Performance Requirements For Laboratory Fume Hoods

As Manufactured Performance Tests

As Installed Performance Tests

Annual Performance Tests

May 2018

U.S. Environmental Protection Agency
Safety and Sustainability Division

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LIST OF ABBREVIATIONS AND ACRONYMS

ACH	Air Changes Per Hour
ADA	Americans with Disabilities Act
AFV	Average Face Velocity
AI	As Installed
AIHA	American Industrial Hygiene Association
AM	As Manufactured
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
B&F	Building and Facilities
BSC	Biological Safety Cabinet
BZ	Breathing Zone (As Defined by ANSI Z9.5/ASHRAE 110)
CAV	Constant Air Volume
CFM	Cubic Feet Per Minute
EPA	U.S. Environmental Protection Agency
FPM	Feet Per Minute
FPT	Functional Performance Test
GFCI	Ground Fault Circuit Interrupter
HVAC	Heating, Ventilating and Air Conditioning
LEV	Local Exhaust Ventilation
LFH	Laboratory Fume Hood
NFPA	National Fire Protection Association
NSF	NSF International
PPM	Parts Per Million
POR	Point of Reference
SHEMP	Safety, Health and Environmental Management Program
SME	Sash Movement Effect
SSD	Safety and Sustainability Division
TAB	Testing, Adjusting and Balancing
VAV	Variable Air Volume

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1. PURPOSE AND INTRODUCTION

This document describes the test procedures to evaluate the performance of laboratory fume hoods (LFHs) at U.S. Environmental Protection Agency (EPA) laboratories in owned and leased facilities. EPA operates numerous laboratories across the nation and relies upon LFHs to provide safe working conditions. EPA requires testing to verify that LFHs operate per EPA performance criteria. The three types of tests described in this document are as follows:

- **"As Manufactured" (AM) Tests** may be required to be performed (at the discretion of SSD) by fume hood manufacturers before EPA purchases a LFH to determine whether the fume hood meets EPA's performance criteria. If SSD decides AM tests are required for a particular fume hood model, EPA facilities must confirm that LFHs meet the performance criteria based on the performance inspection and tests in Sections 3 and 4 of this document. If AM testing is waived for a particular LFH model, it must be documented in writing by SSD's Fume Hood Subject Matter Expert.

- **"As Installed" (AI) Tests** are performed by a certified, EPA-approved third-party independent testing agency immediately following complete installation, and the acceptance of the Testing, Adjusting and Balancing (TAB) and CX Functional Performance Testing (FPT) reports. These AI tests (1) verify proper performance integration with mechanical heating, ventilation and air conditioning (HVAC) systems, and (2) establish a benchmark for the performance of the fume hood system. All newly installed LFHs at EPA facilities must be AI tested regardless of whether using EPA Building and Facilities (B&F) funds or not. Existing LFHs in laboratories that undergo renovations affecting HVAC systems will also require AI testing.

- **Annual Tests** are performed annually by certified EPA laboratory personnel or certified, EPA-approved third-party contractor to ensure long-term sustainable performance of the fume hood systems. Annual tests confirm that installed LFHs continue to perform as specified.

Each type of test must occur within certain phases of a project (see Figure 1-1).

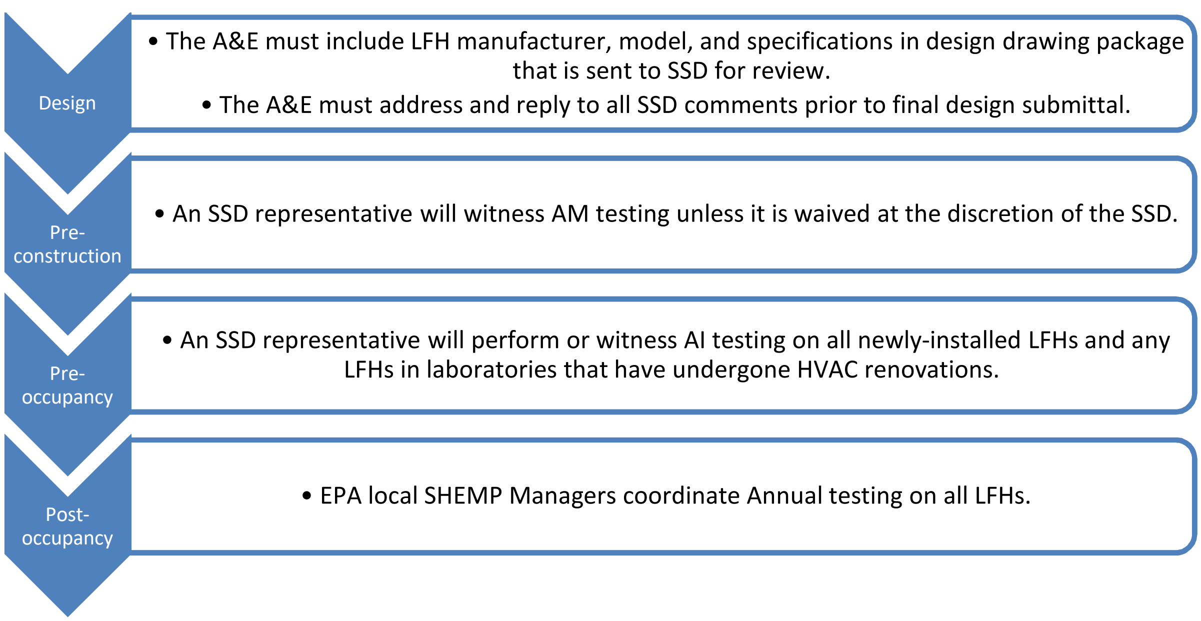


Figure 1-1. EPA Fume Hood Testing Sequence

The AM, AI and Annual test procedures apply to definitive types of laboratory fume hoods that fall into two main overarching categories as listed in Section 2.1:

- High Performance LFHs.
- Traditional LFHs.

There are different performance criteria for High Performance LFHs and Traditional LFHs. EPA encourages the purchase and use of High Performance VAV LFHs, which use less energy than Traditional LFHs during the units' lifetime. A cost benefit analysis should be performed which will include the payback period in energy savings.

Section 2 of this document summarizes LFH design specifications. Section 3 summarizes the inspection and performance test procedures required by EPA. Section 4 provides the performance criteria for High Performance and Traditional LFHs, which are summarized in Table 4-1, Table 4-2 and Table 4-3. A laboratory fume hood, space and exhaust system inspection data sheet is provided in Appendix A. A laboratory fume hood performance test data sheet is provided in Appendix B. Additional information about general requirements for laboratory exhaust and HVAC requirements in EPA laboratories is provided in the current EPA Facilities Manual, Volume 2, Architecture and Engineering Guidelines.

While the focus of this document is on the performance requirements for LFHs, EPA laboratories have many other types of hoods and local exhaust ventilation (LEV) devices such as biological safety cabinets (BSCs), laminar airflow equipment, snorkels, canopy hoods and glove boxes. The information regarding performance requirements and design specifications for the aforementioned LFH systems and LEV devices is available through the SSD at office number (202) 564-1640 and via the American Conference of Governmental Industrial Hygienist's (ACGIH) Industrial Ventilation Manual.

Biological Safety Cabinets (BSCs) at EPA laboratories shall meet minimum standards as established by NSF International (NSF)/American National Standards Institute (ANSI) in NSF/ANSI 49 for biosafety cabinetry certification. The standard covers personnel, environment and product safety. It shall be listed and identified with a distinctive NSF seal. Field certification shall be performed by a competent technician, conducted according to the procedures outlined in the standard, and it will be required once the cabinet (s) is/are installed. The classification of the BSCs shall be determined in consultation with the laboratory manager and staff. In addition, BSCs have special design requirements depending on their use. Foremost, these are intended to:

- Protect personnel from harmful agents released inside the cabinet;
- Protect the work product, experiment, or procedure from external contamination, and thus precluding invalid test results; and
- Protect the laboratory environment from contaminants released inside the cabinet.

2. LFH DESIGN AND PERFORMANCE SPECIFICATIONS

All LFHs shall meet the following design specifications and demonstrate that these systems meet EPA's performance criteria as described in Section 4 following the procedures described in Section 3. These design criteria are applicable to all types and models of LFHs, except where noted in the description of the design specifications as follows or in the most current EPA Facilities Manual Volume 2, Architecture and Engineering Guidelines (contact SSD for the most updated version). All LFH designs must comply with ASHRAE 110, ANSI/AIHA Z9.5, ASTM E84, CAN/CSA C22.2, NFPA 45, SEFA 1, UL and NEMA standards.

2.1 Types of Laboratory Fume Hoods

1. High Performance Laboratory Fume Hoods (Size Range of 3 thru 12ft)
   - Retrofitted Fume Hoods
   - Constant Air Volume (CAV) Fume Hoods
   - Variable Air Volume (VAV) Fume Hoods
   - Floor-Mounted Hoods
   - Distillation Hoods
2. Traditional Laboratory Fume Hoods (Size Range of 3 thru 12ft)
   - Radioisotope Fume Hoods
   - Perchloric Acid Fume Hoods
   - Constant Air Volume (CAV) Fume Hoods
   - Variable Air Volume (VAV) Fume Hoods
   - Floor-Mounted Hoods
   - Distillation Hoods

2.2 Two-Position or Modulating VAV or Integrated VAV Exhaust Systems

When multi-speed exhaust fans/variable-speed motor systems are used, the device that controls both the supply and exhaust air volumes shall be activated and modulated by a LFH sash position sensor and controller.

2.3 Monitor and Alarm

All newly installed High Performance LFHs shall have a digital display monitor with equipped with audible and visible alarms based on calculated or measured face velocity. The alarms shall be calibrated to alert when the face velocity of air drops below the specified low-end passing range value in feet per minute (fpm) (i.e., 60 fpm for a High Performance LFH and 90 fpm for a traditional LFH). The monitor shall display face velocity quantitatively with a minimum accuracy within 5% of the average face velocity. The monitor's digital display and alarm conditions shall be clearly visible in the installed location. (NOTE: OSHA's Occupational Exposure to Hazardous Substances in Laboratories 29 CFR 1910.1450 requires that LFHs and other protective equipment are functioning properly and specific measures shall be taken to ensure proper and adequate performance of such equipment).

2.4 Bypass Grille

The bypass grille shall be designed for contaminant dilution and removal from the hood. When utilized with a CAV ventilation system, the bypass area keeps the laboratory hood face velocity from increasing to an objectionably high value as the sash is lowered. When utilized with a VAV ventilation system, the restricted bypass opening shall not increase areas of recirculation and stagnation with the LFH specifically when the sash is closed.

2.5 Airfoil Sill

An airfoil, which presents a streamlined appearance, similar to the sides, shall be installed at the bottom of the face opening. The airfoil shall be designed and mounted so that it minimizes turbulence, produces a smooth flow of air over the work surface and prevents reverse flow within six inches of the sash plane. It may provide a means for electrical cords to exit the LFH chamber when the sash is fully closed if no other design feature exists to safely secure and channel electrical cords within or outside of the hood.

2.6 Sidewall

The sidewalls shall be of a suitable dimension to accommodate the service piping necessary for operation and use of the LFH. Access to the service piping should be readily available from the interior of the LFHs. It shall have access panels for access to the hood's services. Its face shall be of an aerodynamic design to reduce turbulence of the air entering the hood.

2.7 Interior Walls

The interior walls shall be flush with the face plates with minimal protrusions for at least six inches inside the hood. The work chamber walls, ceiling and baffle shall be constructed of a durable material or, as specified, with a finish that shall be resistant to heat, solvents and corrosives. The interior surfaces shall be easily maintained and cleaned.

2.8 Baffle

The baffle shall be designed to provide effective capture and containment at all sash opening heights. For LFHs equipped with adjustable baffles, no baffle position shall negatively affect performance. A light (or equivalent mechanism) shall be provided for LFHs equipped with automatic adjusting baffles as a means of identifying failure (e.g., green light/working and red light/not working). Any LFH installed with adjustable baffles shall be tested across all potential baffle configurations.

2.9 Light Fixture

A two-tube fluorescent/LED light fixture of the longest practical length (up to four feet) shall be provided inside LFHs. Light fixture shall be located at the top of the LFH. If an alternative lighting design is accepted by EPA, it should be noted on the performance testing documents as to why it is acceptable. It shall provide at least 100 foot-candles of light at the work surface. It shall be designed to accommodate the replacement of lamps from the exterior of the hood. If LFH enclosure panels (e.g., hood-to-ceiling enclosures) are required, access shall be provided to accommodate lamp replacement. Lamps shall be shielded from the hood interior by a tempered glass panel sealed into the hood body. If tubes are provided, they shall be energy efficient (at least T-8) and contain the lowest concentration of mercury that is commercially available.

2.10 Sash

- Sash Construction: The glass material used in the sash shall be a minimum of 7/32-inch thickness and made of clear laminated safety glass. If the sash has a frame, it shall be constructed of 18-gauge metal (minimum) and shall have no metal-to-metal contact with the LFH jamb during operation. The sash frame-to-glass junction shall be sealed to prevent vapor leakage and prevent items being trapped or caught between the glass/glazing and the frame.
- Sash Counterbalance: The sash shall be weight-balanced at any height to keep it from creeping up or down. The sash shall move smoothly with the use of one hand at any point along the bottom edge. Thus, the appropriate force required for pushing up or pulling down the sash shall not exceed five pounds (22.2 Newton).
- Sash Plane: The plane of the sash shall be defined as the vertical outside surface plane of the glass on the outermost sash panel.
- Sash Stops: The LFH shall have releasable sash stops located at the design opening height. The design opening height is defined as 80 percent of the full vertical sash opening height.
- Sash Sensor and controller: The sash sensing device for VAV fume hoods shall provide a signal that indicates the sash position with a tolerance of ±0.25 inches.

2.11 Automatic Sash Closers:

The EPA recommends that all newly-purchased fume hoods shall be equipped with an automatic sash closing controller. This shall be mounted above the sash with a passive infrared movement detector (PIR). If no operating personnel are in front of the LFH, the sash will close after a set period of time, based on recommended PIR model.

2.12 Exhaust Outlet:

A suitable fume hood collar shall provide a leak-free connection to the LFH exhaust system. The exhaust outlet shall have a monitoring port installed to measure hood static pressure above the outlet collar.

2.13 Electrical Switches and Outlets

Electrical switches and outlets shall be ground fault circuit interrupter (GFCI)-protected and meet the requirements of NFPA Standard 70, National Electric Code. A minimum of one duplex 120-volt outlet per side shall be installed or the number of required by EPA specifications. The electrical outlet(s) shall be located on the exterior of the LFH.

2.14 Benchtop

The benchtop shall have a 1/4-inch recessed work surface indicating the area for conducting experiments or containment of spills.

2.15 Work Surface

The work surface shall be of one-piece construction with a recess of at least 1/4 inches below the front edge of the bench or surface; sides and back should be provided with a seamless vertical lip at least ¼ inches high to contain spills. The work surface shall also have a ledge all around its perimeter. The ledge at the front of the work surface shall not extend more than three inches beyond the sash plane to prevent materials from being placed or stored on the ledge. The work surface may have a line embedded in it from side to side at least six inches to the rear of the sash plane to indicate that all equipment and operations must be located and/or performed behind the line. The interface between the work surface and the hood liner must be sealed to prevent leakage.

2.16 Hood Superstructure Dimensions

The following dimensions shall apply unless different dimensions are specified in writing by EPA. The superstructure outside dimensions for bench-mounted hoods shall not exceed 65 inches in height or 36 inches in depth. LFHs may have a depth up to 39 inches. The outside length dimension shall be 48, 60, 72, or 96 inches, as specified by EPA. Interior clear working height shall be at least 47 inches, measured from the work surface. The minimum sash opening, including the space below the bottom airfoil, shall be at least 28 inches in height.

2.17 Mechanical Air Supply for High Performance LFHs

The practice of mechanically introduced air flow to provide containment performance is acceptable as long as satisfactory containment is achieved through aerodynamic design features. The air flow design must meet EPA standards and LFH performance criteria.

2.18 LFH Retrofit

A LFH retrofit is a modification of an existing LFH design to improve performance (e.g., modifications to baffles or air foil design) and save energy (e.g., lowering the exhaust flow rate). A retrofitted fume hood must comply with the High Performance LFH specifications and criteria. Once the retrofit is installed and complete, the LFH and associated HVAC systems must undergo Testing, Adjusting and Balancing (TAB), CX Functional Performance Testing (FPT) and be followed up with AI testing.

3. INSPECTION AND PERFORMANCE TEST PROCEDURES

Performance tests are conducted to evaluate the capability of LFHs to meet EPA design specifications and performance criteria. The tests are based on guidelines and recommendations contained in the latest versions of:

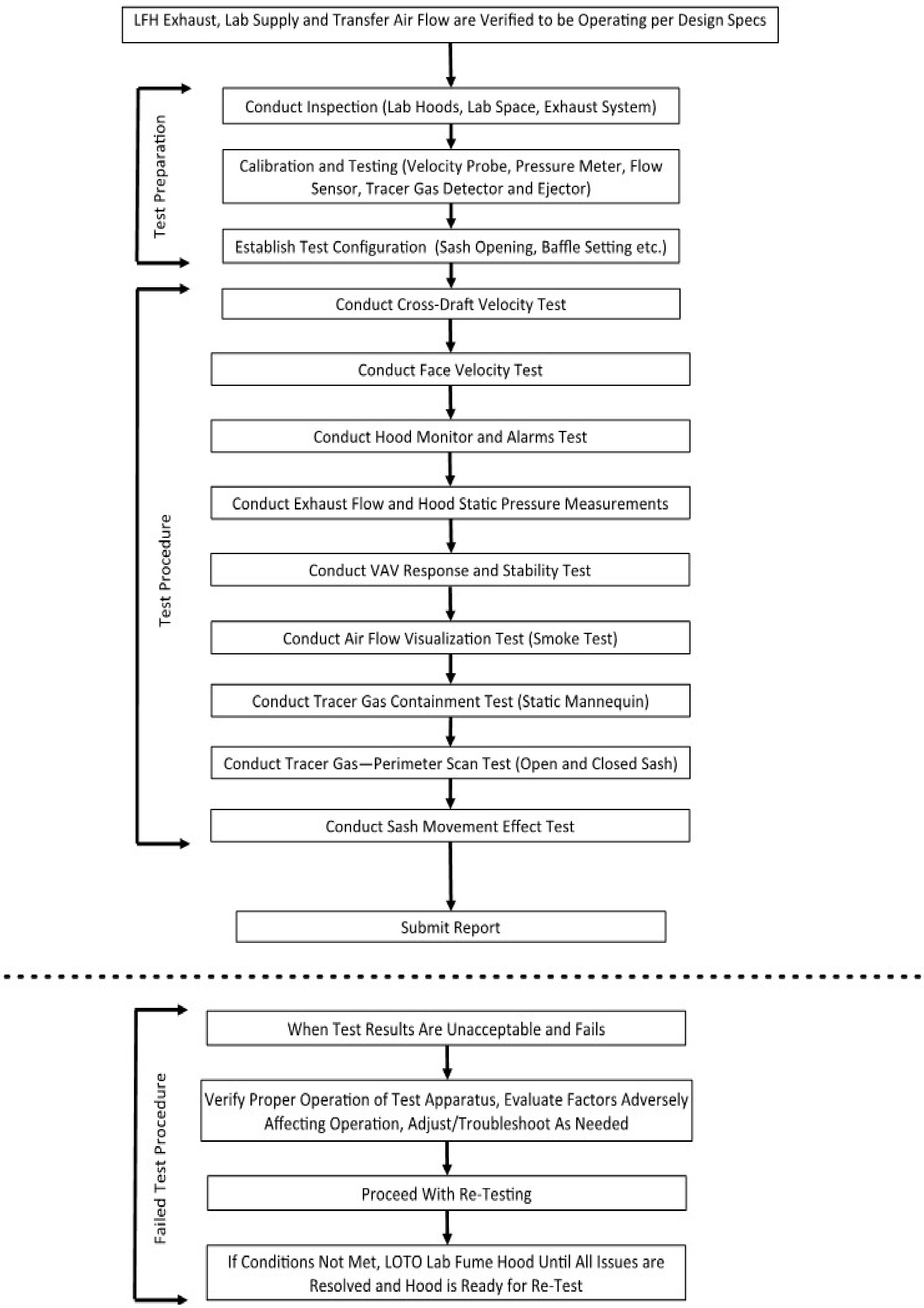
- ANSI/American Industrial Hygiene Association (AIHA) Z9.5 American National Standard for Laboratory Ventilation.
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 110, Methods for Testing Performance of Laboratory Fume Hoods.

For all referenced standards, the most recent revisions apply. Unless otherwise specified, all terms used in this document are defined as described in the ANSI Z9.5/ASHRAE 110. The performance test procedures have been modified accordingly to accommodate EPA-specific requirements.

All Tests and Inspections shall be conducted by a certified, EPA-approved third-party laboratory ventilation expert. Annual test may be performed by certified EPA laboratory personnel or certified, EPA-approved third-party contractor. Any LFHs that fail and do not meet the performance criteria for passing must be locked out/tagged out with a label to ensure safety of the user(s) and the laboratory environment. Prior to conducting tests and inspections, if the LFH being tested/inspected is part of a VAV system, the technician shall be given a physical copy of the VAV system's sequence of operations.

As stated also in Section 4.2, any substantive changes or modifications to the HVAC system in laboratories, equipped with LFHs shall require re-testing (AI). Also, at any time a retrofit is installed, the LFH must undergo Testing, Adjusting and Balancing (TAB), CX Functional Performance Testing (FPT) and be followed up with AI testing.

Figure 3-1 illustrates a flowchart that outlines the sequence for conducting AM or AI performance tests, and Figure 3-2 illustrates a flowchart that outlines the sequence for conducting Annual performance tests at EPA facilities. Both also display a required procedure in the occurrence of a test failure.



Resource: EPA HQ

Figure 3-1. Sequence for Conducting AM and AI Performance Tests

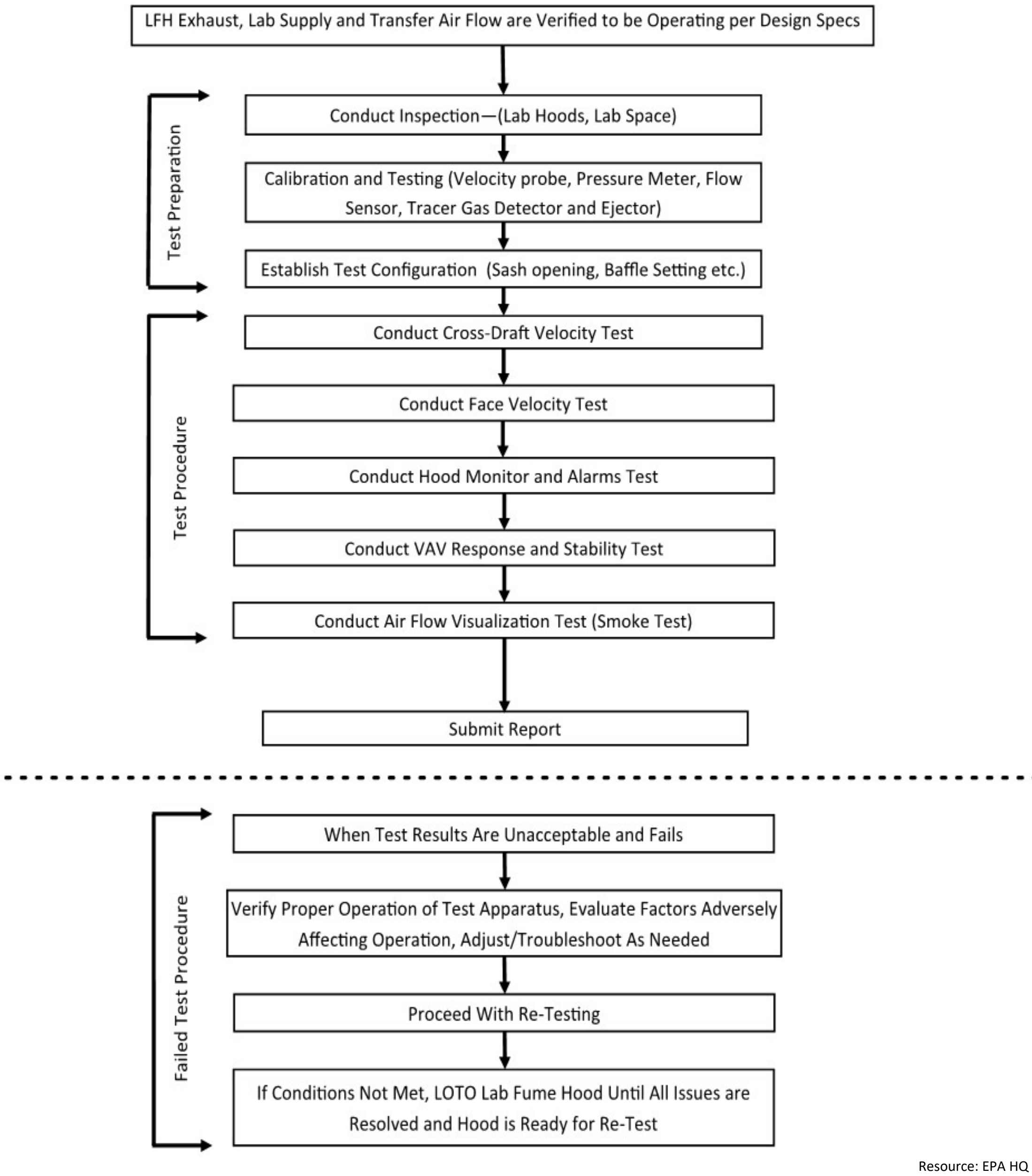


Figure 3-2. Sequence for Conducting Annual Performance Tests

Table 3-1 lists the inspection and performance testing elements that comprise LFH testing and indicates when each component is required. The remainder of Section 3 provides a detailed description of the procedures that should be followed for each of the inspection and testing elements listed in Table 3-1.

Table 3-1. Inspections and Performance Test Procedures

Inspections	**AM**	**AI**	**Annual**
Laboratory Hood	X	X	X
Laboratory Space	X	X	X
Exhaust System	X	Only required if the LFH does not perform to EPA criteria for operating conditions and containment tests. Refer to TAB report and cross check readings for troubleshooting.	
Performance Test Procedures	**AM**	**AI**	**Annual**
Operating Conditions Tests			
Cross-Draft Velocity Test	X	X	X
Face Velocity Test	X	X	X
Hood Monitor and Alarms Test	X	X	X
Exhaust Flow Measurement	X	X	N/A
Hood Static Pressure Measurement	X	X	N/A
Dynamic VAV Response and Stability Test	X	X	X
Containment Performance Tests			
Airflow Visualization Test (Smoke)	X	X	X
Tracer Gas Containment Test (Static Mannequin)	X[1]	X[1]	N/A
Perimeter Scan Test	X[1]	X[1]	N/A
Sash Movement Effect Test	X	X	N/A

Table Notes:

N/A - Test not applicable.

[1] All LFHs, or those deemed necessary by EPA SSD, must be tracer gas tested during AM and AI testing. The gas shall be sulfur hexafluoride (SF_6) or an alternate gas (with similar characteristics) that is approved by the latest version of ANSI Z9.5/ASHRAE 110 or the EPA authority having jurisdiction.

3.1 Data Recording

Information about each LFH, space and exhaust system undergoing testing must be recorded in the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. This sheet must be filled out for each hood undergoing AM, AI or Annual testing.

Information about each performance test result must be recorded in the Laboratory Fume Hood Performance Test Data Sheet found in Appendix B. The data sheets found in the appendices may be provided in Excel format or acceptable format by SSD to any users upon request. The required number of test cycles shall be dependent on the hood type, sash type, baffle design and specified Average Face Velocity (AFV). All test equipment must comply with the requirements of this standard, and EPA reserves the right to verify calibration of test equipment, photograph or videotape the tests, or take independent measurements before, during, or after all tests.

Data sheets that record equivalent information may be used if preferred by the tester. Copies of completed data sheets from AM and AI tests shall be returned to the SSD office for further review and final approval. Copies of completed data sheets from Annual testing shall be maintained at the local SHEMP (Safety, Health, Environmental & Management) office, and electronic copies of Annual testing data sheets may be provided by the SSD office upon request.

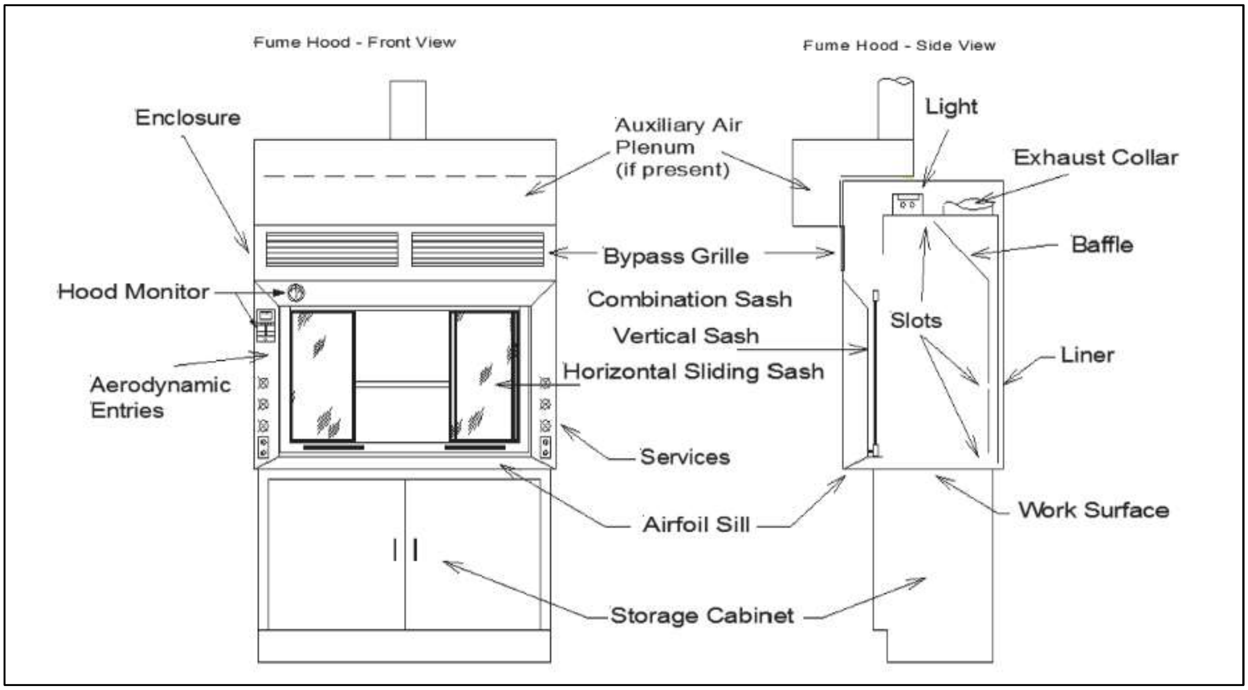
The following information must be collected and recorded in the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet (or equivalent) found in Appendix A:

- Fume hood design features.
- Laboratory space information (for AM testing and AI/Annual troubleshooting), exhaust system information.
- Test equipment calibration information.
- Results of tests and analyses.

3.2 <u>Laboratory Fume Hood, Space and Exhaust System Inspection</u>

Fume hood inspection steps are listed below. Figure 3-3 shows a schematic representation of a typical benchtop LFH.

1. Record the name and contact information of the person conducting the test, the equipment that is used, and all pertinent laboratory fume hood information to identify the type of hood design.
2. Start with a visual inspection, checking for improperly installed components, leaks, cracks and apparent damage.
3. If there is a ventilated storage cabinet below the hood, verify that the base furniture is ventilated separately from the LFH and is not vented directly to the inside of the fume hood. The cabinet can be exhausted to the LFH exhaust system.
4. Proceed to test the operation of the sash. It should slide freely in its track without binding through the full opened position to its completely closed position.
5. Test and confirm the operation of the lights.
6. Check for the presence and proper installation of the airfoil sill.
7. Record the position of baffles, number of capture slots and slot widths. Verify that the baffles reside in the original, factory-set position.
8. Verify the connection between the exhaust collar and exhaust duct. If this observation is not possible due to equipped hood with enclosing panels, proceed to inspect the hood superstructure for negative or positive leaks with a smoke test.
9. Confirm the work surface and the hood liner are clean and that there are no cracks, warping, or excessive leakage. Check for a sash sweep behind the sash at the top of the enclosure.
10. Record the manufacturer, type of monitor, and verify the operation of the audible alarm and visible indicator using manufacturer’s recommendations.



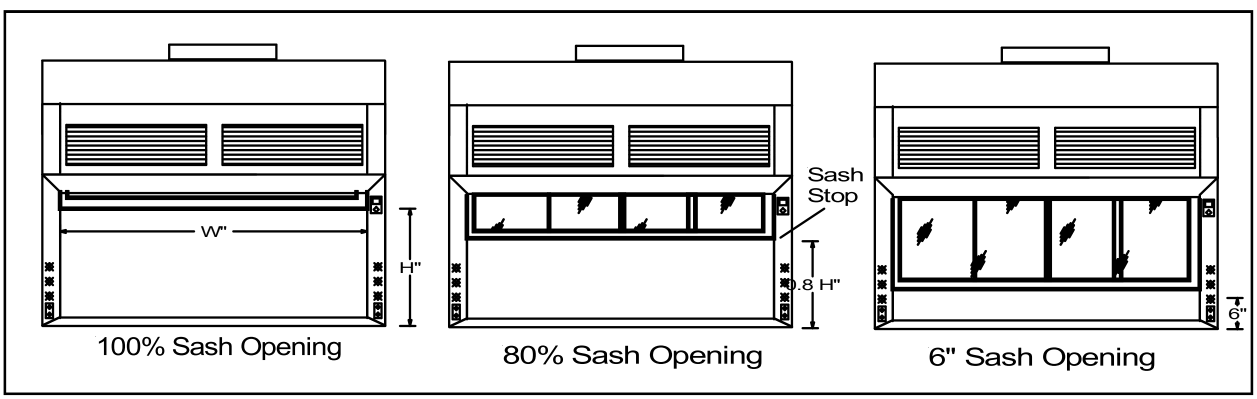
Resource: ASHRAE 110-2016

Figure 3-3. Front and Side View of a Typical Benchtop LFH

3.2.1 Sash Opening Configurations

EPA requires measurements to be taken at varying opening configurations depending on the sash type. The required tests and respective measurement locations are stated below.

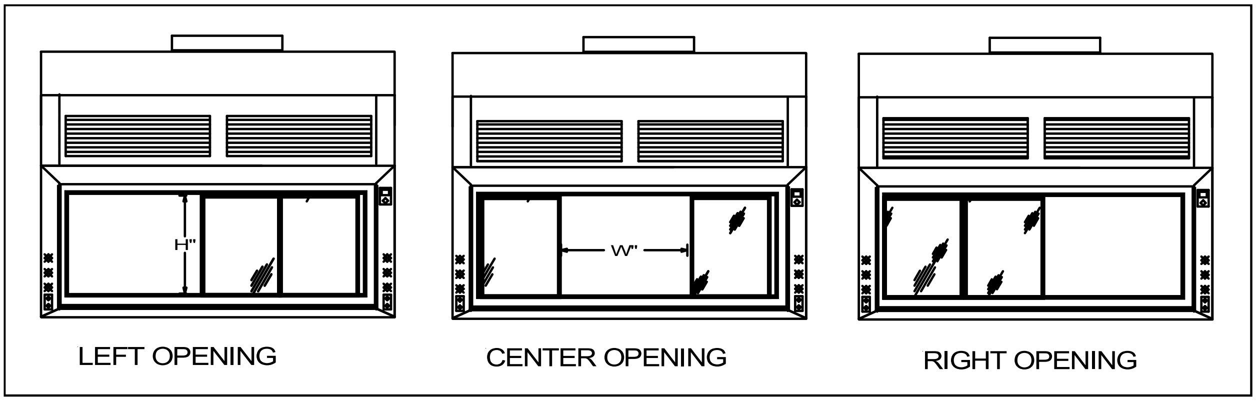
- **Single Vertical Sash:** Benchtop hoods equipped with a vertical sash must be tested at the 100 percent height opening, 80 percent height opening (design height) and six-inch height opening, as shown in Figure 3-4.



Resource: ASHRAE 110-2016

Figure 3-4. Sash Configuration for Benchtop LFH Equipped with Vertical Sliding Sash

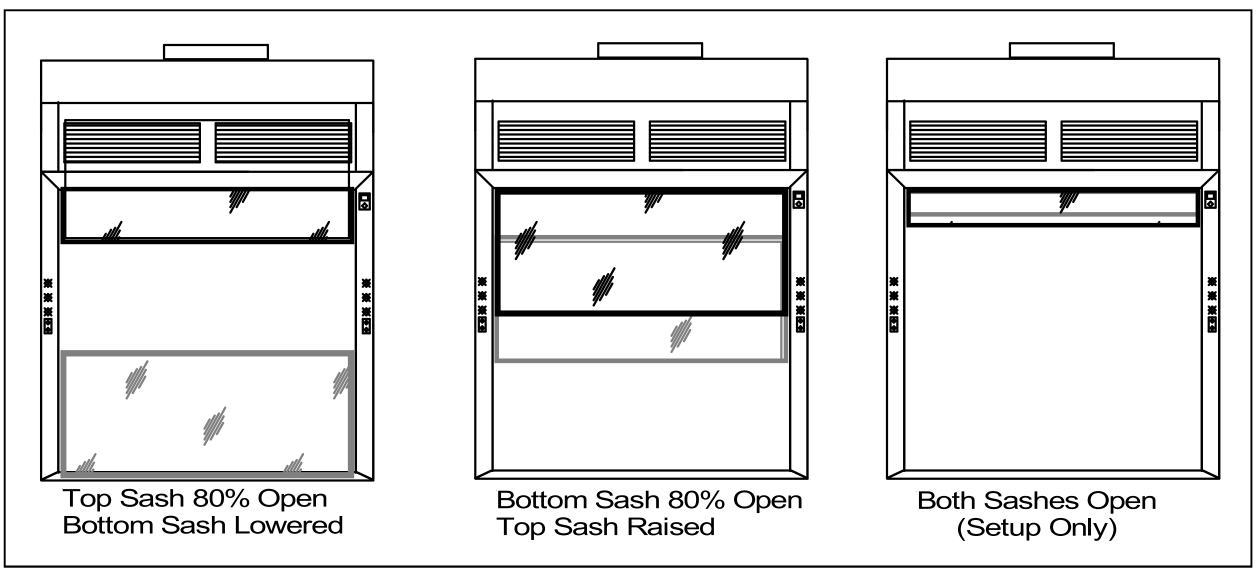
- **Horizontal Sash Hood:** The required sash openings for hoods equipped with horizontal sashes are shown in Figure 3-5 and include the maximum left, center and right opening. Unless otherwise specified, the design sash opening for horizontal sashes shall not exceed a width of 30 inches.



Resource: ASHRAE 110-2016

Figure 3-5. Sash Configuration for Benchtop LFH Equipped with a Horizontal Sliding Sash

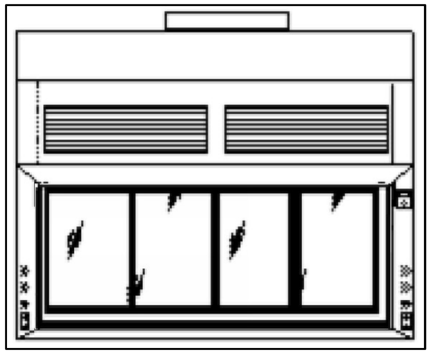
- **Combination Sash Hoods:** Hoods equipped with combination sashes must be tested at the vertical and horizontal sash openings as shown in Figure 3-4 and Figure 3-5.
- **Double Vertical Sash Hoods:** Unless otherwise specified, hoods equipped with double vertical sashes must be tested with sashes configured as shown in Figure 3-6. The design sash opening shall be with the top sash or stop at 80 percent open and the bottom sash fully closed.



Resource: ASHRAE 110-2016

Figure 3-6. Sash Configuration for Distillation or Floor-Mounted LFH Equipped with Double Vertical Sliding Sashes

- **Sash Fully Closed:** Hoods that require minimum flow testing with the sash closed shall follow the sash position as shown in Figure 3-7.



Resource: ASHRAE 110-2016 (modified)

Figure 3-7. Fully Closed Sash Configuration for Minimum Flow Testing

3.2.2 Laboratory Space Inspection

A laboratory space and exhaust system inspection is required for all testing. Troubleshooting for AI and Annual testing should be correlated with a review of the testing, adjusting and balancing (TAB) report or changes made to the lab to accommodate special work practices or procedures. Note that the laboratory space must be properly operating before any hood testing can begin. Where labs have multiple VAV LFHs, the lab inspection shall be carried out to ensure proper flow tracking across the range of sash configurations. Besides the LFH being tested, all other LFHs shall be set to the design opening sash height. Unless otherwise specified, all the requirements in the latest version of ANSI Z9.5/ASHRAE 110 shall be met. The test laboratory must be maintained at a negative differential pressure of 0.005 to 0.05 inches of water gauge with respect to adjacent non-laboratory spaces.

Laboratory test room information shall include:

1. Space dimensions and calculation of volume.
   - Space dimensions are defined as being finish-to-finish, including non-moveable furniture and internal structures.
   - If the laboratory space has an open ceiling, the height dimension is defined as being floor-to-ceiling.
2. Number of hoods open if the laboratory space contains multiple LFHs.
3. Differential pressure measurements across doors and ceiling space above the LFH.
   - All doors and access openings in the laboratory must be closed. The space cannot be tested until all intended ceiling tiles are in place.
   - Use a manometer to measure the pressure difference at two Points of Reference (POR); [POR one: inside the lab] and [POR two: outside the lab], and record the differential pressure.
   - Determine the average room differential pressure by taking three consecutive measurements.

- Repeat pressure measurements with the LFH sashes at design opening height and when fully closed.
- Record final observations. (i.e., are the measurements accurate or precise?)

4. Temperature measurements taken at the center of LFH opening, 18 inches in front of the sash plane.
   - All doors and access openings in the laboratory must be closed.
   - Use a temperature probe near the thermostat to measure the room temperature.
   - Compare the measurement taken with the thermostat reading.
   - Repeat temperature measurements with the LFH sashes at design opening height and when fully closed.
   - Record final observations. (i.e., are the measurements accurate or precise?)
5. Draw a sketch of the laboratory area indicating the location of the hood/cabinet, doors, supply diffusers, significant furniture and other exhaust devices.
6. Note possible sources of cross drafts (Refer to Section 3.3.1 and Figure 3-8 for cross-draft velocity test procedures).

3.2.3 Exhaust System Inspection

1. Evaluate the LFH exhaust system, and record airflow control settings per Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet (Appendix A).
2. If a VAV system is installed, record manufacturer and type of controls.
3. Record LFH outlet dimensions, exhaust duct diameter, and any transitions within 10 feet of the outlet.
4. Verify existence of hood static pressure port above outlet collar and port is capped or connected to an appropriate pressure monitor.

3.2.4 Test Equipment Calibration Information

Unless otherwise specified, the laboratory equipment used during EPA's performance tests shall meet the specifications set in the latest version of ANSI Z9.5/ASHRAE 110, including the required digital collection of data. In addition, equipment specifications such as the model, serial number and latest calibration information for each piece of test equipment shall be recorded and provided with each performance test report. The following procedures verify that test instruments are properly calibrated and operating in compliance with the manufacturer's specifications.

1. Record the type of equipment used (e.g. swinging vane anemometer, hot wire anemometer, etc.), the name of the manufacturer, model number and serial number of all test equipment.
2. Confirm that all velocity and differential pressure meters used during the AM, AI and Annual performance tests have been calibrated within one year of the test date, and verify that calibration certificates are available. All equipment must be traceable to the National Institute of Standards and Technology (NIST).

3. Verify that the tracer gas detector and tracer gas ejector have been calibrated within twenty-four hours preceding any tests and within twenty-four hours (or the manufacturer's recommended length of time) following tests (AM and AI performance tests).

3.3 Fume Hood Performance Tests: Operating Conditions

Performance tests of the following operating conditions will be performed to verify that the fume hood is operating to meet EPA specifications:

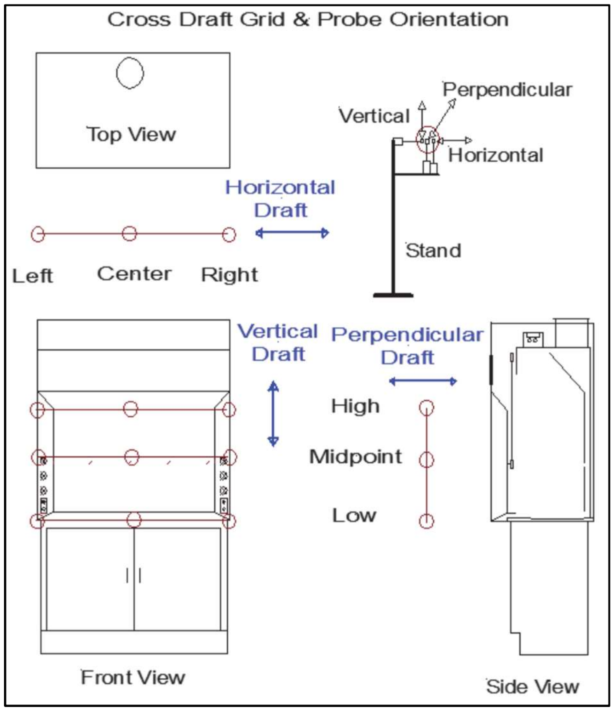
- Cross-Draft Velocity
- Face Velocity
- Hood Monitor and Alarms
- Exhaust Flow
- Hood Static Pressure
- Dynamic VAV Response and Stability
- Airflow Visualization
- Tracer Gas Containment (Static Mannequin and Perimeter Scan)
- Sash Movement Effect

EPA requires measurements to be taken at varying opening configurations depending on the sash type. Refer to Section 3.2.1 for the required tests and respective measurement locations. Performance test results for operating conditions must be collected and recorded in the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet (or equivalent) found in Appendix A.

3.3.1 Cross-Draft Velocity Test

Cross-draft velocities are measured to determine the velocity of room air currents near the LFH opening. Refer to Figure 3-8 for the cross-draft measurement locations.

1. For each individual test, the velocity meter probe shall be located at 18 inches in front of the LFH enclosure. The position of the probe shall not interfere with the measurements of the horizontal, vertical and perpendicular components of velocity. The nine test locations should correspond to the high, midpoint, and low areas at the left, center and right side of the LFH.
2. Measure the cross-draft velocity with the probe oriented in the horizontal, vertical and perpendicular directions at each test location. The perpendicular direction is normal to the sash plane.
3. Over a period of 20 seconds, cross-draft velocities shall be recorded approximately one reading per second. Afterwards, state the minimum, maximum and average velocities measured.



Resource: ASHRAE 110-2016

Figure 3-8. Cross-Draft Measurement Locations

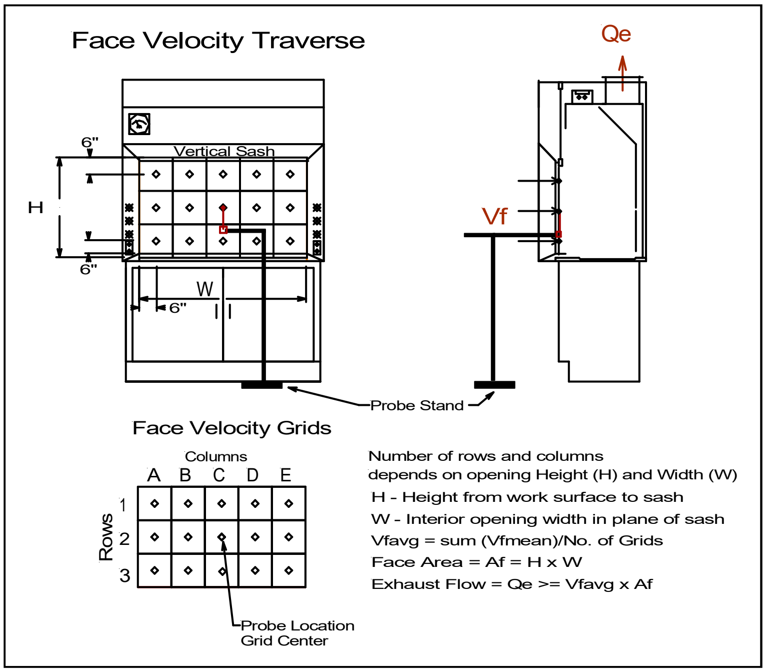
3.3.2 Face Velocity Test

During the test, the interior of the chamber must be empty for AM and AI tests, except for the equipment to conduct the test or any other functioning component in the fume hood. The Annual test does not require the interior of the chamber to be empty unless the lab equipment interferes with the probe.

1. Configure the sash for the appropriate test opening.
2. Measure the sash opening width and height, and calculate the face area in square feet. Make sure to include the area beneath the airfoil sill in the calculation of the face area and any area between the sash and the interior liner at the top of the hood. The sash height is measured from the benchtop to the bottom of the sash (not including the recessed area in the work surface).
3. Measure the total bypass width and height and calculate the area in square feet with the sash open and closed.
4. Ensure that the exhaust blower is operating.
5. Divide the opening into equal area grids of no greater than one square foot. Table 3-2 shows the recommended grid array and Figure 3-9 shows the examples of grid patterns.

Table 3-2. Face Velocity Traverse Grids for Different Size Openings

Opening	Width (Feet)							
Height (in.)	**≤1 ft.**	**≤2 ft.**	**≤3 ft.**	**≤4 ft.**	**≤5 ft.**	**≤6 ft.**	**≤7 ft.**	**≤8 ft.**
≤12 in.	1×1	1×2	1×3	1×4	1×5	1×6	1×7	1×8
≤24 in.	2×1	2×2	2×3	2×4	2×5	2×6	2×7	2×8
≤36 in.	3×1	3×2	3×3	3×4	3×5	3×6	3×7	3×8



Resource: EPA HQ

Figure 3-9. Sample Grid Configurations with Fixed Probe at Center of Traverse Grid

6. Measure face velocity readings with a calibrated unidirectional hot-wire anemometer fixed at the center of each grid. Place the probe in the sash plane (defined as the front of the glass on the outermost sash panel) and stabilize it with a ring stand and clamp or equivalent. Ensure the probe is aligned to measure the velocity vector perpendicular to the sash plane.

7. Measure face velocity readings at least 20 times at each grid location. To avoid disrupting airflow patterns, no one should be standing in front of the reading area while the velocity test is being conducted.

8. Calculate the average value of the total readings taken at each grid location. Unless otherwise specified herein, the airflow and baffles shall be readjusted if the average grid velocities are not within the ±20 percent tolerance. Compare the arithmetic mean value with the face velocity criterion to assess whether it is required to repeat the test.

9. Record the average value as the average face velocity (AFV).

10. Compare the AFV to the face velocity criterion. Velocity measurements shall be repeated at each test configuration as defined herein.

3.3.3 Auxiliary Air Velocity Test

Auxiliary air fume hoods require special test procedures for determining the average face velocity and down flow auxiliary air velocity. Use the same method described above to determine the AFV. But in this case, the auxiliary air must be turned off or redirected by blocking the outlet of the auxiliary air plenum. The following method shall be used to determine the down flow velocity after the AFV has been calculated:

1. Ensure the auxiliary air supply is operating and the plenum outlet is not obstructed.
2. Raise the sash to the full open position.
3. Divide the outlet into equal area grids of no more than 12 inches per side.
4. Measure the vertical component of velocity at the center of each grid with the probe mounted approximately six inches below the plenum outlet.
5. Record at least 20 auxiliary air velocity readings for each grid location.
6. Calculate the average value of the auxiliary air velocity readings taken at each grid location.
7. Record the average value as the Average Auxiliary Air Velocity (AAAV).

3.3.4 Hood Monitor with Digital Velocity Reading, Visual and Audible Alarms Test

For AM and AI testing, the following method shall be used to verify the integrity of the monitor and alarms:

1. Adjust the sash position to the defined design height.

1. The monitor shall be tested at 10% below minimum required face velocity, 10% above maximum limit of face velocity, and at target face velocity values via changing flow set points using the BAS.
2. Calibration of monitors will require face velocity measurements using the grid procedures as described in Section 3.3.2.
3. To test the alarms next, configure the face velocity to a value that is within the range(s) of acceptance (e.g. 65 fpm for High Performance LFHs).
4. Manually increase/decrease flow, so that the face velocity increases/decreases above/below the set limitations of the range(s) of acceptance.
5. Verify that the visual alarm indicates unacceptable operation and the audible alarm enunciates when the unacceptable condition has been in effect for longer than 10 seconds.
6. Confirm that the monitor has sent the alarm condition to the BAS.

For Annual testing, the following method shall be used to verify the integrity of the monitor and alarms:

1. Confirm that the monitor indicates values within ±5% range of the measured face velocity.
2. Utilize the manufacturer’s recommendations within the O&M manual to confirm proper operation and upkeep of the visual and audible alarms.

3.3.5 Exhaust Flow Measurements

1. Perform a pitot tube traverse in the exhaust duct if the calculated exhaust flow value is not available in the Testing, Adjusting and Balance report or has not been previously collected. The test shall be in conformity with the ASHRAE 41.2, Standard Methods for Laboratory Air-Flow Measurement. Measured exhaust flow data must be available for the sash design opening area and sash closed position and for both occupied and unoccupied operating modes (if applicable).

2. For AM and AI testing, use a pitot tube, an inclined manometer or similar pressure sensing devices to measure the duct traverse exhaust flow in both the design sash open and closed position. For Annual testing, face velocity measurement at 6” sash opening multiplied by the total hood opening area shall serve as the surrogate test for minimum flow.

3. Inspect the exhaust ductwork above the LFH and locate an accessible run of straight duct of at least seven duct diameters in length. Straight duct runs may be difficult to locate and shorter runs may increase measurement errors. The ideal test location is between the fume hood and the exhaust valve/damper, but may be located downstream of the exhaust valve/damper if necessary for a suitable traverse location. Note on the test report where the Pitot tube traverse was conducted.

4. Proceed to drill two 3/8-inch holes at 90° angle from each other at the downstream of the straight duct run. Holes made for the Pitot tube should be drilled and not punched. Make sure the holes are plugged and sealed with a chemical resistant material after the test has been completed. Note: Avoid drilling holes on the bottom of horizontal duct runs.

5. Measure the inside diameter of the duct, and calculate the cross-sectional area of the duct using the equation:

$$\mathrm{Ad} = \frac{\left(\mathrm{D}^2\pi\right)}{4}$$

where:

A_d = Cross-Sectional Area of Duct
D = Diameter
π = Pi (3.14159)

6. Determine exhaust air temperature, elevation and barometric pressure to correct for prevailing air density. If the data requires correction, record both the corrected and uncorrected data. Ensure measurements are corrected for non-standard conditions.

7. Connect the two ports [the static port (P_{static}) and the total pressure port (P_{total})] on the pitot tube to the manometer utilizing flexible tubing. Insert the Pitot tube probe in each hole and take velocity pressure or velocity readings at the center of annular rings of equal area. A minimum of 20 readings shall be taken across each cross section. The reading shall be taken at a distance equal to the duct diameter multiplied by the factors listed in Table 3-3.

Table 3-3. Pitot Traverse Points in a Circular Duct of Known Duct Diameter

Traverse Point	1	2	3	4	5	6	7	8	9	10
Distance = D ×	0.026	0.082	0.146	0.226	0.342	0.685	0.774	0.854	0.918	0.974

8. If velocity pressure readings were taken in Step 7, convert these readings to velocities. Calculate the sum and average of the velocities. Negative values, if recorded during the traverse, are added in at zero value but are counted in the number of sample locations for calculation of the average. A negative value indicates non-uniform duct velocity and an inaccurate traverse. Calculated flow from inaccurate traverses should be noted.

   Most manometer scales are calibrated in inches of water. Using readings from such an instrument, the air velocity may be calculated using the basic formula:

   $$V = 1096.7\sqrt{\frac{h}{d}} \begin{cases} = 4004.4\sqrt{h} \text{ for } 0.75 \text{lb/ft}^3 \text{ dry air} \\ \quad @70°\text{F, 29.92 in. Hg Baro.} \end{cases}$$

   Where: V = Velocity in feet per minute.
   h = Velocity pressure in inches of water.
   d = Density of air in pounds per cubic foot.

   To determine dry air density, use the formula:

   $$d = 1.325\frac{Pb}{T}$$

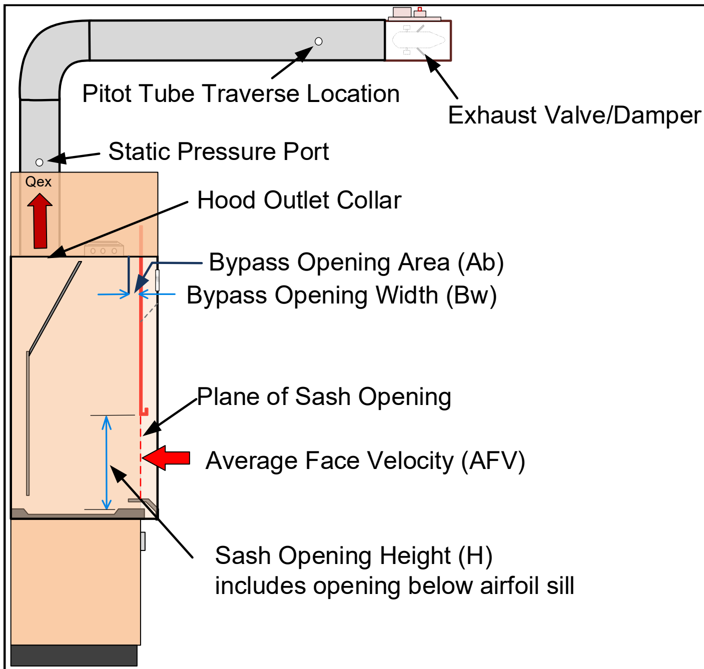
   Where: d = Density of air in pounds per cubic foot.
   Pb = Barometric (or absolute) static pressure in inches of mercury.
   T = Absolute temperature (indicated temperature in °F plus 460°).

9. Record the average duct velocity. Multiply the duct area by the duct velocity to obtain the resultant exhaust flow. Record measured exhaust flow over range of operating conditions.

3.3.6 Hood Static Pressure Measurements

1. Measure (if applicable) and record the LFH static pressure at the sash design opening and with the sash closed and at the occupied or unoccupied flow set points. The static pressure should be measured at the outlet collar static pressure test port or at the traverse test location if within 10-ft of the fume hood and between the fume hood and the exhaust valve.

2. Record static pressure data and the measurement location over the range of operating conditions.



Exhaust Flow Measured (Qex measured) by Pitot Tube Traverse Standard

Average Face Velocity (AFV) Measured by ASHRAE 110 Method

Sash Opening Area (As) = Opening Width (Sw) x Opening Height (Sh)

Bypass Opening Area (Ab) = Bypass Width (Bw) x Bypass Length (Bl)

Hood Opening Area (Ah) = Sash Opening Area (As) + Bypass Area (Ab)

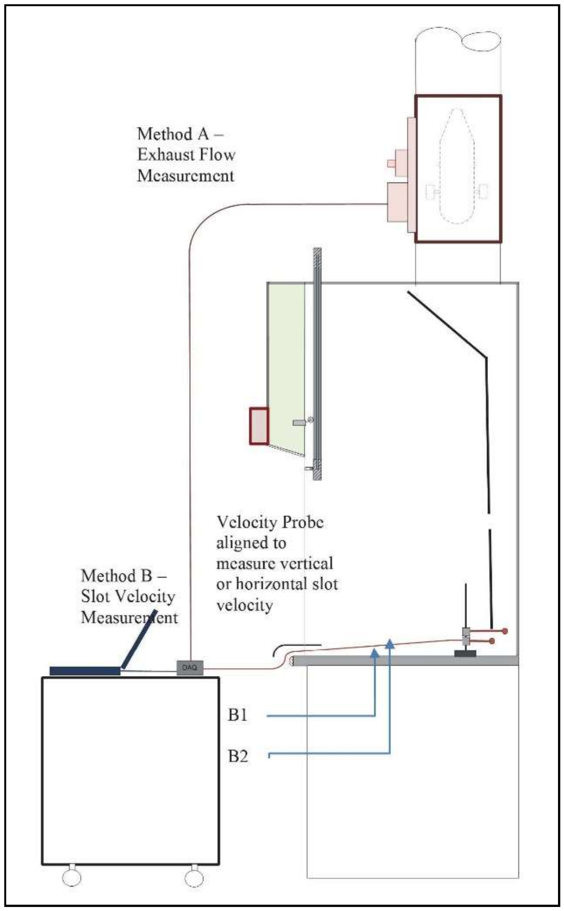
Exhaust Flow Calculated (Qex Calculated) = AFV x Ah

Resource: EPA HQ

Figure 3-10. Components Considered to Calculate Exhaust Flow

3.3.7 Dynamic VAV Response and Stability Test

This test applies to systems equipped with VAV controls that modulate flow in response to sash movement. Flow response is determined by measuring exhaust flow (Method A) or by measuring slot velocity (Method B) (see Figure 3-11). Measurements are recorded at a rate of one reading per second using a data logger while opening and closing the LFH sashes. Each five-minute test consists of three cycles of opening and closing the sash. For each cycle, the sash is closed for 30 seconds and open for 60 seconds. The results are analyzed to determine the speed of response, time to reach steady state and repeatability of flow response.

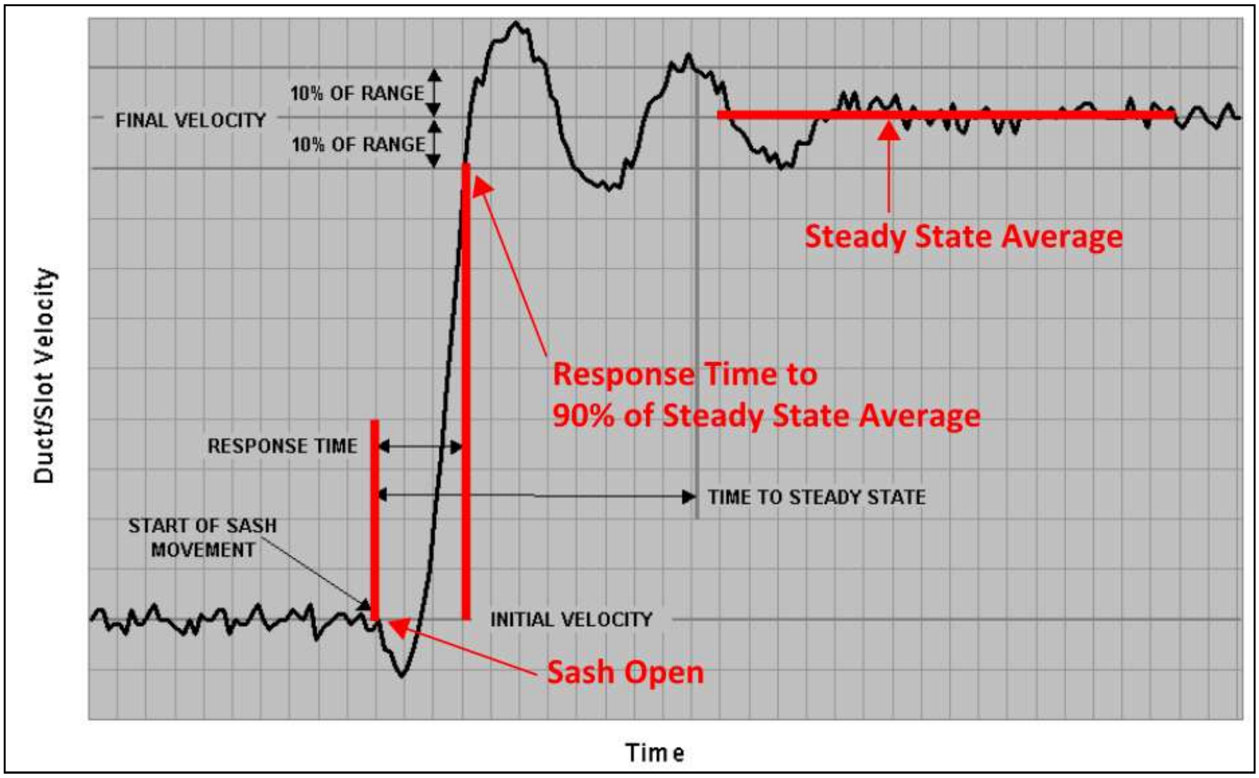


Resource: ASHRAE 110-2016

Figure 3-11. Setup for VAV Response and Stability Tests

1. Position the sensor in a location with stable flow (turbulent fluctuations with variations less than 10%) (see Figure 3-11 for a diagram of test setup methods).
   - Method A: Use a flow sensor or a velocity meter in the centerline of the exhaust duct.
   - Method B: Use slot velocity; for this, the velocity probe is mounted in a secure stand with the probe located in the center of the bottom baffle slot opening. Flow response is determined by placing the tip of the velocity probe in the slot behind the baffle where changes in slot velocity are directly proportional to changes in flow.
2. Close all sashes and record monitor reading.
3. Begin recording the slot velocity or airflow at a rate of at least one sample per second using a data acquisition system or data logger while raising/opening and lowering/closing the sash.
4. After 30 seconds, open the sash from the closed position to the design opening area at a rate of approximately 1.5 feet per second (ft/sec). Note and record with the data logger the time corresponding to the beginning of sash movement.
5. After 60 seconds close the sash at a rate of approximately 1.5 ft/sec.

6. Determine the speed of response in seconds (VAV response time) following the start of sash movement until the airflow reaches 90% of the final steady state flow.
7. Repeat Steps 4 through 6 two more times to obtain a total of three sash opening/closing cycles. Each cycle shall have the sash closed for 30 seconds and open for 60 seconds.
8. With the data logger results, plot the VAV flow response and record results.
9. Compare and correlate slot velocities with exhaust flow measurements at maximum and minimum design sash openings.



Resource: ASHRAE 110-2016 (modified)

Figure 3-12. Visual Example of VAV Flow Response Plot

3.4 <u>Fume Hood Performance Tests: Containment</u>

The following tests are designed to ensure the hazardous materials are prevented from dispersing into the laboratory space, or released only at an acceptable level:

- Airflow visualization test; to identify airflow patterns.
- Tracer gas containment; to confirm hood containment
- Sash movement effect; to verify containment during dynamic sash operation

3.4.1 Airflow Visualization Test

During the visualization test, the interior of the chamber must be empty for AM and AI tests, except for the equipment to conduct the test or any other functioning component in the fume hood. The Annual test does not require the interior of the chamber to be empty unless the lab equipment interferes with the test. Conduct a smoke visualization test ("local visualization challenge") with the vertical and horizontal sashes fully open. Repeat the test with the sash at the design opening height, (e.g., 80 percent open). Refer to 3.1.2. for correct sash opening configurations.

The smoke visualization test shall be conducted without a mannequin. Results shall be reported as a qualitative judgment of airflow distribution according to the ratings described in Table 3-4. Visual guidance for unacceptable and acceptable airflows is provided in Figure 3-13. If the rating is other than ”Pass”, then, this shall be a sufficient cause to reject the laboratory fume hood.

Table 3-4. Rating of Observed Airflow Patterns

Rating	Description
Fail	• Smoke is visually observed escaping outside the plane of the sash. • Reverse flow of smoke is evident within six inches of opening. • Lazy flow into hood along openings. • Slow capture and clearance (greater than 1 minute). • Observed potential for escape.
Pass	• Good capture and quick clearance. • Limited vortex flow inside hood. • No reverse flow regions. • Smoke is captured and clears readily (less than 30 seconds). • No visible escape.

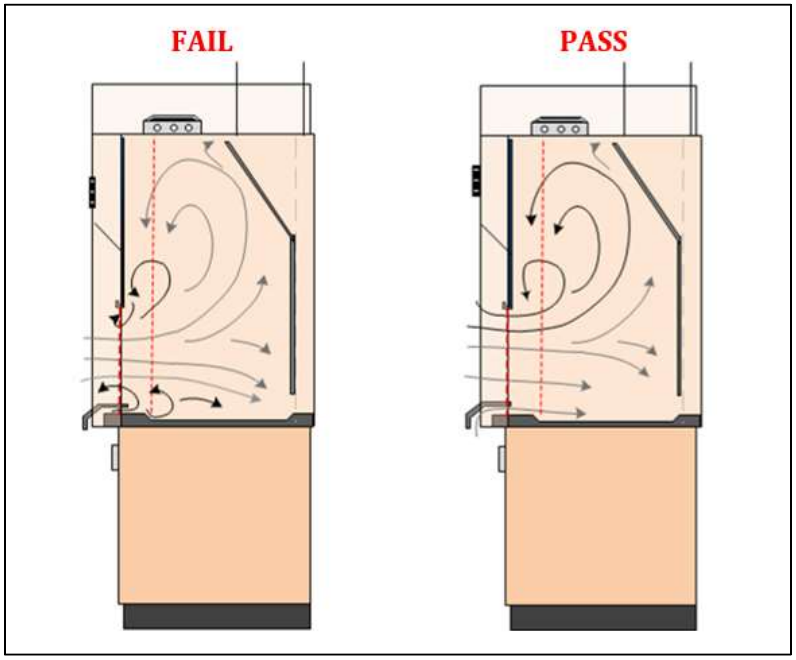
1. Low Volume Visualization Challenge

   - Generate the smoke (e.g., smoke tube, smoke stick or smoke generator) in accordance with the manufacturer's recommendations. Aerosol cans of smoke are not acceptable for EPA performance testing. It shall be generated along the openings and the airfoil sill. The smoke should flow smoothly into the fume hood. Observe the airflow patterns and record final observations.
   - Run the smoke generator slowly beneath the airfoil sill and observe the flow patterns. The smoke should be exhausted smoothly across the surface and not be entrained in the vortex.
   - Note that if a smoke generator is used, the volume of smoke generation is correlated with the rate of smoke fluid consumption. For low volume, the smoke fluid consumption shall be set at a minimum of 3ml/min and at a maximum of 6 ml/min. Discharge a stream of smoke along the surface and interior walls at six inches inside the sash plane. Observe and record the airflow patterns captured by the slots and exhaust. Look for areas of lazy airflow, reverse airflow, and vortex development at the top of the hood. Define the air movement towards the opening of the hood as reverse airflow.
   - Use caution to avoid exposure (e.g., inhalation or dermal) to smoke sources. If it is observed that any smoke escapes the hood opening, stop, and correct the problem immediately.

2. High Volume Visualization Challenge

   - Use a suitable source and release a large volume on the work surface and at the top of the hood at approximately six inches behind the sash plane. Ensure that the smoke source does not have high-velocity components in the direction of the opening. Observe and record airflow patterns, capture and time of clearance after generation has ceased. Tests shall be halted if any smoke is observed escaping the hood opening.

- Note that if a smoke generator is used, the volume of smoke generation is correlated with the rate of smoke fluid consumption. For high volume, the smoke fluid consumption shall be set at a minimum of 7ml/min and at a maximum of 10 ml/min.



Resource: EPA HQ

Figure 3-13. Unacceptable and Acceptable Airflow Patterns

3.4.2 Tracer Gas Containment Test (Static Mannequin)

Unless otherwise specified, the tracer gas test procedure and test requirements shall follow the methods described in the latest version of ANSI Z9.5/ASHRAE 110. Note that tracer gas concentrations shall be recorded at a rate of one sample per second after 30 seconds of opening the tracer gas block valve. The “As Manufactured” (AM) tracer gas test shall include at least two series of tests at two mannequin heights for each sash configuration. The two vertical sash heights that must be tested are: 1) 80% open and 2) 100% open). Table 3-5 shows the required test configurations. Additional tests may also be required to evaluate all possible baffle configurations and effects of flow changes. The AM tracer gas test for low-volume shall include at least one series of tests at the design sash opening and mannequin height. The EPA may require tracer gas testing for any fume hoods when deemed necessary. The LFH shall not be approved for use at flow rates or sash positions that do not meet EPA performance criteria. Failure to meet the performance requirements shall be sufficient cause to reject the LFH.

1. Mannequin Height. The mannequin height shall be based on the hood type and sash type. For benchtop hoods, the mannequin height is based on the height of the breathing zone (BZ) above the work surface, where the BZ correlates to the center of the mannequin’s lips. The corresponding mannequin height shall be maintained for all tracer gas tests. For distillation hoods and floor-mounted hoods, the height of the mannequin is based on the distance between the top of the mannequin’s head and the floor. Where appropriate, the

fume hood shall be tested at two mannequin heights during AM and one mannequin height during AI performance tests. Refer to Table 3-5 for specified mannequin heights at each hood type, sash configuration and test type.

Table 3-5. Mannequin Heights for Tracer Gas Tests of Different Fume Hood Types

Hood Type	Sash Type	Tracer Gas Test[1]	Mannequin Height—in.	BZ Height—in.	AM	AI
Bench-Top Hood	Vertical	1	n/a[2]	22	X	X
		2	n/a	18	X	
Bench-Top Hood	Horizontal	1	n/a[2]	22	X	X
		2	n/a	18	X	
Distillation Hood	Multi-Vertical	1	61	n/a	X	X
		2	42	n/a	X	
Floor-Mounted	Multi-Vertical	1	61	n/a	X	X
		2	42	n/a	X	
Floor-Mounted	Horizontal	1	61	n/a	X	X
		2	42	n/a	X	

Table Notes

[1] Perform Tracer Gas Test for each sash configuration (minimum of two vertical sash heights - design operating height or 80 % open and sash 100% open) for each mannequin/breathing zone height.

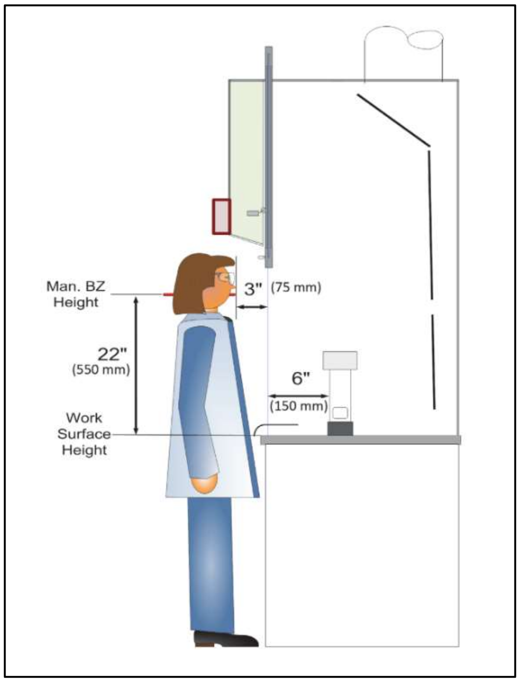
[2] Mannequin heights can be derived from the breathing zone and benchtop height.

2. Detector Insertion, Ejector Location and Gas Composition. For all LFHs, the detector probe shall be inserted into the mannequin and the tip distance shall be no greater than 1 inch. The ejector shall be located six inches behind the plane of the sash. The plane of sash is the vertical plane corresponding to the front of the glass panel on the forward most sash panel. The tracer gas shall be sulfur hexafluoride (SF_6) or a gas of similar molecular weight and stability and shall be supplied from a cylinder capable of maintaining a pressure of approximately 30 psig at the test release rate for at least one hour. If an alternate gas is used, it must be approved by the latest version of ANSI Z9.5/ASHRAE 110 or EPA authority having jurisdiction. The tracer gas release rate shall be 4.0 liters per minute and shall be commercial grade or reagent grade and at least 99% pure. Substitution of another tracer gas may be made if the standard tracer gas is deleterious to materials in the hood or the laboratory or if work in the laboratory would lead to significant interference in the detection of the tracer gas. In such cases, the release rate provided shall be equal to that of the standard tracer gas and the detector capabilities shall provide greater sensitivity than required for the presumed control level of the hood being tested.

   a. For benchtop hoods or fume hoods having interior tables, the ejector shall be placed on the work surface (table top) and located in front of the mannequin at each test position (see Figure 3-14).
   b. For distillation and floor-mounted hoods that are not equipped with internal tables, the ejector shall be mounted on a stand with the base of the ejector at least 36 inches above the floor (see Figure 3-15).

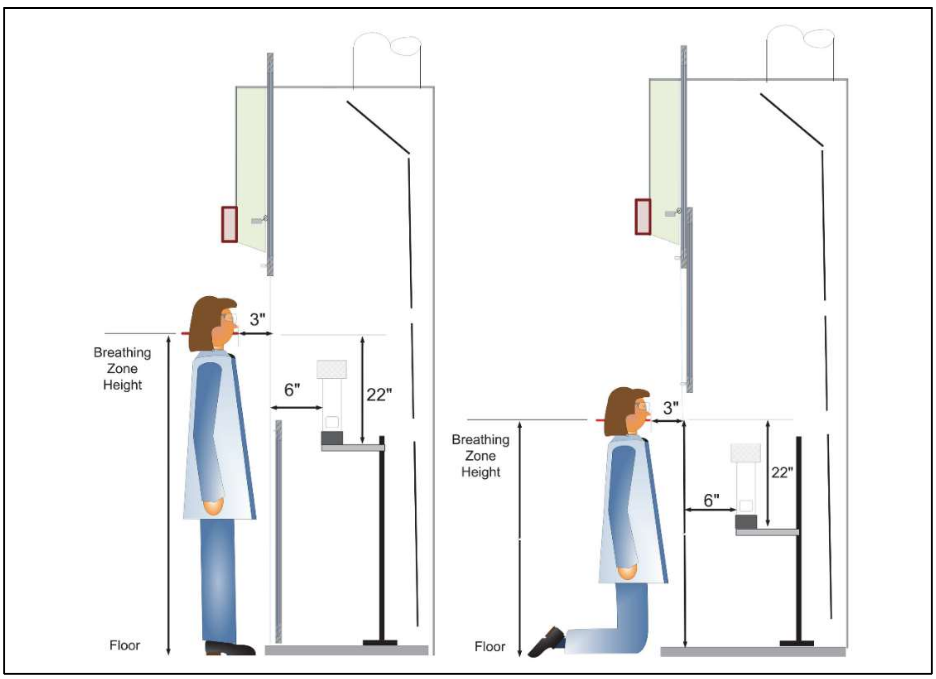
3.4.3 Tracer Gas – Perimeter Scan Test

Remove the mannequin and open the blocked valve to the ejector. The periphery of the hood openings shall be traversed with the probe at the sash fully open. Stand to the side of the hood to reduce measurement errors. The probe shall be held 1 inch (25 mm) away from the edge of the hood opening. Move slowly around each opening at a rate of speed not greater than 3 inches (75 mm) per second. Record the maximum concentration and location. Repeat the same steps with the sash closed.



Resource: ASHRAE 110-2016

Figure 3-14. Placement of Mannequin and Tracer Gas Ejector for Benchtop LFHs



Resource: ASHRAE 110-2016

Figure 3-15. Positions of Mannequin and Tracer Gas Ejector for Distillation and Floor-Mounted LFHs Equipped with Double Vertical Sashes

3.4.4 Sash Movement Effect Test

The Sash Movement Effect test is conducted to determine the potential for gas release from the fume hood to the laboratory space under dynamic sash conditions. Typically, the movement of the sash from closed (lowering) to design opening height (raising) is 80% open or sash safe. These tests and methods are applicable to both constant-volume and VAV hood systems. Tables 4-1, 4-2 and 4-3 show the performance criteria for AM, AI and Annual, respectively.

1. Set up the mannequin, the detector and the tracer gas ejector. Put the mannequin and ejector in the front at the center point of the hood opening.
2. Close the sashes.
3. Begin generation of gas at four liters per minute. Use 99% pure SF_6 (sulfur hexafluoride) or a gas of similar molecular weight and stability. If an alternate gas is used, it must be approved by the latest version of ANSI Z9.5/ASHRAE 110. After 30 seconds, begin recording tracer gas concentrations at a rate of one sample per second with a data acquisition system or a data logger.
4. After 30 seconds, open the sash/sashes to the design opening height at a rate of approximately 1.5 ft/sec. Record the time corresponding to the beginning of sash movement.
5. After 60 seconds, close the sash/sashes at a rate of approximately 1.5 ft/sec.
6. Repeat Steps 5 and 6 two more times to obtain a total of three sash opening/closing cycles.
7. Close sash/es for 30 seconds.
8. Calculate the average tracer gas concentration for the five-minute test. Note the maximum 30-second rolling average associated with each opening and closing of the sash.
    - A rolling average is calculated by taking the mean of a given set of values, where the set of values is ever-changing. The newest data point replaces the oldest data point, thus, the set of values is constantly “rolling” to create the latest in present time.

4. PERFORMANCE TEST CRITERIA

4.1 AM Test Performance Criteria

Unless waived by SSD, the "As Manufactured" (AM) performance criteria test shall be conducted for any LFH type, model or size prior to agency purchase or acceptance. The AM test is intended to evaluate the performance and design of the LFH under prescribed operating conditions.

The following conditions apply:

1. The LFH manufacturer shall verify the proper performance of the fume hood in accordance with EPA's performance criteria. The LFH performance test shall be conducted in a test facility provided by the manufacturer, and at no-cost to the government agency.
2. The LFH manufacturer shall contact SSD to coordinate a physical observation of the test at least 45 days in advance of the proposed test date. In addition, the manufacturer shall set detailed testing schedule 15 business days prior to the established test date.
3. The LFH manufacturer shall provide the specifications, drawings, and any other descriptive information pertaining to the test.
4. An EPA representative shall witness the test to assist with the verification of results. Failure to meet the performance criteria shall be a sufficient cause for rejection of the LFH. EPA reserves the right to verify the calibration of test equipment (i.e., before and after use), photograph or videotape, and even take independent measurements during the test.
5. If the LFH manufacturer renames, sells, or transfers the model design to a new company; or makes insignificant changes to the design, the EPA shall only adopt the design based on the approved model data. Therefore, the model shall be adopted if SSD states that the change/s made would not be significant to the LFH performance. Otherwise, the LFH manufacturer shall provide updated drawings that include the modified components in the new model design.

Refer to Table 4-1 for a description of the applicable inspection, operating and containment criteria for AM fume hood performance evaluation. Figure 3-1 provides a flow chart showing the recommended sequence for conducting the AM tests. The Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet in Appendix A and the Laboratory Fume Hood Performance Test Data Sheet in Appendix B shall be completed and submitted to SSD for review.

Table 4-1. AM Test Performance Criteria

AM Test	Description/ Configuration	High Performance LFH Performance Criteria[1]	Traditional LFH Performance Criteria[2]
Inspection			
Laboratory Hood	Complete the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. An electronic copy of this form can be provided by SSD.		
Laboratory Space	Room Differential Pressure (Doors Closed)	(-) 0.005 to (-) 0.05 inches of water gage.	
	Room Temperature (Doors Closed)	72 ± 5 degrees Fahrenheit.	
Exhaust System	Complete the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. An electronic copy of this form can be provided by SSD.		
Operating Conditions Tests			
Cross-Draft Velocity Test	Vertical 100% and Design Sash	• Measured velocities shall be no greater than 30 fpm or less than 50% of AFV, whichever is more stringent.	
	Horizontal Max Center Open		
Face Velocity Test[3]	Vertical 100% Open	AFV = 60-70 fpm (if LFH has full sash sensing ability to 100% open)	AFV = 90-110 fpm
	Vertical Design Sash Open[4]	AFV = 60-70 fpm	AFV = 90-110 fpm
	Horizontal Max Open (Left, Center and Right)	AFV = 60-70 fpm	AFV = 90-110 fpm
	Vertical Sash 6 in. Open	AFV > 60 fpm	AFV > 90 fpm
Auxiliary Air Velocity Test (if applicable)	Vertical 100% Open	• Average Auxiliary Air Velocity ≤ 2.5 times the design opening AFV or ≤ 70% of the LFH exhaust volume.	
Hood Monitor and Alarms Test	All sash configurations used for face velocity tests	• Indicated velocity or flow ±5% variation from corresponding measured value.	
Exhaust Flow Measurement	Vertical Design Sash	• Design flow ±5% to achieve EPA AFV criteria.	
	Horizontal Sash Max Center Open		
	Sashes Closed		
Hood Static Pressure Measurement	Vertical Design Sash	• Hood static pressure ≤ 0.5 in. w.g. • There may be some concession for large distillation and floor-mounted hoods.	
	Horizontal Sash Max Center Open		
	Sashes Closed		
Dynamic VAV Response and Stability Test	Vertical Design Sash Open	• VAV Response: time required for VAV to modulate flow with sash closed to 90% of steady state flow with sash at design opening (includes the time required to raise the sash) must be ≤ 5 seconds. • VAV Stability: the variation determined by the coefficient of variation shall be less than 10% of the steady state flow with the sash closed or with the sash at the design sash opening. • The coefficient of variation is calculated as: %COV = 100 × (3 × standard deviation)/average steady state flow.	
	Horizontal Max Open		

Table 4-1. AM Test Performance Criteria

<table>
<tr><th>AM Test</th><th>Description/ Configuration</th><th>High Performance LFH Performance Criteria[1]</th><th>Traditional LFH Performance Criteria[2]</th></tr>
<tr><td colspan="4">Containment Performance Tests</td></tr>
<tr><td rowspan="3">Airflow Visualization Test (Smoke)</td><td>Vertical 100% Open</td><td colspan="2" rowspan="3">• No visible escape beyond plane of sash.
• Smoke should not be discharged at high velocity and directed towards the opening.
• VAV hoods should undergo an additional challenge by raising and lowering the sash.
• Smoke observed beyond plane of sash when generated six inches inside the plane of the sash fails the test.
• Hood must have a smoke rating of Fair or Good.
• A Rating of Fail or Poor constitutes failure of the hood.</td></tr>
<tr><td>Vertical Design Sash Open</td></tr>
<tr><td>Horizontal Max Open
(Left, Center and Right)</td></tr>
<tr><td rowspan="4">Tracer Gas Containment Test (Static Mannequin)</td><td>Vertical 100% Open:
• Left, Center and Right Test Positions
• Tall Mannequin Height, 22 in. BZ
• Short Mannequin Height, 18 in. BZ</td><td colspan="2" rowspan="6">• Average five-minute concentration ≤ 0.05 ppm.
• Maximum 30 second rolling average ≤ 0.1 ppm.
• Peak concentration ≤ 0.5 ppm.
• The maximum five-minute average concentration applies to any test configuration or mannequin position.
• 30-second rolling averages shall be calculated during perimeter scan and sash movement tests. The 30-second rolling average negates instrument detection methods and replaces peak escape.</td></tr>
<tr><td>Vertical Design Sash Open:
• Left, Center and Right Test Positions
• Tall Mannequin Height, 22 in. BZ
• Short Mannequin Height, 18 in. BZ</td></tr>
<tr><td>Horizontal Max.
(Left, Center and Right Open):
• Center Position Test Position
• Tall Mannequin Height 22 in. BZ
• Short Mannequin Height 18 in. BZ</td></tr>
<tr><td>Perimeter Scan:
• Vertical Design Sash
• Horizontal Max
(Left, Center and Right Open)</td></tr>
<tr><td rowspan="2">Sash Movement Effect Test</td><td>Vertical Design Sash (Center)</td></tr>
<tr><td>Horizontal Max Center Opening</td></tr>
</table>

Table Notes:

[1] As stated in section 2.1, all retrofitted LFHs must adhere to the "High Performance LFH Performance Criteria".

[2] As stated in section 2.1, all radioisotope and perchloric LFHs must adhere to the "Traditional LFH Performance Criteria".

[3] Monitor must indicate within 5% of actual face velocity.

[4] The design sash is the height at which the sash is 80% open.

4.2 AI Test Performance Criteria

The “As installed” (AI) performance criteria test is designed to evaluate the LFH performance under design operating conditions. AI test shall be conducted after Testing, Adjusting and Balancing (TAB) and CX Functional Performance Testing (FPT) of the air supply and ventilation system, but prior to laboratory occupancy or use. Any substantive changes or modifications to the HVAC system in laboratories equipped with LFHs shall require an AI test. Also, at any time a retrofit is installed, the LFH must undergo TAB, CX FPT and be followed up with AI testing.

The following conditions apply:

1. All LFH components shall be properly installed and operated according to the manufacturer’s specifications prior to the AI performance test.
2. The AI performance tests shall be conducted by a qualified third-party and an independent testing agency with a minimum of five years of ANSI Z9.5/ASHRAE 110 testing experience.
3. The installer shall contact SSD to coordinate a physical observation of the AI test at least 45 days in advance of the proposed test date. In addition, the contractor shall set detailed testing schedule 15 business days prior to the established test date.
4. The LFH installer shall provide the specifications, drawings, and any other descriptive information pertaining to the test.
5. An EPA representative shall witness the test to assist with the verification of results. Failure to meet the performance criteria shall be a sufficient cause for rejection of the LFH. The EPA reserves the right to verify the calibration of test equipment (i.e., before and after use), photograph or videotape, and even take independent measurements during the test.

Refer to Table 4-2 for a description of the applicable inspection, operating and containment criteria for the AI fume hood performance evaluation. Figure 3-1 provides a flowchart showing the recommended sequence for conducting the AI tests. The Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet in Appendix A and the Laboratory Fume Hood Performance Test Data Sheet in Appendix B shall be completed and submitted to SSD for review.

Table 4-2. AI Test Performance Criteria

AI Test	Description/Configuration	High Performance LFH Performance Criteria[1]	Traditional LFH Performance Criteria[2]
Inspection			
Laboratory Hood	Complete the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. An electronic copy of this form can be provided by SSD.		
Laboratory Space	Complete the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. An electronic copy of this form can be provided by SSD.		
Exhaust System	Only required if the LFH does not perform to EPA criteria for operating conditions and containment tests at both minimum and maximum sash opening configurations.		
Operating Conditions Tests			
Cross-Draft Velocity Test	Vertical 100% and Design Sash	• Measured velocities shall be no greater than 30 fpm or less than 50% of AFV, whichever is more stringent.	
	Horizontal Max Center Opening		
Face Velocity Test[3]	Vertical 100% Open	AFV = 60-70 fpm (if LFH has full sash sensing ability to 100% open)	AFV = 90-110 fpm
	Vertical Design Sash Open[4]	AFV = 60-70 fpm	AFV = 90-110 fpm
	Horizontal Max Openings (Left, Center and Right)	AFV = 60-70 fpm	AFV = 90-110 fpm
	Vertical Sash 6 in. Open	AFV > 60 fpm	AFV > 90 fpm
Auxiliary Air Velocity Test (if applicable)	Vertical 100% Open	• Average Auxiliary Air Velocity ≤ 2.5 times the design opening AFV or ≤ 70% of the LFH exhaust volume.	
Hood Monitor and Alarms Test	All Sash Configurations used for Face Velocity Tests	• Indicated velocity or flow ±5% variation from corresponding measured value.	
Exhaust Flow Measurement	Vertical Design Sash	• Design flow ±5% to achieve EPA AFV criteria. • Minimum Air Changes per Hour (ACH) is 250.[5]	
	Horizontal Sash Max Center Opening		
	Sashes Closed		
Hood Static Pressure Measurement	Vertical Design Sash	• Hood static pressure ≤ 0.5 in. w.g. • There may be some concession for large distillation and floor-mounted hoods.	
	Horizontal Sash Max Center Opening		
	Sashes Closed		
VAV Response and Stability Test	Vertical Design Sash Open	• VAV Response: time required for VAV to modulate flow with sash closed to 90% of steady state flow with sash at design opening (includes the time required to raise the sash) must be ≤ 5 seconds. • VAV Stability: the variation determined by the coefficient of variation shall be less than 10% of the steady state flow with the sash closed or with the sash at the design sash opening. • The coefficient of variation is calculated as: %COV = 100 × (3 × standard deviation) / average steady state flow.	
	Horizontal Max Opening		

Table 4-2. AI Test Performance Criteria

<table>
<tr><th>AI Test</th><th>Description/Configuration</th><th>High Performance LFH Performance Criteria[1]</th><th>Traditional LFH Performance Criteria[2]</th></tr>
<tr><td colspan="4">Containment Performance Tests</td></tr>
<tr><td rowspan="3">Airflow Visualization Test (Smoke)</td><td>Vertical 100% Open</td><td colspan="2" rowspan="3">• No visible escape beyond plane of sash.
• Smoke should not be discharged at high velocity and directed towards the opening.
• VAV hoods should undergo an additional challenge by raising and lowering the sash.
• Smoke observed beyond plane of sash when generated six inches inside the plane of the sash fails the test.
• Hood must have a smoke rating of Fair or Good.
• A Rating of Fail or Poor constitutes failure of the hood.</td></tr>
<tr><td>Vertical Design Sash</td></tr>
<tr><td>Horizontal Max Openings (Left, Center and Right)</td></tr>
<tr><td rowspan="3">Tracer Gas Containment Test (Static Mannequin)</td><td>Vertical Design Sash
• Left, Center, Right Test Positions
• Mannequin Height, 22 in. BZ</td><td colspan="2" rowspan="5">• Average five-minute concentration ≤ 0.1 ppm.
• Maximum 30-second rolling average ≤ 0.1 ppm.
• Peak concentration ≤ 0.5 ppm.
• The maximum five-minute average concentration applies to any test configuration or mannequin position.
• 30-second rolling averages shall be calculated during perimeter scan and sash movement tests. The 30-second rolling average negates instrument detection methods and replaces peak escape.</td></tr>
<tr><td>Horizontal Max Openings (Left, Center and Right)
• Center Test Position at Each Horizontal Opening
• Mannequin Height 22 in. BZ</td></tr>
<tr><td>Perimeter Scan
• Design Sash
• Horizontal Max (Left, Center and Right Openings)</td></tr>
<tr><td rowspan="2">Sash Movement Effect Test</td><td>Vertical Design Sash (Center)</td></tr>
<tr><td>Horizontal Max Center Opening</td></tr>
</table>

Table Notes:

[1] As stated in section 2.1, all retrofitted LFHs must adhere to the "High Performance LFH Performance Criteria".

[2] As stated in section 2.1, all radioisotope and perchloric LFHs must adhere to the "Traditional LFH Performance Criteria".

[3] Monitor must indicate within 5% of actual face velocity.

[4] The design sash is the height at which the sash is 80% open.

[5] LFHs shall maintain a minimum Air Changes per Hour (ACH) that ensures contaminants are properly diluted and exhausted to prevent hazardous concentrations within the LFH. LFHs are also subject to a risk assessment based on evaluation of the dilution capability. The requirements set forth in Section 3.3.3 of ANSI/AIHA Z9.5 shall be taken into account when considering an alternate minimum ACH. This requirement is specific to the LFH's internal function. Refer to EPA Facilities Manual Section 7.2.9. for design guidelines in regards to ACH and occupancy mode ventilation rates for laboratory space. This does not apply to perchloric LFHs because VAV fume hoods are not appropriate for perchloric acid use, as decreased duct velocities due to sash adjustment could increase the potential for condensation within exhaust ductwork and generate dangerous conditions. VAV control dampers or any other device within perchloric acid ductwork should be avoided.

4.3 Annual Test Performance Criteria

The Annual performance tests shall be conducted by a qualified laboratory personnel or contractor to ensure LFH performance is within the established specifications. Any substantive changes or modifications to the HVAC system in laboratories equipped with LFHs shall require an AI test instead of an Annual test.

The following conditions apply:

1. EPA laboratory personnel or a qualified contractor shall evaluate the integrity of the LFH.
2. EPA laboratory personnel or a qualified contractor shall ensure that LFH operating conditions remain within acceptable limits (i.e., AFV and smoke containment are within the acceptable threshold as mentioned in Table 4-3).
3. EPA laboratory personnel or a qualified contractor shall calibrate the LFH monitor.
4. All testing and measurements must be documented and retained for inspection by either EPA SSD's personnel or OSHA inspectors upon request.

Refer to Table 4-3 for a description of the applicable inspection, operating and containment criteria for the Annual fume hood performance evaluation. Figure 3-2 provides a flow chart showing the recommended sequence for conducting the Annual tests. The Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet in Appendix A (or equivalent) and the Laboratory Fume Hood Performance Test Data Sheet in Appendix B (or equivalent) shall be completed. It is the responsibility of the local SHEMP and/or facility manager to maintain all Annual LFH testing records. All Annual testing data shall be submitted to SSD for review upon request or during an SSD SHEM audit.

Table 4-3. Annual Test Performance Criteria

Annual Test	Description/Configuration	High Performance LFH Performance Criteria[1]	Traditional LFH Performance Criteria[2]
Inspections			
Laboratory Hood	Complete the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. An electronic copy of this form can be provided by SSD.		
Laboratory Space	Complete the Laboratory Fume Hood, Space and Exhaust System Inspection Data Sheet found in Appendix A. An electronic copy of this form can be provided by SSD.		
Exhaust System	Only required if the LFH does not perform to EPA criteria for operating conditions and containment tests at both minimum and maximum sash opening configurations.		
Operating Conditions Tests			
Cross-Draft Velocity Test	Vertical 100% and Design Sash	• Measured velocities shall be no greater than 30 fpm or less than 30% of AFV, whichever is more stringent.	
	Horizontal Max Center Opening		
Face Velocity Test[3]	Vertical Design Sash Open[4]	AFV = 60-70 fpm	AFV = 90-110 fpm
	Horizontal Max. Openings (Left, Center and Right)	AFV = 60-70 fpm	AFV = 90-110 fpm
Auxiliary Air Velocity Test (if applicable)	Vertical 100% Open	• Average Auxiliary Air Velocity ≤ 2.5 times the design opening AFV or ≤ 70% of the LFH exhaust volume.	
Hood Monitor and Alarms Test	All Sash Configurations used for Face Velocity Tests	• Indicated velocity or flow ±5% variation from corresponding measured value.	
Dynamic VAV Response and Stability Test	Vertical Design Sash Open	• VAV Response: time required for VAV to modulate flow with sash closed to 90% of steady state flow with sash at design opening (includes the time required to raise the sash) must be ≤ 5 seconds. • VAV Stability: the variation determined by the coefficient of variation shall be less than 10% of the steady state flow with the sash closed or with the sash at the design sash opening. • The coefficient of variation is calculated as: %COV = 100 × (3 × standard deviation) / average steady state flow.	
	Horizontal Max. Opening		
Containment Performance Tests			
Airflow Visualization Test (Smoke)	Vertical 100% Open	• No visible escape beyond plane of sash. • Smoke should not be discharged at high velocity and directed towards the opening. • VAV hoods should undergo an additional challenge by raising and lowering the sash. • Smoke observed beyond plane of sash when generated six inches inside the plane of the sash fails the test. • Hood must have a smoke rating of Fair or Good. • A Rating of Fail or Poor constitutes failure of the hood.	
	Vertical Design Sash		
	Horizontal Max Openings (Left, Center and Right)		

Table Notes:

[1] As stated in section 2.1, all retrofitted LFHs must adhere to the "High Performance LFH Performance Criteria".

[2] As stated in section 2.1, all RI and perchloric LFHs must adhere to the "Traditional LFH Performance Criteria".

[3] LFH Monitor must indicate within 5% of actual face velocity.

[4] The design sash is the height at which the sash is 80% open.

APPENDIX A:

LABORATORY FUME HOOD, SPACE AND EXHAUST SYSTEM INSPECTION DATA SHEET

Inspection Data Sheet

Project: ______________ **Room:** ______________

Test Date: ______________ **Conducted By:** ______________

Type of Test: ☐ *As Manufactured Performance Test* ☐ *As Installed Performance Test*
☐ *Annual Performance Test*

Unit ID / Serial Number: ______________

Unit Manufacturer: ______________ **Model:** ______________

Unit Type: ______________ **Size:** ______________

Manufacturer Contact: ______________

Laboratory Fume Hood Inspection

☐ No visible cracks and damage	☐ Baffles are fixed in position per factory settings
☐ Base furniture is ventilated separately	☐ Exhaust collar/duct connection
from the LFH exhaust system (if applicable)	☐ Work surface is recessed and clean of debris
☐ Sash has freedom of movement	☐ Bypass grille operates as designed
☐ Lights tested and operational	☐ Monitors/indicators are calibrated and operational
☐ Airfoil sill properly installed	☐ Sash stops function verified
☐ Correct amount of air supply is provided	☐ Automatic sash closer mechanism tested and operational

Laboratory Fume Hood Dimensions:

Exterior Dimensions: *Height:* ______ ft. *Width:* ______ ft. *Depth:* ______ ft.

Interior Dimensions: *Height:* ______ ft. *Depth:* ______ ft. *Depth:* ______ ft.

Work Surface Area: ______ sqft. Interior Volume: ______ cubic ft.

Bypass Opening Area: ______ sqft.

Sash Information:

☐ Vertical ☐ Horizontal ☐ Combination ☐ Double Vertical ☐ Hinged ☐ None/Fixed

Number of Sashes: ______ Sash Stop Height: ______

Number of Sash Panels: ______ Panel Widths: ______

Vertical Opening: *Max Opening Height:* ______ in Horizontal Opening: *Max Opening Height:* ______ in

Max Opening Width: ______ in *Max Opening Width:* ______ in

Baffle Information:

☐ Adjustable Internal ☐ Adjustable External ☐ Automatic Adjustable ☐ Fixed ☐ None

Number of Slots: ______ Slot Widths: ______

Monitor Information:

Manufacturer: ______ Model: ______ Factory Installed? (Y/N): ______

Type: ☐ Velocity ☐ Other - Describe: ______

Alarm: ☐ Audible ☐ Visual Displayed Units: ______ Stated Accuracy / Precision: ______

Laboratory Space Inspection

Space Dimensions: *Height:* ________ ft. *Width:* ________ ft. *Depth:* ________ ft.

Volume Calculation: ____________ cubic ft.

- [ ] All doors and access openings are closed
- [ ] All intended ceiling tiles are in place
- [ ] Multiple LFHs in the Laboratory Space

If yes, how many? ____________

Sash Height	Room Differential Pressure (in. H_2O)*	Room Temperature (degrees Farenheit)
Design Sash		
Sash Closed		

*Reminder: Acceptance criteria is negative differential pressure of 0.005 to 0.05 (in. H2O)

Observations and Differences:

Sketch of the laboratory area:

Exhaust System Inspection

System ID: ____________________

Exhaust Type: ☐ VAV ☐ CAV ☐ Other

Exhaust Configuration: ☐ Single Hood - Single Fan ☐ Multiple Hoods - Single Fan ☐ No Exhaust
☐ Single Hood - Multiple Fans ☐ Multiple Hoods - Multiple Fans

Hood Static Pressure Port: ☐ Present and Capped ☐ Missing

Duct Material: ____________________ Duct Diameter: ________ in.

Monitor Type: ____________________ Alarm Type: ____________________

VAV Controls Type: ____________________ VAV Damper Manufacturer: ____________________

Filtration Type: ____________________

Test Equipment Calibration Information:

Detector - Tracer Gas:	*Manufacturer:*		*Model:*	
	Serial Number:		*Latest Calibration Date:*	
Recorder - Data Logger:	*Manufacturer:*		*Model:*	
	Serial Number:		*Latest Calibration Date:*	
Thermal Anemometer:	*Manufacturer:*		*Model:*	
	Serial Number:		*Latest Calibration Date:*	
Smoke Generator:	*Manufacturer:*		*Model:*	
	Serial Number:		*Latest Calibration Date:*	
Pressure Meters:	*Manufacturer:*		*Model:*	
	Serial Number:		*Latest Calibration Date:*	

Additional Notes:

APPENDIX B:

LABORATORY FUME HOOD PERFORMANCE TEST DATA SHEET

Laboratory Fume Hood Performance Data Test Sheet

Project: ______________ **Room:** ______________

Test Date: ______________ **Conducted By:** ______________

Type of Test:

- ☐ *As Manufactured Performance Test*
- ☐ *As Installed Performance Test*
- ☐ *Annual Performance Test*
- ☐ *Other*

Unit ID / Serial Number: ______________

Unit Manufacturer: ______________ **Model:** ______________

Unit Type: ______________ **Size:** ______________

Baffle / Slot Configuration: ______________

Cross-Draft Velocity Test

Horizontal Draft			Vertical Draft			Perpendicular Draft			Measurements
Left	**Center**	**Right**	**Left**	**Center**	**Right**	**Left**	**Center**	**Right**	
									Min. FPM
									Max. FPM
									Average FPM

Notes:

Face Velocity Test

Sash Opening: *Height:* ______ ft. *Width:* ______ ft. *Area:* ______ sq. ft.

Bypass Grille: *Height:* ______ ft. *Width:* ______ ft. *Area:* ______ sq. ft.

☐ Exhaust blower is operational

Vertical Sash LFHs

Sash Opening	Height (in)	Width (in)	Area (in)	Velocity Readings (FPM)						Flow (CFM)	Monitor Reading
Design Sash											@Design Sash
				Min FPM:		Max FPM:		Average:			Sash Closed
100%											@100% Open
				Min FPM:		Max FPM:		Average:			Sash Closed
Restricted	6"										
				Min FPM:		Max FPM:		Average:			@6" Sash

Horizontal Sash LFHs

Sash Opening	Height (in)	Width (in)	Area (in)	Velocity Readings (FPM)						Flow (CFM)	Monitor Reading
Left											
				Min FPM:		Max FPM:		Average:			w/ Left Sash Open
Center											
				Min FPM:		Max FPM:		Average:			w/ Center Sash Open
Right											
				Min FPM:		Max FPM:		Average:			w/ Right Sash Open

Auxiliary Downflow LFHs (if applicable)

☐ Auxiliary air supply is operational ☐ Plenum outlet is not obstructed

Sash Opening	Height (in)	Width (in)	Area (in)	Velocity Readings (FPM)						Flow (CFM)	Monitor Reading
AUX											
				Min FPM:		Max FPM:		Average:			

Notes:

Hood Monitor and Alarms Test

☐ Monitor Sends Alarm Condition to BAS under Unacceptable Conditions (Flow is Lower/Higher than Tolerance Range)

☐ Visual Alarm Indicates Unacceptable Operation

☐ Audible Alarm Enunciates

Notes:

Exhaust Flow and Hood Static Pressure Measurements

Sash Position	Duct Velocity (FPM)	Hood Exhaust Flow (CFM)	Hood Static Pressure (in. H_2O)	Hood ACH	Lab Supply Flow (CFM)	Lab Exhaust Flow (CFM)	Lab Pressure (in. H_2O)	Lab ACH
Design Sash								
Sash Closed								

Notes:

Dynamic VAV Response and Stability Test

	Cycle 1	Cycle 2	Cycle 3
VAV Response Time (seconds): Time to Reach 90% of Final Steady State Flow			
VAV Stability Steady State Flow/Velocity Variation Percentage			

Notes:

Airflow Visualization Test

Low Volume Rating: ☐ *Fail* ☐ *Pass* ☐ N/A

Reasoning for Rating:

High Volume Rating: ☐ *Fail* ☐ *Pass* ☐ N/A

Reasoning for Rating:

Approximate Clearance Time: ☐ *Fail (>1 min)* ☐ Pass (<30 sec) ☐ N/A

Observations / Comments:

Additional Notes:

Tracer Gas Containment Test

Opening Scan: ________________ *ppm* *Grid Location:* ________________

Mannequin Height	Ejector Location	Breathing Zone Height	Sample	Position			Pos. Control Level		
				Left	Center	Right			
Test Series 1									
			Avg. - PPM				*Max Avg:*		*ppm*
			Min. - PPM				*Peak:*		*ppm*
			Max. - PPM				*Rolling Avg:*		*ppm*
Test Series 1a (Sash Movement Effect Test)									
			Avg. - PPM	--		--	*Max Avg:*		*ppm*
			Min. - PPM	--		--	*Peak:*		*ppm*
			Max. - PPM	--		--	*Rolling Avg:*		*ppm*
Test Series 2									
			Avg. - PPM				*Max Avg:*		*ppm*
			Min. - PPM				*Peak:*		*ppm*
			Max. - PPM				*Rolling Avg:*		*ppm*

Notes:

Summary

Performance Rating:

Unit Certification: Yes No Next Inspection Due:

Follow Up Required: Yes No

Additional Notes: