 55 might result in unacceptable speech interference in the laboratory. Use of porous or flammable sound-absorbing interior lining of exhaust ductwork usually is unacceptable **ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 14.9 Noise** Noise level in the laboratory should be considered at the beginning of the design so that noise criterion (NC) levels suitable for scientific work can be achieved. For example, at the NIH, sound levels of NC 40 to 45 (including fume hoods) are required in regularly occupied laboratories. The requirement is relaxed to NC 55 for instrument rooms. If noise criteria are not addressed as part of the design, NC levels can be 65 or greater, which is unacceptable to most occupants. Sound generated by the building HVAC equipment should be evaluated to ensure that excessive levels do not escape to the outdoors. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.c.** For laboratory hoods, noise levels should not exceed NC 60 at the face of the hood unless permitted by the facility safety personnel. (Continued on Next Page)	Fume hoods with a wide open sash and a 100 fpm face velocity can typically produce a sound pressure level of 65dB at the fume hood. Since this is not representative of normal usage and exits directly in front of the fume hood, this sound level is normally acceptable. Note that dBA sound levels refer to sound measurements using the A weighted scale that differs somewhat from the standard NC (noise criteria) curves. VAV laboratory ventilation systems can be very beneficial in maintaining lower ventilation system sound since they reduce room supply airflow as well as the fume hood exhaust airflow as fume hood sashes are closed. This is particularly important in teaching labs where the students need to clearly hear an instructor. *Note: For additional information and detailed explanations of the concepts of sound, sound intensity measurement, and sound reduction refer to Siemens' publication 125-1929, Minimizing Excessive Sound in Ventilation System Design - Applications Guide.*

Topic	Requirement(s)	Commentary
Room Sound Level and Vibration (Continued)	**Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 49: Noise produced by animals and animal care activities is inherent in the operation of an animal facility and noise control should be considered in facility design and operation. Separation of human and animal areas minimizes disturbances to both human and animal occupants of the facility. Exposure to sound louder than 85 dB may necessitate hearing protection for personnel (OSHA 1998). Many species can hear sound frequencies inaudible to humans; rodents, for example, are very sensitive to ultrasound. The potential effects of equipment (such as video display terminals; and materials that produce noise in the hearing range of nearby animals can thus become an uncontrolled variable for research experiments and should therefore be carefully considered. While some vibration is inherent to every facility and animal housing condition, excessive vibration has been associated with biochemical and reproductive changes in laboratory animals and can become an uncontrolled variable for research experiments. The source of vibrations may be located within or outside the animal facility. In the latter case, groundborne vibration may affect both the structure and its contents, including animal racks and cages. Like noise, vibration varies with intensity, frequency, and duration. Attempts should be made to minimize the generation of vibration. Page 143: Noise control is an important consideration in an animal facility and should be addressed during the planning stages of new facility design or renovation. Noise-producing support functions, such as cage washing, are commonly separated from housing and experimental functions. Masonry walls, due to their density, generally have excellent sound-attenuating properties, but similar sound attenuation can be achieved using many different materials and partition designs. For example, sanitizable sound-attenuating materials bonded to walls or ceilings may be appropriate for noise control in some situations, whereas acoustic materials applied directly to the ceiling or as part of a suspended ceiling in an animal room present problems for sanitation and vermin control and are not recommended. Experience has shown that well-constructed corridor doors, sound-attenuating doors, or double-door entry vestibules can help to control the transmission of sound along corridors. Attention should be paid to attenuating noise generated by equipment (ASHRAE 2007b). Fire and environmental-monitoring alarm systems and public address systems should be selected and positioned to minimize potential animal disturbance. The location of equipment capable of generating sound at ultrasonic frequencies is important as some species can hear such high frequencies. Selecting equipment for rodent facilities that does not generate noise in the ultrasonic range should be considered. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Room Sound Level and Vibration (Continued)	Vibration may arise from mechanical equipment, electrical switches, and other building components, or from remote sources (via groundborne transmission). Regarding the latter, special consideration should be given to the building structure type especially if the animal facility will be located over, under, or adjacent to subways, trains, or automobile and truck traffic. Like noise, different species can detect and be affected by vibrations of different frequencies and wavelengths, so attempts should be made to identify all vibration sources and isolate or dampen them with vibration suppression systems (ASHRAE 2007b).	

Topic	Requirement(s)	Commentary
Emergency Control Provisions	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,A4,D9&10:** (a) A written emergency plan should be established and communicated to all personnel; it should include procedures for ventilation failure, evacuation, medical care, reporting, and drills. (b) There should be an alarm system to alert people in all parts of the facility including isolation areas such as cold rooms. (c) A spill control policy should be developed and should include consideration of prevention, containment, cleanup, and reporting. (d) All accidents or near accidents should be carefully analyzed with the results distributed to all who might benefit. (b) Emergency and Personal Protection Training: Every laboratory worker should know the location and proper use of available protective apparel and equipment. Some of the full-time personnel of the laboratory should be trained in the proper use of emergency equipment and procedures. **National Fire Protection Association, Standard NFPA 45, 2011** **A.8.2.2**. It is not the intent of the standard to require emergency or standby power for laboratory ventilation systems. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.1.4** When the type and quantity of chemicals or compressed gasses that are present in a laboratory room could pose a significant toxic or fire hazard, the room shall be equipped with provision(s) to initiate emergency notification and initiate the operation of the ventilation system in a mode consistent with accepted safety practices. Emergency situations (See NFPA 92A-2000) that shall be anticipated and the appropriate ventilation system responses shall include: • CHEMICAL EMERGENCY (Chemical Spill, Eye-Wash or Emergency Shower Activation, Flammable Gas Release, etc.)–For rooms served by VAV ventilation systems, the Chemical Emergency mode of operation should maximize the room ventilation (air change per hour) rate and, if appropriate, increase negative room pressurization. For rooms served by CAV ventilation systems that utilize a reduced ventilation level for energy savings, the Chemical Emergency mode of operation should ensure that the room ventilation and negative pressurization are at the maximum rate. (Continued on Next Page)	Most laboratories are susceptible to fire, a toxic chemical spill, and some sort of personal injury. Therefore it is prudent to have a means in place that facilitates notifying appropriate personnel in an emergency situation. A means to enable prompt notification of an emergency situation would be to provide individual FIRE, CHEMICAL and perhaps MEDICAL EMERGENCY pull stations at the laboratory door. Operation of the pull station would automatically initiate the appropriate alert. Such pull stations can be arranged to also signal the ventilation control system to automatically activate the proper ventilation system response. The AIHA's position is that the appropriate ventilation system response to a chemical emergency maximizes the room ventilation rate in order to increase dilution and removal of chemical fumes. In addition, migration of such fumes and vapors to other building areas is prevented or retarded by increasing the room's negative pressure. The appropriate ventilation system response (per NFPA 92A) to a fire requires stopping all room supply airflow while maximizing the room exhaust. This maximizes the room negative pressure and prevents or retards the spread of smoke and toxic fire gases to adjoining areas. Some local building codes require the same response. In some lab buildings this is impractical. If the lab room envelope is especialialy tight, this vent strategy can exert excessive force on the doors, possibly impeding egress. Somelab managers have found the need to arrange exceptions to the codes.

Topic	Requirement(s)	Commentary
Emergency Control Provisions (Continued)	• FIRE–A means such as a wall mounted "FIRE ALARM" pull station should enable the room occupants to initiate a fire alarm signal and simultaneously activate an appropriate fire emergency mode of operation for the room and/or building ventilation system For rooms served by VAV ventilation systems, the Fire Emergency mode of operation should maximize the exhaust airflow rate from the hoods and other room exhaust provisions, and also shut off the room supply makeup air. For rooms served by CAV ventilation systems that utilize a reduced ventilation level for energy savings, the Fire Emergency mode of operation should ensure that the maximum exhaust airflow rate from the hoods and other room exhaust provisions are in effect, and should also shut off the room supply makeup air. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.13 Fire Safety/Fire Protection** **h. Duct Smoke Detection:** Duct smoke detectors shall not be installed in air handling units of less than 7 m^3/s (15,000 cfm), in air handling units which serve only one fire area, or in fully sprinklered buildings. Where duct smoke detectors are installed they shall be of the photoelectric type, connected to the building fire alarm system, and shall cause shutdown of the associated air handler upon alarm. **Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 141: In the event of power failure, an alternative or emergency power supply should be available to maintain critical services (e.g., the HVAC system, ventilated caging systems or support functions (e.g., freezers and isolators) in animal rooms, operating suites, and other essential areas. As with terrestrial species, aquatic animals should receive daily care from qualified personnel who have a sufficient understanding of the housing system to identify malfunctions and, if they are unable to address a system failure of such magnitude that it requires resolution before the next workday, access to staff who can respond to the problem. Automated monitoring systems are available and may be appropriate depending on system size and complexity. Appropriate emergency response plans should be developed to address major system failures.	ASHRAE's recommendation to maintain "adequate makeup" addresses the issue of excessive forces on the doors. Ventilation system monitoring and automatic emergency responses should be a consideration.

Topic	Requirement(s)	Commentary
Energy Conservation	**Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 46: Modern heating, ventilation, and air conditioning (HVAC) systems (e.g., variable air volume, or VAV, systems) allow ventilation rates to be set in accordance with heat load and other variables. These systems offer considerable advantages with respect to flexibility and energy conservation, but should always provide a minimum amount of air exchange, as recommended for general use laboratories. The use of recycled air to ventilate animal rooms saves considerable amounts of energy but might entail some risk. Many animal pathogens can be airborne or travel on fomites, such as dust, so exhaust air to be recycled into heating, ventilation, and air-conditioning systems that serve multiple rooms presents a risk of cross contamination. The exhaust air to be recycled should be HEPA filtered (high-efficiency particulate air-filtered) to remove airborne particles before it is recycled; the extent and efficiency of filtration should be proportional to the estimated risk. Air that does not originate from animal use areas but has been used to ventilate other spaces (e.g., some human-occupancy areas and food, bedding, and supply storage areas) may be recycled for animal space ventilation and might require less-intensive filtration or conditioning than air recycled from animal use space. Toxic or odor-causing gases, such as ammonia, can be kept within acceptable limits if they are removed by the ventilation system and replaced with air that contains either a lower concentration or none of these gases. Treatment of recycled air for these substances by chemical absorption or scrubbing might be effective; however, the use of nonrecycled air is preferred for ventilation of animal use and holding areas. The use of HEPA filtered recycled air without gaseous filtration (such as with activated-charcoal filters) can be used but only that: • Room air is mixed with at least 50% fresh air (that is, the supply air does not exceed 50% recycled air). • Recycled air is returned only to the room or area from which it was generated, except if it comes from other than animal housing areas. • Recycled air is appropriately conditioned and mixed with sufficient fresh air to address the thermal and humidity requirements of animals in that space. **National Fire Protection Association, Standard NFPA 45, 2011** **8.3.1** Laboratory ventilation systems shall be designed to ensure that chemical fumes, vapors or gasses originating from the laboratory shall not be recirculated. **8.4.1** Air exhausted from chemical fume hoods and other special local exhaust systems shall not be recirculated. **8.4.2** If energy conservation devices are used they shall be designed in accordance with 8.3.1. and 8.3.2. (Continued on Next Page)	*Also refer to the requirements listed in:* "**Exhaust Systems** Recirculated Air and Cross Contamination" Note that as written, NFPA 8.4.1 specifically prevents the recirculation of fume hood exhaust but not laboratory room air. Recirculation of laboratory room air is permissible if the specific requirements of ANSI/AIHA Z9.5 are met. The cost to install exhaust filtering and cleaning systems that would adequately remove hazardous fumes (and the associated risk of a failure in such systems) generally makes it an impractical consideration.

Topic	Requirement(s)	Commentary
Energy Conservation (Continued)	**A.8.4.2** Consideration should be made of the potential contamination of the fresh air supply by exhaust air containing vapors of flammable or toxic chemicals when using devices for energy conservation purposes. **8.4.2.1** Devices that could result in recirculation of exhaust air or exhausted contaminants shall not be used unless designed in accordance with Section 4:10:1, "Nonlaboratory Air," and Section 4:10.2, "General Room Exhaust" of ANSI/AIHA Z9.5, Laboratory Ventilation. **8.4.2.2** Devices that could result in recirculation of exhaust air or exhausted contaminants shall not be used unless designed in accordance with Section 4:10.1, "Nonlaboratory Air," and Section 4:10.2, "General Room Exhaust," of ANSI/AIHA Z9.5, *Laboratory Ventilation*. **8.8.6** For auxiliary air fume hoods, auxiliary air shall be introduced exterior to the hood face in such a manner that the airflow does not compromise the protection provided by the hood and so that an imbalance of auxiliary air to exhaust air will not pressurize the hood interior. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **VS-35-02 (General Use Laboratory Hoods)** J. For energy conservation, use horizontal sliding sash with airfoil sill. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Energy Conservation (Continued)	**ASHRAE, 2011 Handbook - HVAC Applications, Laboratories, Pg. 16.18 – 16.19** **ENERGY** Efforts to reduce energy use must not compromise standards established by safety officers. Energy reduction systems must maintain required environmental conditions during both occupied and unoccupied modes. Energy can be used more efficiently in laboratories by reducing exhaust air requirements. One way to achieve this is to use variable volume control of exhaust air through the fume hoods to reduce exhaust airflow when the fume hood sash is not fully open. Any airflow control must be integrated with the laboratory control system, described in the section on Control, and must not jeopardize the safety and function of the laboratory. Setback controls that reduce ventilation rates when the laboratory is unoccupied can also reduce energy consumption. Timing devices, sensors, manual override, or a combination of these can be used to set back the controls at night. If this strategy is a possibility, the safety and function of the laboratory must be considered, and appropriate safety officers should be consulted. Fume hood selection also impacts exhaust airflow requirements and energy consumption. Modern fume hood designs use several techniques to reduce airflow requirements, including reduced face opening sashes and specifically designed components that allow operation with reduced inflow velocities. Energy can often be recovered economically from the exhaust airstream in laboratory buildings with large quantities of exhaust air. Many energy recovery systems are available, including rotary air to-air energy exchangers or heat wheels, coil energy recovery loops(runaround cycle), twin tower enthalpy recovery loops, heat pipe heat exchangers, fixed-plate heat exchangers, thermo siphon heat exchangers, and direct evaporative cooling. Some of these technologies can be combined with indirect evaporative cooling for further energy recovery. Concerns about the use of energy recovery devices in laboratory HVAC systems include (1) the potential for cross-contamination of chemical and biological materials from exhaust air to the intake airstream, and (2) the potential for corrosion and fouling of devices located in the exhaust airstream. NFPA *Standard* 45 specifically prohibits the use of latent heat recovery devices in fume hood exhaust systems. Energy recovery is also possible for hydronic systems associated with HVAC. Rejected heat from centrifugal chillers can be used to produce low-temperature reheat water. Potential also exists in plumbing systems, where waste heat from washing operations can be recovered to heat makeup water.	Energy recovery systems for laboratory applications require considerable more careful examination than such systems for non-laboratory applications mainly due to the potential for cross-contamination and corrosion.

Topic	Requirement(s)	Commentary
Monitoring	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(h) & D3:** Evaluation. Quality and quantity of ventilation should be evaluated on installation, regularly monitored (at least every 3 months), and reevaluated whenever a change in local ventilation devices is made. Regular instrumental monitoring of airborne concentrations is not usually justified or practical in laboratories but may be appropriate when testing or redesigning hoods or other ventilation devices or when a highly toxic substance is stored or used regularly (e.g., 3 times/week). **American Conference of Governmental Industrial Hygienists (ACGIH) INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **8.4.4** The (cooling) coil and (condensate) pan must be inspected and cleansed on a regular basis. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.5 Air Quality** Adequate access shall be provided for periodic maintenance and cleaning of coils, humidifiers and drain pans. Drain pans shall be designed and installed for proper and immediate drainage of condensed water. A proper hydraulic head shall be provided for drains with positive and negative air plenums to provide drainage and prevent overflow. **ASHRAE, 2011 Handbook HVAC Applications, Laboratories, 2003, Pg. 16.18 OPERATION AND MAINTENANCE:** Centralized monitoring of laboratory variables (e.g., pressure differentials, face velocity of fume hoods, supply flows, and exhaust flows) is useful for predictive maintenance of equipment and for ensuring safe conditions. For their safety, laboratory users should be instructed in the proper use of laboratory fume hoods, safety cabinets, ventilated enclosures, and local ventilation devices. They should be trained to understand the operation of the devices and the indicators and alarms that show whether they are safe to operate. Users should request periodic testing of the devices to ensure that they and the connected ventilation systems are operating properly. (Continued on Next Page)	A centralized monitoring system provides the best assurance that a systematic monitoring plan is carried out. Automatic recording of key operational parameters such as laboratory room supply and exhaust airflows, face velocities, etc. can help ensure that complete records are maintained.

Topic	Requirement(s)	Commentary
Monitoring (Continued)	**Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 47: The successful operation of any HVAC system requires regular maintenance and evaluation, including measurement of its function at the level of the secondary enclosure. Such measurements should include supply-and exhaust-air volumes, as well as static-pressure differentials, where applicable. Page 88: Regular monitoring of the HVAC system is important and is best done at the individual-room level.	Complete and automatically recorded data is perhaps the best evidence to demonstrate a conscientious adherence to established safety standards and compliance with required ambient conditions for animal research.

Topic	Requirement(s)	Commentary
Maintenance	**American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.5 Air Quality** Adequate access shall be provided for periodic maintenance and cleaning of coils, humidifiers and drain pans. Drain pans shall be designed and installed for proper and immediate drainage of condensed water. A proper hydraulic head shall be provided for drains with positive and negative air plenums to provide drainage and prevent overflow. **American Conference of Governmental Industrial Hygienists (ACGIH) INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **8.4.4** The (cooling) coil and (condensate) pan must be inspected and cleansed on a regular basis. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.18 OPERATION AND MAINTENANCE:** Maintenance personnel should be trained to keep laboratory systems in good operating order and should understand the critical safety requirements of those systems. High-maintenance items should be placed outside the actual laboratory (in service corridors or interstitial space) to reduce disruption of laboratory operations and exposure of the maintenance staff to laboratory hazards. Maintenance personnel must be aware of and trained in procedures for maintaining good indoor air quality (IAQ) in laboratories. Many IAQ problems have been traced to poor maintenance due to poor accessibility. **Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 46: Treatment of recycled air for either particulate or gaseous contaminants is expensive and can be rendered ineffective by improper or insufficient maintenance of filtration systems. These systems should be properly maintained and monitored appropriately to maximize their effectiveness. The successful operation of any HVAC system requires regular maintenance and evaluation, including measurement of its function at the level of the secondary enclosure.	Ensuring proper drainage for water that condenses on cooling coils is extremely important. Standing water in drain pans can result in the rapid growth and proliferation of mold, bacteria, and many infectious micro-organisms that can enter the supply air stream (that is, Legionella, Pontiac Fever, etc.)

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing	**U.S. OSHA, 29 CFR, Part 1910, Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances,1910.1450,C4(h):** Quality and quantity of ventilation should be evaluated on installation, regularly monitored (at least every 3 months) and reevaluated whenever a change in local ventilation devices is made. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** The Biosafety Level 3 facility design and operational procedures must be documented. The facility must be tested for verification that the design and operational parameters have been met prior to operation. Facilities should be re-verified, at least annually, against these procedures as modified by operational experience. The Biosafety Level 4 facility design and operational procedures must be documented. The facility must be tested for verification that the design and operational parameters have been met prior to operation. Facilities should be re-verified annually against these procedures as modified by operational experience. **California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5143. General Requirements of Mechanical Ventilation Systems** (5) The ventilation rate of every mechanical ventilation system used to prevent harmful exposure shall be tested after initial installation, alterations, or maintenance, and at least annually, by means of a pitot traverse of the exhaust duct or equivalent measurements. Records of these tests shall be retained for at least five years. **National Fire Protection Association, Standard NFPA 45, 2011** **7.5.3** Explosion shields and special explosion-containing hoods shall be inspected prior to each use fire deterioration, especially transparent shields and sight panels in special explosion-containing hoods. **8.7.3** Fans shall be located and arranged so as to afford ready access for repairs, cleaning, inspection, and maintenance. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing (Continued)	**8.13.1** When installed or modified and at least annually thereafter, chemical fume hoods, chemical fume hood exhaust systems and laboratory special exhaust systems shall be inspected and tested as applicable, as follows: (1) Visual inspection of the physical condition of the hood interior, sash and ductwork... (2) Measuring device for hood airflow (3) Low airflow and loss-of-air-flow alarms at each alarm location (4) Face velocity (5) Verification of inward airflow over the entire hood face (6) Changes in work area conditions that might affect hood performance **8.13.4.1** Air system flow detectors, if installed, shall be inspected and tested annually **8.13.4.2** Where potentially corrosive or obstructive conditions exist, the inspection and test frequency shall be increased. **8.13.5.1** Air supply and exhaust fans, motors, and components shall be inspected at least annually. **A.8.13.5.1** The annual inspection of air supply and exhaust fans, motors, and components should ensure that equipment is clean, dry, tight, and friction-free. Bearings should be properly lubricated on a regular basis, according to the manufacturer's recommendations. Protective devices should be checked to ensure that settings are correct and that ratings have been tested under simulated overload conditions. Inspections should be made by personnel familiar with the manufacturer's instructions and equipped with proper instruments, gauges, and tools. **8.13.5.2** Where airflow detectors are not provided or airflow rate tests are not made, fan belts shall be inspected quarterly; double sheaves and belts shall be permitted to be inspected semiannually. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **8.7.1** Fans, blowers, and drive mechanisms shall be visually inspected weekly. Key observations are abnormal noise or vibration, bearing noise, excessive temperature of motors, lubricant leaks, etc. **8.7.2** V-belt drives shall be stopped and inspected monthly for belt tension and signs of belt wear or checking. **American Conference of Governmental Industrial Hygienists (ACGIH)** **INDUSTRIAL VENTILATION A Manual of Recommended Practice, 27th Edition** **8.4.4** The (cooling) coil and (condensate) pan must be inspected and cleansed on a regular basis. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.18** **OPERATION AND MAINTENANCE:** Preventive maintenance of equipment and periodic checks of air balance should be scheduled.	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada	**Public Health Agency of Canada, Office of Laboratory Security, Biosafety Division, Laboratory Biosafety Guidelines, 3rd Edition 2011:** **5.1.3 Recertification** Recertification of certain containment components should also be performed, the nature and frequency of which depend on a variety of factors. For example, verification of directional airflow, detection of any visual leaks in the room perimeter, recalibration of sensitive controllers and gauges can all be performed on a routine basis without disruption to the operation of the containment facility. Monitoring the resistance across a HEPA filter (that is, using pressure monitoring devices) installed into air handling systems will provide information as to the necessity and frequency of replacing HEPA filters. Retesting the integrity of the room perimeter and ductwork is necessary after any structural change. Retesting of the HVAC control systems for fail-safe operation is not necessary unless the system has undergone logic changes or upgrades. **5.2 Room Integrity** Smoke testing the integrity of a containment room can be done to detect leaks in the room perimeter. All joints, corners and sealed penetrations should be surveyed for leaks. Pressure decay testing the integrity of the containment room provides an indication of the tightness of the room perimeter (that is, the ability of gases and liquids to move through the perimeter membrane and service penetrations). • Containment Level 3 & 4 Room Integrity Testing: Integrity of containment surfaces to be tested visually and with a smoke pencil or other visual aid. Inspect floors, walls, and ceiling for cracks, chips and wear. Verify integrity of wall/floor and wall/ceiling joints. Acceptance criteria: to confirm the integrity of all penetrations (that is, equipment, services, etc.) and seals (that is, around doors, windows, autoclaves, etc.) on the containment barrier. (Continued on Next Page)	Recertification refers to re-testing of the ventilation system(s) and room integrity at certain intervals after the facility has been commissioned and has been in use. Also refer to the section on *Commissioning* at the end of this document for additional details contained in ***Public Health Agency of Canada, Office of Laboratory Security, Biosafety Division, Laboratory Biosafety Guidelines, 3rd Edition 2011*.**

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada (Continued)	• Containment Level 4 Additional Room Integrity Testing: Integrity of containment to be tested by pressure decay testing. Acceptance criteria: two consecutive tests with a minimum of 250 Pa (1 in. w.g.) loss of pressure from an initial 500 Pa (2 in. w.g.) over a 20 minute period. This test is not a mandatory requirement for recertification if no modification or changes have been made that will affect the integrity of the laboratory, and if a visual inspection of the containment barrier membrane indicates that the integrity has not been compromised; if the perimeter integrity is suspect upon visual inspection, the requirement for repeating the pressure decay test should be determined in consultation with the laboratory supervisor, Biological Safety Officer/Institutional Biosafety Committee. **5.2.2 Room Pressure Decay Testing** The basic procedure for room pressure decay testing under negative pressure is as follows: • Isolate the area by closing and securing all doors, valves and bubble tight dampers at the containment barrier (avoid temporary sealing measures in doors, windows and services that would cover permanent seals and not permit their testing for leakage); plug all pressure sensor lines, e.g., magnehelic gauges. • Install a calibrated inclined manometer across the containment barrier such that it is not affected by air distribution. Manometer to have minimum accuracy of 10 Pa (0.05 in. w.g.) and capable of reading pressure up to 750 Pa (3 in. w.g.). • Install a ball valve in the piping between the vacuum pump/fan and the room to allow the room to be sealed once the test pressure has been attained. • Connect a vacuum source to the room and create a 500 Pa (2 in. w.g.) negative pressure differential; allow room to stabilize and close the valve between the vacuum pump/fan and the room to seal room at 500 Pa (2 in. w.g.). • Dynamically trend pressure loss starting at 500 Pa (2 in. w.g.) negative pressure differential; record the differential pressure at 1 minute intervals for 20 minutes. • If repeat test is required, allow 20 minute wait period. • Disconnect the vacuum pump/fan and open the ball valve slowly to allow room pressure to return to normal condition. • If leak rate exceeds the acceptance value: • pressurize the room to a pressure adequate to locate leaks; (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada (Continued)	• with the room under continuous pressure, apply bubble solution to areas to be tested (joints, corners, sealed penetrations, etc.) or, by using audible leak location method, locate audible leaks (electronic sound detection equipment option); • identify places where bubbles are found; • after repair of leak, retest as required. **5.3 Air Handling Systems** Various components of a containment room's air handling system require commissioning. Manufacturers' requirements for airflows for BSCs must be met. Integrity testing of HEPA filters must be performed to ensure that they do not contain leaks in the filter media, the gasketing or the seal to the filter housing. This filter housing test is performed by challenging with a known particulate concentration and scanning for percentage of penetration downstream of the filter. Ductwork systems should be pressure decay tested to confirm that specified leakage rates are not exceeded. The American Society of Mechanical Engineers (ASME) Standard N510 *Testing of Nuclear Air Treatment Systems*, 1989, reaffirmed 1995[2], gives procedures for testing the leak-tightness of ducts and plenums. The performance of room pressure control systems must meet the design intent (e.g., negative pressures must be maintained). The following testing requirements and acceptance criteria must be satisfied for certification of laboratories. • **Air Handling Systems - Containment Level 3 (CL3) Testing Requirements:** 1. Classes I and II BSCs to be tested in situ in accordance with NSF/ANSI 49-2002[3] or CSA Z316.3-95 [4]. 2. Class III BSCs to be tested in situ in accordance with the Laboratory Safety Monograph, NIH 1979[5] and BS EN 12469-2000[6]. 3. Interlocks (that is, Class II Type B2 BSC internal cabinet supply fan and exhaust fan) to be tested in accordance with NSF/ANSI 49:2002[3] to ensure that internal supply fan shuts off whenever exhaust fan fails. 4. Alarms to be tested for detection of BSC and/or exhaust fan failure by simulation of alarm conditions. 5. Integrity of HEPA filters installed into supply as method of backdraft protection and exhaust ductwork to be tested *in situ* by particle challenge testing using the scanning method according to IEST-RP-CC-006.2 (section 6.2)[7]. Acceptance criteria: particle penetration not to exceed 0.01%. Small in-line filters need not be *in situ* scan tested – maintenance program to include visual inspection and regular replacement. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada (Continued)	6. Integrity of HEPA filter housings with inlet and outlet bubble tight dampers installed into supply ductwork, where HEPA filters are used as backdraft protection, and exhaust ductwork to be tested in situ by pressure decay testing in accordance with ASME N510(2).Acceptance criteria: rate of air leakage not to exceed 0.1% of housing vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. This test is not a mandatory requirement for recertification if no physical modification or changes have been made. If modifications have been performed then the laboratory supervisor, in consultation with the Biological Safety Officer/ Institutional Biosafety Committee, shall determine the degree of change and whether this test is subsequently required. 7. Supply ductwork, where backdraft protection is required on supply, and exhaust air ductwork located between containment perimeter and HEPA filter or bubble tight backdraft damper to be tested in situ by pressure decay method in accordance with ASME N510(2).Acceptance criteria: rate of air leakage not to exceed 0.1% duct vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. 8. Item 8 is not required for CL3 labs. 9. Recommendation: Supply and exhaust air ductwork between containment perimeter and HEPA filter or bubble tight backdraft damper to be tested in situ by pressure decay method in accordance with ASME N510(2). Acceptance criteria: rate of air leakage not to exceed 0.1% duct vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. 10. Pressurization relationships across adjacent areas to be verified (that is, clean change to dirty change, dirty change to laboratory). Acceptance criteria: inward directional airflow (under normal operations) to be visually demonstrated (e.g., by holding a smoke pencil at each door leading to adjacent areas). 11. Control systems to be tested for fail-safe operation by failure of system components, (that is, exhaust fan failure, supply fan failure, power failure [where possible], Class II B2 BSC exhaust failure). This is to include audible/visual alarm testing. Acceptance criteria: inward directional airflow. The sustained reversal of airflow across containment barrier is to be prevented. This test is not a mandatory requirement for recertification if no control system hardware or logic changes or upgrades have been done; if modifications have been performed, or if frequent control system problems or failures have been encountered, then the requirement for retesting should be determined in consultation with the Biological Safety Officer/ Institutional Biosafety Committee. Note, this may necessitate the need for decontamination. While not required annually, control systems should be retested periodically. Consult Manufacturer's specifications. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada (Continued)	• **Air Handling Systems - Containment Level 4 (CL4) Testing Requirements:** 1. Classes I and II BSCs to be tested in situ in accordance with NSF/ANSI 49-2002(3) or CSA Z316.3-95 (4). 2. Class III BSCs to be tested in situ in accordance with the Laboratory Safety Monograph, NIH 1979(5) and BS EN 12469-2000(6). 3. Interlocks (that is, Class II Type B2 BSC internal cabinet supply fan and exhaust fan) to be tested in accordance with NSF/ANSI 49:2002(3) to ensure that internal supply fan shuts off whenever exhaust fan fails. 4. Alarms to be tested for detection of BSC and/or exhaust fan failure by simulation of alarm conditions. Integrity of HEPA filters installed into supply as method of backdraft protection and exhaust ductwork to be tested in situ by particle challenge testing using the scanning method according to IEST-RP-CC-006.2 (section 6.2)(7). Acceptance criteria: particle penetration not to exceed 0.01%. Small in-line filters need not be in situ scan tested – maintenance program to include visual inspection and regular replacement. 5. Integrity of HEPA filter housings with inlet and outlet bubble tight dampers installed into supply ductwork, where HEPA filters are used as backdraft protection, and exhaust ductwork to be tested in situ by pressure decay testing in accordance with ASME N510(2).Acceptance criteria: rate of air leakage not to exceed 0.1% of housing vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. This test is not a mandatory requirement for recertification if no physical modification or changes have been made. If modifications have been performed then the laboratory supervisor, in consultation with the Biological Safety Officer/ Institutional Biosafety Committee, shall determine the degree of change and whether this test is subsequently required. 6. Item 7 is not required for CL3 labs. 7. Supply ductwork, where backdraft protection is required on supply, and exhaust air ductwork located between containment perimeter and HEPA filter or bubble tight backdraft damper to be tested in situ by pressure decay method in accordance with ASME N510(2).Acceptance criteria: rate of air leakage not to exceed 0.1% duct vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. 8. Recommendation: Supply and exhaust air ductwork between containment perimeter and HEPA filter or bubble tight backdraft damper to be tested in situ by pressure decay method in accordance with ASME N510(2). Acceptance criteria: rate of air leakage not to exceed 0.1% duct vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada (Continued)	9. Supply and exhaust air ductwork between containment perimeter and HEPA filter or bubble tight backdraft damper to be tested in situ by pressure decay method in accordance with ASME N510(2). Acceptance criteria: rate of air leakage not to exceed 0.1% duct vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. 10. Pressurization relationships across adjacent areas to be verified (that is, clean change to dirty change, dirty change to laboratory). Acceptance criteria: inward directional airflow (under normal operations) to be visually demonstrated (e.g., by holding a smoke pencil at each door leading to adjacent areas). 11. Control systems to be tested for fail-safe operation by failure of system components, (that is, exhaust fan failure, supply fan failure, power failure [where possible], Class II B2 BSC exhaust failure). This is to include audible/visual alarm testing. Acceptance criteria: inward directional airflow. The sustained reversal of airflow across containment barrier is to be prevented. This test is not a mandatory requirement for recertification if no control system hardware or logic changes or upgrades have been done; if modifications have been performed, or if frequent control system problems or failures have been encountered, then the requirement for retesting should be determined in consultation with the Biological Safety Officer/ Institutional Biosafety Committee. Note, this may necessitate the need for decontamination. While not required annually, control systems should be retested periodically. Consult Manufacturer's specifications. 12. Supply and exhaust air ductwork between containment perimeter and HEPA filter or bubble tight backdraft damper to be tested in situ by pressure decay method in accordance with ASME N510(2). Acceptance criteria: rate of air leakage not to exceed 0.1% duct vol/min at 1000 Pa (4 in. w.g.) minimum test pressure. 13. Pressurization relationships across adjacent areas to be verified (that is, clean change to dirty change, dirty change to laboratory). Acceptance criteria: inward directional airflow (under normal operations) to be visually demonstrated (e.g., by holding a smoke pencil at each door leading to adjacent areas). 14. Control systems to be tested for fail-safe operation by failure of system components, (that is, exhaust fan failure, supply fan failure, power failure [where possible], Class II B2 BSC exhaust failure). This is to include audible/visual alarm testing. Acceptance criteria: inward directional airflow. The sustained reversal of airflow across containment barrier is to be prevented. This test is not a mandatory requirement for recertification if no control system hardware or logic changes or upgrades have been done; if modifications have been performed, or if frequent control system problems or failures have been encountered, then the requirement for retesting should be determined in consultation with the Biological Safety Officer/ Institutional Biosafety Committee. Note, this may necessitate the need for decontamination. While not required annually, control systems should be retested periodically. Consult Manufacturer's specifications. Footnotes for *Containment Level 4 (CL4) Testing Requirements* are listed on the following page.	

Topic	Requirement(s)	Commentary
Periodic Inspection and Testing - Canada (Continued)	**Footnotes for *Containment Level 4 (CL4) Testing Requirements* listed on previous pages:** 1. *ARS facilities design standards.* 242.1M-ARS. Facilities Division, Facilities Engineering Branch AFM/ARS, United States Department of Agriculture, 2002. 2. *Testing of nuclear air treatment systems.* ASME N510. New York, NY: American Society of Mechanical Engineers, 1989 (reaffirmed 1995). 3. *Class II (laminar flow) biohazard cabinetry.* Standard 49. Ann Arbor, Michigan: NSF International, 2002. 4. *Biological containment cabinets: installation and field testing.* CSA Z316.3-95. Toronto, ON: Canadian Standards Association, 1995. 5. National Cancer Institute Office of Research Safety and the Special Committee of Safety and Health Experts. *Laboratory safety monograph: a supplement to the NIH guidelines for recombinant DNA research*. Bethesda, MD: National Institutes of Health, 1979. 6. *Biotechnology – performance criteria for microbiological safety cabinets*. BS EN 12469:2000. European Committee for Standardization (CEN), 2000. 7. *Testing cleanrooms*. IEST-RP-CC006.2. Rolling Meadows, IL: Institute of Environmental Sciences and Testing (IEST), 1997.	For complete details, see the respective publication.

Topic	Requirement(s)	Commentary
Test Records	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5143. General Requirements of Mechanical Ventilation Systems** (5) The ventilation rate of every mechanical ventilation system used to prevent harmful exposure shall be tested after initial installation, alterations, or maintenance, and at least annually, by means of a pitot traverse of the exhaust duct or equivalent measurements. Records of these tests shall be retained for at least five years. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **2.5** Complete and permanent records shall be maintained for each laboratory ventilation system. Records shall include: • As-built drawings; • Commissioning report; • Testing and Balance reports; • Inspection reports; • Maintenance logs; • Reported problems; • System modifications; and • Equipment replacement or modifications. **8.5** Records shall be maintained for all inspections and maintenance. If testing involves quantitative values (such as hood throat suction) the observed values shall be recorded. Inspection forms designed for the several categories of testing shall be provided and shall include the normal values for the parameters tested.	
Management	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **2.1 General Requirements** Management shall establish a laboratory ventilation management plan to ensure proper selection, operation, use, and maintenance of laboratory ventilation equipment. *(See Appendix 5 of ANSI/AIHA Z9.5-2003 for a sample table of contents for a laboratory ventilation management plan.)*	Due to the intrinsic health and safety aspects associated with the proper functioning of laboratory ventilation systems, they must be operated and maintained in a manner that typically far exceeds the practices followed for ventilation systems that essentially only provide occupant comfort. A laboratory facility must ensure that those who normally operate, test and service the facility's ventilation systems are aware of the special nature and needs of the systems that serve laboratories. Also see *Appendix 4 - Audit Form in ANSI/AIHA Z9.5-2003,* which provides a comprehensive checklist for the Laboratory Ventilation Management Program.

Exhaust Systems

Topic	Requirement(s)	Commentary
Configuration	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5143. General Requirements of Mechanical Ventilation Systems** (1) The exhaust system shall be so designed, constructed, maintained and operated as to prevent harmful exposure by maintaining a volume and velocity of exhaust air sufficient to gather dusts, fumes, mists, vapors or gases from said equipment or process and to convey them to suitable points of safe disposal, thereby preventing their dispersion in harmful quantities into the atmosphere of work rooms or other places where persons are employed. (2) Exhaust ducts, inlet ducts, and fan plenums shall be so designed, constructed, and supported as to prevent collapse of the ducts and/or failure of the supporting system. (3) Exhaust ducts which convey dusts, fumes, and mists shall be provided with inspection or clean-out doors at intervals not to exceed 12 feet of horizontal running length for ducts up to 12 inches in diameter, but the distance may be greater for larger ducts. A clean-out door or doors shall be provided for servicing the fan and, where necessary, a drain shall be provided. (4) Two or more operations shall not be connected to the same exhaust system where the combination of substances removed may constitute a fire, explosion, or chemical reaction hazard in the duct system. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3** Laboratory exhaust system ductwork shall comply with the appropriate sections of Sheet Metal and Air Conditioning Contractors National Association (SMACNA, 1995) standards. Exhaust ductwork shall be designed in accordance with ANSI/AIHA Z9.2-2001 and Chapter 34 on Duct Design of the ASHRAE 2009 *Fundamentals* and Section 6-5 of NFPA 45-2011. Exhaust duct sizes should be selected to ensure sufficiently high airflow velocity to retard condensation of liquids or the adherence of solids within the exhaust system. If condensation within the duct is likely, all horizontal duct runs shall be sloped downward at least 1 inch per 10 feet in the direction of the airflow to a suitable drain or sump. Branch ducts shall enter a main duct so that the branch duct centerline is on a plane that includes the centerline of the main duct. For horizontal main ducts, branch ducts shall not enter a main duct on a plane below the horizontal traverse centerline of the main duct. Horizontal runs of branch ducts shall be kept at a minimum. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Configuration (Continued)	Longitudinal sections of a duct shall be a continuous seamless tube or of a continuously welded formed sheet. Longitudinal seams that are formed mechanically shall be utilized only for light duty systems with no condensation or accretion inside the duct. Spiral ducts may be one gauge lighter than the required gauge of longitudinal seam duct, except the spiral duct gauge shall always meet the abrasive wear resistance requirements. Traverse joints shall be continuously welded or flanged with welded or Van Stone flanges. (When nonmetallic materials are used, joints shall be cemented in accordance with the manufacturer's procedures.) If the duct is coated with a corrosion-resistant material, the coating may extend from the inside of the duct to cover the entire face of the flange. Flange faces shall be gasketed or beaded with material suitable for the service. **c.** The following design and construction elements shall be considered: • All systems used to exhaust air potentially containing radioactive materials shall have the ability to sample the effluent being discharged (primarily gasses and vapors) and shall be prominently marked for ease of identification. • This sampling point shall be located inside an accessible mechanical room at a point downstream from any exhaust treatment systems (filtration, etc.). • Where radioactive iodination is performed in specific laboratories, the exhaust system serving those laboratories shall be equipped to accept appropriate charcoal filtration systems. • Airborne radioactive effluent sampling systems shall be designed in accord with ANSI Standard N13.1, *Guide to Sampling Airborne Radioactive materials in Nuclear Facilities.* A single-nozzle sampling probe shall be designed to accomplish sampling of gases and vapors, as specified in ANSI Standard N13.1 **C.12.5 Building Vacuum Systems** **a.** Vacuum systems shall be protected with appropriate filtration (0.2 micron hydrophobic filter or the equivalent) to minimize the potential for contamination of vacuum pumps. Filters shall be on the suction side of pumps. Exhaust from vacuum systems shall be routed to the main laboratory exhaust system. Chemical fume hood or outside the facility. Vacuum system exhaust shall not be discharged into mechanical rooms or recirculated into occupied areas. **b.** Filters shall be located as close as possible to the laboratory in order to minimize the potential contamination of vacuum lines, thus minimizing decontamination and decommissioning costs. **c.** Filter systems and housings shall be designed for easy filter replacement and maintenance to reduce the potential for maintenance worker exposure and provide for easy disposal. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Configuration (Continued)	**C.14.4 Hazardous Waste Storage and Handling** **h.** A separate ventilation system shall be installed for the storage room. Exhaust shall be directed away from the building and the buildings' air intakes. This ventilation system shall be connected to the building's standby power system and contain appropriate filtration and monitoring devices. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **i. Autoclaves:** The space must have adequate exhaust capacity to remove heat, steam, and odors generated by the use of the autoclave(s). A canopy hood shall be provided over the door of the autoclave. The autoclave space shall operate at negative pressure to the surrounding areas. **j. Vacuum Systems:** Vacuum system exhaust must be vented to the outside of the building and not recirculated to the mechanical room. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.9 EXHAUST SYSTEMS:** Laboratory exhaust systems should be designed for high reliability and ease of maintenance. This can be achieved by providing multiple exhaust fans that are not necessarily redundant or by sectionalizing equipment so that maintenance work may be performed on an individual exhaust fan while the system is operating. To the extent possible, components of exhaust systems should allow maintenance without exposing maintenance personnel to the exhaust airstream. Access to filters and the need for bag-in, bag-out filter housings should be considered during the design process. Depending upon the effluent of the process being conducted, the exhaust airstream may require filtration, scrubbing or other emission control to remove environmentally hazardous materials. Any need for emission control devices should be considered early in the design so that adequate space can be provided and cost implications can be recognized.	

Topic	Requirement(s)	Commentary
Leakage	**ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.10** **DUCTWORK LEAKAGE:** Ductwork should have low leakage rates and should be tested to confirm that the specified leakage rates have been attained. Designs that minimize the amount of positive-pressure ductwork are desirable. All positive pressure ductwork should be of the highest possible integrity. The fan discharge should connect directly to the vertical discharge stack. Careful selection and proper installation of airtight flexible connectors at the exhaust fans are essential. If flexible connectors are used on the discharge side of the exhaust fan, they must be of high quality and included on a preventative maintenance schedule because a connector failure could result in the leakage of hazardous fumes into the equipment room. The engineer should evaluate these details carefully. Machine rooms that house exhaust fans should be ventilated to minimize exposure to exhaust effluent (e.g., leakage from the shaft openings of exhaust fans).	

Topic	Requirement(s)	Commentary
Components	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5143. General Requirements of Mechanical Ventilation Systems** (3) Exhaust ducts which convey dusts, fumes, and mists shall be provided with inspection or clean-out doors at intervals not to exceed 12 feet of horizontal running length for ducts up to 12 inches in diameter, but the distance may be greater for larger ducts. A clean-out door or doors shall be provided for servicing the fan and, where necessary, a drain shall be provided*. (Note: Also refer to **5154.1** below.)* (2) The air exhausted from blast-cleaning equipment, grinding, buffing, polishing equipment and all other equipment requiring exhausting of dust or particulate shall be discharged through dust-collecting equipment. Dust and refuse discharged from an exhaust system shall be disposed of in such a manner that it will not result in harmful exposure to employees. 5154.1. Ventilation Requirements for Laboratory-Type Hood Operations. (5) Where emissions from the exhaust stack are likely to cause harmful exposure to employees, an effective air cleaning system shall be provided. Where virulent pathogens are likely to be released in the hood, incinerators or equally effective means of disposal shall be provided in the exhaust system to prevent employee exposure. **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** Inspection doors or clean-out doors in exhaust ducts…do not apply to laboratory-type hood operations (*or biological safety cabinets*). (6) Blowers exhausting laboratory-type hoods in which hazardous substances are used shall be mounted outside the building or in service rooms outside the working area. For hoods with single, independent exhaust systems, blowers may be mounted inside the building provided that corrosion-resistant, sealed-joint duct-work is used. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Components (Continued)	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3.3** Each fan applied to serve a laboratory exhaust system or to exhaust an individual piece of laboratory equipment (e.g., a laboratory chemical hood, biosafety cabinet, chemical storage, etc.) shall be adequately sized to provide the necessary amount of exhaust airflow in conjunction with the size, amount, and configuration of the connecting ductwork. In addition, each fan's rotational speed and motor horsepower shall be sufficient to maintain the required exhaust airflow and stack exit velocity and the necessary negative static pressure (suction) in all parts of the exhaust system. Laboratory exhaust fans shall be located as follows: • Physically outside of the laboratory building and preferably on the highest level roof of the building served. • In roof penthouse or a roof mechanical equipment room that is always maintained at a negative static pressure with respect to the rest of the facility, and provides direct fan discharge into the exhaust stack(s). All laboratory exhaust fans shall include provisions to allow periodic shutdown for inspection and maintenance. Such provisions shall include: • Ready access to all fans, motors, belts drives, isolation dampers associated control equipment and the connecting ductwork. • Isolation dampers on the inlet side of all centralized exhaust system fans that have individual discharge arrangements or their own individual exhaust stacks. • Isolation dampers on both the inlet and outlet sides of all centralized exhaust system fans that discharge into a common exhaust stack or plenum. • Sufficient space to allow removal and replacement of a fan, its motor, and all associated exhaust system components and equipment without affecting other mechanical equipment or the need to alter the building structure. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.9 EXHAUST SYSTEMS:** To the extent possible, components of exhaust systems should allow maintenance without exposing maintenance personnel to the exhaust airstream. Access to filters and the need for bag-in, bag-out filter housings should be considered during the design process.	

Topic	Requirement(s)	Commentary
Manifolded Systems	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3.2.2** Laboratory chemical hoods may be combined into a common manifold with the following exceptions and limitations: • Each control branch shall have a flow-regulating device to buffer the fluctuations in pressure inherent in manifolds. • Perchloric acid hoods shall not be manifolded with nonperchloric acid hoods unless a scrubber is installed between the hood and the manifold. • Where there is a potential contamination from hood operations as determined by the Hazard Evaluation and Analysis of Section 2.4, radioisotope hoods shall not be manifolded with nonradioisotope hoods unless in-line HEPA filtration and/or another necessary air-cleaning system is provided between the hood and the manifold. • Carbon bed filters shall be added for gasses. **5.3.2.3** Exhaust streams that contain concentrations of flammable or explosive vapors at concentrations above the Lower Explosion Limit (LEL) as well as those that might form explosive compounds (that is perchloric acid hood exhaust) shall not be connected to a centralized exhaust system. Exhaust streams comprised of radioactive materials shall be adequately filtered to ensure removal of radioactive material before being connected to a centralized exhaust system. Biological exhaust hoods shall be adequately filtered to remove all hazardous biological substances prior to connection to a centralized exhaust system. **5.3.2.4** Unless all individual exhausts connected to the centralized exhaust system can be completely stopped without having a hazardous situation, provision shall be made for continuous maintenance of adequate negative static pressure (suction) in all parts of the system. **5.3.2.12** Manifolds shall be maintained under negative pressure at all times and be provided with at least two exhaust fans for redundant capacity. Emergency power shall be connected to one or more of the exhaust fans where exhaust system function must be maintained even under power outage situations. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.10 Types of Exhaust Systems:** In addition, fume hoods or other devices in which extremely hazardous or radioactive materials are used should receive special review to determine whether they should be connected to a manifolded exhaust system.	VAV type fume hoods that have exhaust control devices (that is, a damper or air valve) will inherently regulate the airflow to respond to static pressure fluctuations in the manifolds. Manifolded systems are also referred to as centralized exhaust systems and combine all laboratory room general exhausts and all fume hood exhausts. They typically provide a longer service life than an individual fume hood exhausts because a centralized exhaust system has higher overall dilution due to the contribution of the room general exhaust to the fume hood exhaust. In addition, the larger and usually higher exhaust stack(s) of a centralized exhaust system will provide higher and better exhaust dispersion than a host of smaller (individual fume hood) exhaust stacks. Experience has demonstrated that fewer larger exhaust fans provide more reliability than a large number of small (individual fume hood) exhaust fans 'scattered' over a large portion of the roof. Many additional benefits are possible with a manifolded exhaust system including: • Lower ductwork cost. • Fewer pieces of equipment to maintain. • Fewer roof penetrations. • Opportunity for energy recovery. • Centralized locations for exhaust discharge. • Ability to take advantage of exhaust system diversity. • Ability to provide a redundant exhaust system by adding a spare fan per manifold.

Topic	Requirement(s)	Commentary
Air Velocity	**National Fire Protection Association, Standard NFPA 45, 2011** **8-6 Duct Velocities**. Duct velocities of laboratory exhaust systems shall be high enough to minimize the deposition of liquids or condensable solids in the exhaust systems during normal operations in the chemical fume hood. **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3.5** A minimum discharge velocity of 3000 fpm (15.2 m/s) is required unless it can be demonstrated that a specific design meets the dilution criteria necessary to reduce the concentration of hazardous materials in the exhaust to safe levels (see Section 2.1) at all potential receptors.	Good design practice has generally established a 1,000 fpm as an adequate velocity within exhaust system ductwork. This ensures that fine particulate is transported and that excessive condensation will not occur. An adequate stack discharge velocity should be a minimum of 3,000 fpm. Since chemical fume condensation droplets will be carried upward at air velocities of 2,600 fpm, it is advisable to design and size exhaust stacks so the internal upward velocity is no more than 2,400 fpm in order to allow condensate to trickle down the inside walls of the stack to a roof drain. By also utilizing a conical shaped top on the stack the discharge velocity can be increased to at least 3,000 fpm in compliance with the standards and good design practice.

Topic	Requirement(s)	Commentary
Stack Height and Discharge Location	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** (1) The air outlet from every dust separator/collector and the dusts, fumes, mists, vapors or gases collected by an exhaust or ventilating system shall discharge to the outside atmosphere, provided that the exhaust system shall discharge to the outer air in such a manner that it will not cause a harmful exposure in any accessible workplace. Collecting systems which return air to work areas may be used if contaminants which accumulate in the work area do not result in harmful exposure to employees. (2) The air exhausted from blast-cleaning equipment, grinding, buffing, polishing equipment and all other equipment requiring exhausting of dust or particulate shall be discharged through dust-collecting equipment. Dust and refuse discharged from an exhaust system shall be disposed of in such a manner that it will not result in harmful exposure to employees. (4) Exhaust stacks shall be located in such a manner with respect to air intakes as to preclude the recirculation of laboratory-type hood emissions within a building. To protect employees on the roof, any one of the follow methods shall be utilized: (A) Chemical treatment, absorption on activated charcoal, or scrubbers; (B) Dilution of toxic materials below prescribed exposure limits prior to discharge; (C) Locked gates, doors or other equivalent means acceptable to the Division which prevent employee access to exhaust stack discharge areas while hoods are in operation unless personnel are provided with appropriate respirators and other personal protection; or (D) Exhaust stacks extending at least 7 feet above the roof and discharging vertically upward. Where rain protection is desired, high velocity discharge or concentric-duct, self-draining stacks or equivalent may be used. Rain caps which divert the exhaust toward the roof are prohibited. (5) Where emissions from the exhaust stack are likely to cause harmful exposure to employees, an effective air cleaning system shall be provided. Where virulent pathogens are likely to be released in the hood, incinerators or equally effective means of disposal shall be provided in the exhaust system to prevent employee exposure. (Continued on Next Page)	When there are nearby buildings, complex architectural features and irregular terrain, it may not be possible to reliably establish the necessary height of a stack by mathematical calculations. In such instances scale modeling of the facility and surrounding area and wind tunnel testing might be the best way to provide a realistic indication of the necessary stack heights and location. Stacks should never have a rain cap or anything else that adversely affects the creation of an unobstructed vertical discharge plume comprised of exhaust and entrainment air. Also see *Appendix 3 - ANSI/AIHA Z9.5-2003,* which provides comprehensive information on Selecting Laboratory Stack Designs.

Topic	Requirement(s)	Commentary
Stack Height and Discharge Location (Continued)	**National Fire Protection Association, Standard NFPA 45, 2011** **8.4.12** Air exhausted from chemical fume hoods and special exhaust systems shall be discharged above the roof at a location, height, and velocity sufficient to prevent re-entry of chemicals and to prevent exposures to personnel. **A.8.4.12** Exhaust stacks should extend at least 3 m (10 ft) above the highest point on the roof to protect personnel on the roof. Exhaust stacks might need to be much higher to dissipate effluent effectively, and studies might be necessary to determine adequate design. Related information on stack height can be found in Chapter 14, Airflow Around Buildings, of the ASHRAE *Handbook of Fundamentals*. **National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **2.3 Roof Exhaust Systems** Roof exhaust systems serving biosafety cabinets should have a stack that extends straight upward at least 10 ft (3 m) above the roof surface to avoid re-entrainment by the building, and should be increased in elevation when necessary to avoid the influence of surrounding structures. Raincaps or any other structure that deflects the straight upward flow of the discharged air should be avoided. No precipitation can enter the stack when air is being exhausted at normal stack velocities. To take care of precipitation during periods when system is shut off, a 1 in. (2.5 cm) hole can be drilled in the lowest point of the fan casing and the water allowed to drain onto the roof **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3.4** The discharge of potentially contaminated air that contains a concentration more than the allowable breathing air concentration shall be: • Direct to the atmosphere unless the air is treated to the degree necessary for recirculation (See Section 9.3); • In compliance with federal, state, or local regulations with respect to air emissions; • Discharged in a manner and location to avoid reentry into the laboratory building or adjacent buildings at concentrations above 20% of allowable concentrations inside the laboratory for routine emissions or 100% of allowable concentrations for emergency emissions under wind conditions up to 1%-wind speed for the site. **5.3.5** The exhaust stack discharge shall be in accordance with the ASHRAE 2003 *HVAC Applications Handbook*, Chapter 44. In any event the discharge shall be a minimum of 10 feet (3 m) above adjacent roof lines and air intakes and in a vertical up direction. (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Stack Height and Discharge Location (Continued)	**American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.7.5 c.** Prevailing winds, adjacent buildings, and discharge velocities must be taken into account so that discharge is not entrained within an outdoor air intake. **C.7.5 d.** Exhaust outlets shall be located away from occupied areas or from doors and windows. The preferred location for exhaust discharge is above roof level. Care must be taken in locating highly contaminated exhausts and discharges from engines, fume hoods, BSC's, kitchen hoods, and paint booths. **C.7.5 c.** If fume hood exhaust systems interconnect with other exhaust duct systems, appropriate engineering equipment, principles, and controls are necessary so that cross-contamination of the general ventilation does not occur. **C.14.4 Hazardous Waste Storage and Handling** **h.** A separate ventilation system shall be installed for the storage room. Exhaust shall be directed away from the building and the buildings' air intakes. **ASHRAE, 2011 HVAC Applications Handbook, 2011, Pg. 16.13 STACK HEIGHTS AND AIR INTAKES** For complex buildings or building with unique terrain or other obtacles to the airflow around the building, either scale model wind tunnel testing or computational fluid dynamics should be considered. HVAC design engineers that do not have the analytical skills required to undertake a dispersion analysis should consider retaining a specialized consultant.	This section of the ASHRAE Handbook provides extensive guidance and other references for determining required exhaust stack height to avoid exhaust re-entrainment.

Topic	Requirement(s)	Commentary
Operational Reliability	**National Sanitation Foundation, NSF 49 -2008, Biosafety Cabinetry: Design, Construction, Performance and Field Certification** **2.3 Roof Exhaust Systems** It is recommended that roof exhaust fans be energized by direct-connected electric motors to avoid failures caused by slipping and breaking of belts. Another advantage of direct connected fans is the ability to use the motor non-function to activate an alarm in the laboratory, whereas when a malfunctioning belted fan is employed, the motor can be operating when the fan is idle **National Fire Protection Association, Standard NFPA 45, 2011** **8.5.8** Controls and dampers when required for balancing or control of the exhaust system shall be of a type that in event of failure, will fail open to ensure continuous draft. *(See 8.10.3 through 8.10.5)* **A-8.2.2.**It is not the intent of this Standard to require emergency or standby power for laboratory ventilation systems **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5 2003** **5.3.2.4** Unless all individual exhausts connected to the centralized exhaust system can be completely stopped without having a hazardous situation, provision shall be made for continuous maintenance of adequate negative static pressure (suction) in all parts of the system. **5.3.2.12** Manifolds shall be maintained under negative pressure at all times and be provided with at least two exhaust fans for redundant capacity. Emergency power shall be connected to one or more of the exhaust fans where exhaust system function must be maintained even under power outage situations. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.14.4 Hazardous Waste Storage and Handling** **h.** A separate ventilation system shall be installed for the storage room. Exhaust shall be directed away from the building and the buildings' air intakes. This ventilation system shall be connected to the building's standby power system and contain appropriate filtration and monitoring devices. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.9 -16.10 EXHAUST SYSTEMS:** Laboratory exhaust systems should be designed for high reliability and ease of maintenance. This can be achieved by providing multiple exhaust fans that are not necessarily redundant or by sectionalizing equipment so that maintenance work may be performed on an individual exhaust fan while the system is operating. Another option is to use predictive maintenance procedures to detect problems prior to failure and to allow for scheduled shutdowns for maintenance.	For reliability, centralized exhaust systems should always have multiple fans. A reliable operational arrangement consists of always having a minimum of two fans running and also having at least one additional non-operating standby fan for a total of three fans. If one of the two operating fans fails, having another operating fan can ensure that a total loss of facility exhaust does not occur during the time required to bring the standby fan into operation. When a building is equipped with emergency power, it is strongly recommended that laboratory exhaust systems be on the emergency power system.

Topic	Requirement(s)	Commentary
Recirculated Air and Cross Contamination	**National Fire Protection Association, Standard NFPA 45, 2011** **8.3.1** Laboratory ventilation systems shall be designed to ensure that chemical fumes, vapors or gasses originating from the laboratory shall not be recirculated. **8.3.2** The location and configuration of fresh air intakes shall be chosen so as to avoid drawing in chemicals or products of combustion coming from either the laboratory building itself or from other structures and devices. **A.8.3.2** Special studies such as air-dispersion modeling might be necessary to determine the location of air intakes for laboratories away from the influence of laboratory exhaust and other local point source emissions. **8.4.1** Air exhausted from chemical fume hoods and other special local exhaust systems shall not be recirculated. **8.4.2.2** Devices that could result in recirculation of exhaust air or exhausted contaminants shall not be used unless designed in accordance with Section 4:10:1, "Nonlaboratory Air," and Section 4:10.2, "General Room Exhaust," of ANSI/AIHA Z9.5, *Laboratory Ventilation*. **A.8.4.2** Consideration should be made of the potential contamination of the fresh air supply by exhaust air containing vapors of flammable or toxic chemicals when using devices for energy conservation purposes. **8.4.4** Air exhausted from laboratory units and laboratory work areas in which chemicals are present shall be continuously discharged through duct systems maintained at a negative pressure relative to the pressure of normally occupied areas of the building. **8.4.5** Positive pressure portions of the lab hood exhaust system (e.g. fans, coils, flexible connections and ductwork) located within the laboratory building shall be sealed airtight or located in a continuously mechanically ventilated room. **8.4.12** Air exhausted from chemical fume hoods and special exhaust systems shall be discharged above the roof at a location, height, and velocity sufficient to prevent re-entry of chemicals and to prevent exposures to personnel. **A.8.4.12** Exhaust stacks should extend at least 3 m (10 ft) above the highest point on the roof to protect personnel on the roof. Exhaust stacks might need to be much higher to dissipate effluent effectively, and studies might be necessary to determine adequate design. Related information on stack height can be found in Chapter 14, Airflow Around Buildings, of the ASHRAE *Handbook of Fundamentals*. (Continued on Next Page)	Note that as written, NFPA 8.4.1 specifically prevents the recirculation of fume hood exhaust but not laboratory room air. Recirculation of laboratory room air is permissible if the specific requirements of ANSI/AIHA Z9.5 are met. The cost to install exhaust filtering and cleaning systems that would adequately remove hazardous fumes (and the associated risk of a failure in such a system) generally makes it an impractical consideration. Air cleaning to remove hazardous particulate for safe discharge of the exhaust air into the atmosphere (as may be required by the local and federal EPA) should not be confused with removing all toxic gasses, vapors etc. as would be required for re-circulation of the exhaust air within a facility. 2.1.1 States as follows: *"The containment and capture of a laboratory chemical hood shall be considered adequate if, in combination with prudent practice, laboratory worker chemical exposures are maintained below applicable in-house exposure limits, OSHA PELs, NIOSH RELs, ACGIH TLVs, etc.*

Topic	Requirement(s)	Commentary
Recirculated Air and Cross Contamination (Continued)	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3.4** The discharge of potentially contaminated air that contains a concentration more than the allowable breathing air concentration shall be: • Direct to the atmosphere unless the air is treated to the degree necessary for recirculation (See Section 9.3); **5.3.6** Nonlaboratory air or air from building areas adjacent to the laboratory may be used as part of the supply air to the laboratory if its quality is adequate. **5.3.6.1** Air exhausted from the general laboratory space (as distinguished from laboratory chemical hoods) shall not be recirculated to other areas unless one of the following sets of criteria is met: 1) Criteria A • There are no extremely dangerous or life-threatening materials used in the laboratory; • The concentration of air contaminants generated by maximum credible accident will be lower than short-term exposure limits required by 2.1.1; • The system serving the laboratory chemical hoods is provided with installed redundancy, emergency power, and other reliability features as necessary. 2) Criteria B • Recirculated air is treated to reduce contaminant concentrations to those specified in 2.1.1. • Recirculated air is monitored continuously for contaminant concentrations or provided with a secondary backup air-cleaning device that also serves as a monitor (via a HEPA filter in a series with a less efficient filter, for particulate contamination only). Refer to Section 9.3.1; • Provision for 100% outside air, whenever continuous monitoring indicates an alarm condition. **5.3.6.2** Exhaust air from laboratory hoods shall not be recirculated to other areas. Hood exhaust air meeting the same criteria as noted in Section 5.3.6.1 shall only be recirculated to the same work area where the hood operators have control of the hood work practices and can monitor the status of air cleaning. **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.14.4 Hazardous Waste Storage and Handling** **h.** A separate ventilation system shall be installed for the storage room. Exhaust shall be directed away from the building and the buildings' air intakes. This ventilation system shall be connected to the building's standby power system and contain appropriate filtration and monitoring devices. (Continued on Next Page)	See applicable commentary on the previous page.

Topic	Requirement(s)	Commentary
Recirculated Air and Cross Contamination (Continued)	**Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council, Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011:** Page 46: The use of recycled air to ventilate animal rooms saves considerable amounts of energy but might entail some risk. Many animal pathogens can be airborne or travel on fomites, such as dust, so exhaust air to be recycled into heating, ventilation, and air-conditioning systems that serve multiple rooms presents a risk of cross contamination. The exhaust air to be recycled should be HEPA filtered (high-efficiency particulate air-filtered) to remove airborne particles before it is recycled; the extent and efficiency of filtration should be proportional to the estimated risk. Air that does not originate from animal use areas but has been used to ventilate other spaces (e.g., some human-occupancy areas and food, bedding, and supply storage areas) may be recycled for animal space ventilation and might require less-intensive filtration or conditioning than air recycled from animal use space. Toxic or odor-causing gases, such as ammonia, can be kept within acceptable limits if they are removed by the ventilation system and replaced with air that contains either a lower concentration or none of these gases. Treatment of recycled air for these substances by chemical absorption or scrubbing might be effective; however, the use of nonrecycled air is preferred for ventilation of animal use and holding areas. The use of HEPA filtered recycled air without gaseous filtration (such as with activated-charcoal filters) can be used but only that: • Room air is mixed with at least 50% fresh air (that is, the supply air does not exceed 50% recycled air). • Recycled air is returned only to the room or area from which it was generated, except if it comes from other than animal housing areas. • Recycled air is appropriately conditioned and mixed with sufficient fresh air to address the thermal and humidity requirements of animals in that space.	See applicable commentary on the previous page.

Topic	Requirement(s)	Commentary
Materials and Fire Protection	**National Fire Protection Association, Standard NFPA 45, 2011** **A.8.1** NFPA 90A, *Standard for the installation of Air-Conditioning and Ventilating Systems*, and NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, contain additional requirements for general environmental ventilating systems. **8.2.1** Laboratory ventilation systems shall be designed to ensure that fire hazards and risks are minimized. **A.8.2.1** For additional information on laboratory ventilation, see ANSI/AIHA Z9.5, *Laboratory Ventilation*. For information on preventing the spread of smoke by means of utilizing supply and exhaust systems to create airflows and pressure differences between rooms or building areas, see NFPA92A, *Standard for Smoke-Control Systems Utilizing Barriers and Pressure Differences*. **A.8.2.2** It is not the intent of this standard to require emergency or standby power for laboratory ventilation systems **8.2.5** Exhaust and supply systems shall be designed to prevent a pressure differential that would impede egress or ingress when either system fails or during a fire or emergency scenario. This design includes reduced operational modes or shutdown of either the supply or the exhaust ventilation system. **8.2.6** The release of chemical vapors into the laboratory shall be controlled by enclosure(s) or captured to prevent any flammable and/or combustible concentrations of vapors from reaching any source of ignition. **8.5.1** Ducts from chemical fume hoods and from local exhaust systems shall be constructed entirely of noncombustible materials except in the following cases: (1) Flexible ducts of combustible construction shall be permitted to be used for special local exhaust systems within a laboratory work area. (2) Combustible ducts shall be permitted to be used if enclosed in a shaft of noncombustible or limited-combustible construction where they pass through non-laboratory areas or through laboratory units other than the one they serve. *(See 8.5.2)* (3) Combustible ducts shall be permitted to be used if all areas through which they pass are protected with an approved automatic fire extinguishing system. *(See 8.5.2)* **8.5.2** Combustible ducts or duct linings shall have a flame spread index of 25 or less when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*. Test specimens shall be of the minimum thickness used in the construction of the duct or duct lining. **8.5.3** Linings and coatings containing such fill as fiberglass, mineral wool, foam or other similar material that could accumulate chemical deposits shall not be permitted within laboratory exhaust systems. (Continued on Next Page)	Laboratory exhaust systems are most commonly comprised of welded stainless steel; however this is not necessarily the most appropriate material for all applications (see the ASHRAE reference). When selecting a material, consideration should also be given to the usage factor. If highly corrosive vapors will seldom be present and the overall use of the hoods will not be intensive, a lower cost and more easily fabricated material may be a more cost effective choice. Metal ductwork has good fire rating characteristics but in many instances has inferior corrosion resistance to ductwork comprised of non-metallic material such as PVC. However non-metallic ductwork may not comply with the local building code. The design of the exhaust system and the quality of the fabrication is often a more important factor than the material itself. A stainless steel exhaust system with welds of marginal quality and comprised of poor overall general workmanship may provide less service life than a well constructed exhaust system of galvanized steel. Duct fittings and horizontal runs where condensation can collect are most susceptible to corrosion.

Topic	Requirement(s)	Commentary
Materials and Fire Protection (Continued)	**8.5.5** Ducts shall be of adequate strength and rigidity to meet the conditions of service and installation requirements and shall be protected against mechanical damage. **8.5.6** Materials used for vibration insulation connectors shall comply with 8.5.2. **8.5.7** Flexible connectors containing pockets in which conveyed material can collect shall not be used in any concealed space or where strong oxidizing chemicals (e.g., perchloric acid) are used. **8.5.8** Controls and dampers when required for balancing or control of the exhaust system shall be of a type that in event of failure, will fail open to ensure continuous draft. *(See 8.10.3 through 8.10.5)* **8.7.1** Fans shall be selected to meet requirements for fire, explosion and corrosion. **8.7.2** Fans conveying both corrosive and flammable or combustible material shall be permitted to be lined with or constructed of corrosion-resistant materials having a flame spread rating of 25 or less when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*. **8.7.3** Fans shall be located and arranged so as to afford ready access for repairs, cleaning, inspection, and maintenance. **8.7.4** Where flammable gases or vapors or combustible dusts are passed through the fans, the rotating element shall be of nonferrous or spark-resistant construction. Alternatively, the casing shall be constructed of or lined with such material. **A.8.7.4.** For Informative material regarding spark-resistant fan construction, see Air Movement and Control Association (AMCA) Standards handbook 99-0401-86, *Classifications for Spark Resistant Construction.* **8.7.4.1** Where there is the possibility of solid material passing through the fan that would produce a spark, both the rotating element and the casing shall be constructed of such material. **8.7.4.2** Nonferrous or spark-resistant materials shall have a flame spread rating of 25 or less when tested in accordance with ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, or ANSI/UL 723, *Standard for Test for Surface Burning Characteristics of Building Materials*. **8.7.5** Motors and their controls shall be located outside the location where flammable or combustible vapors or combustible dusts are generated or conveyed unless specifically approved for the location and use. **8.10.1** Automatic fire protection systems shall not be required in chemical fume hoods or exhaust systems except in the following cases: (1) Existing hoods having interiors with a flame spread index greater than 25 in which flammable liquids are handled. (2) If a hazard assessment shows that an automatic extinguishing system is required for the chemical fume hood, then an applicable automatic fire suppression system standard shall be followed. (Continued on Next Page)	A centralized exhaust system that combines all laboratory room general exhausts and all fume hood exhausts will typically provide a longer service life than a multitude of individual fume hood exhausts. A centralized exhaust system also has higher overall dilution due to the contribution of the room general exhaust to the fume hood exhaust.

Topic	Requirement(s)	Commentary
Materials and Fire Protection (Continued)	**8.10.2** Automatic fire protection systems, where provided, shall comply with the following standards, as applicable: (1) NFPA 11, *Standard for Low, Medium, and High-Expansion Foam* (2) NFPA 12, *Standard for Carbon Dioxide Extinguishing Systems* (3) NFPA 12A, *Standard for Halon 1301 Fire Extinguishing Systems* (4) NFPA 13, *Standard for the installation of Sprinkler Systems* (5) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection* (6) NFPA 17, *Standard for Dry Chemical Extinguishing Systems* (7) NFPA 17A, *Standard for Wet Chemical Extinguishing Systems* (8) NFPA 69, *Standard on Explosion Prevention Systems* (9) NFPA 750, *Standard on Water Mist Fire Protection Systems* (10) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems* **8.10.3.1*** Automatic fire dampers shall not be used in chemical fume hood exhaust systems. **8.10.4** Fire detection and alarm systems shall not be interlocked to automatically shut down chemical fume hood exhaust fans. **Perchloric Acid Exhaust Systems:** **8.11.2** Perchloric acid hoods & exhaust ductwork shall be constructed of materials that are acid resistant, nonreactive, and impervious to perchloric acid. **8.11.3** The exhaust fan shall be acid resistant and spark resistant. **8.11.4** The exhaust fan motor shall not be located within the ductwork. **8.11.5** Drive belts shall be conductive and shall not be located within the ductwork. **8.11.6** Ductwork for perchloric acid hoods and exhaust systems shall take the shortest and straightest path to the outside of the building and shall not be manifolded with other exhaust systems. **8.11.6.1** Horizontal runs shall be as short as possible, with no sharp turns or bends. **8.11.6.2** The ductwork shall provide a positive drainage slope back into the hood. **8.11.6.3** Ductwork shall consist of sealed sections **8.11.6.4** Flexible connectors shall not be used. **8.11.7** Sealants, gaskets, and lubricants used with perchloric acid hoods, ductwork and exhaust systems shall be acid resistant and nonreactive with perchloric acid. (Continued on Next Page)	Note that the NFPA 45 requirement of 8-10.3 to not have fire dampers in the exhaust system and to not automatically shut down the exhaust may conflict with some local codes. Be sure to determine if the local code that has jurisdiction over a particular laboratory facility is in conflict with this. Although the safety standards specifically prohibit fire dampers in fume hood exhaust systems, individual local codes may still require their inclusion. The laboratory ventilation system designer is advised to seek a variance from such a requirement with the 'authority having jurisdiction' (AHJ). If a variance is not attainable, the designer will have to comply with the local code requirement but it is recommended that they confirm by letter to the AHJ that although the exhaust system will have the required fire dampers, it is contrary to NFPA 45, AIHA Z9.5 and other laboratory safety references. If a fire situation should later occur and the integrity of the system design becomes subject to investigation or litigation, the recommended documentation will help substantiate the designer's desire to follow noted safety standards

Topic	Requirement(s)	Commentary
Materials and Fire Protection (Continued)	**American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **5.3** Exhaust system materials shall be in accordance with Chapter 5 of ACGIH's *Industrial Ventilation: A Manual of Recommended Practice,* Chapter 34 on Duct Design of the ASHRAE 2001 Handbook – *Fundamentals*, and Chapter 6-5 of NFPA 45-2011. Exhaust system materials shall be resistant to corrosion by the agents to which they are exposed. Exhaust system materials shall be noncombustible if perchloric acid or similar oxidizing agents that pose a fire or explosive hazard are used. Exhaust airflow volume shall be sufficient to keep the temperature in the duct below 400^0F (204^0C) under all foreseeable circumstances. **5.3.2.3** Exhaust streams that contain concentrations of flammable or explosive vapors at concentrations above the Lower Explosion Limit (LEL) as well as those that might form explosive compounds (that is perchloric acid hood exhaust) shall not be connected to a centralized exhaust system. **Scientific Equipment & Furniture Association** **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods** **4.1.9** No fire dampers of any kind should ever be installed in a chemical fume hood exhaust system. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.11 Materials and Construction** **American Institute of Architects, GUIDELINES FOR PLANNING AND DESIGN OF BIOMEDICAL RESEARCH LABORATORY FACILITIES 1999** **C.13 Fire Safety/Fire Protection** **d. Fire Dampers:** Fire dampers shall not be provided on any fume hood system.	*Note that the Z9.5 reference to NFPA Chapter 6-5 of NFPA 45-2000 has been superseded by the material in Chapter 8 of NFPA 45-2011.)* This section of the ASHRAE HVAC Applications Handbook provides extensive guidance to specific duct materials based on resistance to the primary agents that will be present and the fabrication and usage factors to be considered.

Topic	Requirement(s)	Commentary
Commissioning	**California OSHA – Division of Occupational Health & Safety (DOSH) Subchapter 7. General Industry Safety Orders, Group 16. Control of Hazardous Substances, Article 107. Dusts, Fumes, Mists, Vapors and Gases** **5154.1. Ventilation Requirements for Laboratory-Type Hood Operations:** The ability of the hood to maintain an inward flow as required by (c) above shall be demonstrated using smoke tubes or other suitable qualitative methods upon initial installation. (5) The ventilation rate of every mechanical ventilation system used to prevent harmful exposure shall be tested after initial installation, alterations, or maintenance, Records of these tests shall be retained for at least five years. **U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention publication: Biosafety in Microbiology and Biomedical Laboratories, (BMBL) 5th edition 2009:** The operational integrity of a BSC must be validated before it is placed into service and after it has been repaired or relocated. Relocation may break the HEPA filter seals or otherwise damage the filters or the cabinet. Each BSC should be tested and certified at least annually to ensure continued, proper operation **American National Standard for Laboratory Ventilation ANSI/AIHA Z9.5-2003** **6.2** All newly installed, renovated, or moved hoods shall be commissioned to ensure proper operation by laboratory personnel. **6.2.1** The commissioning process shall be overseen by a responsible person or commissioning authority. **6.2.2** A written commissioning plan shall accompany design documents and be approved by the commissioning authority in advance of construction activities. The commissioning plan shall be available to all potential suppliers and contractors prior to bid along with the other project documents. A commissioning plan shall address operation of the entire ventilation system where the hoods, laboratories, and associated exhaust air and air supply ventilation systems are considered subsystems. The plan shall include written procedures to verify or validate proper operation of all system components and include: • Laboratory Chemical Hood Specification and Performance Tests • Preoccupancy Hood and Ventilation System Commissioning Tests • Preoccupancy Laboratory Commissioning Tests (Continued on Next Page)	*Also refer to the Audit Form in ANSI/AIHA Z9.5-2003, Appendix 4 which provides a comprehensive checklist for the Laboratory Ventilation Management Program including Commissioning Tests.*

Topic	Requirement(s)	Commentary
Commissioning (Continued)	**6.2.3** Preliminary and final commissioning documents shall be issued to the appropriate party(s) by the commissioning authority. These documents shall include: • Design Flow Specifications; • Laboratory and System Drawings for Final System Design; • Copy of the Test and Balance Report; • Commissioning Test Data; • List of Ventilation System Deficiencies uncovered and the details of how (and if) they were satisfactorily resolved. **ASHRAE, 2011 Handbook, HVAC Applications, Laboratories, Pg. 16.20 Commissioning** In addition to HVAC systems, electrical systems and chemical handling and storage areas must be commissioned. Training of technicians, scientists, and maintenance personnel is a critical aspect of the commissioning process. Users must understand the systems and their operation. It should be determined early in the design process whether any laboratory systems must comply with Food and Drug Administration (FDA) regulations because these systems have additional design, commissioning and validation requirements. Commissioning is defined in Chapter 43, and the process is outlined in ASHRAE *Guidelines 0 and 1.1*. Laboratory commissioning can be more demanding than that described in ASHRAE *Guidelines and includes systems* that are not associated with other occupancies. Requirements for commissioning should be clearly understood by all participants, including the contractors and the owner's personnel. Roles and responsibilities should be defined, and responsibilities for documenting results should be established. Laboratory commissioning starts with the intended use of the laboratory and should include development of a commissioning plan, as outlined in ASHRAE *Guidelines.* The start-up and pre-functional testing of individual components should come first: after individual components are successfully tested, the entire system should be functionally tested. This requires verification and documentation that the design meets applicable codes and standards and that it has been constructed in accordance with the design intent and owner's project requirements. Before general commissioning begins, obtain the following data: • Complete set of the laboratory utility drawings • Definition of the use of the laboratory and an understanding of the work being performed • Equipment requirements • All test results • Basis of Design (BOD) that includes the intent of system operation • Owner's Project requirements (Continued on Next Page)	

Topic	Requirement(s)	Commentary
Commissioning (Continued)	For HVAC system commissioning, the following should be verified and documented: • Manufacturer's requirements for airflow for biological safety cabinets and laminar flow clean benches have been met. • Exhaust system configuration, damper locations, and performance characteristics, including any required emission equipment, are correct. • Control system operates as specified. Controls include fume hood alarm; miscellaneous safety alarm systems; fume hood and other exhaust airflow regulation; laboratory pressurization control system; laboratory temperature control system; and main ventilation unit controls for supply, exhaust, and heat recovery systems. Control system performance verification should include speed of response, accuracy, repeatability, turndown, and stability. • Desired laboratory pressurization relationships are maintained throughout the laboratory, including entrances, adjoining areas, air locks, interior rooms, and hallways. Balancing terminal devices within 10% of design requirements will not provide adequate results. Additionally, internal pressure relationships can be affected by airflow around the building itself. See Chapter 24 of the 2009 *ASHRAE Handbook—Fundamentals* for more information. • Fume hood containment performance is within specification. ASHRAE *Standard* 110 provides criteria for this evaluation • Dynamic response of the laboratory's control system is satisfactory. One method of testing the control system is to open and shut laboratory doors during fume hood performance testing. • System fault tree and failure modes are as specified, including life safety fan system shutdown impact on proper provisions for egress from the building within allowable limits of door opening force requirements. • Standby electrical power systems function properly. • Design noise criterion (NC) levels of occupied spaces have been met.	

Topic	Requirement(s)	Commentary
Commissioning - Canada	**Public Health Agency of Canada, Office of Laboratory Security, Biosafety Division, Laboratory Biosafety Guidelines, 3rd Edition 2011:** **5.1 Introduction** For the purposes of this document, "commissioning" is defined as the verification of the physical construction and performance of critical containment components and is one part of the overall certification process. "Certification" is defined as the successful completion of commissioning and verification that the facility and operational protocols meet the requirements outlined in the current edition of the *Laboratory Biosafety Guidelines*. "Recertification" is verification that the facility continues to comply with the current edition of the *Laboratory Biosafety Guidelines* and has undergone a recommissioning process as outlined below. **5.1.1 Commissioning** To ensure that the physical requirements for the intended containment level and use of the facility have been met, each laboratory must undergo a detailed commissioning regimen. This requires verification and documentation of critical containment components, equipment start-up, control system calibration, balancing and performance testing. A complete set of drawings and specifications, an understanding of the intended use and work to be performed, a list of equipment requirements, all test results, and an understanding of the intent of the systems' operation are all part of the commissioning process. Commissioning is a requirement for the certification of containment levels 3 and 4 laboratories. **5.1.2 Certification** A matrix of critical containment components to be verified during initial certification is provided below. Operational protocols must also be established before work with pathogens at the specified containment level can be carried out. Training of personnel is a critical aspect of this process and may involve initial work with pathogens normally requiring a lower containment level. Users must understand the containment systems and their operation in addition to scientific procedures. Detailed records of the certification process and test results must be maintained.	

Referenced Publications

The following publications are referenced in the preceding tables and are recommended sources of additional information associated with the proper design, use and testing of laboratory ventilation systems, HVAC systems and control systems

NOTE: *You are strongly advised to procure a copy of each of the following referenced documents to ensure having the complete, current text on the subject matter.*

- **Guidelines for Planning and Design of Biomedical Research Laboratory Facilities 1999**

Obtain from: American Institute of Architects
1735 New York Avenue, NW
Washington, D.C., 20006-5292
(206) 626-7300
http://www.aiaonline.com

- **ASHRAE Handbooks: 2011 – HVAC Applications & 2009 - HVAC Fundamentals**
- **ASHRAE Standard 110: 2006 – Method of Testing Performance of Laboratory Fume Hoods 2006**

Obtain from: ASHRAE (American Society Of Heating, Refrigeration, & Air Conditioning Engineers, Inc.)
1791 Tullie Circle NE
Atlanta, GA, 30329 -2305
(404) 636-8400 or (800) 527-4723
http://www.ashrae.org/

- **Industrial Ventilation: A Manual of Recommended Practice for Design, 27th Edition -**
- **Industrial Ventilation: A Manual of Recommended Practice, for Operation and Maintenance, 1st Edition - 2007**

Obtain from: ACGIH (American Conference of Governmental Industrial Hygienists)
500 Glenway Avenue
Building D - 7,
Cincinnati, OH, 45211
(513) 661-7881
http://www.acgih.org/home.htm

- **Fire Protection For Laboratories Using Chemicals, NFPA 45, 2011**
- **Standard For Smoke Control Systems, NFPA 92, 2012**

Obtain from: National Fire Protection Association

Batterymarch Park,
Quincy, MA, 02269-9904
(800) 344-3555
http://www.nfpa.org/

- **California OSHA – Division of Occupational Health & Safety (DOSH)**

Subchapter 7. General Industry Safety Orders
Group 16. Control of Hazardous Substances
Article 107. Dusts, Fumes, Mists, Vapors and Gases
http://www.dir.ca.gov/
5143. General Requirements of Mechanical Ventilation Systems http://www.dir.ca.gov/title8/5143.html
5154.1. Ventilation Requirements for Laboratory-Type Hood Operations http://www.dir.ca.gov/title8/5154%5F1.html
5154.2. Ventilation Requirements for Biological Safety Cabinets http://www.dir.ca.gov/Title8/5154_2.html

- **Laboratory Ventilation Standard, ANSI/AIHA No. Z9.5, – 2003**

Obtain from: American Industrial Hygiene Association
2700 Prosperity Ave.
Suite 250 Fairfax, VA, 22031
(703) 849-8888
http://www.aiha.org/

- **National Sanitation Foundation, NSF 49 -2008,**
  Biosafety Cabinetry: Design, Construction, Performance and Field Certification

Obtain from: NSF International
789 North Dixboro Road
P.O. Box 130140
Ann Arbor, MI 48113-0140
(734) 769-8010
http://www.nsf.org

- **SEFA 1–2006 Recommended Practices for Laboratory Fume Hoods**

Obtain from Scientific Equipment & Furniture Association
028 Duchess Drive
MacLean, VA 22102
(703) 790-8661
http://www.sefalabfurn.com/Practices.htm

- **Laboratory Biosafety Guidelines, 2004**

Obtain from: Public Health Agency of Canada
Office of Laboratory Security
Biosafety Division
100 Colonnade Road
Loc: 6201A
Ottawa, ON
Canada K1A 0K9
Tel: (613) 957-1779
Fax: (613) 941-0596
http://www.phac-aspc.gc.ca/publicat/lbg-ldmbl-04/index.html

- **Biosafety in Microbiology and Biomedical Laboratories (BMBL 5th Edition) HHS Publication No. (CDC) 21-1112 Revised December 2009**

Obtain from: U.S. Dept. of Health and Human Services,
Centers for Disease Control and Prevention
Tel: (866) 512-1800
http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm

- **OSHA - Occupational exposure to hazardous chemicals in laboratories; 29 CFR, Part 1910, Standard 1910.1450**

Obtain from: Occupational Safety & Health Administration
200 Constitution Avenue, N.W.
Washington, DC 20210
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10106

- **Guide for the Care and Use of Laboratory Animals, Eight Edition, 2011**

Institute of Laboratory Animal Research, Commission on Life Sciences, National Research Council
Obtain from: The National Academies Press
500 Fifth Street, N.W.
Washington, DC 20001
http://www.nap.edu/catalog/5140.html