	Standards for the Design, Construction, Maintenance, and Use of Laboratory Fume Hoods	**Document Number:**
		Effective Date:
		Revision Date: 5/2006

1.0 Purpose and Applicability

1.1 The intention of this document is to set a standard for the design, construction, maintenance, and use of laboratory ventilation in order to maintain acceptable air quality in the laboratory building and surrounding areas. This standard outlines criteria for stack heights, exhaust exit velocities, and design considerations that shall be addressed and implemented at the University of Massachusetts/Amherst. Together with design standards established by Facilities & Campus Planning, this document will determine requirements for laboratory exhaust ventilation systems. These requirements do not preclude adherence to good engineering practices, the Massachusetts Building Code and standards referenced therein. These requirements will be included in contract specifications for all future contracts submitted by the University of Massachusetts/Amherst. The University will only accept bids which meet these specifications on future contracts.

2.0 Definitions

The following are frequently used terms regarding standards for the design, construction, maintenance, and use of laboratory fume hoods:

building envelope - the three-dimensional space surrounding a building containing the building's makeup air.

downwash - pollutants discharged from an exhaust stack that travel towards the ground due to insufficient discharge velocities, poor wind dispersion, and physical obstructions.

exhaust air - the air that is removed from an enclosed space and discharged into atmosphere (ANSI/AIHA Z9.5, 1992).

face velocity - average velocity of air moving perpendicular to the hood face, usually expressed in feet per minute (fpm) or meter per second (m/s) (ANSI/ASHRAE 110, 1995).

glove box - a box-like structure provided with tight-closing doors or air locks, armholes with impervious gloves sealed to the box at the armholes and exhaust ventilation to keep the interior of the box at negative pressure relative to the surroundings (ANSI/AIHA Z9.5, 1992).

hood face - the plane of minimum area at the front portion of a laboratory fume hood through which air enters when the sash/es is/are fully opened, usually in the same plane as the sash/es when sash/es is/are present (ANSI/ASHRAE 110, 1995).

internal condensation - fumes and vapors that condense into liquids inside of the exhaust stack.

laboratory fume hood - a box-like structure enclosing a source of potential air contamination, with one open or partially open side, into which air is moved for the purpose of containing and exhausting air contaminants, generally used for bench-scale laboratory operation but not necessarily involving the use of a bench or a table (ANSI/ASHRAE 110, 1995).

lpm - liters per minute (ANSI/ASHRAE 110, 1995).

makeup air - outside air drawn into a ventilation system to replace exhaust air (ANSI/AIHA Z9.5, 1992). Makeup air **MUST** always be provided when any exhaust system is designed and installed.

perchloric acid hood - a fume hood constructed with water wash so it is safe for use with perchloric acid or other reagents that might form flammable or explosive compounds with organic materials of construction (ANSI/AIHA Z9.5, 1992).

recirculation - air withdrawn from a space, passed through a ventilation system, and delivered again to an occupied space (ANSI/AIHA Z9.5, 1992).

reentry - The flow of contaminated air that has been exhausted from a space back into the space through air intakes or openings in the walls of the space (ANSI/AIHA Z9.5, 1992).

replacement air - see makeup air.

return air - air being returned from a space to the ventilation fan that supplies air to a space (ANSI/AIHA Z9.5, 1992).

special purpose hood - an exhaust hood, not otherwise classified, for a special purpose such as, but not limited to, capturing gases from equipment such as atomic absorption, gas chromatographs, liquid pouring or mixing stations, and heat sources (ANSI/AIHA Z9.5, 1992).

variable air volume fume hood - a fume hood designed so the exhaust volume is varied in proportion to the opening of the hood face by changing the speed of the exhaust blower or by operating a damper in the exhaust hood (ANSI/AIHA Z9.5, 1992).

velocity - speed and direction of motion (ANSI/AIHA Z9.5, 1992).

walk-in hood - a fume hood designed to be floor mounted with sash and/or doors for closing the open face (ANSI/AIHA Z9.5, 1992).

3.0 Roles and Responsibilities

Environmental Health & Safety:

- Inspects the entire fume hood operating systems including the fume hood, associated duct work, exhaust blowers, and stacks;
- Places a sticker on fume hoods with average face velocity if the hood operating systems "PASS";
- Places a "DO NOT USE" sign on the hood sash if the hood operating system does "NOT PASS";
- Puts in a work order on behalf of the department head to Physical Plant for repair;
- Notifies the Department Head, Department Health and Safety Coordinator, Physical Plant, and Facilities Planning of any hoods which are deemed "OUT OF SERVICE."

Physical Plant and Facilities Planning:

- In a timely manner, makes all necessary repairs/modifications to the fume hood operating system and any associated equipment which affects the fume hood operating system in order to make the entire system safe to use;
- Notifies Environmental Health and Safety (EH&S) after all repairs/modifications are completed. EH&S then retests the system;
- Notifies EH&S on a monthly basis in writing as to the status of repair/replacement of fume hoods based on work orders/work requests submitted.

Department Head:

- Ensures that any fume hoods which are deemed "OUT OF SERVICE" **will not be used** until notified by EH&S that the hood can be used;
- Ensures that repairs/modifications are completed in a timely manner to any fume hoods which have been deemed "OUT OF SERVICE";
- Notifies EH&S and Physical Plant of any fume hoods which are not operating properly.

Personnel Using Fume Hoods:

- Follow all safety and health procedures specified in the Laboratory Health and Safety Manual and by the faculty supervisor in the laboratory;
- Attend all required health and safety training sessions;
- Do not use fume hoods which are "OUT OF SERVICE";
- Report fume hoods which are not operating properly, accidents, unhealthy and unsafe conditions to the faculty supervisor;
- Notify faculty supervisor of any pre-existing health conditions that could lead to serious health situations when using a fume hood.

4.0 Procedure

4.1 Laboratory exhaust ventilation systems designed, constructed, maintained, and used at the University of Massachusetts/Amherst shall comply with the specifications and standards set forth in this document and in the publications listed (see **5.0 Key References**). Failure to meet these standards shall be referred to the Institutional Chemical Safety Committee (ICSC).

4.2 **Fume Hood Design and Construction –** The Standards for the Design, Construction, Maintenance, and Use of Laboratory Fume Hoods will concentrate on the aspects of fume hood system design and operation that are critical to protecting the health and safety of faculty, staff, students, and visitors and also minimizing nuisance odors. Properly designed systems function to capture contaminants from the work area and disperse them in the outside environment. Exhaust stacks function to release contaminants from the inside of a building in order to minimize contaminant re-entrainment.

The critical design aspects of fume hood systems that are discussed in this document are: the quality of the fume hood enclosure, the quality and quantity of supply air provided to the fume hood, face velocity of the fume hood, exhaust stack height, exit velocity of air being exhausted from the stack. In addition, effluent dispersal is contingent upon factors such as exhaust stack/air intake separation, stack height, stack height plus momentum, topography of the building and surrounding environment, and wind dynamics.

Although system performance depends heavily on the above design elements, it must be noted that the fume hood performance in a room is affected by room layout and supply air distribution. System performance depends on the fan and duct layout as well as fan type and discharge conditions. These issues are dealt with in detail in the mechanical design standards developed by Facilities & Campus Planning (FCP).

4.2.1 **Laboratory Chemical Hoods: Minimum Specification**

The design and construction of laboratory chemical hoods shall conform to the applicable guidelines presented in the latest edition of ACGIH's "Industrial Ventilation: A Manual of Recommended Practice," and all other applicable local codes, guidelines and regulations.

The following are recommended design features for fume hoods:

- Work surfaces should be recessed at least 3/8 inches below the front edge of the bench or surface. Side and back of the fume hood should have a seamless lip at least 3/8 inches high in order to contain spill.
- Provide airfoils or other sidewall designs to reduce leakage and airflow eddy at the front edge of the bench and on the front side posts external to the sash.
- Utilities should be located outside the hood. Other non-electrical utilities, if required, can be located inside the fume hood provided they have outside cut offs and should not subject the operators to exposure from materials inside the hood.
- Laboratory fume hoods and associated exhaust ducts should be constructed of non-combustible, nonporous material that will resist corrosion. They should be equipped with vertical or horizontal sashes that can be closed, air foils that are built into the fume hood at the bottom and the sides of the sash opening, and baffles to attain a uniform face velocity under different conditions of hood use.
- Baffles should be designed to capture material generated within the hood and distribute the flow throughout the opening to minimize potential escape.
- Combination horizontal and vertical sashes shall be provided unless special conditions dictate otherwise. Types of sashes available are:
    1. Vertical raised sash
    2. Horizontal sliding sash
    3. Combination vertical raising and horizontal sliding sash

Additionally, recognized good design and construction features are listed in ANSI/AIHA Z9.5 2003. Sashes shall not be removed when the hood is in use. Sash limiting devices, if installed, shall not be removed if the design opening is less than a full opening. Vertical raised sashes shall be limited to an 18 inch opening or at half sash. Combination sashes should have the same limiting device at 18 inches (or half vertical sash opening).

4.2.2 **Laboratory Chemical Fume Hoods - Hoods Types**

Bypass hood - Bypass fume hoods should be designed so the the bypass opens progressively and proportionately as the sash travels to the fully closed position. The hood exhaust volume shall remain essentially unchanged (.5% change) when the sash is fully closed (ANSI AIHA Z9.5-2003).

Conventional fume hoods (CAV) - These hoods shall meet the requirement in Section 4.3. The exhaust volume shall remain unchanged with the sash in full open position or in the design open position (half sash). As the sash is lowered the face velocity will increase. Velocity should be at maximum when the sash is opened at about 18 inches or at half sash.

Auxiliary supplied air fume hoods - These hoods also have to meet the requirement in 4.3. Auxiliary supplied air hoods are not recommended unless special energy conditions or design circumstance exits. The following requirements must be met in an auxiliary hood design:

1. The supply plenum shall be located externally and above the hood face;
2. The auxiliary air shall be released outside the hood;
3. The supply jet shall be distributed so as not to affect hood containment and or increase potential for air escape from the hood.

Perchloric acid laboratory chemical hoods - Perchloric acid hoods are laboratory hoods which meet the requirement of Section 4.3 and NFPA 45. In addition, the following requirement must be met for perchloric acid hoods:

- All inside surfaces shall use materials that will be stable and not react with perchloric acid to form corrosive, flammable and/or explosive compounds or by-products.
- All interior hood duct fan and stack surfaces shall be equipped with water wash down capacities.
- All ductwork shall have smooth welded seams and also be made of material that would not react with perchloric acids and or its by-products.
- No part of the system should be manifolded to a nonperchloric acid exhaust system.
- No organic material including gaskets, which can react with the perchloric acid and its byproduct, should be used for the construction of perchloric acids fume hoods.
- Perchloric acid hoods should be labeled clearly as: "Perchloric acid Hood" (source: ANSI/AIHA Z 9.5-2003).

Floor mounted hoods (also called walking fume hoods) - Floor mounted fume hoods can be used when the vertical working space of a bench hood is inadequate for the work or apparatus to be used in the hood. The base of the hoods should be contiguous with the sidewalls and a vertical lip at least 1 inch or equivalent to provide for spill containment. Door and panel should be constructed to allow it to be opened for the installation of apparatus.

4.2.3 ***Variable air volume(VAV) hoods***

General Purpose VAV Fume Hoods shall be capable of varying the exhaust air volume in proportion to the hood face opening by either changing the speed of the exhaust blower or by adjusting a damper in the exhaust duct for general laboratory fume hood operations.

Special Purpose VAV Fume Hoods shall be capable of varying the exhaust air volume in proportion to the hood face opening by either changing the speed of the exhaust blower or by adjusting a damper in the exhaust duct for fume hoods containing approved equipment or apparatus on a permanent basis. Note: VAV fume hoods are not permitted for radiation and perchloric acid activities.

General VAV Fume Hood Control System Requirements:

1. Airflow sensors and quick response (three seconds or less) pressure independent valves shall be installed in each exhaust duct, preferably at roof level, to maintain face velocity and to prevent backflow or air volume fluctuations.

2. Exhaust volume shall be directly measured (and face velocity appropriately varied) using closed-loop feedback control.

3. Documentation certifying the performance of the control valve technology shall be included as part of the preliminary design documents.

4. The control technology selected for VAV fume hoods shall use a proven successful technology with a demonstrated track record of three or more years.

5. Laboratories using VAV fume hoods shall incorporate temperature compensation to avoid undesirable temperature variations.

4.2.4 **Glove box**

4.2.5 **Recirculating hoods -** Recirculating or ductless fume hoods are *not permitted* for the removal of chemical contaminants.

4.3 **Fume Hood Design and Construction – Performance Specification Criteria:**

As manufactured (AM) - Fume hoods should be tested before a hood leaves the manufacturer using the modified ANSI/ASHRAE 110-1995 standard, “Method of Testing Performance of Laboratory Fume Hoods,” developed by the National Institutes of Health (NIH), fume hood testing protocol for Constant Volume Fume Hoods (Sect. 15991) and Variable Air Volume Fume Hoods (Sect. 15992), as applicable. See Appendix Z for NIH fume hoods testing protocols.

All new hoods shall meet the ANSI/ASHRAE requirements for Class 1 hoods including a tracer gas performance of AM 0.05 (parts per million) or better at a tracer gas release rate of 4.0 liters per minute. Documentation shall be provided with the results of the test. Performance is measured by specific tests: 1) Flow visualization, 2) Face velocity measurements, 3) Test method for Variable Air Volume (VAV) Fume Hoods, 4) VAV Response Test, 5) Tracer gas containment.

1) **Flow visualization -** qualitatively tests a hood's ability to contain vapors. This test consists of a small local challenge (use of a smoke tube), and a gross challenge (use of a smoke candle or smoke generator) to the hood. Smoke is released in the hood to visually determine if a hood or associated duct work leaks when it is actually used.

2) **Face velocity measurements -** determine the average velocity of air moving perpendicular to the hood face usually expressed in feet per minute (fpm). Face velocities will often provide information concerning the fume hood's ability to properly control contaminants. All fume hoods shall include some means of monitoring face velocity with a visual and audio alarm.

3) Test Method for Variable Air Volume (VAV) Fume Hoods – Variable air volume fume hoods shall be installed unless accepted design practice dictates otherwise. A VAV hood is one that is fitted with a face velocity control which varies the amount of air exhausted from the fume hood in response to the sash opening to maintain a constant face velocity. These hoods produce an acceptable face velocity over a relatively large sash opening and also provide significant energy savings by reducing the flow rate from the hood when it is closed.

4) Each **variable air volume (VAV**) fume hood shall maintain an average face velocity of 90-110 fpm at the maximum allowed full open hood sash position (28 inches) and half sash position (18 inches).

Each constant volume (CAV) fume hood shall maintain an average face velocity of 90-110 fpm in the half open sash position or 18 inches.

A written request for an exception to this requirement must be submitted to EH&S and will be granted only by EH&S. Face velocity measurements are to be made with a recently calibrated mechanical or electrical anemometer. Measurements should be made of 1 square foot areas across the face of the hood and no single face velocity measurement should be more than plus or minus 20% of the average. For further information, refer to ANSI/ASHRAE 111-1988, Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems.

Supply air - The proper volume, distribution, and quality of supply air shall be provided to laboratories containing fume hoods. ANSI/AIHA Z9.5 1992 and ANSI/ASHRAE 62 provide these standards. Make up air (replacement air) should be equal to at least 95% of the volume exhausted from the laboratory. This air shall not be recirculated from other laboratory areas. Although laboratory supply air seldom requires air cleaning, ASHRAE (HVAC Application Handbook 1995) provides technical information for the reduction of contamination from atmospheric dust and dirt.

Air supply systems for rooms containing chemical fume hoods shall not create room air drafts at the face of any hood greater than one half (preferably one third) the face velocity of the hood. For most laboratory hoods, this means 50 fpm or less terminal throw velocity at 6 feet above the floor. ACGIH's "Industrial Ventilation: A Manual of Recommended Practice," provides design criteria to help achieve these standards.

Exhaust stack discharge and exit velocities - Exhaust stacks shall be designed and built to prevent recirculation of contaminated air from the fume hood exhaust system into the fresh air supply of the facility or adjacent facilities. The effluent exhaust shall escape the building envelope. The stack shall also provide significant effluent dispersal so that effluent downwash does not occur at ground level. They shall be designed and built with the latest applicable ASHRAE standards using ANSI/ASHRAE Z9.5. ASHRAE 1997 Fundamentals Handbook and the publication "Laboratory Stack Height Determination and Evaluation Methods," present three methods for specification and evaluation of stack heights from laboratory hood exhaust fans.

Effluent discharge shall be: 1) direct to the atmosphere (unless treated for recirculation), 2) conform to federal, state, and local air emission regulations, 3) released so that reentry of effluent from the discharging building or a surrounding building is reduced to allowable concentrations inside of the building. (Allowable concentrations shall be determined using information on the nature of the contaminants to be released, recommended industrial hygiene practice, and applicable safety codes.)

Exhaust discharge from stacks shall: 1) be in a vertical up-draft direction at a minimum of 10 feet above adjacent roof lines and located with respect to surrounding air inlets as to avoid contaminant reentry, and 2) have a minimum exit velocity of 3,000 fpm.

ACGIH's Industrial Ventilation Manual provides information on perchloric acid fume hoods, biological safety cabinets, and glove boxes. All Class II biological safety cabinets must meet the National Sanitation Foundation Standard Number 49 for Class II Biohazard Cabinetry for design, manufacturing and testing.

5) A **tracer gas** leak test will quantitatively determine if the fume hood is properly containing contaminants. A tracer gas is released in the hood and a continuous-reading instrument is positioned outside the hood to monitor for the escape of the tracer gas. The preferred tracer gas is sulfur hexafluoride (SF_6)

4.4 **Testing Fume Hood Exhaust Systems and Biological Safety Cabinets**

New or renovated fume hood systems will be tested after installation and before use utilizing the Procedures for Testing New or Renovated Fume Hood Systems. Fume hood systems in new or renovated laboratories that do not meet the testing criteria and specifications <u>will not be accepted</u> for use by EH&S and the University of Massachusetts/Amherst.

Established fume hood systems will be tested at least annually and after major repairs using the Procedures for Testing Established Fume Hood Systems. When a fume hood fails to meet acceptable performance requirements, the hood will be declared OUT OF SERVICE. Fume hood systems that do not meet these requirements <u>must not be used</u>. These systems will be evaluated by Physical Plant and, if necessary, Facilities & Campus Planning. For Procedures for the Testing and Repair of Fume Hood Systems and Responsibilities for the Proper Operation and Use of Chemical Fume Hoods, see **4.8 Procedures for Testing New or Renovated Fume Hood Systems**.

The operational integrity of a new biological safety cabinet (BSC) must be validated by certification before it is put into service or after a cabinet has been repaired or relocated. In addition, it will be the responsibility of the faculty member to have the BSC tested and certified annually. Certification will be performed by an accredited Biohazard Cabinet Field Certifier using National Sanitation Foundation (NSF) Standard Number 49 for Class II Biological Safety Cabinets, (MA Higher Education Consortium list).

4.5 **Use of Laboratory Fume Hoods**

All personnel using fume hoods, biological safety cabinets, and glove boxes will follow the policies and procedures outlined in University of Massachusetts/Amherst Laboratory Health and Safety Manual. ANSI/AIHA Z9.5 1992 and ACGIH's Industrial Ventilation Manual provide additional work practices to minimize emissions and employee exposure when working with fume hoods.

CDC/NIH's publications: *Biosafety in Microbiological and Biomedical Laboratories* and *Primary Containment for Biohazards: Selection, Installation, and Use of Biological Safety Cabinets* provide additional information on the use of biological safety cabinets. Horizontal and vertical laminar flow clean benches are not biological safety cabinets. These clean benches provide a very clean environment for the manipulation of **non-hazardous** materials and can be used for activities such as the dust-free assembly of sterile equipment or electronic devices. Since the operator sits in the downstream exhaust from the clean bench, this equipment must never be used for the handling of toxic, radioactive, infectious, or sensitizing materials.

4.6 **Decontamination and Removal of Fume Hood Systems or Biological Safety Cabinets**

When a fume hood is scheduled for removal, the hood, fan, and associated ductwork must be tested for the presence of radioactive materials and hazardous chemicals (e.g., perchlorate salts, asbestos, oxidizers, sulfides, cyanides, lead, and mercury). EH&S will determine the need for testing and decontamination of the hood and ductwork. If decontamination is necessary, fume hood(s) must be decontaminated before removal. Biological safety cabinets must be decontaminated before removal or a move to a different location. Costs associated with testing and/or decontamination shall be included in the total project cost.

4.7 **Contractors Working With Fume Hoods and Associated Fans and Ductwork**

Before beginning work, all contractors and subcontractors involved with a renovation project regarding fume hoods, associated fans and ductwork must consult with EH&S for recommendations for training and personal protective equipment for their employees.

4.8 **Procedures for Testing New or Renovated Fume Hood Systems**

When new hoods are installed or when existing hoods are included as part of a significant renovation as a condition of acceptance, this test is to be conducted. In addition, tests will be conducted annually or whenever a significant change is made to the operating characteristics of the hood. Tests to be performed include face velocity measurements and containment tests.

Test Conditions:

1. General room ventilating systems, both supply and exhaust, including fume hood exhaust, must meet Facilities Planning Design Specifications and shall be in full normal operation. Airflow systems in the laboratory shall be properly balanced and commissioned prior to this test. This includes calibration of airflow controls, calibration of automatic temperature controls, balance of supply air, etc. (See Prudent Practices for Handling Hazardous Chemicals in Laboratories, 1995 and ANSI/ASHRAE 110-1995.) Laboratories must be under negative pressure relative to corridor unless special design conditions prevail.

2. Hoods are tested in fully open position, half-open position, and 25% open position.

3. All other hoods in the same room are in half-open position.

4. All other hoods on the same floor exhaust system are in half-open position.

5. The hood being tested should be empty.

6. The doors to the laboratory will be closed.

7. When adjustments are made to hood sashes, supply and exhaust air in the room will be allowed to stabilize before testing is done.

8. Hood monitor is calibrated and not in alarm.

4.9 **Determination of Average Face Velocity for Variable Air Volume (VAV) Hoods**

The open face of the hood shall be divided into imaginary rectangles of equal area approximately 1 square foot and velocity shall be measured in each rectangle.

1. Instruments used: Shortridge micromanometer with velgrid. Average the readings to determine average face velocity.

2. Note reading of face velocity on Shortridge.

3. Average face velocity must be 90-110 fpm at maximum allowed hood opening. Maximum opening is the point above which the face velocity deteriorates below 90 fpm.

4. Shortridge readings must be within +/- 20% of the average face velocity.

5. Face velocities will also be measured at the one half and one quarter open positions. The average face velocities at these openings should be +/- 10% of the average at the fully open position.

4.10 **Determination of Average Face Velocity for Constant Air Volume Hoods**

The open face of the hood shall be divided into imaginary rectangles of equal area approximately 1 square foot and velocity shall be measured in each rectangle.

1. Instruments used: Shortridge micromanometer with velgrid. Average the readings to determine average face velocity.

2. Note reading of face velocity on Shortridge.

3. Average face velocity must be 90-110 fpm at the one-half open position.

4. Shortridge readings must be within +/- 20% of the average face velocity.

4.11 **Smoke Testing To Determine Direction of Airflow and Air Turbulence and Contaminant Reentry**

1. Using a smoke tube, puff smoke 6 inches within the face of the hood around the outside edge of the opening. Determine direction of smoke flow. If visible fumes flow out of the front of the hood, make necessary adjustments.

2. Ignite a smoke candle in the hood and visually observe if there is leakage of smoke from the ductwork or if smoke is being drawn back into building or surrounding buildings.

4.12 **Conditions for Passing Hoods**

General room ventilating systems, both supply and exhaust, including fume hood exhaust shall be in full normal operation. The hood must have an acceptable face velocity and must pass the smoke testing. In addition, there must be no leakage of exhaust from ductwork and no reentry of hood exhaust into buildings.

4.13 **Procedures for Testing Established Fume Hood Systems**

Conducted annually, this test will check the performance of established fume hoods or whenever there is a significant change in the operating characteristics of the hood. Tests to be performed include face velocity measurements and containment tests.

Test conditions:

1. General room ventilating systems, both supply and exhaust, including fume hood exhaust shall be in full normal operation. Laboratories must be under negative pressure relative to corridor unless special design conditions prevail.

2. Hoods are tested in fully open position, half-open position, and 25% open position.

3. All other hoods in the same room are in the half-open position.

4. All other hoods on the same floor exhaust system are half-open position.

5. The hood being tested must be empty.

6. The doors to the laboratory will be closed.

7. When adjustments are made to hood sashes, supply and exhaust air in the room will be allowed to stabilize before testing is done.

8. Hood monitor is calibrated and not in alarm.

4.14 **Determination of Average Face Velocity for Variable Air Volume (VAV) Hood**

The open face of the hood shall be divided into imaginary rectangles of equal area approximately 1 square foot and velocity shall be measured in each rectangle.

1. **Instruments used -** Shortridge micromanometer with velgrid. Average the readings to determine average face velocity.

2. Note reading of face velocity on Shortridge.

3. Average face velocity must be 90-110 fpm at maximum allowed hood opening. Maximum opening is the point above which the face velocity deteriorates below 90 fpm.

4. Shortridge readings must be within +/- 20% of the average face velocity.

5.0 **Key References**

ACGIH. "Industrial Ventilation: A Manual of Recommended Practice." American Conference of Governmental Industrial Hygienists, 24th Edition. 2001.

Available from:
ACGIH
1330 Kemper Meadow Drive
Cincinnati, OH 45240

ANSI /AIHA Z9.5-2003. “American National Standard: Laboratory Ventilation.”

Available from:
American Industrial Hygiene Association

2700 Prosperity Ave. suite 250
Fairfax, VA 22031

ANSI/ASHRAE 110-1995. "Method of Testing Performance of Laboratory Fume Hoods." (1995).

Available from:
ASHRAE
1791 Tullie Circle, N.E.
Atlanta, GA 30329

ANSI/ASHRAE 111-1988. "Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems."

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Prudent Practices in the Laboratory: Handling and Disposal of Chemicals. Committee on Prudent Practices for Handling, Storage, and Disposal of Chemicals in Laboratories. Board on Chemical Sciences & Technology. Commission on Physical Sciences, Mathematics, and Applications. National Research Council. Washington, D.C.: National Academy Press, 1995.

Ratcliff, M. and Sandra E. "Laboratory Stack Height Determination and Evaluation Methods: Possible Additions to the ANSI/AIHA Z9.5 Standard on Lab Ventilation." ASHRAE Winter Meeting, 1998.

United States. Department of Health and Human Services *Biosafety in Microbiological and Biomedical Laboratories*. Washington, D.C.: G.P.O., 1999.

United States. Department of Health and Human Services. *Standard On Fire Protection For Laboratories Using Chemicals*. NFPA Standard 45. National Fire Protection Primary Containment for Biohazards: Selection, Installation, and Use of Biological Safety Cabinets. Washington, D.C.: G.P.O., 1995.

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<table>
<tr><td colspan="2" align="center">Appendix G</td></tr>
<tr><td colspan="2" align="center">WARNING
DO NOT USE</td></tr>
<tr><td>Building:</td><td>Date:</td></tr>
<tr><td>Room:</td><td>Hood #</td></tr>
<tr><td>Inspector:</td><td>Repair Tag #:</td></tr>
<tr><td>Work Order #
(Note: Call in under ACTION CODE 24)</td><td>Date Submitted:</td></tr>
<tr><td colspan="2" align="center">This fume hood was tested for performance but was found to be
OUT OF SERVICE
for the following reasons:</td></tr>
<tr><td colspan="2">.</td></tr>
<tr><td colspan="2" align="center">Physical Plant personnel have been notified and will make the necessary repairs.
DO NOT remove this sign or use the fume hood until it has been re-tested by Environmental Health and Safety. For more information, call Physical Plant Customer Service at 5-0600 or Environmental Health and Safety at 5-2682.</td></tr>
<tr><td colspan="2" align="center">Physical Plant Personnel
Tear off at perforation and return to EH&S for hood performance re-evaluation</td></tr>
<tr><td colspan="2" align="center">PHYSICAL PLANT USE ONLY</td></tr>
<tr><td>Building:</td><td>Room #:</td></tr>
<tr><td>Hood #:</td><td>Date Repaired:</td></tr>
<tr><td>Work Order #:</td><td rowspan="2">Comments:</td></tr>
<tr><td>Physical Plant Technician:</td></tr>
</table>

APPENDIX H

APPENDIX H: **National Institute of Health Testing fume hoods testing protocols**

FUME HOOD TESTING PROTOCOL
FOR CONSTANT VOLUME FUME HOODS

PART I. GENERAL
Test identified below was created by Farhad Memarzadeh of the National Institutes of Health in 1997 and further revised by Memarzadeh and Brightbill in 1999.

1.01 DESCRIPTION OF WORK
A. The work of this section consists of testing the performance of constant volume chemical fume hoods.
B. On Site Testing of Fume Hoods shall be work of this Section.
C. This section specifies procedures that are common to the scope of Section 11800 – Laboratory Hoods.

1.02 SUBMITTALS
A. TESTING EQUIPMENT AND FACILITIES
1. Submit 3 copies of specification sheets on all equipment proposed for on site testing specified in Part III of this section.
2. Submit 3 copies of sample test reports for approval. Contractor shall demonstrate the ability to perform necessary calculations on site the day of the test for the on site testing requirements.
3. Submit 3 copies of layouts of the testing facility.

1.03 CERTIFICATIONS
A. Submit test data attesting that each type of hood to be provided has been tested in accordance with the Modified ANSI/ASHRAE 110-1999 and meets the requirements of this specification.
1.04 QUALITY ASSURANCE
A. Testing agency for On Site testing shall be independent of the fume hood control system manufacturer.
B. Independent testing agency shall be approved by the NIH project officer. Testing agency shall submit Statement of Qualifications demonstrating experience relating to fume hood testing. As a minimum testing agency shall:

1. Have a registered Professional Engineer or Industrial Hygienist executing the testing.
2. Demonstrate prior execution of indicated tests and submit a sample of the test report.
1.05 REFERENCE DOCUMENTS
A. American National Standard Institute
B. ANSI/ASHRAE 110-1999 Standard for testing performance of fume hoods
C. National Fire Protection Association NFPA 45 - Fire Protecting for Laboratories Using Chemicals
D. ANSI/ASHRAE III Testing and Balancing
E. ANSI/AIHA Z9.5 Laboratory Ventilation Standard

PART II. PRODUCTS

2.01 TEST AND MEASUREMENT EQUIPMENT

A. Anemometers:

1. Accuracy: ±5% of reading
2. Internal Time Constant: <= 100ms

B. Tracer Gas Ejector in accordance with ANSI/ASHRAE 110

C. Tracer Gas (SF6) Sensor:

1. Sensitivity: 0.01 to 100 ppm
2. Accuracy:

a) Above 0.1 ppm: ±10% of reading

b) Below 0.1 ppm: ±25% of reading

D. Data Acquisition System: minimum 6 channel system capable so simultaneous sampling at 10 hz or greater

PART III. EXECUTION

3.01 FUME HOOD CONTAINMENT TESTING (ON SITE)

A. General: Laboratory areas and constant volume fume hoods shall be tested as installed to assess the level of containment. Testing shall be conducted as outlined below for 50% of the hoods provided in the project.

B. Testing shall be conducted in accordance with ASHRAE 110 - Method of Testing Performance of Laboratory Fume Hoods with the following modifications. This is primarily a test of the hood and laboratory configuration.

1. Hoods will be tested with simulated apparatus. This apparatus will consist of: two each 3.8 L round paint cans, one 300mm by 300mm by 300mm cardboard box, three each 150mm by 150mm by 300mm cardboard boxes. These items will be positioned from 150mm to 250mm behind the sash, randomly distributed, and supported off the work surface by 50mm by 50mm blocks.
2. The test gas will have a 6 LPM flow rate.
3. The test will be conducted at the center position for the manikin only.
4. Each test duration will be 5 minutes.
5. Acceptable test results will be 0.05 PPM or better.
6. At the conclusion of each 5-minute test there will be three rapid walk-by at 300mm behind the manikin. Each walk-by will be spaced 30 seconds apart. If there is a rise in test gas concentration, it cannot exceed 0.10 ppm and must return to 0.05 ppm within 15 seconds.
7. There will be a minimum of three and a maximum of five people in the test room during the test procedure.
8. Representatives of the NIH will witness the tests.

C. Face velocity testing shall be conducted to determine flow rates and turbulence at the face of the hood.

1. Face Velocity Parameters shall include:

a) Measured Face Velocity (FVm expressed in m/s): Face velocity measured in the plane of the sash at three locations at any point in time. Samples for each sensor shall be recorded simultaneously at no less than 10 Hz. The sensors shall basically be point sensors located in the middle of 1’ by 1’ grid sectors. Move the three sensors to other sectors for subsequent testing periods. Averages shall be calculated for any point in time to assess overall measured face velocity. However, individual sensor samples shall be used in calculating TI for each sensor. These face velocity measurements shall be made with sash(es) open and “closed.” Open shall mean the sashes positioned to their maximum design position. (To sash stop typically 18” to 22”.) Closed shall mean open to 6” for a vertical rising only sash and center panels open 6” on the horizontally sliding panels with the vertically rising sash closed.

b) Steady State Face Velocity (SSFV): The average of all sampled face velocities for a 5 second period. Two SSFVs will be determined for both measured face velocity and calculated face velocity; one before the event (SSFVb) and one after (SSFVa). The SSFVa will start two seconds after the end of TSS. The second suffix of m for measured and c for calculated shall be used to indicated the type of assessment.
c) Turbulence Intensity (TI expressed in m/s): Calculated root mean square of the fluctuating face velocity determined using FVm, calculated as follows: sqrt[Sum 1-n{(FVm1-SSFV)^2+...+(FVmn-SSFV)^2}/n]. This value shall be calculated for each of the steady state conditions preceding and following each event. This shall be correlated to a "Box Leakage Factor" using the following graph of the installation using the Methodology for Optimization of Laboratory Fume Hood Containment" (MOLHC) by NIH Office of the Director, Farhad Memarzadeh principal investigator. While this value does not have a pass/fail requirement, it is the fundamental indicator of containment and therefore shall be clearly reported.
D. Hood Static Pressure: Take traverse readings to measure exhaust rate and measure the hood static pressure two straight-line duct diameters downstream from the point of connection between the hood and the exhaust line. The readings shall be taken with a face velocity of .51 m/s ±.05 m/s at the full open sash position. (Open sash typically is 18” to 22”.)

E. Performance Parameter Requirements:
1. Tracer Gas Leakage per ANSI/ASHRAE – 110: 4.00 AM 0.05
2. Average Face Velocity
a) Sash(es) open:.51 m/s ± .05m/s (Open to sash stop typically 18” to 22”)
b) Sash(es) Closed: <1.53 m/s ± .15 m/s (exhaust rate shall not change)
3. SSFV Deviation Across Face: <15% of average face velocity
4. Pressure Drop Through the Hood: <= 13 mm water gage
F. Test Execution: Testing agency shall be equipped to execute the testing and assess all performance parameters on site the day of the test. Data acquisition of required parameters shall be simultaneous.
G. Test Documentation: All testing, calculated, and recorded parameters shall be presented in a report that shows the recorded parameters graphically and tabulates and summarizes all the results. Performance of the hood, the hood controls, and the laboratory in general shall be described and summarized.

FUME HOOD TESTING PROTOCOL FOR VARIABLE VOLUME FUME HOODS

PART I. GENERAL
Test identified below was created by Farhad Memarzadeh of the National Institutes of Health in 1997 and further revised by Memarzadeh and Brightbill in 1999.
1.01 DESCRIPTION OF WORK
A. The work of this section consists of testing the performance of variable air volume chemical fume hoods.
B. On Site Testing of Fume Hoods shall be work of this Section
C. This section specifies procedures that are common to the scope of other sections including:
1. {Section 11800 – Laboratory Hoods}
2. {Section 15920} – Fume Hood Control Systems (Off Site Mock Up)
1.02 SUBMITTALS
A. TESTING EQUIPMENT AND FACILITIES
1. Submit 3 copies of specification sheets on all equipment proposed for on site testing specified in Part III of this section.
2. Submit 3 copies of sample test reports for approval. Contractor shall demonstrate the ability to perform necessary calculations on site the day of the test for the on site testing requirements.
3. Submit 3 copies of layouts of the testing facility
1.03 CERTIFICATIONS
A. Submit test data attesting that each type of hood to be provided has been tested in accordance with the Modified ANSI/ASHRAE 110-1999 and meets the requirements of this specification.

1.04 SEQUENCING
A. Contractor shall submit testing certifications in accordance with these specifications for both the factory test of the fume hoods and the off site mock up of the fume hood controls prior to or along with the product data and shop drawings.
1.05 QUALITY ASSURANCE
A. Testing agency for On Site testing and Off Site Mock up shall be independent of the fume hood manufacturer and the fume hood control system manufacturer.
B. Independent testing agency shall be approved by the NIH project officer. Testing agency shall submit Statement of Qualifications demonstrating experience relating to fume hood testing. As a minimum testing agency shall:
1. Have a registered Professional Engineer or Industrial Hygienist executing the testing
2. Demonstrate prior execution of indicated tests and submit a sample of the test report
1.06 REFERENCE DOCUMENTS
A. American National Standard Institute
B. ANSI/ASHRAE 110-1999 Standard for testing performance of Fume hoods
C. National Fire Protection Association NFPA 45 - Fire Protecting for Laboratories Using Chemicals
D. ANSI/ASHRAE III Testing and Balancing
E. ANSI/AIHA Z9.5 Laboratory Ventilation Standard
PART II. PRODUCTS
2.01 TEST AND MEASUREMENT EQUIPMENT
A. Anemometers:

1. Accuracy: ±5% of reading
2. Internal Time Constant: <= 100ms
Definition:
a. The Internal Time Constant (ITC) is the amount of time it takes the sensor to respond 63% of the way to a step change.
b. The Response Time is the length of time to get to within the stated accuracy of the sensor.
c. Response Time = ITC * 3 or 5 depending on what accuracy. Example: If the Response Time is 200 ms, the ITC = 40-70 ms.
B. Tracer Gas Ejector in accordance with ANSI/ASHRAE 110
C. Tracer Gas (SF6) Sensor:
1. Sensitivity: 0.01 to 100 ppm

2. Accuracy:
a) Above 0.1 ppm: ±10% of reading
b) Below 0.1 ppm: ±25% of reading
D. Data Acquisition System: minimum 6 channel system capable so simultaneous sampling at 10 hz or greater
PART III. EXECUTION
3.01 FUME HOOD CONTAINMENT TESTING (ON SITE)
A. General: Laboratory areas and Variable volume fume hoods shall be tested as installed to assess the level of containment. Tests shall be performed during static and dynamic conditions. Testing shall be conducted as outlined below for 50% of the hoods provided in the project. Tests shall be characterized and referred to in two basic categories "Static" and "Dynamic." While elements of both static and dynamic testing exist in both test categories, these names are generally used for reference.
B. Static Testing: Testing shall be conducted in accordance with ASHRAE 110 - Method of Testing Performance of Laboratory Fume Hoods with the following modifications. This is primarily a test of the hood and laboratory configuration.
1. Hoods will be tested with simulated apparatus. This apparatus will consist of: two each 3.8 L round paint cans, one 300mm by 300mm by 300mm cardboard box, three each 150mm by 150mm by 300mm cardboard boxes. These items will be positioned from 150mm to 250mm behind the sash, randomly distributed, and supported off the work surface by 50mm by 50mm blocks.
2. The test gas will have a 6 LPM flow rate.
3. The test will be conducted at the center position for the manikin only.
4. Each test duration will be 5 minutes.
5. Acceptable test results will be 0.05 PPM or better.
6. At the conclusion of each 5-minute test there will be three rapid walk-by at 300mm behind the manikin. Each walk-by will be spaced 30 seconds apart. If there is a rise in test gas concentration, it cannot exceed 0.10 ppm and must return to 0.05 ppm within 15 seconds.
7. There will be a minimum of three and a maximum of five people in the test room during the test procedure.
8. Representatives of the NIH will witness the tests.
C. Dynamic Testing: These tests primarily test the dynamic performance of the fume hood control system. This group of tests measures hood performance parameters through various dynamic "events." Events shall include four sash movements up and down across differing ranges: 25% - 100% and 50% - 100%, sash movements of other hoods on the exhaust duct, walk-bys in front of the hood, and opening and closing the laboratory door commensurate with a person entering and exiting the room.

1. Hood parameters to be determined for each event are defined as follows (refer to the figure below for a graphical representation of some parameters):
a) Measured Face Velocity (FVm expressed in m/s): Face velocity measured in the plane of the sash at three locations. Samples for each sensor shall be recorded simultaneously at no less than 10 Hz. Sensing methodology shall have an internal time coefficient of no more than 100 ms and be matched with a data acquisition recorder with 10 Hz or better frequency. The sensors shall basically be a point sensors located in the middle (of the short dimension) of the face opening when the sash is at the minimum position during the tested event. Sensors shall be equally distributed across the long dimension. Averages shall be calculated for any point in time to assess overall measured face velocity. However, individual sensor samples shall be used in calculating TI for each sensor.
b) Total Exhaust Air Flow (TEF expressed in L/s): Total exhaust flow measured in the main exhaust duct leaving the hood. This parameter shall be recorded at no less that 10 Hz. The sensing methodology used for the recorded data shall represent the total airflow through the full range of flows and be validated by independent multi-point measurement. If the fume hood control system uses a flow sensing element, that element may be used assuming it can be calibrated across the full range of flow. Sensing elements must have an internal time coefficient of no more than 100 ms.
c) Variable Face Area (FAv expressed in meters): Face Area of the hood that varies as the sash is moved within specified limits
d) Fixed Face Area (FAf expressed in meters): Face area of the hood with sash at minimum position (minimum position should correlate with the minimum bypass flow through the hood)
e) Hood Airflow Leakage (HAL expressed in L/s): The difference in airflow between the measured airflow through the face (at minimum position) and the total air flow measured in the exhaust duct.
f) Calculated Face Velocity (FVc): Face velocity determined from the following equation: ((TEF-HAL)*1000)/(FAv + FAf)
g) Steady State Face Velocity (SSFV): The average of all sampled face velocities for a 5 second period. Two SSFVs will be determined for both measured face velocity and calculated face velocity; one before the event (SSFVb) and one after (SSFVa). The SSFVa will start two seconds after the end of TSS. The second suffix of m for measured and c for calculated shall be used to indicated the type of assessment
h) Face Velocity Baseline (FVBL): The average of SSFVa and SSFVb
i) Control Linearity (CL expressed in %): Abs(SSFVa-SSFVb)/(FVBL)*100
j) Time to Steady State (TSS10 and TSS5 expressed in seconds): The elapsed time from the initial sash movement until the FVc reaches and stays within ± 10% or ± 5% of FVBL (as indicated by the subscript)

k) Face Velocity Overshoot/Maximum Deviation-(FVO expressed in %): Calculated using the Calculated Face Velocity sample furthest from the FVBL (FVf) throughout the test per the following equation: (Abs(FVf-FVBL)/FVBL)*100. Samples include initial face velocity deviation immediately following the sash movement as the controls initially respond to the movement of the sash.
l) Response Time Constant (RTC expressed in seconds): Elapsed time between initial movement of the sash and the initial subsequent movement of the exhaust valve.
m) Steady State Deviation (SSD expressed in %): Face velocity variation from SSFVa or SSFVb as applicable. Calculated using the furthest sample from the applicable SSFV (FVf) using the following equation:

(Abs(FVf-SSFVx)/SSFVx)*100
n) Controllability (expressed in mV/mm): Describes controller response to changing sash position, ie: Controllers response signal change per unit distance of sash movement
o) Sash Position (SP expressed in mm): For vertical sashes - Vertical distance from the sill of the hood to the bottom of the sash. The minimum sash position shall correlate to the position of the sash when the minimum flow through the hood is all through the face. Maximum sash position shall be defined as a distance of 550-650mm. This parameter shall be recorded at no less than 10 hz.
p) Controller Output (CO expressed in Volts): Control output to the controlling exhaust air valve. This parameter shall be measured and recorded at no less than 10 Hz.
q) Turbulence Intensity (TI expressed in m/s): Calculated root mean square of the fluctuating face velocity determined using FVm, calculated as follows: sqrt[Sum 1-n{(FVm1-SSFV)^2+...+(FVmn-SSFV)^2}/n. This value shall be calculated for each of the steady state conditions preceding and following each event. This shall be correlated to a "Box Leakage Factor" using the following graph of the installation using the Methodology for Optimization of Laboratory Fume Hood Containment" (MOLHC) by NIH Office of the Director, Farhad Memarzadeh principal investigator. While this value does not have a pass/fail requirement, it is the fundamental indicator of containment and therefore shall be clearly reported.

2. Parameter Performance Requirements:
a) Face Velocity Baseline (FVBL): .51 m/s ± .05m/s
b) Control Linearity (Cl expressed in %): < 2%
c) Time to Steady State10 (TSS10 expressed in seconds): < 2 Seconds
d) Time to Steady State5 (TSS5 expressed in seconds): < 3 Seconds
e) Face Velocity Overshoot/Maximum Deviation: < 15% which means at no point throughout the test shall a sample be recorded <0.43 m/s or > 0.59 m/s
f) Response Time Constant (RTC expressed in seconds): < 0.5 Seconds
g) Steady State Deviation (SSD expressed in %): < 5% assessed using calculated face velocities
h) Controllability (expressed in mV/mm): > 12 mV/25.4mm
3. Alternate Parameter Performance Requirements: The following performance parameters are alternate requirements that can be used in assessing acceptable dynamic responses.
a) Face Velocity Baseline (FVBL): .51 m/s ± .05m/s
b) Calculated Face Velocity (FVc): All samples >0.255 m/s and <.89 m/s meaning that at no time during the event shall the calculated face velocity go outside that range. Any sample recorded beyond that range will result in assessing the response as unacceptable.

c) Control Linearity (Cl expressed in %): < 2%
d) Time to Steady State10 (TSS10 expressed in seconds): < 1.6 Seconds
e) Time to Steady State5 (TSS5 expressed in seconds): < 2 Seconds
f) Response Time Constant (RTC expressed in seconds): < 0.5 Seconds
g) Steady State Deviation (SSD expressed in %): < 5% assessed using calculated face velocities
h) Controllability (expressed in mV/mm): > 12 mV/25.4mm
D. Test Execution: Testing agency shall be equipped to execute the testing and assess all performance parameters on site the day of the test. Data acquisition of required parameters shall be simultaneous.
E. Test Documentation: All testing, calculated, and recorded parameters shall be presented in a report that shows the recorded parameters graphically and

tabulates and summarizes all the results. Performance of the hood, the hood controls, and the laboratory in general shall be described and summarized. The following goes only in the control manufacturer's spec.

3.02 FUME HOOD CONTROL TESTING (OFF SITE MOCK UP)

A. The manufacturer of the proposed fume hood control system shall mock up a fume hood installation and demonstrate the performance their system to validate that they can meet the requirements specified in Section 15992 - Testing of Variable Air Volume Fume Hoods. The off site test shall include all parameters under the control of the control system (FVBL, TSS, CL, RTC, SSD, and Controllability). It is not necessary to mock up the installation and assess TI. Events to be tested off site include all specified sash movements on the hood being tested. Walk-bys and door opening affects are not required for the off site test.

B. The testing shall be accomplished by an independent testing agency approved by the A/E and NIH. Reports shall be provided with the laboratory control submittals and no approval will be given for the fume hood control system until documentation of successful demonstration of the performance requirements are submitted.